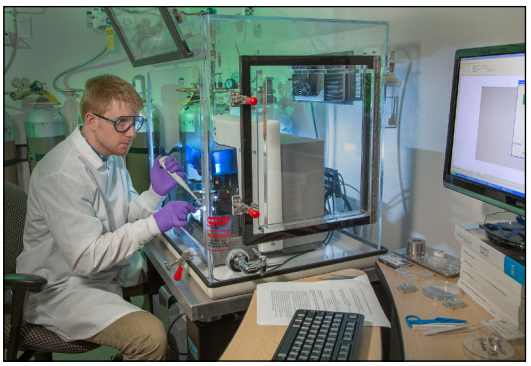
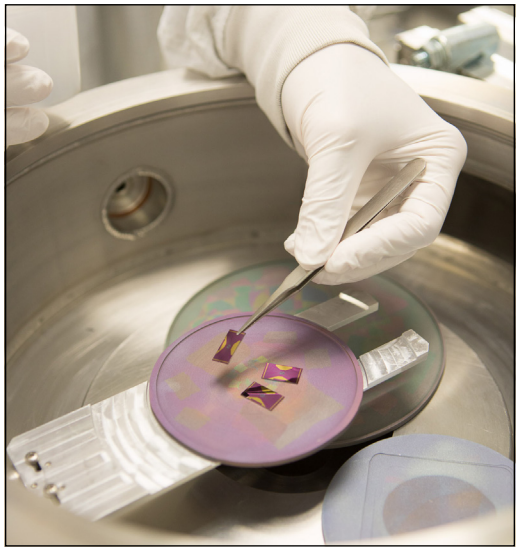
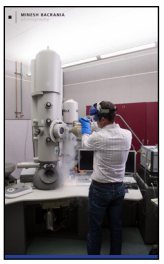
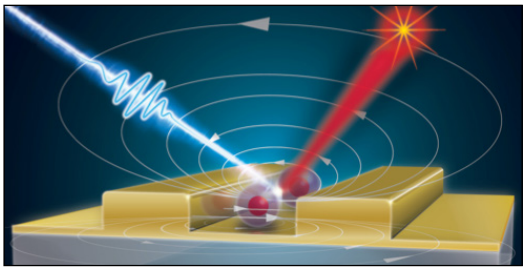
SAND2016-3615R

The Center for Integrated Nanotechnologies CINT







Facility Overview and Operations Review Document

prepared April 12, 2016

U.S. DEPARTMENT OF ENERGY | Office of Science

Los Alamos NATIONAL LABORATORY EST. 1943

Center for Integrated Nanotechnologies CINT Sandia Los Alamos

Sandia National Laboratories

The Center for Integrated Nanotechnologies (CINT)

Facility Overview and Operations Review Document

Prepared April 12, 2016

Director – Quanxi Jia
Co-Director (acting) – Sean J. Hearne
User Program Manager – Heather Brown
Communications and Outreach Manager – Antonya Sanders

Nanophotonics & Optical Nanomaterials Thrust Leader – Stephen Doorn
Nanoscale Electronics & Mechanics Thrust Leader – Brian Swartzentruber
Soft, Biological & Composite Nanomaterials Thrust Leader – Millicent Firestone
Theory & Simulation of Nanoscale Phenomena Thrust Leader – Gary Grest

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. Los Alamos National Laboratory, an affirmative action equal opportunity employer, is operated by Los Alamos National Security, LLC, for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396.

Executive Summary

The Center for Integrated Nanotechnologies (CINT) plays a leadership role in integration of nanostructured materials to enable novel capabilities and applications through its function as a Department of Energy/Office of Science Nanoscale Science Research Center (NSRC) national user facility. By coupling open access to unique and world-class capabilities and scientific expertise to an active user community, CINT supports high-impact research that no other single institution could achieve—the whole of CINT including its user community is greater than the sum of its parts.

CINT's vision is one scientific community focused on nanoscience integration.

Deriving the ultimate benefit from nanoscience will require the assembly of diverse nanoscale materials across multiple length scales to design and achieve new properties and functionality; in other words, nanomaterials integration. Integration has played a pivotal and revolutionary role in the development of nearly all science and technology. The most familiar and dramatic illustration is the development of very large-scale integrated circuits where active and passive devices based on semiconductors, dielectrics, insulators, and metals are monolithically integrated on a single platform for specific applications. Even greater challenges exist as nanomaterials are integrated into new architectures to form functional systems. Interfaces and defects are formed whose structures and properties can dominate the chemical, mechanical, electronic, and optical properties of the system. The effects of synthesis and fabrication processes on performance must be investigated and new directed- and self- assembly approaches developed for greater functional control. Combined bottom-up and top-down synthesis and assembly techniques must be optimized and/or invented to allow the intention design of hierarchical materials. Establishing the fundamental principles that underpin the integration of nanomaterials that display unique properties, such as quantum confinement, is of paramount importance to nanoscience and ultimately nanotechnology.

Understanding and enabling nanotechnology as well as supporting the CINT user program are central to the missions of both Los Alamos and Sandia National Laboratories. Sandia's charge of ensuring a safe, secure and effective nuclear deterrent hinges on the labs ability to be at the forefront of energy research and providing the nation with foundational capabilities to draw upon for energy security. As stated in Sandia's strategic plan:

"Our broad, multidisciplinary research base is forward-looking, and it encourages bold technical outcomes that can qualitatively advance the Laboratories' capabilities. With these resources, Sandia is well prepared to anticipate emerging threats to national security and apply deep scientific understanding to demonstrated engineering solutions."

Similarly, as stated in Los Alamos's Materials for the Future Science Pillar:

"Pursuing the discovery science and engineering required to establish design principles, synthesis pathways, and manufacturing processes to control functionality in materials relevant to ensuring the U.S. nuclear deterrent, reducing global threats, and solving energy security challenges.

Understanding the link between the functional properties of materials and their structure and composition, as realized through synthesis, fabrication, and manufacturing."

Since our most recent triennial review in September 2013, CINT has continued on the path to full realization of this vision. The partnership between the two host laboratories (Sandia and Los Alamos) has grown stronger with the maturing of the Center. As CINT has increasingly developed an identity that transcends Laboratory boundaries, we have evolved our overall leadership structure to a more streamlined and cost/labor-efficient one. We continue to strengthen coherence in and communication among the scientific thrusts by working on our integration grand challenges and engage an enthusiastic, energetic user community. This focus has led to sustained excellence in our user program and enhanced scientific impact. During the period between 2013 and

2015, 693 user proposals were submitted (a 6% increase over the previous triennial period), of which 571 were accepted. In this same period, we sponsored 1425 total users (a 34% increase). Our scientific productivity as evidenced by the total number of archival publications (refereed journal articles) has also increased in this review period to 676 (a 18 % increase). Significantly, 30% of our publications in this review period were published in NSRC high-impact journals.

The principal focus in our user program continues to be on maintaining the highest possible project impact with a goal of at least one quality publication per project. To this end, we note that our ratio of archival publications from user science per accepted user project for this current review period is approaching unity (563 user publications from 571 accepted projects, some of which are still active). The overall upward trend in our user program statistics cited above—demonstrating our increasing impact on the international nanoscience landscape—coupled with our unique user-inspired focus on nanoscience integration, were clear contributing factors in the determination by the Basic Energy Sciences Advisory Committee Facility Prioritization Review Committee[1] that CINT is "*Absolutely Central for U.S. World-leading Science*."

The internal scientific program within CINT continues to evolve in response to changes in the focus of nanoscience in the international research community to the new expertise and capabilities represented by our recent new staff hires and as each science thrust has become more closely linked to our overall vision of nanoscience integration. Key to this evolution has been interlacing the Theory and Simulation thrust into the other thrusts to both bridge and provide a fundamental understanding of the foundational science. The vision, progress, and plans for each scientific thrust are summarized in the thrust review documents accompanying this overview document. Key scientific opportunities outlined there include research in:

Nanophotonics and Optical Nanomaterials (NPON) – Our emphasis is on understanding and controlling fundamental photonic, electronic, and magnetic interactions in nanostructured optical materials. Key integration science challenges include (1) chemical and physical synthesis of optical, electronic, and magnetic nanomaterials; (2) collective and emergent electromagnetic phenomena (plasmonics, metamaterials, photonic lattices, and solitons); (3) multifunctional behavior in hybrid nanostructures comprising optical components; and (4) energy transformations on the nanoscale.

Nanoscale Electronics and Mechanics (NEM) – We focus on understanding and controlling electrical and mechanical properties arising from confinement on the nanoscale and interactions within nanostructures. Significant challenges in integration science issues include (1) nanowire integration science for new energy concepts; (2) manipulation of spin properties of single electrons in semiconductors; (3) surface- and interface-driven mechanics of nanoscale materials; (4) understanding structure-property relationships in nanostructured materials; and (5) developing multifunctional composite materials through exploiting electronic, mechanical, and magnetic interactions.

Soft, Biological, and Composite Nanomaterials (SBCN) – This thrust focuses on solution-based, "bottom-up" approaches for development of integrated nanomaterials. Our emphasis will be on key scientific areas that underlie the challenge of nanoscience integration. These include (1) controlling interfaces and their interactions; (2) developing new characterization tools that provide information on multiple length and time scales; and (3) exploring the roles of disorder and dynamics in determining materials performance.

Theory and Simulation of Nanoscale Phenomena (TSNP) – We develop analytical and computational approaches that enable the simulation/predication of the competing interactions and the resultant material structure and properties that occur in integrated nanomaterials systems. Our strategy emphasizes the development and application of advanced techniques drawn from combinations of many-body, local density, molecular dynamics, and other methods capable of describing complex nanostructured materials.

Realization of our vision of nanoscience integrations will continue to require the active engagement of our user community through a variety of mechanisms that both promote the essential practices of integrating nanomaterials and serve to build robust communities around key integrations challenges. To ensure continuing progress with an enhanced role of our user community, we will build on the following suite of integration vehicles:

Discovery Platforms™, microscale modules for the study of nanomaterial properties, and their integration into microsystems – We are continuing to evolve our suite of Discovery Platforms through upgrades and development of new platforms that support our user community by addressing integration science challenges. For example, our electrochemistry TEM Discovery Platform for *in-situ* investigations has been widely used by our user community to investigate anode cycling mechanisms for Li-ion and Na-ion batteries. To advance our liquid-cell TEM capabilities, we are integrating mechanical control over a nanoscale wire/thin-film specimen into our electrochemical TEM discovery platform. This is the first-of-its-kind platform for quantitative mechanical loading within a hermetically sealed liquid environment for high-resolution TEM analysis and provides enhanced environmental control over a specimen.

Development of User Communities around Integration Science – As our vision of integration science has developed within the thrusts, exciting scientific issues have emerged that are challenging scientists across our thrusts and our user community. Together with our user community, we have identified three grand challenges facing nano-integration. These challenges are innovative nanofabrication, integration, and "up-scaling" methods to incorporate quantum-size nanostructures into arbitrary 2-D and 3-D architectures; hybrid materials interactions for generation and manipulation of light; and hierarchical structure and dynamics in soft matter.

New Instrumentation and Capabilities – We will continue to capitalize on our expertise to develop new tools and processes in close collaboration with our user community. In parallel, we will focus existing resources and aggressively compete for new resources to re-capitalize our existing capabilities to ensure that we are consistently providing world-class tools to our user community. We continually leverage the capabilities developed by our host institutions to expand the ability of our user community to perform world-leading research.

Looking forward to the future, we note that new frontiers in science deriving from nanoscale integration continue to emerge. Clearly indicated by the BESAC report ("Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery," November 2015), the scientific community needs to fully exploit a suite of user facilities to maintain our world-leading status. Controlling matter and energy at the molecular, atomic, and quantum levels could spark revolutionary changes in technologies that would help us meet some of humanity's most pressing needs, including the need for renewable, clean, and affordable energy. At CINT, we regard this new area as an enormous opportunity to contribute both to our fundamental scientific expertise and our user facility resources. In short, we regard nanoscience integration as the critical step to accelerate materials discovery; to predict materials performance using computation and modeling powers; to produce new materials with remarkable characteristics in the realms of toughness, desired properties, and responsiveness; and to further transform key technologies to marketplace. In addition, we see enormous opportunities to fully develop our concept of CINT as a center of innovation that brings together communities of researchers and broadly promotes industry/academia/federal research facility collaborations and collaborative networks. Within the context of centers of innovation, we also recognize the critical importance of an expanded role of CINT in integrating our user communities with our co-located user facilities (the National Science Foundation-funded Pulsed Field Facility of the National High Magnetic Field Lab). Lastly, we see significant opportunities to contribute to the success of Office of Science sponsored research across the entire spectrum of its programs, from single PI projects through Energy Frontier Research Centers (EFRCs) to Innovation Hubs. To realize this future vision of enhanced impact and program growth, we have identified three principal challenges to which we must turn our attention and secure additional resources.

1. Ensure that we have the necessary expertise to both meet the demands of a growing user community and respond to new scientific challenges associated with new scientific frontiers. This challenge entails

attracting new strategic hires to targeted positions (e.g., integration specialists), as well as retaining and expanding our current workforce to maintain our forefront role in nanoscience integration.

2. Address key infrastructure issues relating to instrumentation and facilities. Much of our existing high-replacement cost hardware is reaching its nominal lifetime. Recapitalization is becoming an increasingly urgent issue to ensure that we are positioned to provide quality support to our user community. To remain competitive, we must ensure that we are strategic in investing existing capital resources to remain at the forefront.

3. Respond aggressively and successfully to the emergence of new opportunities like the Mesoscale Science frontier and Quantum Materials Integration. It is a virtual certainty that challenges at these frontiers will require new capabilities that we cannot even fully anticipate at this point. Thus we must remain poised to respond and develop these next-generation tools, including synthesis, fabrication, characterization, and theory to address emerging needs.

Implicit in these challenges is the need for additional resources (operating and capital) from Basic Energy Sciences (BES) to enact our strategic hiring plan, shore up decade-old experimental resources, invest in new experimental resources, and ultimately enhance our facilities to accommodate this growth. In the current, very challenging fiscal climate, any such requests must of course reflect keen attention to prioritization so that truly essential needs are addressed first. We are committed to working with BES program management to ensure appropriate stewardship of all resources. It is noted that as a vibrant partnership between LANL and SNL, CINT leverages the unmatched scientific and engineering expertise as well as special capabilities of our host DOE laboratories. We have world-leading scientific expertise in four thrust areas, and specialized/unique capabilities to synthesize, fabricate, characterize and understand nanomaterials in increasingly complex integrated environments which differentiate CINT from other NSRCs.

In summary, CINT has continued to mature and evolve during the period from 2013 to 2015, in response to a growing user program with increasing scientific impact and through the addition of dynamic new staff, expertise, and capabilities across the full spectra of synthesis, fabrication, characterization, and theory that will ensure further growth and greater impact in the coming years. We are enthusiastic about the prospects for the future in which we will build on our solid foundation to extend the impact of the NSRC model of a science-based user facility focusing on the major challenges of nanomaterials integration and to establish CINT as the leader in nanoscience integration by the broad scientific community.

Table of Contents

List of Acronyms

ACF	Autocorrelation Function
AFM	Atomic Force Microscope
ARPAE	Advanced Research Projects Agency-Energy
ATP	Aqueous Two Phase
BES	Basic Energy Sciences
BESAC	Basic Energy Science Advisory Council
BSL	Bio Safety Level
CBO	Crossed Beam Optical
CCP	Capacitive Coupled Plasma
CINT	Center for Integrated Nanotechnologies
CNT	Carbon Nanotube
CVD	Chemical Vapor Deposition
DFG	Difference Frequency Generation
DFT	Density Functional Theory
DSC	Differential Scanning Calorimetry
DSLF	Downstream Low Frequency
EBIC	Electron Beam Induced Current
EBL	Electron Beam Lithography
EDS	Electron Dispersion Spectroscopy
EERE	Office of Energy Efficiency & Renewable Energy
EFRC	Energy Frontier Research Centers
EMT	Executive Management Team
ERD	Elastic Recoil Detection
ES&H	Environmental, Safety, and Health
FCS	Fluorescence Correlation Spectroscopy
FCS	Fluorescence Correlation Spectroscopy
FDTD	Finite-Difference Time-Domain
FIB	Focused Ion Beam
FLDW	Femtosecond Laser Direct Writing
FLIC	Fluorescence Interference Contrast Microscopy
FRAP	Fluorescence Recovery After Photo-Bleaching
FRAP	Fluorescence Recovery After Photobleaching
FROG	Frequency-Resolved Optical Gating
FTE	Full Time Equivalent
FTIR	Fourier Transform Infrared Spectroscopy
FWP	Field Work Proposal
GEP	Genetically Encoded Polymers
GI	Grazing Incidence
GO	Graphene Oxide
g-QD	"Giant" Quantum Dot
GXRD	Glazing-Angle X-ray Diffraction
HAADF	High-Angle Annular Dark-Field
HAZ	Heat Affected Zone

HDP-CVD	High Density Plasma Chemical Vapor Deposition
I3TEM	In-situ Ion Irradiation Transmission Electron Microscope
IBML	Ion Beam Materials Laboratory
ICP	Inductively Coupled Plasma
IDPs	Intrinsically Disordered Proteins
LAMMPS	Large-scale Atomic/Molecular Massively Parallel Simulator
LANL	Los Alamos National Laboratory
LEEM	Low Energy Electron Microscope
LEEM-PEEM	Low Energy Electron Microscopy - Photoemission Electron Microscopy
LFA	Lateral Flow Assay
LPCVD	Low Pressure Chemical Vapor Deposition
LUMOS	Laboratory for Ultrafast Materials and Optical Science
MBE	Molecular Beam Epitaxy
MD	Molecular Dynamics
MESA	Microsystems and Engineering Sciences Application
MESA	Microsystems Engineering and Science Applications
MOU	Memorandum of Understanding
NA-ESMD	Non-Adiabatic Excited States Molecular Dynamics
NEM	Nanoscale Electronics and Mechanics
NHMFL	National High Magnetic Field Laboratory
NIST	National Institute of Standards and Technology
NNSA	National Nuclear Security Administration
NP	Nanoporous
NP	Nanoparticle
NPON	Nanophotonics and Optical Nanomaterials
NRA	Nuclear Reaction Analysis
NSOM	Nanoscale Optical Microscope
NSRC	Science Nanoscale Science Research Center
NTA	Nanoparticle Tracking Analysis
NW	Nanowire
OGO	Ozonated Graphene Oxide
OIM	Orientation Imaging Microscopy
OPA	Optical Parametric Amplifiers
OPA	Optical Parametric Amplifiers
OPTP	Optical-pump, THz-probe
ORR	Oxygen Reduction Reaction
PAC	Scientific Advisory Committee
PIXE	Particle Induced X-ray Emission
PL	Photo Luminescence
PL	Photoluminescence
PLD	Pulsed Laser Deposition
PMT	Program Management Team
PRC	Proposal Review Committee
PV	Photovoltaic
PVD	Physical Vapor Deposition
QCL	Quantum Cascade Laser

QD	Quantum dot
RBS	Rutherford backscattering spectrometry
REU	Research Experience for Undergraduates
RGO	Reduced Graphene Oxide
RHEED	Reflective High Energy Electron Diffraction
RTA	Rapid Thermal Anneal
SAXS	Small-Angle X-ray Scattering
SBCN	Soft, Biological, and Composite Nanomaterials
SECARS	Surface-Enhanced Coherent Antistokes Raman Spectroscopy
SEG	Second-Harmonic Generation
SEM	Scanning Electron Microscopy
SEM	Secondary Electron Microscopy
SHG	SecondHarmonic Generation
SHG/THG	Second/Third Harmonic UV Generation
SISGR	Single-Investigator and Small-Group Research
SLS	Solution-Liquid-Solid
smFRET	Single Molecule Fluorescence Resonance Energy Transfer
SNL	Sandia National Laboratories
SNSPD	Superconducting Nanowire Single-Photon Detector
s-SNOM	Scanning Near-field Optical Microscope
STEM	Science, Technology, Engineering, and Mathematics
STM	Scanning Tunneling Microscopy
TEM	Transmission Electron Microscopy
TGA/DSC	Thermogravimetric Analysis and Differential Scanning Calorimetry
THz-TDS	THz time-domain spectroscopy
TIRF	Total Internal Reflectance Microscopy
TMAH	Trimethylammonium Hydroxide
TMDRIE	Time Multiplexed Deep Reactive Ion Etch
TOF	Time of Flight
TOx	Thermal Oxidation
TR	Time Resolved
TSNP	Theory and Simulation of Nanoscale Phenomena
TUNA	Conducting-Tip Microscopy
UEC	User Executive Committee
UHV	Ultra High Vacuum
VLS	Vapor Liquid Solid
VTI	Variable Temperature Insert
XMLD/XMCD	X-Ray mMgnetic Linear/Circular Absorption Dichroism
XRD	X-ray Diffraction

0. Introduction

The Center for Integrated Nanotechnologies (CINT) is a Department of Energy/Office of Science Nanoscale Science Research Center (NSRC) operating as a national user facility devoted to establishing the scientific principles that govern the design, performance, and integration of hieratical materials starting at the nanoscale. Jointly operated by Los Alamos and Sandia National Laboratories, CINT explores the continuum from scientific discovery to use-inspired research, with a focus on the integration of nanoscale materials and structures to achieve new properties and performance. Through its Core Facility at Sandia National Laboratories and its Gateway Facility at Los Alamos National Laboratory, CINT provides open access to tools and expertise needed to explore the continuum from scientific discovery to the integration of nanostructures into the micro- and macro-worlds. In its overall operations, CINT strives to achieve the following goals common to all Nanoscale Science Research Centers:

- Conduct forefront research in nanoscale science
- Operate as a user facility for scientific research
- Provide user access to the relevant BES-supported expertise and capabilities at the host national laboratory

And these additional goals specific to the unique CINT mission:

- Establish and lead a scientific community dedicated to solving nanoscale science integration challenges enabling the predictable design and fabrication of hierarchical materials
- Maintain a single user facility program that combines expertise and facilities at both Los Alamos and Sandia National Laboratories
- Leverage relevant capabilities developed within Los Alamos and Sandia National Laboratories to enhance scientific opportunities for the nanoscience user community

The CINT user program provides the international scientific community with open access to world-class scientific staff and state-of-the-art facilities for nanomaterials synthesis, fabrication, characterization, and theory, and unique capabilities for nanoscale materials integration, from the level of nanoscale synthesis to the fabrication of microscale and macroscale structures and devices. The staff of CINT includes laboratory scientists, postdocs, and technical support staff who are leaders in the nanoscience research programs in CINT scientific thrust areas.

CINT focuses on four science thrust areas that are key to unlocking the door to nanoscience integration. The Nanoscale Electronics and Mechanics thrust focuses on the electronic and mechanical properties of nanosystems and issues related to integration of a wide variety of nanoscale materials across many length scales. The scientific challenge of understanding and controlling fundamental photonic, electronic, and magnetic interactions in nanostructured optical materials fabricated using both chemical and physical syntheses is addressed by the Nanophotonics and Optical Nanomaterials thrust. The Soft, Biological, and Composite Nanomaterials thrust aims to understand and develop integrated nanomaterials based on solution-based, "bottom-up" approaches. A full understanding of the fundamental nanoscale phenomena that underlie integrated nanomaterials will rely on advances in theory and simulation—the focus of the Theory and Simulation of Nanoscale Phenomena thrust. We have continually evaluated and evolved our thrusts over the past decade by engaging the broader scientific community through discussions with potential CINT users and with attendees at our CINT workshops, as well as by attracting some of today's top nanoscience talent to become staff at CINT.

Advances in the development and understanding of new nanomaterials with novel behavior and response are being made at a tremendous rate. The promise of these new materials is both exciting and broad, with revolutionary implications spanning energy technologies, electronics, computing, sensing phenomena, and biochemical diagnostics. However, advances in nanoscience are increasingly dependent on not just understanding the behavior of individual, isolated nanostructures, but on combining and organizing nanoscale structures to understand and

discover their interactions and collective properties and realize entirely new functionality from integration. Deriving the ultimate benefit from nanoscience will require the assembly of diverse nanoscale materials across multiple length scales in non-equilibrium states to design and achieve new properties and functionality, in other words, nanomaterials integration.

Integration has played a pivotal and revolutionary role in the development of nearly all science and technology as it enables the move from the study of components, or individual materials, to the study of systems that can impact and advance humanity.

Perhaps the most dramatic illustration is the development of very large-scale integrated circuits. The impact of this development on technology, our economy, and our quality of life cannot be overstated. The scientific and engineering challenges that had to be overcome to make this a reality were indeed tremendous, ranging from the synthesis of high-purity silicon to the exquisite materials patterning and processing techniques that permit the functional integration of semiconductors, metals, and dielectrics.

In the nanoscience arena, similar or even greater integration challenges exist. Much of the fascinating behavior at the nanoscale stems from the high surface area, reduced dimensions, and unique atomic structure of nanomaterials. As these materials are coupled with other materials to form functional systems (e.g., formation of interfaces and contacts for control of active nanosystems, incorporation of nanostructures into matrix materials, introduction of heterostructured nanomaterials into new environments), it is imperative to understand how this integration affects the properties and behavior of the nanomaterials. Structural and chemical modifications at newly formed interfaces can dramatically modify the chemical, mechanical, electronic, and optical properties of nanomaterials. The effects of synthesis and processing on performance must be investigated and new directed- and self-assembly approaches developed for greater functional control. Combined bottom-up and top-down assembly techniques must be invented to allow controlled, large-scale formation of micro-scale systems.

Nanomaterials synthesis and fabrication techniques that produce materials of the highest possible quality and structural control must be developed so that functioning and reliable systems can be formed. Finally, a detailed theoretical foundation of static, kinetic, and dynamic phenomena associated with nanomaterials integration must be achieved that will lead to a predicative capability for new functional materials and systems. To achieve the promise of nanomaterials, these and other integration challenges must be overcome for this highly diverse class of materials.

Thus nanoscience integration extends from the synthesis and fabrication of individual nanoscale building blocks, which may in turn involve combining different materials into specific heterostructures, to the assembly of these building blocks, and finally to the generation of complex functional structures and systems. Such integration is the key to exploiting nanomaterials in applications and provides a basis for scientific investigations that will ultimately impact national and international needs in areas such as energy, environment, and security.
To move forward in nanoscience integration, one can formulate key science questions that are independent of particular areas of materials research. A few examples of such general underlying questions include

How does one

. . . control energy and electron (carrier) transfer and other interactions across interfaces and over multiple length scales?

. . . understand and control the interactions and interfaces between nanoscale building blocks to assemble specific integrated structures?

. . . design and exploit interactions within assembled structures to achieve new properties and particular functionalities?

. . . predict and use emergent behavior of collectives of nanostructures?

These types of high-level questions serve to guide research within each of the thrust areas in CINT where specific classes of materials are investigated.

One illustrative example can be found in the area of nanowires. A growing class of materials can now be synthesized in a wire form. This configuration enables unique control of transport-related phenomena and offers many functional benefits in areas such as photovoltaics, thermoelectrics, electrical energy storage, and sensors, just to name a few. However, to capitalize on these unique properties, the nanowires must be integrated with other materials into systems to provide the full function required of the application. This integration poses myriad challenges that range from the synthesis of hybrid nanowire materials and interfaces to the assembly of the optimized architecture of micro- (or macro-) scale systems. Fundamental science issues emerge, such as:

- The synthesis of heterostructured nanowires of dissimilar materials (longitudinal or radial composition modulation)
- The efficiency of energy harvesting (photon, charge, and/or phonon) and energy transport in nanowires and across complex interfaces and how the efficiency can be controlled
- Optimizing bottom-up and top-down nanowire architectures and developing assembly techniques to efficiently exploit their properties

A second example lies in the area of nanocomposites. The integration of nanostructures into bulk composites can lead to enhanced mechanical, electrical, optical, and chemical behavior. In particular, novel phenomena can be achieved by creating composites of very dissimilar materials, such as semiconductor or metallic quantum dots within polymer and even biological matrixes. The integration of these materials raises numerous fundamental science challenges, including

- managing the interface effects between individual nanostructures in interconnected networks and composite mesoscale structures;
- bridging the gap between emergent nanoscale functionality and macroscale performance;
- developing geometries that harness the exceptional axial diffusion behaviors of 1-D systems; and
- determining the ion and electron transport behaviors at the junctions of nanostructures.

CINT was conceived to play a world-leading role addressing the challenges of nanomaterials integration through synergistic coupling of our uniquely designed facilities, user program, and internal science. The scientific challenges of integration demand a spectrum of synthesis, characterization, and systems integration activities that span the sub-nanometer to micron length scales and beyond. Our working definition for integration science is: Assembling hierarchical architectures across length scales to design and achieve new materials properties and functionality.

Nanoscale integration thus extends from the synthesis and fabrication of individual nanoscale building blocks (which may combine different materials into specific heterostructures), to the assembly of these building blocks (for example, as nanocomposites or patterned arrays), and finally to their incorporation into complex functional structures and systems.

To spur the study and predictive understanding of nanoscience integration within CINT, we are continually developing new capabilities to offer to the user community. The following four examples highlight just a few of the new capabilities developed in FY13–FY15. More details of these and other new capabilities and their impacts are included in Section 5 of this document.

Terahertz Magneto-Optical Spectroscopy
In recent years, THz time-domain spectroscopy (THz-TDS) has been used as a non-contact probe of the conductivity in a wide range of materials. More recently, the ability to do THz-TDS measurements in a high magnetic

field has allowed researchers to probe exotic phenomena in condensed matter physics, such as the quantum Hall effect. We have recently developed a THz magneto-optical spectroscopy system (unique within the NSRCs), allowing us to perform THz-TDS measurements on a variety of samples in magnetic fields up to 8 Tesla and temperatures as low as 1.5 K. More recently, we have added the ability to optically photoexcite samples and measure the photoinduced changes in the transmitted THz pulse (optical-pump, THz-probe [OPTP] spectroscopy) at low temperatures and high magnetic fields. Moving forward, the next improvement to the system will allow us to photoexcite samples with intense THz electric fields, making it one of only a few such systems in the world. These changes will enable us to examine the physics of a wide variety of materials (e.g., semiconductor nanostructures, Dirac materials, and superconductors) in previously unexplored regimes, revealing a wide range of novel physical phenomena such as the dynamics of electromagnons in multiferroics and photoinduced transitions between Dirac and Weyl semimetal states, among many other things.

Discovery Platforms

The thrusts develop a variety of new instrumentation to advance the science in their areas. One effort unique to CINT is the Discovery Platform. These platforms are modular micro-laboratories designed and batch-fabricated by CINT to allow easy integration of nanomaterials into microscale structures. Their purpose is to facilitate studies of nanomaterial properties and their integration. They should allow easy connections, a range of diagnostic and experimental measurement conditions, and a degree of standardization and reproducibility in nanoscale measurements. The inception, creation, and evolution of Discovery Platforms have evolved in close collaboration with our user community. Most recently we have recognized the potential broad user community appeal to other experimental platforms that facilitate the synthesis of—as well as work with—nanoscale materials. In this spirit, we have also recently introduced a Microfluidic Synthesis Discovery Platform.

Electrochemical Discovery Platform The Electrochemistry TEM Discovery Platform (Figure 1.1) has continued to evolve and be at the forefront of nanoscience research. This platform offers the ability to perform electron microscopy of a real environment with electrical access. The system has 10 individually controlled electrodes for multiple experiments within the same environmental conditions and low-current control for quantitative analysis between the electrochemical data to structural/chemical information of nanoscale electrode areas. The development of this system was made possible by the SUMMIT V 8-layer MEMS microfabrication capability at the MESA facility at Sandia National Laboratories.

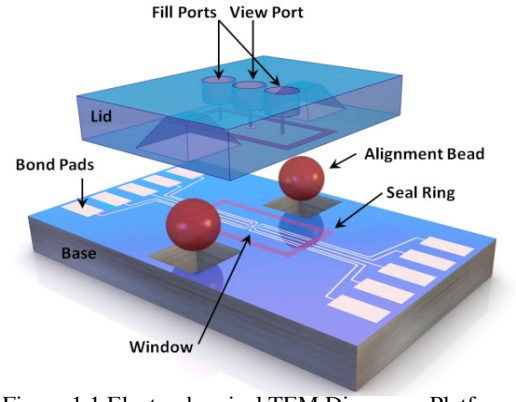


Figure 1.1 Electrochemical TEM Discovery Platform

Microfluidics Discovery Platform - The new Microfluidic Synthesis Discovery Platform is an extremely flexible system for nanoparticle synthesis, functionalization, and real-time characterization. The microfluidic system can use a variety of chip materials including glass, metals, and polymers, with designs that vary from small droplet-forming chips to high-volume serpentine reaction chips. The chips have a standardized fluidic header and can be held in a custom-made aluminum baseplate with two options for precision temperature control: a thermoelectric system for sub-ambient cooling and near ambient heating and a resistively heated system for reactions up to 350 °C. Real-time reaction monitoring via visible and fluorescence microscopy and UV-vis and NIR spectroscopy have already been deployed in the system, and planned additions include mid-IR spectroscopy and dynamic light scattering.

New Semiconductor and Hybrid Semconductor-Metal Optical Emitters

CINT's internationally recognized program in nanocrystalline quantum dot (QD) light emitters is founded on our development of core-shell "giant" QDs (g-QD). These fundamental building blocks of hieratical structures are characterized by strongly suppressed fluorescence blinking, photobleaching, and non-radiative Auger recombination. To extend and accelerate this capability, we have developed a custom, computer-controlled

reactor system (Figure 1.2) comprising eight parallel reactors that are individually addressable with a combined capability for: (1) fully automated, software controlled "round-the-clock" chemical-precursor additions; (2) automated sampling; and (3) programmed in-situ optical characterization (absorption, fluorescence, turbidity). This unique system will prove a versatile and powerful tool for controlled, quasi-combinatorial solution-phase synthesis of simple and complex nanostructures, especially heterostructured nanoparticles like thick-shell ("giant") core/shell quantum dots and multicomponent/multifunctional nanoparticles. It will enable more rapid discovery of new nanomaterials, as well as optimization and scale-up of known optical nanomaterials.

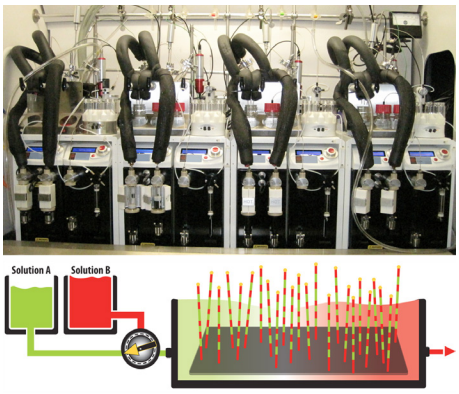


Figure 1.2. Illustration of automated reactor system for solution-phase synthesis of nanowires and quantum dots.

1. Facility Overview

The Center for Integrated Nanotechnologies (CINT) is a Department of Energy/Office of Science Nanoscale Science Research Center. Jointly operated by Los Alamos and Sandia National Laboratories as a national user facility, CINT is devoted to establishing the scientific principles that govern the synthesis, fabrication, characterization, and theory of nanoscale materials integration into hierarchical structures. Through its Core to Sandia Facility and Gateway to Los Alamos Facility and the existing space designated as the Gateway to Sandia Facility, CINT provides access to the tools and expertise needed to explore the continuum from scientific discovery to the integration of nanostructures into the micro and macro worlds. While physically spanning multiple sites at both Los Alamos and Sandia National Laboratories, CINT is managed as an integrated program by a joint management team (Section 1b).

Building on the strengths of Sandia and Los Alamos National Laboratories to pursue the goal of developing the science and technology of nanoscience integration, CINT has defined four science thrust areas that serve as integrated synergistic building blocks: Nanoscale Electronics and Mechanics (NEM); Nanophotonics and Optical Nanomaterials (NPON); Soft, Biological, and Composite Nanomaterials (SBCN); and Theory and Simulation of Nanoscale Phenomena (TSNP). The Nanoscale Electronics and Mechanics thrust focuses on the electronic and mechanical properties of nanosystems and issues related to integration of a wide variety of nanoscale materials. The Nanophotonics and Optical Nanomaterials thrust addresses the overall scientific challenge of understanding and controlling fundamental photonic, electronic, and magnetic interactions in nanostructured optical materials fabricated using both chemical and physical syntheses. The Soft, Biological, and Composite Nanomaterials thrust focuses on solution-based, "bottom-up" approaches for development of integrated nanomaterials. The Theory and Simulation of Nanoscale Phenomena thrust focuses on theoretical and simulation understanding of the fundamental nanoscale phenomena that underlie integrated nanomaterials. Through our interactions with current and prospective CINT users, our CINT workshops, annual user conferences, and other communication/information exchange mechanisms, we have engaged in the broader scientific community in developing our capabilities and refining the objectives of our science thrusts.

1.a Facility and Instrument Overview

The major CINT facilities are the CINT Core Facility, located in Albuquerque, NM, and operated by Sandia National Laboratories (SNL); and the Gateway to Los Alamos Facility, located in Los Alamos, NM, and operated by Los Alamos National Laboratory (LANL). CINT also has access to certain capabilities at both Laboratories that provide users with access to unique world-leading capabilities developed by the home institutions. For example, the Core facility leverages the Microsystems and Engineering Sciences Application (MESA) facility at Sandia for development of CINT Discovery Platforms and the In-situ Ion Irradiation Transmission Electron Microscopy (I3TEM) for understanding the response of nanomaterials in radiation environments. Through the Gateway to Los Alamos, the CINT community has access to other user facilities (National High Magnetic Field Lab) and leveraged capabilities such as the Laboratory for Ultrafast Materials and Optical Science and the Ion Beam Materials Lab at LANL.

Figure 1.3 The CINT Core Facility

The CINT Core Facility, Figure 1.3, is located in Albuquerque, near Sandia, but just outside the Kirtland Air Force Base, which allows for more open access. The single-level, 96,000-gross-square-foot building contains capabilities to support all the CINT Science Thrusts, including a 9,000-gross-square-foot, class-1000 clean room space with local regions of up to class 100 for lithographic patterning and deposition. It also houses 24 laboratories for physical, chemical, and biological materials synthesis, scanning probes and optical spectroscopies, electron and optical microscopies, and office space for 150 people. To promote interaction, the spacious building has several areas for

small informal gatherings, six conference rooms (two with video-conferencing), a larger seminar room equipped for videoconferencing, and a lunch/break room with access to one of two exterior courtyard areas. CINT scientists employed by Sandia and Los Alamos, technologists, students, postdocs, and visiting scientists from universities, government research institutions, and industry are assigned to the Core Facility.

Figure 1.4. The CINT Gateway Facility

The Gateway to Los Alamos Facility, Figure 1.4, is located on the Los Alamos campus, providing the user community direct access to nanoscale materials science and bioscience capabilities. It is located in the center of LANL's materials science complex, which is in the open security environment and enables easy access to existing nanoscale materials science, chemistry and bioscience resources. Traditionally, materials science, chemistry, and bioscience have been viewed as separate activities and are housed primarily in separate parts of the Laboratory campus. The Gateway to Los Alamos provides CINT users with a unique research environment that combines these three major capabilities and expertise under one roof, surrounded by supporting resources accessible to CINT users.

The Gateway Facility is a 36,500-square-foot building that contains office, meeting, and scientific interaction spaces to support staff from CINT and the Laboratory's bioscience, chemistry, theory, and materials science/physics communities, external CINT users, and visitors. Included are 30 offices that house ~60 occupants, one conference room, and one larger seminar room, both with video-conference capabilities, permitting frequent joint meetings and seminars with scientific colleagues at CINT's Core Facility. The Gateway facility features roughly 11,000 square feet of laboratory space (Figure 1.5) dedicated to chemical and biological synthesis and characterization, biomaterials fabrication and characterization, optical microcopy and spectroscopy, physical synthesis, thin film deposition, and nanoscale imaging and scanned probes.

The major CINT capabilities (described in Section 2) embody not only the unique CINT scientific staff expertise but also suites of instrumentation located in our two facilities. Early in the CINT project design phase, scientific teams identified and prioritized major capital equipment to be procured during the construction project and located at each facility. This unified planning and subsequent location of specific instruments at each site are factors that enabled CINT to operate as one research center, fully exploiting the surrounding infrastructure of Los Alamos and Sandia National Laboratories.

The major CINT capabilities and associated significant instrumentation are:

- Synthesis of Nano-Particles, Tubes & Wires
  - Carbon Nanotube Chemistry, Processing and Synthesis
  - Non-blinking quantum dots: Synthesis and application
  - Magnetic Nanoparticle Synthesis
- Growth of Films & Composites
  - Polymeric monolayer systems
  - Epitaxial and nano-composite metal-oxide films
- Molecular Beam Epitaxy
  - Veeco Gen20 Molecular Beam Epitaxy System
  - EPI 1240 Molecular Beam Epitaxy System
- Assembly of Bio-Materials
  - Biomolecular motors synthesis, engineering, and applications

Figure 1.5. CINT User Saumen Chakraborty working in the Bio Suite at the Gateway.

  - Peptideand DNA-based assembly of optical and nanomaterials
- Nano/Micro Fabrication
  - Low-pressure Chemical Vapor Deposition
  - Atomic Layer Deposition System
  - Nanoscribe Metamaterials and Plasmonic nanofabrication
  - Ultrafast Laser System for Rapid Prototyping
- Electron Beam Lithography
  - JEOL JBX-6300FS electron beam lithography system
- Transmission Electron Microscopy
  - FEI Tecnai F30 Transmission Electron Microscope

Figure 1.6. Senator Martin Heinrich using the CINT nanomanipulator at the Core.

- Quantum Transport Measurement
  - Variable and low temperature electronic transport
- Laser-Based Spectroscopies
- Scanning Probes & Imaging
  - Nanomanipulator for construction of nanowire devices
  - Low energy electron microscope (LEEM)
  - Environmental Scanning Electron Microscope
- Nanomechanics
  - Holographic optical trapping and force measurement system
  - Hysitron PI-85 SEM Picoindenter
- Discovery Platforms
  - Electrochemistry of Nanoscale Structures
- Nanostructure Analysis
- Optical Microscopy
  - Multi-Photon Laser Scanning Confocal and Fluorescence Lifetime Imaging Microscope
  - NanoSight LM10-HSB Multi-Parameter Nanoparticle Characterization System
- Theory, Modeling & Simulation
  - Theory and modeling of ac transport in nanostructured materials and devices
  - TRAMONTO code
  - Socorro code
  - Computational modeling of nonlinear optical responses

Environmental, safety, and health (ES&H) responsibilities at the dedicated CINT Facilities are managed under the integrated safety management plans in place at both SNL and LANL. These plans include the management and staff responsibilities, procedures for evaluating risks, training requirements, and appropriate controls to ensure compliance with safe practices. Copies of the established ES&H policies and procedures for SNL (which has institutional ES&H responsibility for the Core Facility and the Gateway to Sandia Facility) and LANL (which has institutional ES&H responsibility for the Gateway to Los Alamos Facility) are available for review.

The clear, unambiguous, and integrated line of management responsibility for ES&H at CINT begins with an ES&H coordinator at each CINT Facility. The ES&H coordinators are qualified individuals with ES&H

background, training, and certification. They have full authority to oversee the implementation of the Integrated Safety Management Process at CINT and to stop and/or pause any user program activity at any time for ES&H reasons.

CINT users comply with the training requirements for every capability needed to perform the approved user project. Whenever possible, web-based training is offered in advance of arrival at CINT. On-site training is scheduled by the CINT visit facilitators at each location and provided by the responsible CINT scientists or qualified technologists. User training is linked with the user access control (CINT visitor badges) to ensure that untrained personnel cannot gain unauthorized access to CINT laboratories. By virtue of being jointly operated, CINT has a unique opportunity to identify and implement ES&H "best practices." CINT is actively coordinating the training requirements at LANL and SNL to avoid redundant requirements for users.

The laboratory-specific procedures for user operations in the two facilities are contained in the CINT Project documentation. Briefly, these procedures begin with the description of the scope of work in the specific laboratory, assessment of the risks, development of standard operating procedures to accomplish the work, identification of necessary training to perform the work safely and properly, implementation of the training and work processes, and periodic evaluations to verify compliance and seek opportunities of improvement. The overall process is documented at both SNL and LANL with electronic (database) and local (on-site) records and management tools.

1.b Management structure

CINT is jointly operated by Los Alamos and Sandia National Laboratories. Figure 1.7 shows the CINT management structure. The operating structure, the roles and responsibilities of the principal leaders, and the basis for joint operation of the CINT program are codified in a Memorandum of Understanding (MOU) signed by the directors of each Laboratory. This institutional commitment is reflected in the true integration of LANL and SNL personnel throughout the CINT organizational structure and functional groupings described below. CINT's operational vision is to be a "single user facility with two sites."

A short description of the major elements in our structure, as defined by the original CINT MOU (see Appendix 1-A) and amended recently, is given below. Figure 1.8 indicates the organizational structure of CINT within each of the host laboratories—Sandia (Figure 1.8a) and Los Alamos (Figure 1.8b).

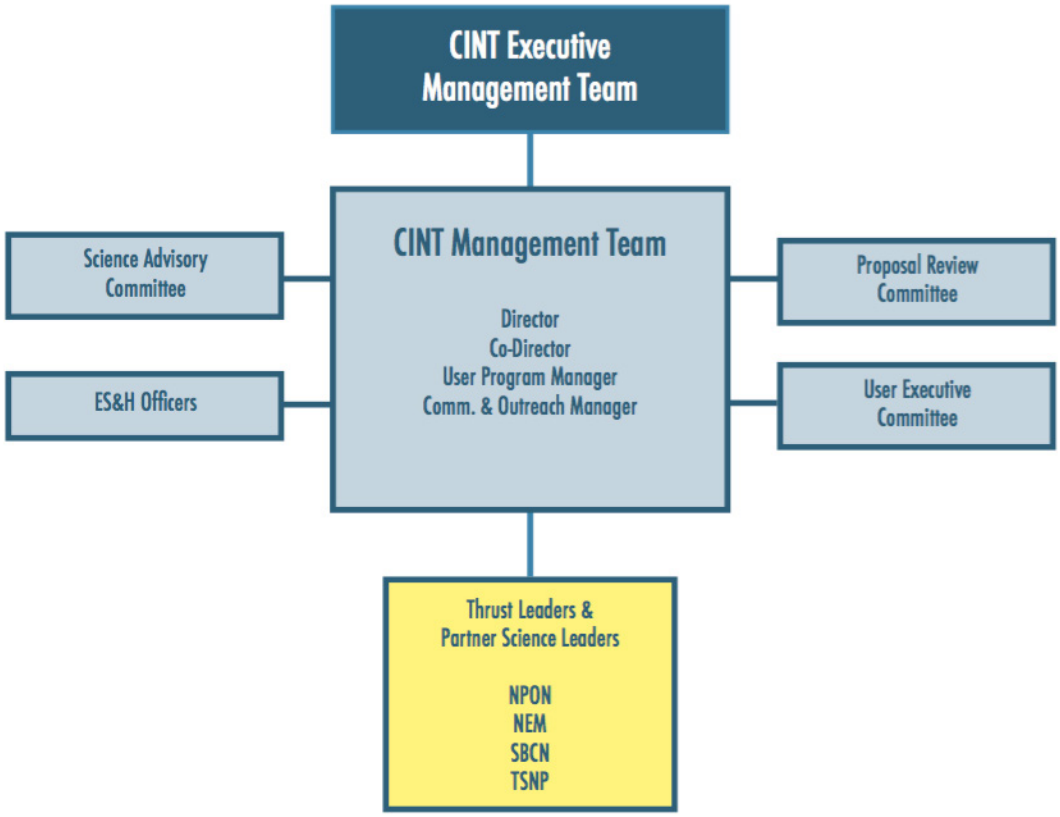


Figure 1.7 CINT Management Structure

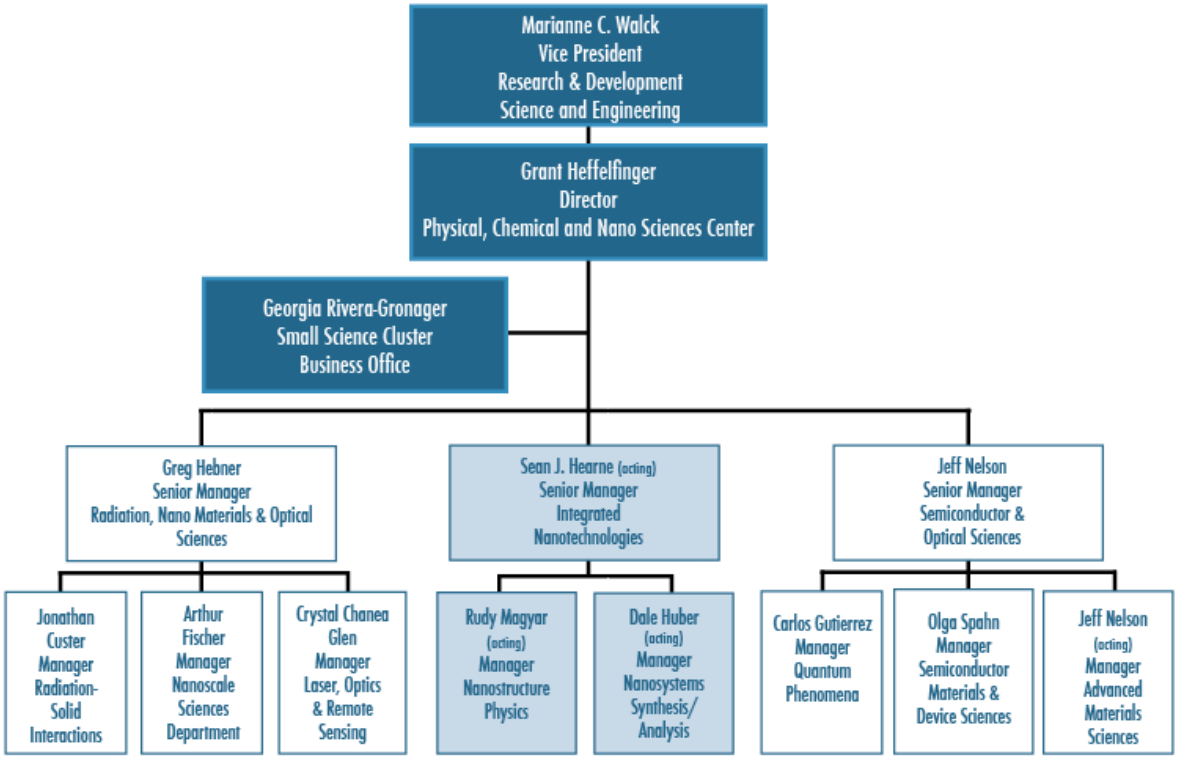


Figure 1.8a Sandia National Laboratory Management Structure

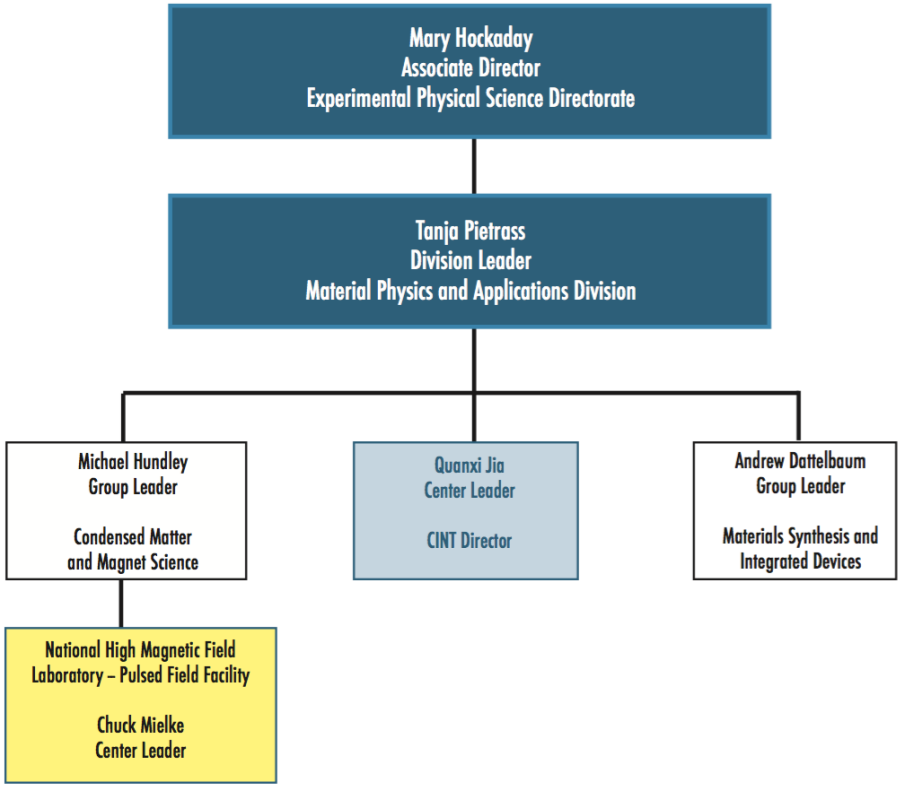


Figure 1.8b Los Alamos National Laboratory Management Structure

CINT Executive Management Team – The Executive Management Team (EMT) is composed of senior leaders from each Laboratory (Mary Hockaday, Associate Director for Experimental Physical Sciences, and Tanja Pietrass, Director for Materials Physics and Applications Division at Los Alamos; and Marianne Walck, Sandia Vice President for Research & Development Science and Engineering, and Grant Heffelfinger, Director of the Physical, Chemical and Nano Sciences Center at Sandia). The EMT has full authority to oversee the operation of CINT, including the approval of bylaws and the appointment of management, user policy, and scientific directions.

The CINT Leadership Team includes the Program Management Team (PMT), which provides overall leadership and management for all aspects of the Center, and the Thrust Leaders and Partner Science Leaders, who (with the PMT) ensure the highest quality science program for the Center.

CINT Program Management Team (PMT) – The CINT PMT is responsible for leading a strong scientific program whose highest priority is to meet or exceed the expectations of the Office of Basic Energy Sciences. Simultaneously, the PMT is responsible for building and nurturing a strategic partnership between the two national laboratory partners. The partnership must recognize and couple to the strategic interests of each partner. CINT's core mission is as a BES user facility in support of fundamental science. In addition, CINT will maximize its impact by translating the fundamental science results supported by BES to mission impact by capitalizing on opportunities through other sponsors. These requirements dictate that the leadership of CINT be shared between the two laboratories. The most senior level leadership responsibilities and accountabilities within CINT's PMT are vested in the director and co-director. The director chairs the PMT. The co-director serves as co-chair of the PMT and acts for the director in his/her absence.

The Program Management Team includes the CINT director (Quanxi Jia, LANL), CINT co-director, Acting (Sean J. Hearne, SNL), the user program manager (Heather Brown, SNL), and the communications and outreach manager (Antonya Sanders, LANL). The principal responsibilities of each team member are

- Director: overall success of CINT and interface to DOE and EMT;
- Co-Director: internal operation of CINT and interface to the Science Advisory Committee;
- User Program Manager: interface to user community; and
- Communications and Outreach Manager: management of all communications and community outreach tools.

The PMT meets weekly to discuss CINT management issues. Minutes are taken at this meeting, along with action items that are tracked.

Thrust Leaders – The CINT thrust leaders are laboratory scientists at either LANL or SNL whose primary responsibility is to ensure the success of a major scientific thrust pursued by CINT. Thrust leaders work closely with the PMT and CINT scientists to guide scientific directions for CINT. The thrust leaders are:

- Nanoscale Electronics and Mechanics (NEM): Brian Swartzentruber
- Soft, Biological, and Composite Nanomaterials (SBCN): Millie Firestone
- Nanophotonics and Optical Nanomaterials (NPON): Steve Doorn
- Theory and Simulation of Nanoscale Phenomena (TSNP): Gary Grest

Partner Science Leaders – The CINT partner science leaders serve as the complementary primary points-of-contact for each thrust at the opposite host Lab of the thrust leader. They also have the lead in working with the UEC to organize the annual user workshop. The partner science leaders are:

- Nanoscale Electronics and Mechanics (NEM): Nathan Mara
- Soft, Biological and Composite Nanomaterials (SBCN): George Bachand
- Nanophotonics and Optical Nanomaterials (NPON): Igal Brener
- Theory and Simulation of Nanoscale Phenomena (TSNP): Jianxin Zhu

CINT Scientists – The CINT scientists are laboratory scientists at either LANL or SNL who provide capabilities (expertise, hardware, software) to CINT users and also conduct original nanoscience research to ensure that CINT is at the intellectual forefront of discovery science.

CINT Technologists – These are laboratory technologists/technicians who support CINT capabilities and work with CINT users to perform approved user projects.

Environmental, Safety, and Health Officers – ES&H is a top priority for CINT. Each facility has an ES&H officer (Seth Nelson at the Core facility and Betsy Grindstaff at the Gateway facility) who is primarily responsible for leading the ES&H programs within CINT and coordinating the activities with the host laboratory programs. These officers also represent CINT on the NSRC ES&H committee and work directly with the SC ES&H officer to continue the work in defining best practices in the processing and handling of nanomaterials.

Scientific Advisory Committee – The Scientific Advisory Committee (SAC) is composed of external scientists and is chartered with evaluating scientific programs, providing advice on future science directions and infrastructure needs, evaluating user facility operations, and ensuring that CINT maintains a highly effective user program. The current leadership of the SAC includes Chair Tony Heinz of Stanford University and Co-Chair Julia Fulghum of the University of New Mexico.

Proposal Review Committee – The Proposal Review Committee (PRC) is composed primarily of external (to LANL and SNL) scientists charged with evaluating the technical quality of user proposals. A small number of LANL and SNL scientists with technical expertise in the areas covered by CINT, but with no direct connection to the CINT user or scientific program, are also on the PRC to facilitate the review of a few expedited user proposals submitted outside the normal review cycle.

User Executive Committee – This committee is formed from CINT users and reports to the CINT PMT concerning the effectiveness of the CINT user program and facilities and the quality of the on-site user environment. The current chair of the UEC is Don Lucca of Oklahoma State University.

1.c Staffing Details and FY 15 Funding Levels

		FY -- Funding (%)[a]					
CINT Staff	Role	CINT Program	Other BES	Other DOE	LDRD	Work for Others	Indirect
Shinn, Neal	Director						100
Jia, Quanxi	Co-Director						100
Brown, Heather	User Program Mgr.	100					
Sanders, Antonya	Comm & Outrch Mgr.	50					50
Brener, Igal	Thrust Leader	70	15		15		
Firestone, Millie	Thrust Leader	65		5	30		
Grest, Gary	Thrust Leader	75			25		
Swartzentruber, Brian	Thrust Leader	80			20		
Bachand, George	Partner Science Lead	60	30		10		
Doorn, Steve	Partner Science Lead	50			50		
Mara, Nate	Partner Science Lead	60	15	5	20		
Zhu, Jianxin	Partner Science Lead	55	5	15	25		
Camacho, Ryan	CINT Scientist	25			70	5	
Chen, HouTong	CINT Scientist	45			55		
Efimov, Anatoly	CINT Scientist	65			15	10	
Frischknecht, Amalie	CINT Scientist	50	30		15		5
Goodwin, Peter	CINT Scientist	50		25	25		
Harris, Tom	CINT Scientist	70	30				
Hollingsworth, Jen	CINT Scientist	50	20		30		
Htoon, Han	CINT Scientist	55	20		25		
Huber, Dale	CINT Scientist	70	10				20
Ivanov, Sergei	CINT Scientist	60			40		
Jungjohann, Katie	CINT Scientist	50	50				
Lilly, Mike	CINT Scientist	20				80	
Luk, TS Willie	CINT Scientist	50	20		30		
Martinez, Jen	CINT Scientist	50			40	10	
Modine, Normand	CINT Scientist	40		30	30		
Montano, Gabe	CINT Scientist	50	10		35	5	
Nogan, John	CINT Scientist	100					
Paxton, Wally	CINT Scientist	50	10		20	20	
Prasankumar, Rohit	CINT Scientist	40	20		40		
Reno, John	CINT Scientist	50	10		20		
Stevens, Mark	CINT Scientist	50	25		25		

		FY -- Funding (%)[a]					
CINT Staff	Role	CINT Program	Other BES	Other DOE	LDRD	Work for Others	Indirect
Tretiak, Sergei	CINT Scientist	45			55		
Trugman, Stuart	CINT Scientist	50	5		45		
Werner, Jim	CINT Scientist	50			20	30	
Yoo, Jinkyoung	CINT Scientist	60			35	5	
Baldwin, Kevin	Technologist	55	10		35		
Dowden, Paul	Technologist	50			40		10
Hance, Bradley	Technologist	70					30
Hargett, Terry	Technologist	100					
James, Tony	Technologist	100					
Lang, David	Technologist	100					
Lucero, Joseph	Technologist	100					
McCulloch, Quinn	Technologist	40			50		10
Pete, Doug	Technologist	100					
Phipps, Lisa	Technologist	100					
Sheehan, Chris	Technologist	100					
Webb, Denise	Technologist	100					
Williams, Darrick	Technologist	100					
Campione, Salvatore	Postdoc	50	50				
Dawood, Farah	Postdoc	50			20		
Delker, Collin	Postdoc	100					
Frank, Ian	Postdoc	10			10	80	
Hartmann, Nicolai	Postdoc	50			50		
Hayden, Steven	Postdoc	100					
Henderson, Ian	Postdoc	90	10				
Keller, Aaron	Postdoc	25			50		
Leenheer, Andrew	Postdoc	90		10			
Lin, Yung-Chen	Postdoc	40			25	15	
Ma, Xuedan	Postdoc	40	40				
Magurudeniya, Harsha	Postdoc	35					
Pathak, Sid	Postdoc	50	5	45			
Pramanik, Rajib	Postdoc	85			15		
Salerno, Kenneth	Postdoc	70			20	10	
Simocko, Chester	Postdoc	20	80				
Singh, Akhilesh	Postdoc	50			50		

		FY -- Funding (%)[a]					
CINT Staff	Role	CINT Program	Other BES	Other DOE	LDRD	Work for Others	Indirect
Tomes, Matthew	Postdoc	40					
Vandelinder, Virginia	Postdoc	40	10		30		
Wang, Feng	Postdoc	50	50				
Watt, John	Postdoc	70	10		20		
Wolf, Omri	Postdoc	60	20		20		
Yang, Yuanmu	Postdoc	10	10				
Cartwright, Anthony	Technical Student	25			25		
Martinez, Ricardo	Technical Student	50			30		
Swingle, Kirstie	Technical Student	65	20				
Grindstaff, Betsy	ES&H						100
Nelson, Seth	ES&H						100
Li, Nan	Scientist/Support	15	15		70		
Mook, Bill	Scientist/Support	100					
Ohta, Taisuke	Scientist/Support	20			70	10	
Rocha, Reg	Scientist/Support	25		25	50		
Subramania, G.	Scientist/Support	20	10		40	30	
Chavez, Linda	User Program Staff	40					60
Gorman, Anna	Financial Analyst	50					50
Capener, Kayla	Admin Support						100
Madrid, Edith	Admin Support						100
Parsons, Corey	Admin Support	100					
Vanderburg, Jessica	Admin Support						100
Flores, Amanda	Admin Student	80					
May, Mackenzie	Admin Student	60					
Morris, SongLi	Admin Student	10					
Phillips, Emma	Admin Student	30					5

[a] Individual FY15 funding levels that sum to less than 100% reflect employment in CINT for less than a full year.

1.d User Meetings and Workshops

Figure 1.9. NSRC Directors and Program Manager hosted a symposium at the American Chemical Society Meeting.

The ambitious vision of a Nanoscale Science Research Center includes not only a user facility with advanced capabilities but also a community of researchers—users and facility staff—working together to provide scientific leadership to the nation and beyond. To this end, CINT continues to build its scientific community via technical meetings related to nanoscience integration.

In the current fiscal environment, it is imperative to leverage existing platforms to reach a broad community of researchers. CINT and the other NSRC facilities have worked closely with well-established national meetings to organize symposia sessions that highlight CINT research at the national level. The NSRCs have also started holding joint workshops to expose the various levels of research and user projects that are ongoing at the five centers. These exchanges of information have provided the staff at the NSRCs with the opportunity to learn about topics/thrusts in nanoscience at the other centers and to develop an understanding of the different areas of expertise among the staff members.

In the following list, we acknowledge recent conferences, workshops, and symposia co-organized by CINT staff and users. Summaries of the CINT user meetings and selected national meeting symposia and joint NSRC workshops are presented below. Additional program information for these events is given in Appendix 1-E.

Meetings/Symposia Organized

1. G.B. Montano, Symposium Organizer "Communication, Negotiation and Collaboration: Prepare for Your Future in a STEM Career", SACNAS, , Santa Fe Community College, Saturday, Sept 26, 2015
2. H.-T. Chen, Technical Program Committee, "The 40th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz-2015)," Hong Kong, China, Aug. 23 – 28, 2015.
3. H.-T. Chen, Organizing Sub-Committee, "OSA Optical Sensors", Boston, MA, Jun. 27 – Jul. 1, 2015.
4. H.-T. Chen, Workshop Organizer, "The 6th International Workshop on Electromagnetic Metamaterials," Santa Fe, NM, Sept. 22 – 23, 2014.
5. H.-T. Chen, International Advisory Committee, "The 39th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz-2014)," Sept. 14 – 19, 2014.
6. I. Brener, Organizer, Symposium at CLEO 2013, San Francisco, CA, 2013.
7. I. Brener, Organizer, IWEM 2014, Santa Fe, NM, 2014.
8. I. Brener, Technical Committee, SPIE Optics and Photonics, San Diego, CA, 2013, 2014, 2015.
9. I. Brener, Technical Committee, Nanometa, Seefeld, Austria, 2013.
10. I. Brener, Technical Committee, SPIE Europe, 2013, 2014, 2015.
11. I. Brener, Technical Committee, Surface Plasmon Photonics, Jerusalem, Israel, 2015.
12. I. Brener, Technical Committee, Metamorphose, Copenhagen, Denmark, 2014.
13. J.H. Werner, Co-organizer, Joint NSRC Workshop on Big, Deep, and Smart Data Analytics in Materials Imaging, Oak Ridge National Laboratory, June 8-10, 2015.
14. J.S. Martinez, Conference Organizer "Advanced Qualification of Additive Manufacturing Materials" Santa Fe, NM July 2015

15. J.S. Martinez, Symposium Organizer "Nanoscience in Global Security" Los Alamos, NM, October 2014
16. K.L. Jungjohann, Workshop Organizer, "In Situ Electrochemical Electron Microscopy," Sponsored by the Joint Center for Energy Storage Research, Argonne, IL, June 2, 2014.
17. N. Mara, Co-organizer, "Mechanical Behavior Related to Interface Physics II" 2014 TMS annual meeting symposium, 2014.
18. N. Mara, Co-organizer, "Multiscale Perspectives on Plasticity in BCC Metals" 2013 MS&T meeting symposium, 2013.
19. N. Mara, Co-organizer, "Modeling and Experimental Validation of Multiscale Mechanical Behavior from Atomic Scale to Macro Scale" 2013 TMS annual meeting symposium, 2013.
20. N. Mara, Organizer of Honorary Symposium at Plasticity 2014 for Professor Amiya Mukherjee 2014.
21. N. Mara, Co-organizer, LANL Global Security-Nanomaterials Deep Dive, 2014.
22. N. Mara, Conference Co-organizer "Advanced Qualification of Additive Manufacturing Materials", Santa Fe, NM, 2015.
23. N. Mara, Co-organizer, "Real-time imaging od controlled nanoscale phenomena using S/TEM" CINT user workshop symposium, 2015.
24. N. Mara, Organizer, "Nanomechanical Response of Composite, Complex, and Thin Film Structures" CINT user workshop symposium, 2014.
25. Q. X. Jia, Organizing committee, Electronic Materials and Applications 2013, Orlando, FL, Jan. 23 - 25, 2013.
26. Q. X. Jia, Symposium Organizer, "Recent Developments in High Temperature Superconductivity," Electronic Materials and Applications 2013, Orlando, FL, Jan. 23 - 25, 2013.
27. Q. X. Jia, Symposium Organizer, "Solution Synthesis of Inorganic Functional Materials – Films, Nanoparticles, and Nanocomposites," MRS 2013 Spring Meeting, San Francisco, CA, April 1 - 5, 2013.
28. Q. X. Jia, Symposium Organizer, "Recent Developments in High Temperature Superconductivity," Electronic Materials and Applications 2014, Orlando, FL, Jan. 22 - 24, 2014.
29. Q. X. Jia, Symposium Organizer, "Solution Synthesis of Inorganic Functional Materials," MRS 2014 Spring Meeting, San Francisco, CA, April 21 - 25, 2014.
30. Q. X. Jia, Organizing Committee, Mesoscale Science Frontiers, 34th CNLS Annual Conference, Santa Fe, NM, May 13 - 16, 2014.
31. Q. X. Jia, Symposium Organizer, "Multifunctional Oxides," Materials Science & Technology 2014 Conf. & Exhibition (MS&T'14), Pittsburgh, PA, Oct. 12 - 16, 2014.
32. Q. X. Jia, Program Advisory Committee, Quantum Matter Workshop, Santa Fe, NM, May 18 - 21, 2015.
33. Q. X. Jia, International Advisory Board, XVIII International Sol-Gel Conf., Kyoto, Japan, Sept. 6 - 11, 2015.
34. Q. X. Jia, Symposium Organizer, "Multifunctional Oxides," Materials Science & Technology 2015 Conf. & Exhibition (MS&T'15), Columbus, OH, Oct. 4 - 8, 2015.
35. S. Tretiak, Co-organizer Multidisciplinary Program Planning Group on "Computational Materials and Nanoscience: Theory meets experiment" for the 251st ACS National Meeting, San Diego, CA, March 2016.
36. S. Tretiak, Co-organize, "Frontiers in Solar Light Harvesting Processes" for the 251 ACS National Meeting, San Diego, CA, March 2016.
37. S. Tretiak, Co-organizer, 2016 Mesilla Chemistry Workshop on "Electrochemical Processes: Photovoltaics and Charge Transfer in Nanomaterials" Mesilla, New Mexico, USA, January, 2016.

38. S. Tretiak, Organizer, "Modeling and Analyzing Exciton and Charge Dynamics in Molecules and Clusters" for the International Chemical Congress of Pacific Basin Societies conference (Pacifichem 2015), Honolulu, Hawaii, December, 2015.
39. S. Tretiak, Co-organizer of the session "Physical Chemistry of Interfaces and Nanomaterials" for the SPIE NanoScience and Engineering conference, San Diego, CA, 2013, 2014, 2015, 2016.
40. S. Tretiak, Organizer, conference series in the Center for Nonlinear Studies at Los Alamos National Laboratory: "Excited State Processes in Electronic and Bio Nanomaterials (ESP)", 2014, 2016.
41. S. Tretiak, Co-organizer, Telluride workshop:"Nonequilibrium Phenomena, Nonadiabatic Dynamics and Spectroscopy", Telluride, CO, 2013, 2015.
42. S. Tretiak, Co-organizer, International Conference on "Organic Solar Cells: Theory and Experiment, From Description to Prediction" (OPV-2013), Santa Fe, NM, May 2013.
43. S.K. Doorn, Symposium Organizer, 2014 Conf. & Exhibition (MS&T'14), Pittsburgh, PA, Oct. 12 - 16, 2014.
44. S.K. Doorn, Symposium Organizer, Symposium on Carbon Nanotubes and Nanostructures: Fundamental Properties and Processes, 223rd Electrochemical Society Meeting, Toronto, May 2013.
45. S.K. Doorn, Primary organizer, WONTON 2013: 5th International Workshop on Nanotube Optics and Nanospectroscopy, Santa Fe, June 2013.
46. S.K. Doorn, Symposium Organizer, "Carbon Nanotubes and Nanostructures: Fundamental Properties and Processes", 225th Electrochemical Society Meeting, Orlando, May 2014.
47. S.K. Doorn, Advisory Committee, NT14: Fifteenth International Conference on the Science and Applications of Carbon Nanotubes, Los Angeles, June 2014.
48. S.K. Doorn, Symposium Organizer, "Carbon Nanostructures for Energy Conversion", 227th Electrochemical Society Meeting, Chicago, May 2015.
49. S.K. Doorn, Symposium Organizer, "Carbon Nanotubes: From Fundamentals to Devices", 227th Electrochemical Society Meeting, Chicago, May 2015.
50. S.K. Doorn, Advisory Committee, NT15: Sixteenth International Conference on the Science and Applications of Carbon Nanotubes, Nagoya, Japan, June 2015.
51. S.K. Doorn, Symposium Organizer, "Hybrid Photonic Materials Interactions for Integration and Novel Response", CINT Annual User Conference, Santa Fe, Sept. 2015.
52. W.F. Paxton, Symposium Organizer, "Bioinspired Micro- and Nano-Machines and Devices-Challenges and Perspectives", MRS 2015 Spring Meeting, San Francisco, CA, April 6 - 10, 2015.
53. W. F. Paxton, Workshop Organizer, "International Workshop on Micro- and Nanomachines," Volkswagen Foundation, Hannover, Germany, July 2-4, 2014
54. W. F. Paxton, Symposium Organizer, "Nanomotors & Molecular Machines: Understanding and Controlling the Catalytic Transport of Matter," 2015 CINT User Meeting, Santa Fe, NM, September 21-22, 2015
55. W. F. Paxton, Workshop Organizer, "International Workshop on Micro- and Nanomachines," Volkswagen Foundation, Hannover, Germany, June 29-July 1, 2016
56. R. Prasankumar, NSRC Nanophotonics Symposium, part of CLEO/QELS 2013
57. R. Prasankumar, Quantum and Dirac Materials for Energy Applications Conference, 2015
58. R. Prasankumar, Ultrafast Dynamics in Complex Functional Materials, symposium WW in MRS Spring Meeting, 2015
59. R. Prasankumar, International Year of Light Event, University of New Mexico, 2015

1.d.1 Summary of Annual CINT User Meetings

Each year, CINT and the UEC jointly organize a user meeting to highlight recent CINT user/staff research results, explore new scientific opportunities, and inform attendees about CINT capabilities and future plans. Meeting agendas and symposia synopses are provided in Appendix 1-E.

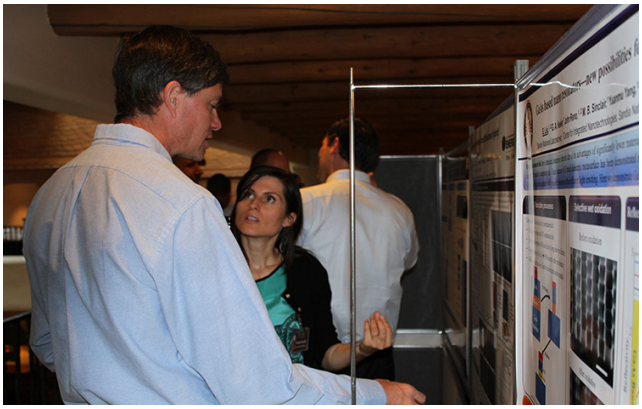


Figure 1.10. CINT User Enkeleda Dervishi discusses her research with CINT Scientist Steve Doorn at a User Meeting poster sesion.

In 2013, the user meeting attracted 145 registered participants from 26 universities, 3 industries, and 6 government agencies and laboratories. Three plenary presentations opened up the conference, beginning with Zhenan Bao (Stanford University), then Ichiro Takeuchi (University of Maryland), followed by Axel Scherer (California Institute of Technology). Continuing with our tradition of science symposia around active areas of user projects and research at CINT, three concurrent symposia were held during the event; (1) Dynamics of Soft and Biological Nanocomposites: Manipulation and Integration, (2) Complex Metal Oxides and Unconventional, and (3) Light emission and interaction with Si and Ge nanostructures. A poster session with contributions from users and CINT scientists was also held at the conference. The programmable Membrane Nanocomposite Integration Focus Area (IFA) held a satellite workshop before the 2013 CINT User Conference focused on "Membrane Nanocomposites and Materials Synthesis." Guest speakers included Dr. Michael Therien and Dr. Gabriel Lopez, both of Duke University; Dr. Richard Vaia of the Air Force Research Laboratory; Dr. Vincent Rotello of the University of Massachusetts Amherst; and Dr. Alfredo Alexander-Katz of the Massachusetts Institute of Technology.

In 2014, the user meeting hosted 202 registered participants from 48 universities, 4 industries, and 5 government agencies and laboratories. The meeting was held in conjunction with the Sixth International Workshop on Electromagnetic Metamaterials (IWEM-VI) organized by CINT scientists Igal Brener and Hou-tong Chen. Plenary speakers included William Gerberich (University of Minnesota), Federico Capasso (Harvard University), and Michael Rubinstein (University of North Carolina). Three parallel symposia were held during the event: Technical Symposium I: Sixth International Workshop on Electromagnetic Metamaterials (IWEM-VI); Technical Symposium II: Nanostructure in Polymers; and Technical Symposium III: Nanomechanical Response of Composite, Complex, and Thin Structures.

Figure 1.11. CINT User Meeting plenary session.

The 2015 user meeting opened up with three plenary presentations: Ian Robertson (University of Wisconsin-Madison), Carlo Montemagno (Alberta Ingenuity Laboratory), and Claus Ropers (University of Göttingen). Three parallel symposia were held during the event: Technical Symposium I: Real-Time Imaging of Controlled Nanoscale Phenomena Using S/TEM; Technical Symposium II: Hybrid Photonic Materials Interactions for Integration and Novel Response; and Technical Symposia III: Nanomotors & Molecular Machines: Understanding and Controlling the Catalytic Transport of Matter. A poster session with contributions from 40 users and CINT scientists was also held at the conference.

1.d.2 Outreach and Communications Activities

In pursuit of CINT's vision to bring together researchers to propose, design, and explore the integration of new nanoscale materials into novel architectures and microsystems, CINT has created an outreach program with four primary goals:

1. To increase CINT's brand recognition among peers
2. To recruit a vibrant user community, including industry
3. To enhance interactions among our external and internal (LANL and SNL) communities, and
4. To share our commitment to nanoscience integration through educational outreach.

Through these goals, we strive to reach a diverse audience, continually maturing from traditional methods to electronic real-time communications and outreach.

Figure 1.11. CINT graduate student Christina Hanson demonstrating chemiluminescence found in spinach and lifesavers to students at Santa Fe High School.

As a highly visible BES-sponsored nanoscience center, CINT has a responsibility to contribute to the most in-depth understanding of nanoscience/nanotechnology—its promise and risks—by the general public. CINT staff and management are often asked to speak to audiences of varying educational levels and interests. A sampling of these events includes Los Alamos High School, Santa Fe High School, Los Alamos Middle School, Rotary Clubs of New Mexico, Nano Days at the Bradbury Science Museum, Albuquerque Economic Development, UNM's Art of Systems Biology and Nanoscience, and Sandia's Technology Showcase.

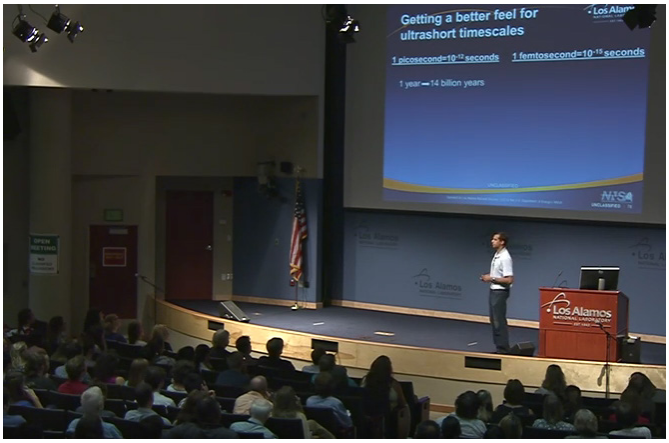


Figure 1.12. CINT Scientist Rohit Prasankumar delivering a TEDx talk titled "Ultrafast Science - Quicker than the blink of an eye."

CINT holds a constant presence on social media. With more than 1000 followers, the Facebook page is where the CINT office, staff, users, and external nano enthusiasts can share articles and media stories of nanoscience. We also advertise the facility, our highlights, and user calls on Facebook. In addition, CINT has capability and highlight videos on YouTube, a discussion panel on LinkedIn, and Rohit Prasankumar has given two TEDx talks about nanoscience and ultrafast spectroscopy.

In 2015, an NBC Nightly News film crew came to LANL and interviewed Jennifer Hollingsworth and her team regarding the potential for nanoscience to change cancer detection and treatment. The video produced can be viewed here.

We have also just finished an update to the 2013 CINT exhibit at LANL's Bradbury Science Museum, which is open to the public and receives roughly 75,000 people per year. This is a permanent exhibit with an expected lifetime of ~10 years. The exhibit teaches visitors about the user facility in general, nanoscience integration and how it takes many disciplines to tackle a challenge, some of the unique properties at the nanoscale, and some potential energy applications from work being done at CINT. We focus on two industrial user projects that are working their way into being publicly available: one on tackling cancer detection with nanoparticles and the other is an inexpensive, portable anthrax detector.

Beyond the general public, we are aware of the need to have communications that express our science to an audience that is knowledgeable but may not have a higher degree in a technical field.

In 2012, CINT organized a working group to create a joint NSRC capabilities website. Working together, the NSRCs jointly converged on a set of capability basis vectors consisting of synthesis, fabrication, characterization and theory techniques. From this list, CINT led the design, message, and creation of the NSRC Capabilities Portal, https://nsrcportal.sandia.gov. This website allows potential users to search for a specific capability across the NSRCs. Along with assisting users to find the best facility for their research, it helps differentiate the NSRCs, showing the strengths and specializations of each Center. The capabilities listed are not only based on equipment, but significant capability descriptions are based on the expertise of the NSRC scientists.

CINT science was selected as demonstration presenters at the 2015 and 2016 DOE National Laboratory Day events. In 2015, a CINT user from Senior Scientific LLC represented CINT, demonstrating cancer diagnosis techniques using CINT's nanoparticles. In April 2016, CINT research on the use of giant quantum dots for lighting applications will be demonstrated. (The event is in preparation as of the submission of this document.) CINT is also an active member of the National User Facility Organization (NUFO), which has hosted annual meetings for user program staff to benchmark and learn best practices and an annual exhibition on Capitol Hill. At the exhibition, CINT representatives presented posters and discussed the work of CINT and the NSRCs with Congress members and staffers, often explaining the benefits of CINT and the NSRCs to their various constituents.

Figure 1.13. CINT Industrial User Erica Vreeland discussing her user project on cancer detection with Energy Secretary Moniz at DOE National Lab Day in 2015.

Effectively communicating the impact of the science at CINT and publicizing the capabilities and expertise available to prospective users requires more than a presence at the conferences and meetings reported above. Our staff and management frequently give CINT overview presentations to external audiences (See section 4f) and brief visiting delegations to LANL and SNL from dozens of universities and companies.

Based on feedback to increase the interaction with industry, we recently started the CINT Industrial Seminar Series. The intent of the series is for CINT staff and available users to learn about nanoscience research needs in industry. The first industrial leader was Dr. Michele Ostraat, Downstream Research Center Leader for Aramco Research Center in Boston. She gave a seminar titled "Global-Scale Concerns, Nano-Scale Solutions: Leveraging nanotechnology to address complex materials challenges in the oil and gas industry." Her talk focused on the need for materials applications related to corrosion, catalysis, and membranes for gas separation. Dr Ostraat also toured some of our labs and met with numerous CINT scientists to learn about our capabilities. Through this interaction, Aramco Research Center has already submitted one user proposal, and another is in progress. We are currently scheduling the next two seminar series speakers from Northrop-Grumman and IBM.

CINT also connects strongly with the student programs at LANL and SNL, providing opportunities for summer students and interns to engage in meaningful research experiences from the brief hands-on demonstration to extended thesis work (see section 4e). Although many of these connections are arranged on an individual staff/student level, CINT does have formalized partnership arrangements with larger Laboratory programs. One such example is with the University of New Mexico Nanoscience and Microsystems Research Experience for Undergraduates (REU) collaboration. The objectives of this interaction are two-fold: (1) STEM undergrads who

are interested in research careers need to learn how to formulate and communicate a research idea; the two-page CINT user proposal (asking not for money but for access to do work) is a relatively painless way for students to learn and practice this skill; and (2) CINT provides capabilities to enable user research; undergrads doing research should enhance their projects by using CINT, if relevant.

Another student program CINT engages in is the DOE Science Undergraduate Laboratory Internships (SULI). Through a competitive interview process between the mentor and the available students, CINT hires one or two SULI students each summer. The SULI program encourages undergraduate students to pursue science, technology, engineering, and mathematics (STEM) careers by providing research experiences under the guidance of a technical staff member.

In the forthcoming years, CINT will continue the outreach program described above and will continue to focus on electronic communication, the overwhelming medium-of-choice for the newest generation of CINT users. Working with our User Executive Committee, we will explore and test mechanisms to engage researchers who would not typically benefit from BES user facilities. Just as the NSRCs are themselves an evolution from the traditional instrument-access user facility model, so too must we adapt our interaction methods with the research community.

1.e Ongoing research and development activities at CINT intended to enhance future capabilities

The development of new capabilities is a foundational part of CINT's user program and vision for advancing the science of nanomaterials integration. There are two major components to enhance our capabilities for users: 1) Discovery Platforms and 2) development and/or acquisition/renovation of unique capabilities for synthesis, fabrication, integration, characterization, and modeling of nanostructured materials. In this section, we briefly describe some representative activities in these areas. Detailed descriptions of broad activities in synthesis, fabrication, integration, characterization, and theory can be found from individual FWPs (NEM, NPON, SBCN, and TSNP).

1.e.1 Discovery Platforms

A Discovery Platform™ is a microfabricated structure or device expressly designed and produced to create or characterize nanostructured materials and components. This might be a complex device with many "experiments" on chip or a relatively simple microfabricated structure that is utilized in conjunction with other laboratory instruments (e.g. an array of metal contacts on a wafer). To facilitate their use by the broadest range of researchers, Discovery Platforms™ are designed for maximum flexibility while remaining optimized for their intended purpose. The potential incorporation of a Discovery Platform into external diagnostic and characterization tools available at CINT is a major design consideration, thereby creating opportunities for an "experiment within an experiment".

The more complex Discovery Platforms leverage the fabrication capabilities of the Microsystems and Engineering Sciences Application (MESA) facility at Sandia National Labs. By working with MESA engineers, we have designed sophisticated structures on silicon wafers that could not be produce at CINT. In developing Discovery Platforms, we take input from users, CINT scientists and MESA engineers in an effort to develop capabilities that would be generically useful to researchers, but not easily fabricated at institutions without a cleanroom or silicon foundry.

At present, CINT is mainly developing and exploiting two Discovery Platforms which are described below. These have been designed and developed by CINT scientists in collaboration with users. These platforms are the Electrochemical TEM Discovery Platform and Liquid-Mechanical Discovery Platform and TEM.

Electrochemical TEM Discovery Platform

Using the Electrochemical Transmission Electron Microscopy (TEM) Discovery Platform (see Figure 1.1), we have successfully demonstrated our impact within the area of electrochemical research in nanomaterial growth and assembly and battery research. We are contributing to the community with both user access to this platform and advanced capabilities for enhanced environmental control within the liquid cell. In comparison to commercial electrochemical TEM cells, we provide the advantages of experimental customization of the electrode materials and layouts, evenly distributed thin liquid layers, 10 individually controlled electrodes for multiple experiments within the same environmental conditions, and low-current control for quantitative analysis of the electrochemical data and the structural and chemical information of nanoscale electrode areas.

Liquid-Mechanical Discovery Platform and TEM

To advance our liquid-cell TEM capabilities, we are integrating mechanical control over a nanoscale wire/thin-film specimen into our Electrochemical TEM Discovery Platform. This is a first-of-its-kind platform for quantitative mechanical loading within a hermetically sealed liquid environment for high-resolution TEM analysis; the platform provides enhanced environmental control over a specimen, including quantitative stress control and electrochemical and elevated temperature control. The platform will be used to study the nanoscale mechanisms of stress-induced failure of electrodes in battery materials, stress-corrosion-cracking, and the mechanical characterization of nanoscale bio-composites.

We are also developing enhanced stage control to manipulate samples within the TEM discovery platforms. Holder designs will be produced in order to lend the stages and platforms out to users for experimental research conducted with these unique CINT capabilities at their home institutions. Dissemination of our resources will broaden the impact of CINT's TEM discovery platforms for use anywhere in the world on compatible JEOL and FEI TEMs.

1.e.2 Synthesis and Integration

Integrated Quantum Materials for Nanoelectronics

Integrated nanostructures offer the promise of exploiting the quantum nature of nanoscale materials, by building hierarchical structures that bridge to the macroscopic world we live in. An example of this is silicon as it is a promising material to study single spin devices with long electron spin lifetimes and coherence time. Single electron devices can reveal new interaction physics, are important for semiconductor quantum computing, and have a variety of interesting quantum effects. In working with the user community CINT has developed techniques to isolate, measure, and control single electron spins in silicon devices. One such device that CINT has offered to its user community is the donor-dot structure. The donor (P, Sb) provide a well-known potential well for holding a single electron and allow coupling to the nuclear spin degree of freedom. Electron spins have lifetimes that exceed seconds, and nuclear spins can have lifetimes longer than 10 minutes. The quantum dots, on the other hand, allow very refined gate control of the electron number and control over the interaction between adjacent surface quantum dots. Quantum dots can also be used to move electrons laterally on the surface for studying transport of coherent spin states. The CINT community has been using this rich capability to study the spin and electron coupling between donors and dot, and develop the base knowledge needed to integrate multiple donor / dot systems together in silicon metal oxide semiconductor, GaAs, SiGe, and STM atomic-scale lithography fabricated nanostructures.

The study of single-electron devices and their integration relies on high purity, low disorder materials. Part of CINT's effort on single-electron nanostructures is focus on improving material characterization, growth and fabrication. At low temperature and energy, all low energy states such as valley states in silicon, valley-orbit coupling, and disorder near the quantum dot can affect single spin behavior. Making integrated nanoelectronics requires significant processing of materials. This processing can result in additional fixed charges near the sensitive single electron regions, e.g., as a result of bombarding the device with charged ions during a dry etch or using atomic layer deposition to make an oxide with a small number of unsatisfied bonds. We are developing characterization methods to identify the largest issues and improve fabrication techniques and material quality to minimize the impact of disorder and low energy states.

Emergent Functionality of Mesoscopic Assemblies

Integration of emitters with dielectric meta-material and photonic crystal structures will be pursued as an alternative means for manipulation of fundamental and quantum optical processes of g-QDs and the defect/dopant states of 1D and 2D systems. We have already achieved successful coupling of g-QDs and oxygen-doped CNTs to Si dielectric meta-material cavities (see Figure 1.14). Results on doped carbon nanotubes have revealed that the cavity can reorient the linearly polarized dipole of the CNT dopant states. Studies on g-QD silicon pillar cavity coupled systems have also demonstrated the light collimation properties of Si pillars, predicted theoretically. In collaborating with our users, we will fabricate doped CNT-photonic crystal coupled structures and investigate their quantum

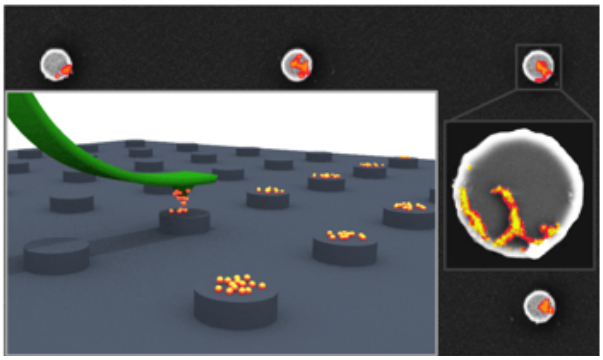


Figure 1.14 Illustration of dip-pen deposition of g-QDs on to individual Si dielectric pillars. SEM images show actual deposition of InPcore/CdSe:CdS shell g-QDs. Deposition is developed for a range of particle sizes from 10 nm to 50 nm.

optical properties. We also plan to integrate these coupled structures into prototype devices to achieve enhanced efficiency and polarization characteristics of single-photon emission in the case of electrically driven single-photon sources and to achieve the strong coupling necessary for photon switching. In addition to these single quantum emitter–photonic coupled structures, we will also study metal nanoparticle-g-QD superlattice arrays fabricated through bio-inspired self-assembly approaches for manifestation of collective phenomena such as plasmon assisted lasing and super-radiance.

Surface Chemistry, Functionalization, and Synthesis of Carbon Nanomaterials

Low-level covalent functionalization of carbon nanotubes to introduce sp3 defects (see Figure 1.15) is reinvigorating the area of nanotube photonics by dramatically improving photoluminescence quantum yields (through exciton trapping at these new defect sites) and introducing new functionality (such as truly correlated receptor/transduction sites for sensing, photon up-conversion, and room-temperature single-photon emission). We will continue to develop functionalization strategies that directly pair dopant sites with desired functionality (such as receptors or redox behavior towards energy harvesting applications). Strategies for increasing trap defect-site depth will be implemented as a route for pushing trap-site emission to telecom wavelengths and increasing the thermal stability of this emission behavior. Synthetic routes to local pairing of coupled dopant sites will also be pursued. Improved matrices are also required for doped tube device integration, as there is a need to move from the polar environment of our solid-state doping approach as a means to further stabilize properties for single-photon emission. New matrices will also enable a wider range of deposition strategies for integration into other photonic device and cavity structures as an enabling route to additional user projects. Through collaborative efforts and user projects, we are initiating the development of novel polymer wrappings compatible with solution-phase doping as a route to incorporate the doped tubes into reduced-polarity polymer matrices. These systems will also directly enable studies aimed at the elucidation of suggested phonon couplings and extending energy-harvesting functionality. Efforts will also continue to integrate CINT graphene synthesis capability with strategies to create hybrid materials. Examples will include efforts toward large-area single domain growth of twisted bilayer materials in which the resulting optical resonances will be tuned to overlap with anticipated induced plasmons arising from integration with g-QDs. We will also advance our large-area graphene synthesis approaches to include single domain methods that will enable generation of twisted bilayers with defined twist angles. These should have interesting resonance behaviors to look for in coupled QD heterostructures. We will continue to work towards graphene integration with nanowire energy storage materials and complex oxides as well.

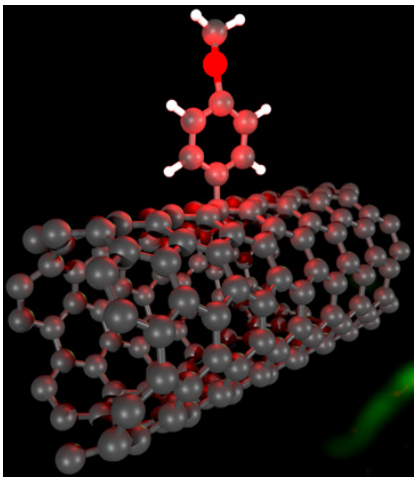


Figure 1.15 Illustration of covalently bound aryl-diazonium dopant intro-ducing an isolated sp3 defect in the carbon nanotube structure.

Hybrid Metamaterials and Metasurfaces for Advanced Functionality and Optical Nonlinearities

There is much recent progress in creating and understanding metasurface structures for manipulating light propagation, polarization conversion, wavefront engineering, and beam forming. While we will continue this important direction through designing novel metasurface structures for integrated photonics, the planar metasurface structures facilitate the integration of functional materials for active control and novel device architecture for improved performance, and the cavity resonances also enable enhanced light-matter interactions, which tremendously magnify the functionality from the integrated materials. We will investigate the photoluminescence, photovoltaics, and photoconductivity of thin-film quantum dots and semiconductors, and 2D van der Waals materials, including graphene, transition metal dichalcogenides, and black phosphorus, when they are integrated within metasurface absorbers. Switchable and frequency-tunable metasurfaces represent an utmost important research direction. We will focus on new switching approaches, device architectures, and functionality, such as graphene metasurface spatial light modulators of interest for multiplexed operation for imaging

and communications. We will also extend our success in metasurface antireflection towards the investigation of nonlinear processes of high-refractive-index materials such as strontium titanate at low temperatures, without which it would be otherwise technically challenging to efficiently couple THz radiation into these ferroelectric materials.

In the area of all-dielectric metasurfaces, recent third-harmonic-generation experiments have shown very high efficiencies when magnetic or electric dipole modes were excited. Creating these metasurfaces (or ultimately, 3D metamaterials) from different materials that possess high intrinsic second-order nonlinearities would allow for new directions in nonlinear optics and a combined generation-manipulation structure for harmonic generation. We have recently established a process to fabricate metasurfaces from AlGaAs-based semiconductors, and preliminary results show record high efficiencies for second-harmonic generation. We will explore other high-index semiconductors and nanofabrication strategies that will allow creation of 2D and 3D dielectric metamaterials at even shorter wavelengths. Further integration of such all-dielectric metamaterials with light-emitting nanostructures (i.e., quantum dots or quantum wells) would allow for exquisite control of the radiative rates in combination with far-field beam-shaping possibilities. The integration of 1D and 2D materials (CNTs, TMD s, etc.) with these all-dielectric metasurfaces will also be explored. In the area of light harvesting, we will explore the use of ENZ modes based on available enhancements that create strong oscillating fields at materials interfaces. This can induce DC currents through a rectification process in homo- or hetero-pn junctions. Experimental demonstration of this phenomenon in a metal-oxide-semiconductor structure using longitudinal optical phonons as the ENZ material was recently published. We plan to use plasmonic ENZ materials (such as In2O3, CdO, and doped InAs) and two-layer pn junction structures to produce this rectification effect. By using hyperbolic metamaterials, both ENZ frequency and mode dispersion can be tuned readily and can dramatically enhance performance through better coupling and broader spectral response.

Several new paths for creating very high Q resonances from all-dielectric metasurfaces have recently been unveiled by us and other groups. We plan on investigating transient phenomena of these new metasurfaces when optically pumped below and above the bandgap of the constituents. We anticipate interesting venues for optical switching since these high Q resonances can be affected by two-photon absorption, creation of electron-hole pairs, and/or transient bandgap renormalization. Devising very high Q resonances for metasurfaces also offers interesting possibilities for chem-bio sensing, and these will be explored in collaboration with our user community.

Multilength scale fluidics for optimized synthesis of nanoparticles

Building on our prior efforts in microfluidics for NP synthesis and real-time characterization, we will work to fabricate and test multilength scale (millimeters to nanometers) fluidic devices. A specific area of investigation during this funding period will be droplet-generating chips used in NP and/or genetically encoded polypeptide synthesis. Efforts in this area have been hampered by the inability to precisely control the size and shape of the small orifices used to generate droplets with sizes ranging from 10 μm to 100 μm. The limitation in small-droplet production arises primarily from restricted flow due to excess backpressure in the channels of reduced dimension (<100 μm). Multiscale fabricated fluidic platforms will offer a means to address this limitation through stepping the internal channel structure/dimensions. A multilength scale fluidic device featuring massively parallel micron to submicron channel structures will also permit tunable flow focusing and systematic variation in droplet sizes and will increase throughput. Traditionally, however, creation of nanoscale or multiscale fluidic structures has required different (and incompatible) fabrication techniques, making it impractical to combine varying length scales into a single device. SBCN's planned efforts for introducing capabilities for 2D and 3D soft matter fabrication will allow us to address this limitation by combining a wide range of length scales into unique single devices. By combining 3D printing, laser cutting, and two-photon nanolithography, we will create features from nanometers to multiple millimeters in a single device. This can be achieved in a number of ways. Nanoscale features will be printed using our planned institutional investment in the Nanoscribe instrument. The Nanoscribe uses a tightly focused laser to perform photolithography in a nanoscopic voxel where the high flux of photons allows the simultaneous absorption of two photons. This allows 3D lithography to be performed at resolutions

that exceed the diffraction limit. The Nanoscribe can conveniently fabricate parts that are nanopatterned (containing, for example, nanoscopic orifices) but micron-scale overall. This allows the parts to be integrated into a microfluidic system that is fabricated using 3D printing and/or laser cutting, and this system can then be integrated into a larger-scale millifluidic device. The coupling of microfluidic parts to millifluidic packages in a simple and convenient approach has been recently demonstrated at CINT (see Figure 1.16). We expect this new capability to enable a wide range of new fluidic approaches to materials synthesis and characterization, allowing unprecedented control and tuning of shear and flow over many orders of magnitude.

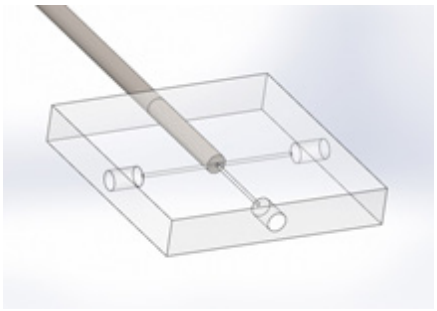


Figure 1.16 3D rendering of the integration of nanoscale- patterned pores/channels into a micro- or millifluidic platform.

1.e.3 Characterization

Novel Spectroscopic Capabilities

A particular strength of CINT is the close interaction between capabilities for materials generation and optical characterization. New materials behaviors drive development of new spectroscopic capability. As one example, a user project requiring correlation of spectroscopic and structural properties of individual g-QDs is driving development of an approach to perform advanced single nanostructure spectroscopies (Raman, PL, time-resolved PL, photon correlation spectroscopy, etc.) and high-resolution scanning electron microscopy (SEM) and transmission electron microscopy (TEM) on the same set of individual nanoscale materials. We have also integrated a four-channel, superconducting nanowire, single photon detector into the existing single-nanostructure optical spectroscopy system. We can now perform Hanbury Brown Twiss and Hong-Ou-Mandel quantum optics experiments on individual nanostructures emitting in the 1.0- to 1.5-micron wavelength range. Only a few groups in the US have demonstrated such a capability. Additionally, a novel fs pump, second-harmonic generation (SHG) probe technique for probing coupled multiferroic behaviors in oxide heterostructures has been added to our world-class ultrafast spectroscopy capability. CINT ultrafast capability was also harnessed for establishing a new surface-enhanced coherent anti-Stokes Raman microscopy system that exploits gold nanopyramids as active substrates well suited for probing solution-based monolayers, bio membranes, and other soft and complex materials. Finally, a custom Z-scan approach for measuring Kerr nonlinearities and two-photon absorption was established in support of a startup firm (EigenChem) to develop nonlinear photonic devices.

We are currently acquiring a 9 tesla superconducting magnet and a microscopy cryostat to build a new system capable of performing advanced single-nanostructure spectroscopies (Raman, PL, time-resolved PL, photon correlation spectroscopy, etc.) under a strong magnetic field. A separate microscopy cryostat will allow us to control the temperature of the nanostructures from 4 to 400 K. Combined with existing state-of-the-art lasers and electronic and photon detectors, including the four-channel superconducting nanowire single-photon detector (SNSPD) system, this facility will become a unique capability for exploring electronic fine structure and quantum optical properties of the spin states of a variety of nano materials. Notably, development of this facility will proceed in parallel with extension of our continuously tunable Raman excitation sources further into the UV (to ~270 nm) via a wavelength–double dye system. The capability will expand the range of materials on which CINT can perform resonance Raman experiments (with initial targets being exploration of phonon coupling in hybrid multiferroic materials) and will provide an extensive range of excitation (from near-IR to UV) for the magneto microscopy capability. In the area of nanostructure PL imaging, we are extending our correlated two-color techniques to include capability for back focal plane imaging, which will provide a new tool for probing the control of emission polarization and directionality and for approaching strong coupling regimes in many of our hybrid emitter/photonic structured materials. The SECARS microscope noted above will be further developed towards meeting the challenging goal of obtaining good S/N from a biological monolayer, such as lipid membranes within a reasonable acquisition time and at frequencies other than the standard C-H vibration. Advancing our system should allow attempting functional imaging of biosamples. Finally, we are adapting

our femtosecond time-resolved SHG system for THz/mid-infrared pumping, which will enable us to photoexcite low energy excitations and specifically probe the resulting surface/interfacial response in a variety of materials.

Spatiotemporal Imaging on Nanoscale

smFRET has emerged as a powerful tool for studying biomolecular conformation and conformational dynamics. However, most smFRET studies to date examine molecules immobilized on a surface (for increased observation time) or molecules rapidly diffusing through a small, nearly diffraction-limited probe volume in solution, providing only a brief snapshot of molecular conformation. To overcome these problems of traditional smFRET, our laboratory recently expanded our 3D single-molecule tracking microscope to simultaneously monitor two colors (a fluorescence donor and acceptor) such that one can follow a single FRET-labeled biomolecule in 3D while simultaneously monitoring its conformation and conformational dynamics (see Figure 1.17).

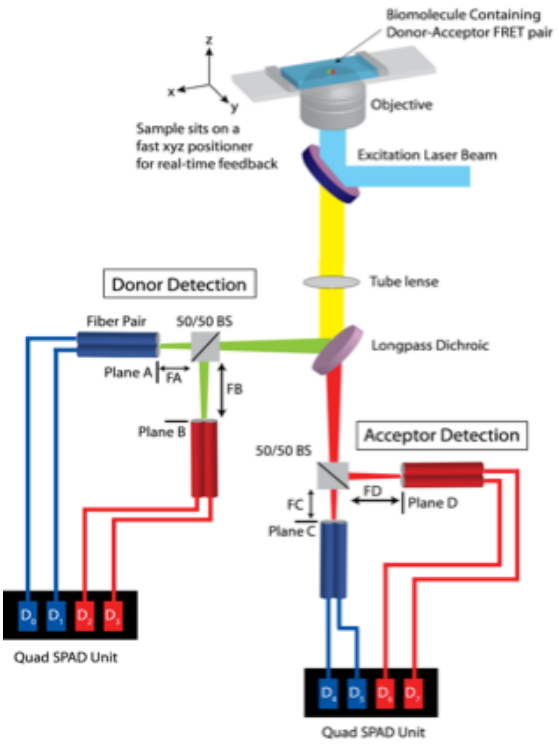


Figure 1.17 Schematic of two-color tracking microscope system.

This new two-color 3D tracking instrument may have a large impact on the study of intrinsically disordered proteins (IDPs), in particular those IDP systems that fold upon binding a target biomolecule. This new instrument should be able to follow the conformation of individual IDPs before, during, and after binding a target. Our initial focus is on the folding dynamics of small acid-soluble proteins (SASPs) that are intrinsically disordered but fold into a helix turn helix motif upon binding DNA. We hypothesize that SASP folding upon binding will be better described by a conformational selection mechanism of interaction (where proper folding proceeds DNA binding) than by an induced fit mechanism (where proper folding follows binding to DNA). We emphasize that unlike smFRET on immobilized samples, 3D tracking smFRET is amenable to studies directly inside living cells, which we propose to perform by introducing FRET-labeled SASPs directly into live cells by electroporation.

In situ Mechanical Characterization of Nanostructured Materials

We are expanding our efforts in high-temperature nanoindentation with a new Hysitron Triboindenter 950 installed at the Gateway. This state-of-the-art nanoindenter is a replacement and upgrade for the antiquated Agilent/Keysight nanoXP, which served a large user base but was no longer supported by the manufacturer. New capabilities include small scale mechanical testing under an inert gas environment at temperatures up to 800 °C and dynamic mechanical measurements, such as continuous stiffness at elevated and ambient temperatures at loads ranging from nanoNewtons up to ~5 Newtons. CINT was the first site in the world to have this unique combination of capabilities. In addition to the previous user base of the nanoXP, new users will use the high temperature capability.

We have been collaborating with nanomechanical equipment vendors to further develop small-scale test techniques to probe materials under extreme environments. For such technique development endeavors, CINT is an ideal collaborator because of its access to a library of materials for service in extreme environments.

1.e.3 Theory - Model and Methods Development

Future work within hierarchical structure and dynamics in soft matter will include an increased focus on charged and magnetic polymers. Charged nanoparticle systems can form hierarchical structures, which can be modified by rather easily adjustable conditions (e.g. salt concentration). Having added dipolar interactions in our MD code LAMMPS, CINT users will be able to study the magnetic hierarchical nanoparticle systems. Furthermore, a growing effort within excitation and transport in nanostructured systems is supporting our vision of hybrid material interaction for energy/information generation and manipulation in integrated structures.

A goal that unifies the efforts within the science direction is the development of theoretical tools to bridge between the nanoscale/atomic and the macroscopic scale, which sits at the core of hybrid structures, and the atto and femtosecond intrinsic time scales of electronic and vibrational dynamics to the pico and nanosecond time scales associated with transport and energy redistribution in nanostructures. Combined with the subatomic spatial resolution of modern theoretical methods, this major capability development will allow us to understand how the dynamical properties of macroscale systems arise from the behavior of the system at extremely various length and time scales. TSNP scientists will work together to address this challenging area and in particular ramp up the efforts on the calculations of electronic, magnetic, and optical properties in complex oxides and other functional materials. These focused efforts will significantly enhance our capability to address the challenge in the research at mesoscale. Through the ongoing user projects, we will develop new computational package dedicated to explore the structure and function relations first in transition-metal oxide nanocomposites and later on extended to other functional materials. In particular, we will also leverage our institutional expertise to construct ab-initio informed low-energy tight-binding based models into this new package for multiscale modeling of emergent phenomena.

1.f Complete budget breakdown for FY15

FY15 Actual Budget:

R&D (CINT Scientists)	9,199 K
Consultants	27 K
Technical Professionals	3,340 K
Postdocs	1,777 K
Students	262 K
Materials & Supplies	2,597 K
Service Contracts	834 K
Improvements/Upgrades	391 K
Equipment	1,235 K
User Office & Support Staff	769 K
ES&H	17 K
Utilities	1 K
Travel	323 K
Total	**$20,773 K**

Nanophotonics and Optical Nanomaterials

Staff (5.1 FTE)	$2,337 K
Technicians (0.7 FTE)	203 K
Post-docs (5.7 FTE)	782 K

Nanoscale Electronics and Mechanics

Staff (7.2 FTE)	$2,755 K
Technicians (8.3 FTE)	2,080 K
Post-docs (2.6 FTE)	379 K

Soft, Biological, and Composite Nanomaterials

Staff (4.7 FTE)	$2,147 K
Technicians (3.8 FTE)	1,057 K
Post-docs (3.3 FTE)	448 K

Theory and Simulation of Nanoscale Phenomena

Staff (4.0 FTE)	$1,960 K
Post-docs (1.3 FTE)	169 K

FY15-FY18 Actuals/Projected Budgets

	FY15 (Actuals $K)	FY16 ($K)	FY17 ($K)	FY18 ($K)
NPON	4,088	3,516	3,669	3,805
NEM	7,660	7,839	8,067	8,315
SBCN	4,299	3,855	3,973	4,141
TSNP	2,232	2,653	2,757	2,869
Admin/Utilities/ES&H/Maintenance	2,103	2,145	2,188	2,232
Capital/Major Equipment*	391	2,200	2,200	2,200
Total	**$20,773**	**$22,208**	**$22,847**	**$23,561**

*Costs in this category in FY15-18 are major equipment procurements for recapitalization and/or capability enhancement. Individual items are less than capital ($ 500 K) and/or requests will be made to BES for capital conversion.

2. Instruments and Laboratories

As one of the DOE/Office of Science Nanoscale Science Research Center (NSRC) national user facilities, CINT offers prospective users the opportunity to access not only advanced instrumentation but also the expertise of our scientific staff, each of whom is a research leader in nanoscience integration. CINT users clearly value this combination, as demonstrated by the fact that approximately half of our user projects involve more than one CINT Scientist and consequently utilize multiple associated experimental/computational techniques. This characteristic of CINT user projects, and possibly other NSRC user projects as well, contrasts with the operating mode of conventional user facilities in which user proposals typically only seek access to a specific single instrument.

Figure 2.1 Users working in the CINT Integration Lab.

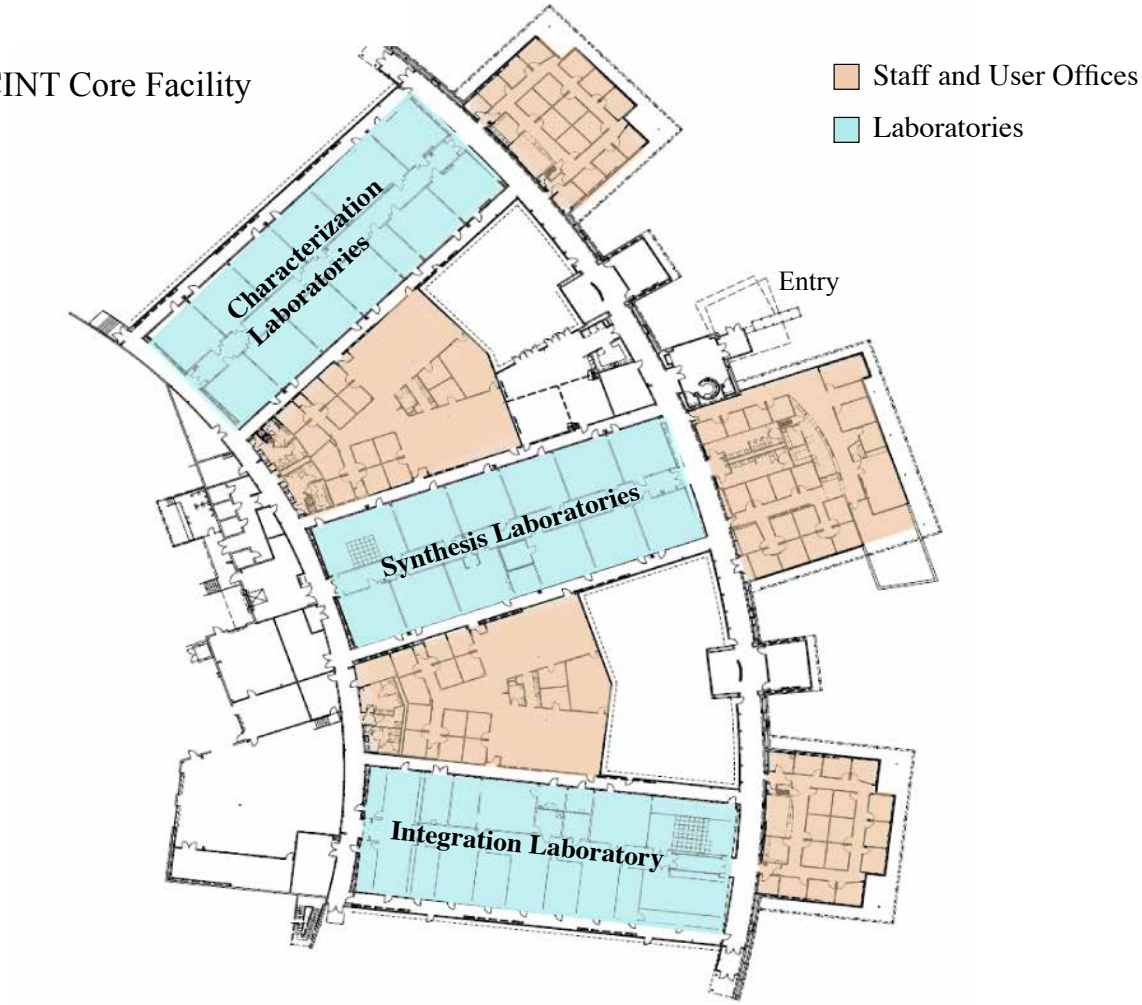
In the sections below, we present maps of the two CINT facilities followed by a brief description of the buildings. Detail about the individual laboratories is presented in a subsequent listing of CINT's 15 major capabilities. Each capability includes the technical leadership provided by one or more CINT Scientists who utilize experimental instrumentation, computational tools, and laboratory infrastructure to assist the user community in the science of nanoscale integration.

For some capabilities (e.g., transmission electron microscopy), many users can be trained to properly operate the associated instrumentation with minimal supervision by CINT personnel. Thereby, the capability availability is limited by the instrument duty cycle rather than by CINT personnel.

For most CINT capabilities, a user project may be approved only if the proposal is ranked highly by the proposal review process and each requested CINT Scientist has the availability required for their part of the user project. This availability includes the capabilities of instrumentation that requires dedicated operation by CINT personnel for safety reasons (e.g., Class 3 or 4 laser systems) or complexity (e.g., molecular beam epitaxy). Therefore, the capability availability is generally limited by the available staff time—notby the instruments' duty cycle. Actual capability usage is determined from quarterly reports by CINT Scientists which detail the user time delivered to each of their assigned user projects. Delivered user time may exceed actual staff time only when a user can safely conduct research in the CINT facilities with less supervision or staff involvement than originally anticipated. While CINT has been effective in maximizing the delivered user-hours per staff-hour, greater user access to most of our capabilities will require more CINT personnel..

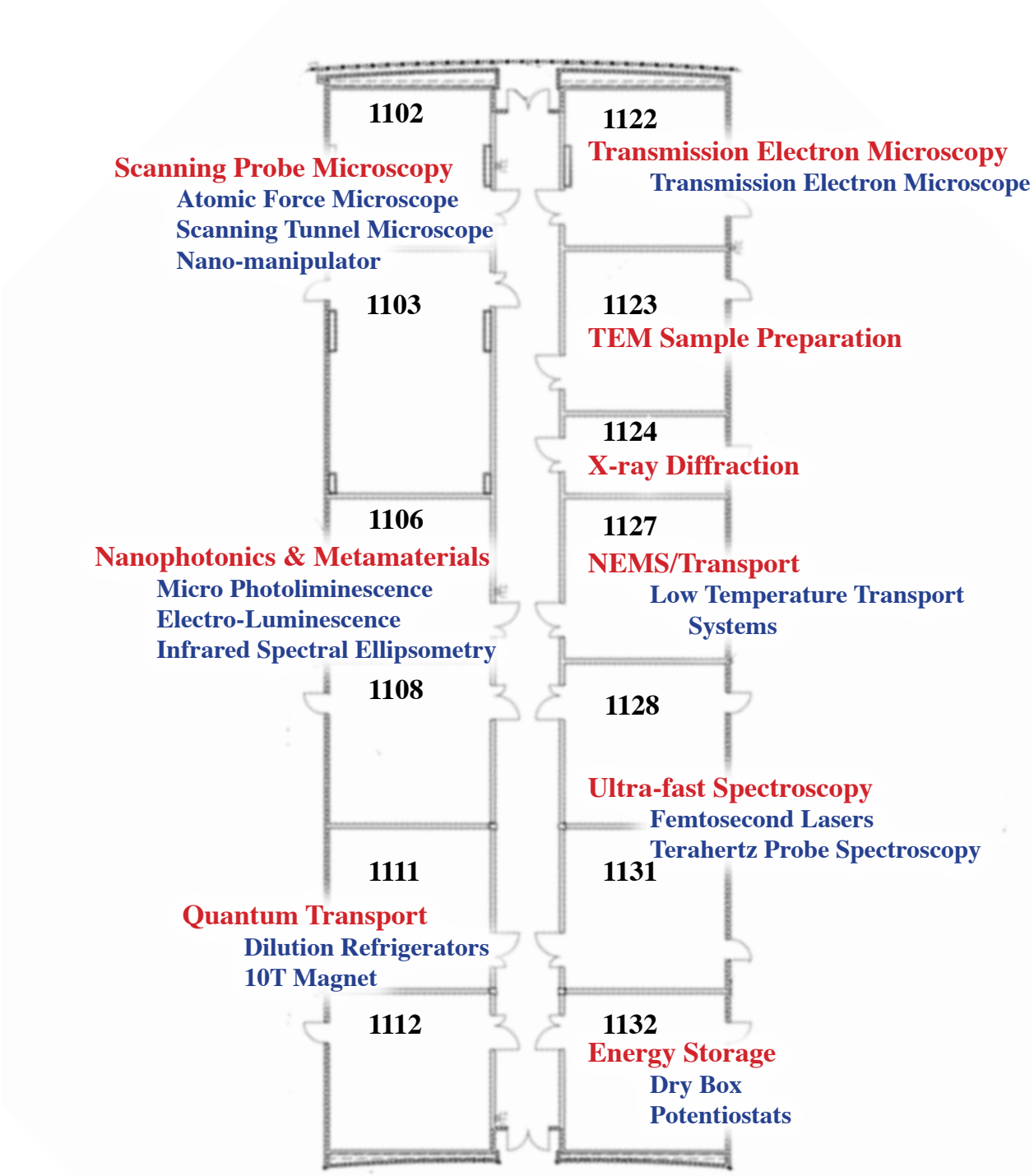
2.a Floor Plans

CINT Core Facility

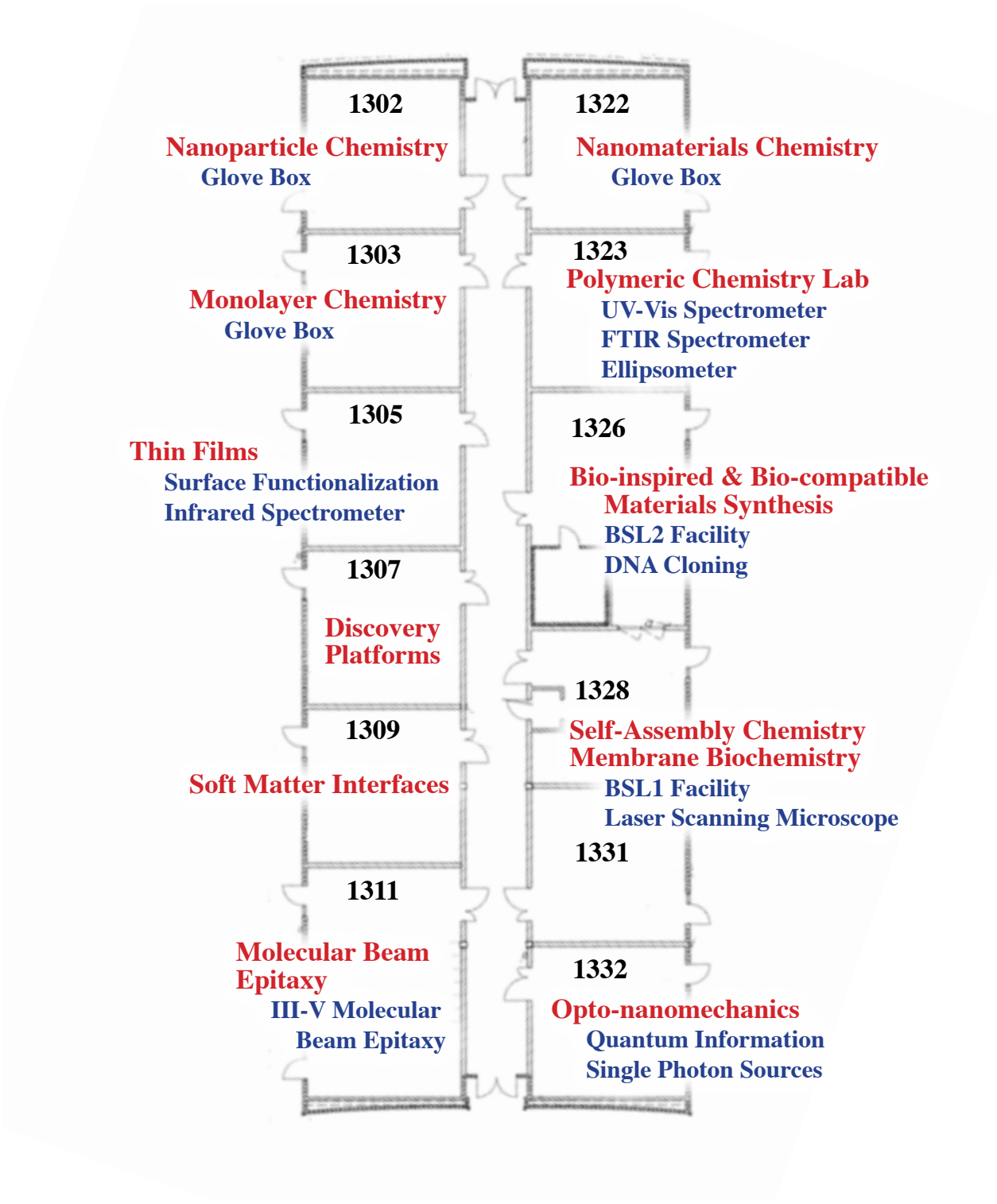


CINT Gateway Facility

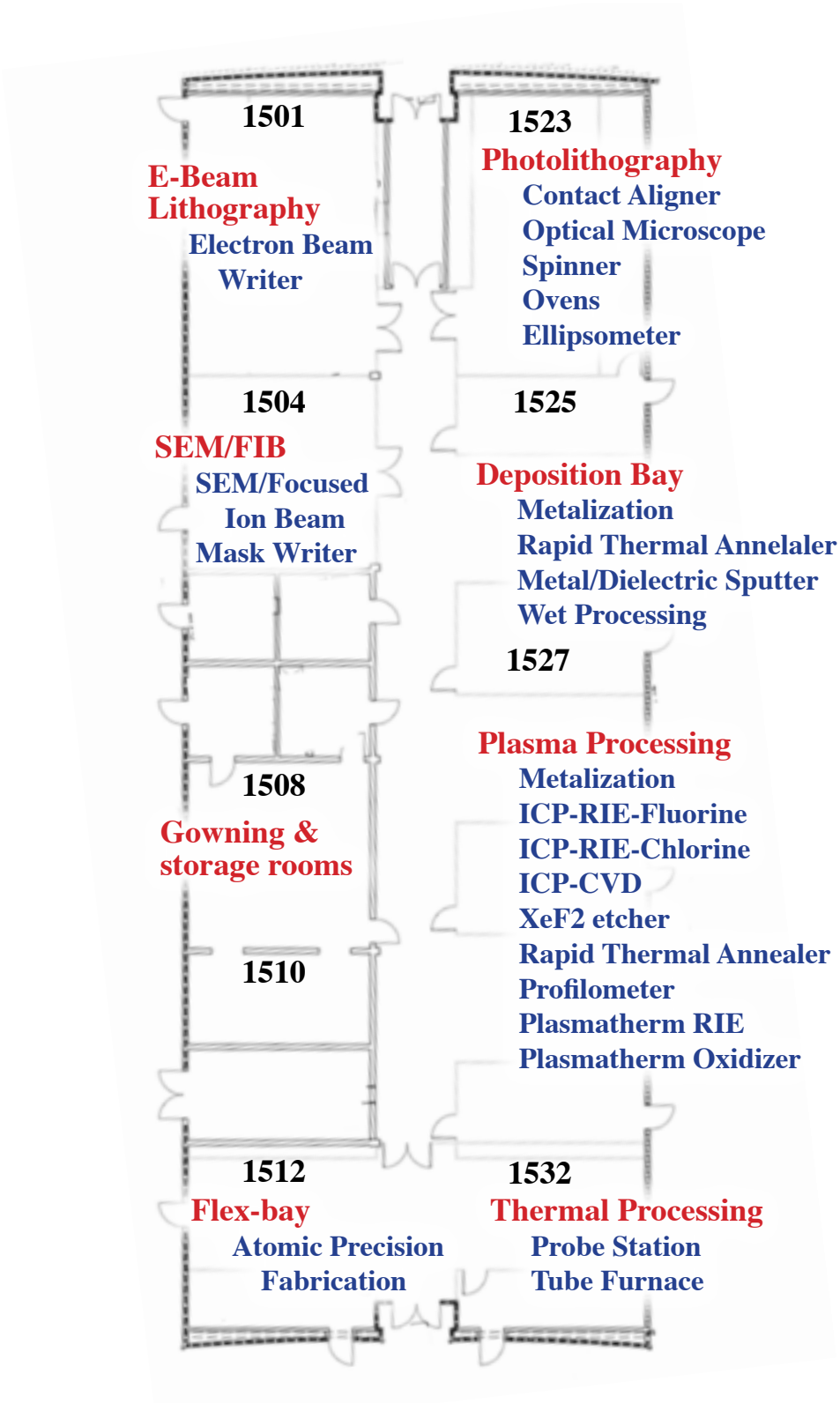
Core Facility - Characterization Laboratories



Core Facility - Synthesis Laboratories

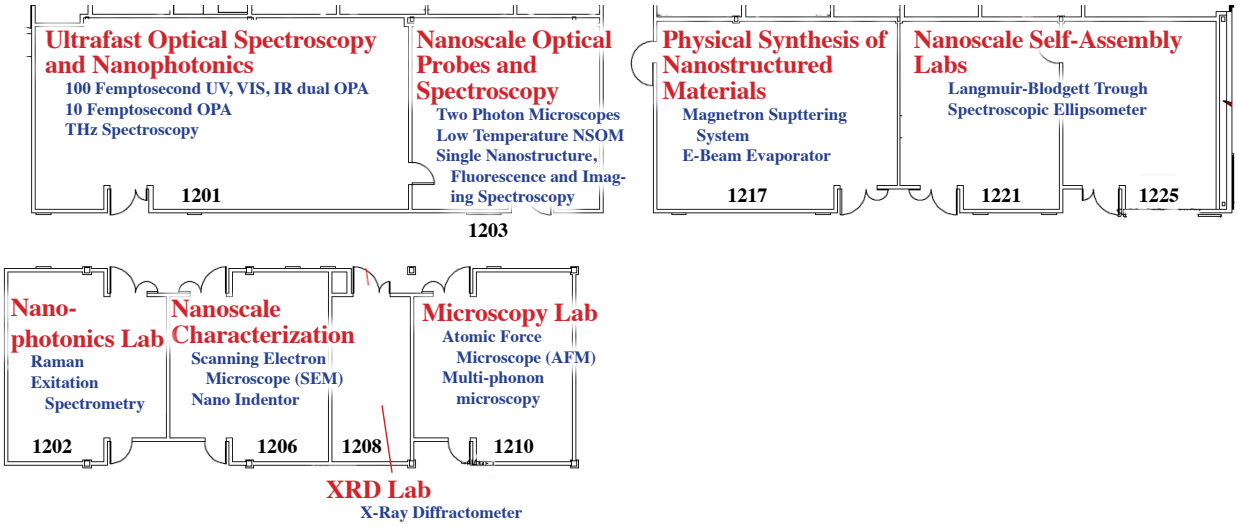


Core Facility - Integration Laboratory

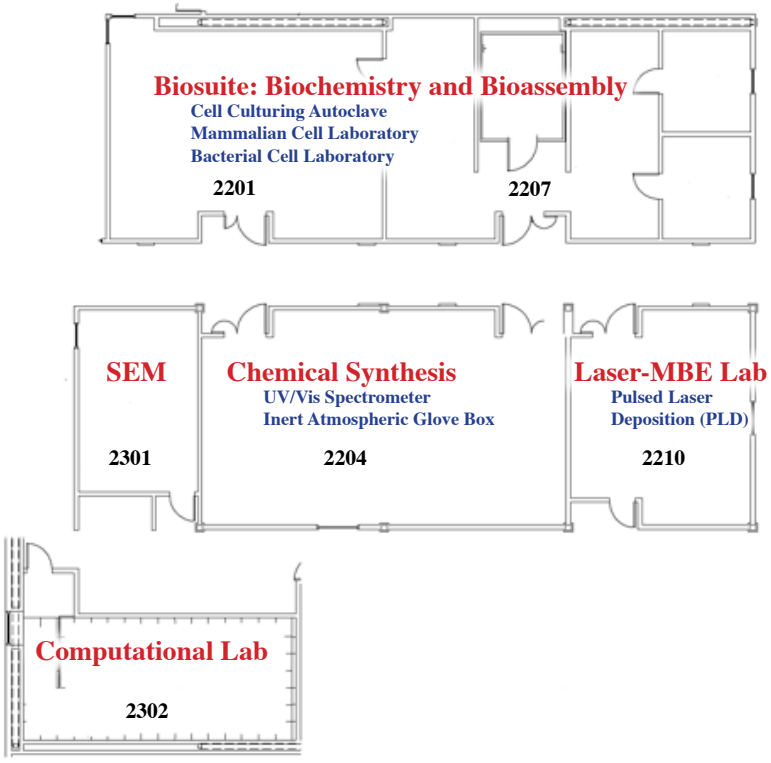


Gateway to Los Alamos Facility

First Floor



Second Floor



2.b Capabilities Summary Table

Number	Capability/Instrument name and type	Staffing level (#FTE allocated)			Available (operational) hours (uptime)			Hours used (excl maint & training)			% used by general User Program			% used by facility staff (not General User Prog)			# Unique users[1]			# Publications[2] using instrum./capabil.		
		2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
1	Nano-Particles, Tubes & Wires	0.46	0.46	0.46	13,500	13,500	13,500	11,740	12,136	13,716	92%	94%	93%	8%	6%	7%	96	81	80	24	21	37
2	Films & Composites	0.67	0.67	0.67	22,500	22,500	22,500	10,909	10,949	6,985	88%	88%	81%	12%	12%	19%	136	125	143	56	52	49
3	Molecular Beam Epitaxy	0.38	0.38	0.38	4,500	4,500	4,500	1,338	954	1,026	81%	74%	76%	19%	26%	24%	48	20	21	7	20	10
4	Biomolecular Materials	0.71	0.71	0.71	18,000	18,000	18,000	6,777	9,857	9,601	79%	86%	85%	21%	14%	15%	52	55	45	4	10	13
5	Nano/Micro Fabrication	0.75	0.75	0.75	27,000	27,000	27,000	9,272	10,640	11,840	85%	87%	88%	15%	13%	12%	84	85	61	19	21	21
6	Electron Beam Lithography	0.50	0.50	0.50	4,500	4,500	4,500	4,000	4,100	4,197	98%	98%	98%	2%	2%	2%	20	28	43	0	0	1
7	Transmission Electron Microscopy	0.75	0.75	0.75	4,500	4,500	4,500	2,412	2,556	1,948	79%	80%	74%	21%	20%	26%	33	43	50	0	6	6
8	Quantum Transport	0.33	0.33	0.33	9,000	9,000	9,000	7,683	4,955	6,235	91%	87%	89%	9%	13%	11%	45	28	44	2	4	9
9	Optical Characterization and Spectroscopy	1.88	1.88	1.88	31,500	31,500	31,500	17,782	24,318	21,742	79%	85%	83%	21%	15%	17%	90	95	103	51	52	85
10	Scanning Probes & Imaging	1.63	1.63	1.63	27,000	27,000	27,000	12,542	18,582	17,750	75%	83%	82%	25%	17%	18%	116	99	83	7	13	17
11	Nanomechanics	0.33	0.33	0.33	13,500	13,500	13,500	3,313	2,601	3,601	80%	74%	82%	20%	26%	18%	78	76	63	17	17	20
12	Discovery PlatformsTM	0.17	0.17	0.17	13,500	13,500	13,500	4,317	3,741	3,861	92%	91%	91%	8%	9%	9%	43	51	49	4	1	11
13	Nanostructure Analysis	0.96	0.96	0.96	13,500	13,500	13,500	5,934	6,006	8,010	80%	81%	85%	20%	19%	15%	65	74	59	13	25	23
14	Optical Microscopy	0.67	0.67	0.67	13,500	13,500	13,500	8,325	10,013	9,821	84%	87%	86%	16%	13%	14%	68	60	58	17	27	24
15	Theory, Modeling & Simulation	2.00	2.00	2.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	63	55	56	42	54	55

[1]Count all capabilities/instruments that each user accessed. (A user may have accessed more than one.)

[2]Count one publication for each capability/instrument that contributed to that one publication.

2.c Lab Overview for CINT Core Facility and Gateway to Los Alamos

2.c.1 CINT Facilities

CINT operates two physical facilities that were planned, designed, and built by the CINT Construction Project management team, including HDR Architecture and Hensel Phelps Construction Company. These facilities are the CINT Core Facility, operated by Sandia National Laboratories in Albuquerque, NM, and the CINT Gateway Facility, operated by Los Alamos National Laboratory in Los Alamos, NM. These two dedicated facilities enable CINT users to access a suite of capabilities leveraged from both host laboratories.

The CINT Core Facility, Figure 2.2, is located near Sandia just outside the Kirtland Air Force Base. This single-level 96,000-square-foot building contains a 9,000 square-foot class 1000 cleanroom with local regions of up to class 100 for lithographic patterning and deposition. It also houses 24 laboratories for physical, chemical and biological materials synthesis, scanning, optical spectroscopies, electron and optical microscopies, and office space for 150 people. To promote interactions the building offers several areas for small informal gatherings, six conference rooms (two with videoconferencing), a large seminar room, and a lunch/break room that accesses one of two exterior courtyards. CINT scientists employed by Sandia and Los Alamos, plus technologists, students, postdocs and other CINT users work in the Core Facility.

Figure 2.2 CINT Core Facility

The CINT Gateway Facility, Figure 2.3, is located on the Los Alamos campus, and provides the user community direct access to nanoscale materials science and bioscience capabilities. It is located in LANL's materials science complex, which is in the open security environment that enables easy access to both nanoscale materials science and bioscience resources. Traditionally, materials science and bioscience have been viewed as separate activities and housed primarily in separate Lab areas. The Gateway Facility provides CINT users with a unique research environment that combines nanoscale materials science and biosciences capabilities and expertise under one roof, surrounded by supporting resources accessible to CINT users. CINT scientists employed by Sandia and Los Alamos, plus technologists, students, postdocs and other CINT users work in the Gateway Facility.

Figure 2.3 CINT Gateway to Los Alamos Facility

The Gateway Facility is a 36,500 square-foot building containing office, meeting and scientific interaction spaces to support CINT staff and the Laboratory's bioscience, chemistry, materials physics and theory communities, external CINT users, and visitors. The building has 29 offices and can house up to 45 occupants. Its two conference rooms with video-conference capabilities permit frequent joint meetings and seminars with colleagues at CINT's Core facility. The Gateway facility features roughly 11,000 square-feet of laboratory space dedicated to chemical and biological synthesis and characterization, biomaterials fabrication and characterization, optical microcopy and spectroscopy, physical synthesis, thin film fabrication, nanoscale imaging and scanned probes, advanced computation, and visualization.

Environmental Safety and Health responsibilities at the dedicated CINT facilities are managed under the integrated safety management plans in place at both SNL and LANL. These plans include management and staff responsibilities, procedures for evaluating risks, training requirements, and appropriate controls to ensure compliance with safe practices. Copies of the established ES&H policies and procedures for SNL (which has institutional ES&H responsibility for the Core Facility) and LANL (which has institutional ES&H responsibility for the Gateway Facility) are available for review.

The well-defined, integrated ES&H management responsibilities at CINT begin with line management at each CINT facility. Management is responsible for directly overseeing the execution of work, managing their staff, overseeing daily operations, and ensuring implementation of Work Planning and Controls. The ES&H Coordinators assigned to each facility act as the CINT representative and liaison in safety matters, environmental issues, and health & wellness concerns. They are knowledgeable in corporate and government ES&H requirements and serve as advisors and consultants to help management and staff implement Work Planning and Controls. Each member of the workforce and CINT user is to ensure that they work within laboratory operation limits; and, when a new hazard is discovered or introduced, each CINT user and workforce member has the right, responsibility, and obligation to suspend work until the hazard has been evaluated and mitigated.

CINT users comply with all training requirements for every capability needed to perform the approved user project. Whenever possible, web-based training is offered to users in advance of their arrival at CINT. On-site training at each location is scheduled by CINT visitor facilitators and provided by the responsible scientists or qualified technologists. User training is linked with the user access control via CINT visitor badges to ensure that untrained personnel cannot gain unauthorized access to CINT laboratories. By virtue of being jointly operated, CINT has a unique opportunity to identify and implement ES&H “best practices” at its facilities. CINT is actively coordinating training reciprocity at LANL and SNL to avoid redundant requirements for users.

Laboratory-specific procedures for user operations at each facility are contained in the CINT project documentation. Briefly, these documentations describe the scope of work in the specific laboratory, including a risk assessment, standard operating procedures, identification of training required to perform work safely and properly, implementation of training and work processes, and periodic evaluations to verify compliance and seek opportunities for improvement. This overall process is documented at both SNL and LANL with electronic (database) and local (on-site) records and management tools.

2.c.2 Major Capabilities

CINT has 15 major capabilities available to users. In aggregate, CINT delivered a total of 315,233 hours to users over the three-year review period of FY13 through FY15.

	Major Capability	**FY13 User Hours**	**FY 14 User Hours**	**FY 15 User Hours**
1	Nano-Particles, Tubes & Wires	10,824	11,220	12,800
2	Films & Composites	9,576	9,616	5,652
3	Molecular Beam Epitaxy	1,088	704	776
4	Biomolecular Materials	5,360	8,440	8,184
5	Nano/Micro Fabrication	7,872	9,240	10,440
6	Electron Beam Lithography	3,900	4,000	4,097
7	Transmission Electron Microscopy	1,912	2,056	1,448
8	Quantum Transport	7,016	4,288	5,568
9	Optical Characterization & Spectroscopy	14,032	20,568	17,992
10	Scanning Probes & Imaging	9,392	15,432	14,600
11	Nanomechanics	2,648	1,936	2,936
12	Discovery Platforms ™	3,984	3,408	3,528
13	Nanostructure Analysis	4,768	4,840	6,844
14	Optical Microscopy	6,992	8,680	8,488
15	Theory, Modeling & Simulation	6,176	5,904	6,008
	Total User hours delivered	**95,540**	**110,332**	**109,361**

Listed below are more detailed descriptions of CINT's 15 major capabilities and the associated laboratories, instruments and infrastructure that enable that capability. For capabilities that require extensive user training or if the user cannot safely work unaccompanied, the available user time is constrained by the time CINT Scientists and technologists supporting that capability are available.

Each CINT Scientist is expected to devote no less than 50% of their CINT-paid time to user project activities. This corresponds to approximately 500 hours/year of user project availability per scientist (50% x 0.5FTE x 40 hours/week x 48 weeks/year). Yet, in actuality, most CINT Scientists devote far more time to user projects due to their enthusiasm for the research and commitment to the user project success. For a full-time CINT technologist, their corresponding time available to support users is 900 hours/year. The duties of CINT technologiests include capability maintenance, capability development and support of CINT research, and user project support. CINT-funded postdocs are not assigned to support user projects.

1. Nanoparticles, Tubes, & Wires

Associated CINT Scientists: Sergei Ivanov, Jennifer Hollingsworth, Jinkyoung Yoo, Steve Doorn

	FY 13	FY14	FY15
Available Operational hours (1)	13,500	13,500	13,500
Staff Availability for Users (2)	916	916	916
Delivered hours - External Users	5,688	5,821	5,792
Delivered hours - LANL/SNL	5,136	5,399	7,008

(1) 3 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 4 scientists + 1 Technologist

Core Rooms 1303 and 1322: Nanomaterials Chemistry Laboratory

In CINT's nanomaterials chemistry laboratories, the preparation of high-quality semiconductor, metal, and magnetic nanocrystals is emphasized. Success is defined in part by the ability to control size dispersity, particle crystallinity, particle stability, and particle optical/electronic/magnetic properties. Typically, nanocrystals are prepared with a target functionality in mind and by working closely with physicists and spectroscopists who, through advanced characterization tools, provide feedback on the synthetic work. Lab researchers strive to understand, the effects of particle size, morphology, surface structure and functionalization on nanocrystal properties and, subsequently, to optimize these properties. They also focus on the preparation of new compositions (core and core/shell materials; UV to visible to infrared absorbers/emitters; ferromagnetic to superparamagnetic nanoparticles, etc.), new shapes (isotropic to highly anisotropic), composite materials (e.g., high-density nanocrystal/sol-gel processable blends), and bio-compatible nanocrystals (water-soluble and functionalized for binding to various biomolecules), as well as self- and directed-assembly of films and composite structures. In addition, nanocrystal chemical-precursor development and ligand/surfactant development are pursued when necessary.

Gateway Room 2204: Optical Nanomaterials and Chemical Synthesis Laboratory

The synthesis lab enables the design, preparation and integration of semiconductor nanocrystals from quantum dots (QDs) to nanowires (NWs), as well as nanoparticles comprising metal oxides, simple metals, and/or magnetic materials. From standard to custom capabilities, the lab is fully equipped for nanomateri- als discovery, optimization, production and scale-up. The lab has six chemical fume hoods, each with a Schlenk line, as well as two inert-atmosphere gloveboxes for air-free operations. Organometallic, inorganic, organic, colloidal and biochemical synthetic methods can be performed and combined in this lab in order to prepare new precursors, ligands and bi-functional linkers for the synthesis and assembly of novel nanocrystal compositions (e.g., alloys and multi-shell architectures) and structures (e.g., controlled shapes and defined nanocrystal aggregates). Nanocrystal surface chemistry can be controlled in order to facilitate self-assembly strategies, processing into sol-gel or polymer matrices, and integration into biological systems. The lab also houses a UV-Vis-NIR spectrophotometer and a UV-Vis-NIR fluorimeter for monitoring absorption and emission characteristics of the prepared nanoparticles, where the latter is supplemented by a temperature-controlled sample holder for assessing the effect of temperature on a photoluminescence effiarticle tracking analysis system that allows rapid and direct assessments of particle concentration and size. An electrochemical workstation and peripherals are also available for the synthesis of metal NWs in porous-oxide templates, as well as the fabrication of novel ultrathin substrate-bound and free-standing porous alumina membranes. In support of integration activities, e.g., device construction, the lab offers dip-coating, spin-coating and metal-deposition (dual sputtering/thermal-evaporation) tools, along with a state-of-the-art dip-pen nanolithography system described below.

Activities in the Synthesis lab have focused on the development of novel heterostructured nanomaterials from non-blinking quantum dots ("giant" QDs that emit visible-red and green lightwaves, and out to the telecommunications wavelengths) to superlattice NWs. To support this unique capability in complex/controlled nanomaterials growth, the Gateway 2204 synthesis lab is equipped with several custom microfluidics/fluidics-based platforms:

(1) a unique chip designed for superlattice NW/QD-in-wire growth, (2) a novel re-sealable dielectrophoretic chip for size/charge-based precision-selection of QD fractions, and (3) a custom automated reactor and sampling system designed to support complex nanomaterials heterostructuring, materials discovery, and scale-up.

Co-located with the nanomaterials-synthesis lab is a Nanoink dip-pen nanolithography system (now supported by ACS Technology) that allows precise placement and patterning of active nanomaterials such as nanocrystals, nanowires and nanotubes, as well as soft and biological materials, combined with the possibility for direct integration with pre-fabricated 3-D and nanoscale structures (Figure 2.4).

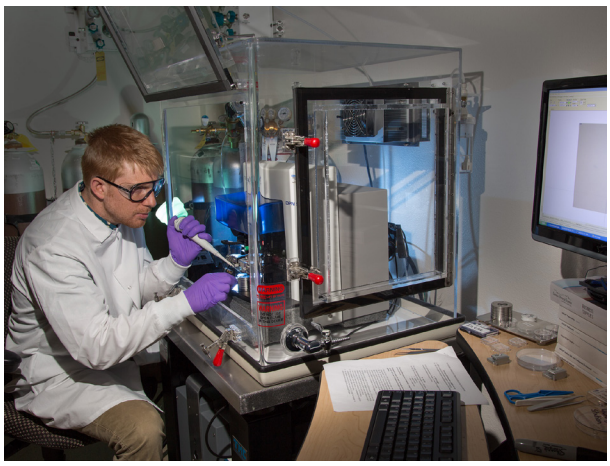


Figure 2.4 Nanoink dip-pen lithography

Specific equipment includes:

- Inert-atmosphere gloveboxes with freezers (one dedicated to quantum dot chemistry, e.g., heavy metals, and one to sol-gel/organic chemistry).
- Chemical fume hoods and equipment for handling highly toxic and carcinogenic chemicals.
- Schlenk lines and Schlenk glassware suitable for quantum dot, nanowire, nanoparticle, metal-organic/organometallic precursor, ligand, and polymer synthesis and manipulation.
- CEM Discover Microwave Reactor.
- Syrris FRX Microfluidic Reactor (includes 3 FRX pumps and FRX Pressurization Module, Volcano, IKA Hotplate, Reagent Module and 3-input 250 μL chip).
- Dolomite Custom Microfluidic Chips: (1) Chip and Chip Holder for "substrate-bound" nanoparticle synthesis in-flow at high temperature and (2) Electrophoresis Module for nanoparticle separation by "free-flow" electrophoresis.
- Electrochemical Analyzer/Workstation: CH Instruments 660C Potentiostat/Galvanostat (±10 V, ±250 mA), and associated DC power supply (0-110 V, 0-3 A) and high-voltage power supply (to 30 kV, 100 mA).
- UV-Vis-NIR absorption spectrophotometer.
- UV-Vis-NIR fluorimeter with integrating sphere and temperature controlled sample holder.
- AJA International custom metal deposition system: dual sputtering and thermal evaporation chamber.
- Nanoink DPN 500 system for "direct-write" capability allowing rapid design, creation, analysis and integration into nano and microstructures.
- Syrris Inc. Custom Automated Reactor System (in procurement) for automated synthesis, sampling, and in situ characterization of nanomaterials growth processes toward a quasi-computational approach to nano-development and, ultimately, product scale-up.
- General: analytical balances, centrifuge, microcentrifuge, automated/ programmable syringe pumps, vortex, pH meter, dry bath incubator, circulator/chiller, ultrapure water system, ultrasonic cleaner, glassware ovens, vacuum oven, tube furnace, refrigerators/freezer, UV lamps.
- Equipment located nearby: time-resolved fluorimeter, optical Microscope for ultra-widefield single-nanocrystal blinking experiments, and a desktop Delong America LVEM5 desktop TEM.

CVD Nanowire Growth Facilities at LANL

The nanowire growth facilitiy utilize chemical vapor deposition (CVD) reactors, which are dedicated to growth of high-quality and electrically doped Si/Ge nanowire heterostructures with controlled interfaces and to nanowire

growth of various semiconducors. The cold wall reactor for Si/Ge nanowire heterostructures has capabilities of reproducible control of growth temperature, in-situ optical growth monitoring using reflectance measurement, precise controlled precursor flow regulation, fast switching of process gases, adjustable process chamber pressure in a wide range from UHV to LPCVD, and rotatable substrate holder. All the features of the CVD system for Si/Ge nanowire heterostructures guarantee precise control of electrical doping concentration and interfacial widths of heterostructure, uniformity in a substrate, reproducible growth of sophisticated nanowire heterostructures. The growth method is based on the vapor-liquid-solid (VLS) technique, which uses metallic nanodot seeds to control the location and size of the nanowires.

An unique capability of the CVD reactor is flowing metalorganic precursors to control elemental composition of metal catalyst seeds for nanowire growth. In-situ making alloyed catalyst enables users to achieve abrupt interfaces (interfacial width is much smaller than size of catalyst seed) at the junctions in a single nanowire.

The other CVD system has recently been built to explore nanowire synthesis of various materials to cover increasing needs of materials synthesis from nanowire research community. The CVD reactor is hot wall and solid source-based system, equipped with furnace, 1 substrate and 2 solid source holders of which locations are controlled by computerized system, and pressure control apparatus. Nanowires of various materials are available with the system by change of solid source. Since the CVD system was built in the first quarter of 2013, growth condition of InAs nanowires has been established, and other semiconductor nanowires such as InP and III-V materials are being explored. Moreover, the CVD system has a capability of nanowire heterostructure using in-situ sequential growth of two different materials loaded in two solid source holders in a reactor. The growth method of solid source-based CVD system is also VLS technique.

The combination of elaborate Si/Ge nanowire CVD system and versatile solid source CVD system greatly expands materials combination of nanowire heterostructures at the Center for Integrated Nanotechnolgies (CINT). Furthermore, CINT nanowire growth capability provides chance of research of heterogeneous integration of semiconductor nanomaterials on exotic substrates such as III-V nanowires on Si and semiconductor nanowires on nano-patterned extrinsic substrate. For precise control of nanowire geometry and dimensions, a dual source e-beam evaporation thin film system and e-beam lithography system are available for additional specialized and size-, position-controlled metal seed depositions.

2. Films & Composites

Associated CINT Scientists: Quanxi Jia*, Dale Huber, Millie Firestone, Wally Paxton, Jen Hollingsworth, Nate Mara

	FY 13	FY14	FY15
Available Operational hours (1)	22,500	22,500	22,500
Staff Availability for Users (2)	1,334	1,334	1,334
Delivered hours - External Users	5,752	5,424	3,368
Delivered hours - LANL/SNL Users	3,824	4,192	2,284

* CINT Director

(1) 5 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)

(2) Staffing limited: 5 scientists + 1 Technologist

Core Room 1323: Polymeric Monolayer Chemistry Laboratory

Primary concerns of this lab are the surface properties and interfaces as theyoften define the properties of integrated nanostructures and the control of surface properties such as wetting, adhesion, and friction. Through monolayer synthesis, researchers tailor surface properties utilizing small molecule organic synthesis and polymerization techniques. Either in-situ or ex-situ syntheses can be performed where appropriate and multilayers or gels may be produced using similar techniques.

Lab capabilities include:

- Monolayer design and formation on planar, particulate, chip-based, or other samples of inorganic oxides, non-oxidized metals, semiconductors, polymers, etc.
- Synthesis of functional coupling agents, in particular those with functionality.
- In-situ modification of monolayer functionalities where desired functionalities lack compatibility.
- In-situ growth of polymer monolayers and mixed polymer monolayers using free radical, ionic or coordination polymerization reactions.
- A suite of characterization methods to determine or verify monolayer functionality, structure, wetting properties, etc.

Core Room 1305: Thin Film Laboratory

This chemical synthesis laboratory is designated for experiments involving the surface functionalization of nanomaterials and microsystems with materials such as self-assembled monolayers to control both the assembly and functionality of solution-derived nanocomposites. The laboratory contains a wide range of equipment for characterizing thin films, including a Brucker IFS 66 v/S infrared spectrometer with attenuated internal total reflectance and polarization modulation capabilities, a Cary UV-visible spectrometer, a Q-Sense Quartz Crystal Microbalance, a Langmuir-Blodgett trough, and a PARSTAT 2273 Advanced Electrochemical System for probing nanomaterials developed for electrochemical energy storage.

Gateway Room 1217: Physical Synthesis of Nanostructured Materials Laboratory

The lab's physical vapor deposition (PVD) capabilities, such as electron beam evaporation and magnetron sputtering, are used to synthesize metal, alloy, ceramic or composite materials where the internal nano-structuring dimension such as layer thickness, grain size or particle size can be well controlled down to the nanometer level. Some examples include, but are not limited to, nano-layered composites, metals or alloys with nanometer-scale grain size, crystalline or amorphous matrices embedded with nano-dots with well-controlled sizes and spacing, nano-twinned materials, nano-porous films, etc. The total thickness of the sample may vary from sub-micrometer to a few tens of micrometers. Through appropriate masking techniques, the films can be patterned in shapes, e.g., as self-supported tensile samples. Energetic ion or neutral atom bombardment during growth are used to tailor the nanostructuring dimension, residual stress, texture, epitaxy, etc. Post-deposition vacuum annealing and/or ion-bombardment facilities are also available for modification of the residual stresses and

structures of the PVD-synthesized materials. The unusual mechanical, radiation damage tolerance and physical properties of these PVD-synthesized nanomaterials are characterized using the various characterization tools available in CINT.

The lab has procured a new hybrid sputtering-evaporation PVD chamber from AJA International, Inc. with the following capabilities:

- Reactive sputtering without poisoning the target to make thick multi-layers where one layer is ceramic, e.g., TiN.
- Heating /biasing the substrate for both the electron beam evaporator and the sputter system (substrate heat to 850 °C; and bias up to 100 watts RF) in order to make thick foils of single crystal metal-metal and metal-ceramic multi-layers that eliminate porosity and control growth stress.
- Performing co-depositions in the sputter chamber using up to 4 different materials. (All targets are confocal and the substrate rotates. Targets are 2 inches wide and uniform across a 4 inch substrate (+-2%) to make multi-layers with controlled alloy chemistries, e.g., multi-element metallic glass nano-layers).
- Performing longer depositions with sputter down configuration and water-cooled chimneys that will prevent target shorting (water cooling of the chimneys help with thermal expansion and prevent metal flaking) to make make thick samples, ≈ 100 microns, for nano-mechanical testing in different directions with respect to the interface plane.
- Sputter magnetic materials using all 4 sputter guns if required (sputter guns have different magnetic assemblies that can be installed).
- Performing RF pre-cleaning of substrate in both chambers (substrate holders are both 4 inch and will accommodate up to a 4 inch wafer).
- Performing ion-assisted depositions in the electron beam chamber (the ion source is filament so that reactive gases can be used if required to eliminate porosity and control growth stress.
- Allowing the evaporation of a single crystal seed layer, and transfer of it to sputter andgrow further layers. This is possible since both chambers have a vacuum load lock that allows (1) Loading while the main chamber stays under vacuum, and (2) Transfer between the 2 chambers for depositions as required.

Other PVD systems used in this program are:

- Magnetron sputtering chamber with 3 guns, each with 1.5 KW dc power supply (rf power capability on 1 gun); load lock; substrate bias; and, fully computer controlled (LabView) for multilayer deposition.

Additional capabilities in this laboratory include X-ray fluorescence, profilometry, and reflection high energy electron diffraction.

Gateway Rooms 1221 and 1225: Nanoscale Self-Assembly Laboratories

The nanoscale self-assembly labs enable the preparation and characterization of nanostructured materials, including graphene oxide materials, functionalized carbon nanotube suspensions, silica nanostructured films and nanoparticles, and self-assembly monolayers. The lab is also equipped to perform a variety of synthetic chemistry processes to modify the materials upon assembly. In addition, materials and equipment are available to prepare and manipulate assemblies that mimic biological systems, such as supported lipid membrane architectures, which mimic cellular membrane structures.

Specific laboratory capabilities include:

- Preparation of graphene oxide and its functionalization.
- Transfer and manipulation of graphene-based films.
- Preparation and separation of surfactant, DNA and other polymer coated carbon nanotubes.
- Sol-gel chemistry, including preparation of functionalized silica nanoparticles and.
- mesostructured/ mesoporous silica films.
- Preparation and functionalization of self-assembled monolayers.

- Liposome preparation via extrusion.
- Generation of patterned hybrid and supported bilayer assemblies on derivatized substrates.
- Inverted fluorescence microscope coupled with intensified CCD camera and CCD spectrometer for simultaneous imaging and spectroscopic characterization.
- Fluorescence recovery after photo-bleaching (FRAP) characterization of lateral mobility in fluid assemblies.
- Spectroscopic ellipsometry for characterization of films in ambient or aqueous conditions.
- BAS potentiostat for electrochemical characterization.
- A system to measure incident photon to current efficiency of solar cells.
- A solar cell I-V measurement system to determine external solar cell efficiency.
- Mass Spectrometry characterization.
- Ultrasonication apparatus.
- Ultracentrifuge.
- Density gradient maker.
- Differential scanning calorimeter and Thermogravimetric analysis.

Gateway Room 2210: Laser-MBE Laboratory

Laser-MBE is commonly referred to as pulsed laser deposition (PLD) in an ultra-high vacuum combined with reflective high energy electron diffraction (RHEED) for in-situ processing monitoring. The Laser-MBE Lab offers the merits of PLD and MBE by permitting the growth of a wide range of materials with atomically controlled lattices. In a typical pulsed laser deposition process, a laser beam with short and high energy pulses is focused on a target of desired composition. Material is then vaporized from the very top surface of the target and deposited as a film on a substrate. This process can occur in vacuum or in the presence of a background gas. PLD is applicable to almost any material. It is especially powerful for compounds that are difficult or impossible to produce in film form by other deposition techniques. The main advantages of PLD are good stoichiometric preservation for multicomponent materials and operation in a wide range of atmosphere. CINT's laser-MBE is equipped with computer controlled multi-target holders which allow the growth of layered and/or super-lattice structures. The lab's research includes: the growth of complex functional materials with an emphasis on multifunctional epitaxial nanocomposite metal-oxide films and other nanostructured materials; the use of strain engineering to tune the physical properties of metal-oxide films; the identification of the fundamental mechanisms of the lattice-strain; and, size effect on the properties of nanoscale metal-oxide films.

A synthesizing tool that is capable of generating targeted nanoparticles in a film matrix is crucial to accomplishing the goal of process-aware materials performance and developing materials by design. A dual-laser MBE capability is being installed in the CINT Gateway Facility. This new capability has the potential to control the density, size, and spatial distribution of nanoparticles in a film matrix. It holds great promise to synthesize novel multifunctional nanostructured materials where nanoscale particles are the building blocks.

The lab's specific capabilities and materials of interest include:

- Epitaxial growth of metal-oxide films including both simple and complex metal-oxides.
- Deposition of epitaxial nanocomposite (particulate, layered, and vertically aligned) films.
- Deposition of nitride films.
- Metal-oxides including, but not limited to, insulating, dielectric, semiconductive, ferroelectric, ferromagnetic, piezoelectric, multiferroic, metallic, and superconductive materials.
- Nitrides including, but not limited to, insulating, dielectric, semiconductive, and metallic materials.

3. Molecular Beam Epitaxy

Associated CINT Scientists: John Reno

	FY 13	FY14	FY15
Available Operational hours (1)	4,500	4,500	4,500
Staff Availability for Users (2)	1,400	1,400	1,400
Delivered hours - External Users	832	472	680
Delivered hours - LANL/SNL Users	256	232	96

(1) Lab, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 1 scientist + 1 technologist

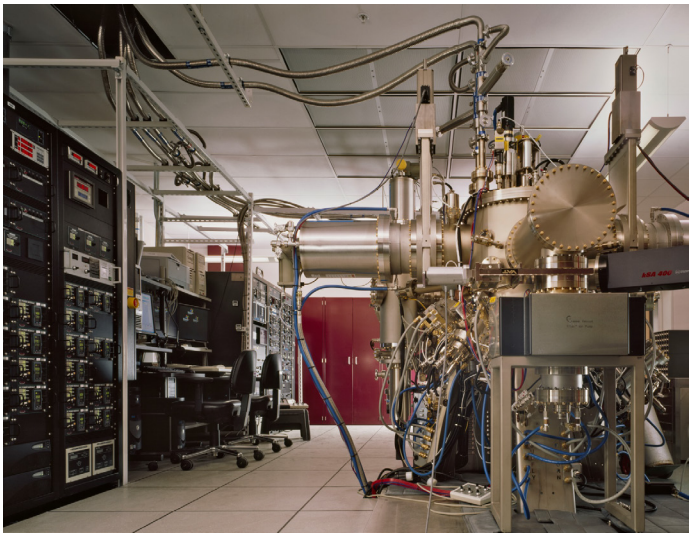


Figure 2.5 MBE Lab

Core Room 1311: III-V Semiconductor Molecular Beam Epitaxy Laboratory

The molecular beam epitaxy (MBE) capability at this lab consists of two MBE machines: a Veeco Gen20 and an EPI 1240, each capable of growing up to 4 inch wafers (Figure 2.5). They are both configured for the growth of As-based III-V compound semiconductors. These systems specialize in high-purity and high-mobility materials grown with monolayer precision. Extensive multiple quantum well structures are commonly grown. Both n-type doping using Si and p-type doping using C from a graphite source are available. Areas of interest for growth that are available to CINT Users include: low dimension semiconductor systems, quantum transport and contacts, and electronic devices based on intra-sub-band transitions.

4. Biomolecular Materials

Associated CINT Scientist: George Bachand, Jennifer Martinez, Gabe Montano, Wally Paxton

	FY 13	FY14	FY15
Available Operational hours (1)	18,000	18,000	18,000
Staff Availability for Users (2)	1,417	1,417	1,417
Delivered hours - External Users	1,872	1,856	3,944
Delivered hours - LANL/SNL Users	3,488	6,584	4,240

(1) 4 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 4 scientists + 1 Technologist

Gateway Rooms 2201 and 2207: Biochemistry and Bioassembly Laboratories

The biomaterials and bioassembly labs enable the development of integrated bio-inspired and biocompatible materials. The bio-laboratory suite is approximately 2000-square-feet with an integrated cold room, two instrument rooms, a mammalian cell culture facility, a bacterial culture room, and a molecular biology/biochemistry/chemistry suite. This Bio Safety Level Two (BSL-2) facility is able to culture mammalian cells and bio-threat surrogates for nano-enabled biosensor testing. Beyond standard laboratory techniques, such as recombinant DNA cloning, innovative research techniques performed include: creating fluorescent silver and gold nanoclusters for applications in sensing and imaging; creating genetically engineered polymers for application in regenerative medicine and opto- electronics; proliferating and differentiating stem cells, and testing their interaction with materials; and finally, creating recognition molecules through biological means (phage display).

Specific laboratory capabilities include:

- Phage display (proprietary and custom peptide, protein, polymer, and scFv libraries).
- Genetic engineering.
- Expression, purification, characterization, and functionalization of recombinant proteins.
- Synthesis and functionalization of biocompatible fluorescent nanoclusters.
- Genetically engineering of polymers including design, synthesis and application.
- Microwave-assisted peptide synthesis (natural and non-natural modifications), high throughput purification, and mass spectrometric (Quad-TOF) analysis.
- Mammalian cell culture (stem cell differentiation and cell/sub-cellular targeting of nanoparticles).
- Self-assembly strategies based on molecular recognition. Peptide and DNA self-assembly.
- BSLII facilities.

Core Rooms 1326 and 1328: Biomolecular / Bio-inspired Materials Synthesis Laboratories

The capabilities in these laboratories enable researchers to isolate, engineer, and integrate structural and functional biomolecular components with nanoscale synthetic materials and systems. Because native biomolecular nanomaterials are, in general, poorly suited for integration with synthetic systems, a primary focus is engineering biomaterials specifically designed to function in synthetic hieratical structures. Additionally, functionalization of biological molecules is being studied with respect to developing strategies for integrating living and non-living components that share a common interface. The specific capabilities available to CINT users include: (1) culturing of a range of organisms (e.g., primary and immortalized eukaryotic cells, fungi, bacteria, thermophiles, halophiles, etc.), (2) recombinant DNA cloning, engineering, expression and char- acterization in both prokaryotic and eukaryotic systems, (3) expression, purification, characterization, and functionalization of native and recombinant biomolecular nano-machines, (4) functionalization of bio- compatible semiconductor, magnetic, and metal nanocrystals, (5) design of heterfunctional biomolecules for complex materials assembly, and (6) in vitro toxicity assays for engineered nanomaterials. Significant optical characterization capabilities also housed in these laboratories and include high resolution, differential interference contrast microscopy, dark field microscopy, wide-field epifluorescence microscopy, spinning disk confocal microscopy, fluorescence interference contrast microscopy (FLIC), total internal reflectance microscopy (TIRF) microscopy, and single particle/

molecule tracking.

Core Rooms 1309: Soft Matter Interfaces Laboratory

The Soft Matter Interfaces lab is primarily used for three purposes: (1) The chemical functionalization of solid substrates, (2) the preparation, modification, and purification of small molecules and polymers, including amphiphilic block copolymers, and (3) the characterization of colloidal suspensions of self-assembled and aggregated structures. To accomplish these objectives, this lab is equipped with a chemical fume hood, Schlenk line, rotary evaporator for the chemical synthesis of organic and polymer compounds. The purification of macromolecule targets is facilitated by a prep-scale gel permeation chromatography system (Waters). This lab is also used for the preparation of self-assembled and aggregated structures - including polymer and lipid vesicles - that are characterized by a dynamic light scattering system (Zetasizer Nano ZS, Malvern). This lab is also equipped with electrochemical workstation (CHI660D, CH Instruments) for lab-scale electrodeposition and electrochemical characterization of materials. Finally, this lab is equipped with a laminar flow cabinet for the preparation of substrates used for microcontact printing and the assembly of supported lipid and polymer bilayers.

Core Room 1331: Self-assembly Chemistry and Membrane Biochemistry Laboratory

This laboratory is a Bio Safety Level One (BSL-1) facility (Figure 2.6). There are fume hoods for preparation and handling of organic solutions, and various chemical processes. Capabilities for liposome, planar lipid assemblies, and block-copolymer membrane assemblies exist as well as capabilities for isolation and purification of biological membrane and membrane components. Equipment includes a Misonix sonicator 3000 for membrane and cell disruption, various size exclusion and affinity chromatographies for membrane complex isolation and purification. Characterization techniques include UV-Vis spectroscopy (Jasco V-530)—a more powerful Cary 3000 UV-Vis-NIR also exists in the CINT Core Facility. The lab also houses fluorescence spectroscopy capabilities (PTI-QM4) with steady-state excitation from a Xenon lamp source and emission from 200 nm-1700 nm using PMT and InGaAs detectors and lifetime measurements of ~100 ps to ms lifetime resolution and excitation wavelengths of 273 nm, 380nm, 405 nm, 463 nm and 635 nm. Additionally, an Asylum MFP-3D Atomic Force Microscope is used primarily for in-situ measurements. An anoxygenic chamber is also available for growth of anoxygenic photosynthetic bacteria; and, a Microfluidics Microfluidizer provides for cell disruption with a range of 30k PSI. A FV1000 laser scanning confocal microscope offers multi-line argon, HeNe and 635 nm diode laser lines; and, a Mai-Tai Ti: sapphire laser and MCP PMT can be used for picosecond time resolution capabilities.

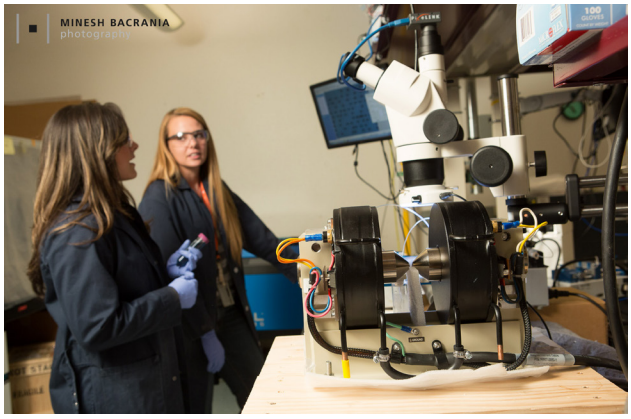


Figure 2.6 The Self-assembly Chemistry and Membrane Biochemistry Laboratory

5. Nano/Micro Fabrication

Associated CINT Scientists: John Nogan (Cleanroom Manager), Quinn McCulloch

	FY 13	FY14	FY15
Available Operational hours (1)	27,000	27,000	27,000
Staff Availability for Users (2)	4,750	4,750	4,750
Delivered hours - External Users	5,640	8,424	3,280
Delivered hours - LANL/SNL Users	6,640	7,096	3,312

(1) Cleanroom available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) One cleanroom manager, one technologist, 4 FTE dedicated cleanroom technologists (8 hours/day, 5 days/week, 50 weeks/year)

The CINT Integration Lab is a 9000 square-foot, class 1000 cleanroom designed to allow CINT staff and users to integrate nano-enabled components using up to 100 mm wafer processing technology. A typical back-end or MEMS device processed in the laboratory would consist of one to three mask layers with a minimum feature size of 1 micron for contact mask lithography or 10 nm for e-beam lithography. It would contain one or more electron beam or sputter deposited metals and incorporate plasma etch steps, atomic layer deposition, plus plasma enhanced or low pressure chemical vapor deposited film processing steps. The facility is staffed with engineers to assist and/or perform process development and device fabrication as needed. This enables the facility to be flexible enough to allow experienced users and staff to fabricate their own devices while also permitting inexperienced users to obtain complex structures for their projects. The laboratory capabilities have been subdivided into five generic processing areas: Contact Lithography, Plasma Systems, Wet Processes, Physical Vapor Deposition and Thermal Processes.

Core Room 1523: Contact Lithography

A vast majority of devices fabricated within the Integration Laboratory require one or more lithography steps to define the features of interest. Therefore, our lithography area has been organized to allow multiple users to process wafers in parallel. A Heidelberg dwl66fs laser lithography system provides a means for low volume, low cost contact lithography mask production. The mask aligners are typically configured for i- and g-line resists, but are also capable of deep UV, which allows the flexibility to process a variety of different photoresists and polymers. Processes are currently under development to introduce large area, nanometer scale Nano Imprint Lithography (NIL) capabilities to the lab. In addition, there are multiple spinning, baking, development, stations in the photolithography bay that offer varying degrees of automation depending on the needs of the process and users.

Core Room 1527: Plasma Systems

The integration lab has three inductively coupled plasma (ICP)etch system, one capacitive coupled plasma (CCP) etch system, a single High Density Plasma Chemical Vapor Deposition (HDP-CVD) system, a Downstream Low Frequency (DSLF) plasma ash system, and a Direct Current (DC) Ion Beam Milling system. The HDP-CVD system allows a conformal, low temperature deposition of Si based materials such as hydrogenated αSi, silicon nitride, and silicon dioxide. The other ICP etch systems include Time Multiplexed Deep Reactive Ion Etch (TMDRIE) for Si Nanowire formation or high aspect ratio silicon structures, and separate ICP reactors with chlorine or fluorine based chemistries for the precision dry etching of a variety of metals, dielectrics and III-V compound semiconductor materials. The CCP RIE system, with common fluorine and oxygen etch chemistries, greatly simplifies processing of small or delicate samples. The DSLF plasma ash system provides methods for both the selective removal of insoluble organic materials from a substrate's surfaces and the isotropic etching of silicon based dielectric materials. With the DC Ion Beam Mill, selective anisotropic physical etching of a wide variety of low volatility materials is possible. Overall, there are very few materials that cannot be processed with the lab's collection of physical and reactive ion etch systems.

Core Room 1525: Wet Processes

Throughout the facility there are multiple acid and base wet processing stations with integrated cascade deionized water rinse baths, and process specific solvent benches. In order to reduce contamination risks, specific wet benches are dedicated to photolithography and metal lift-off operations. Most chemical processing is limited to small beaker size quantities utilizing less than a few hundred milliliters of chemical. Each chemical processing station is set up to allow a user to quickly mobilize the necessary bench top equipment for their experiments. Once complete, the station can easily be broken down in preparation for the next user. The lab has a single dedicated chemical bath of concentrated trimethylammonium hydroxide (TMAH) for highly selective anisotropic Silicon etching.

Core Room 1525/1527: Physical Vapor Deposition

To compliment the lab's HDP-CVD and LPCVD capabilities, there are Physical Vapor Deposition (PVD) vacuum systems for both conformal and directional deposition of high purity metal, metal-alloys, dielectric and ceramic materials typically used in lift-off and subtractive etching processes. PVD techniques include electron beam evaporation, thermal evaporation and sputter. The electron beam deposition systems use a rotational turret that holds up to six materials to allow for multi-layer deposition without breaking vacuum. A third fully automatic load-locked single source electron beam deposition system meets low level production demands while maintaining optimal control over the purity of source materials. The sputter system consists of three, independently selectable RF or DC magnetron sources. In general, the electron beam and thermal evaporation systems are designated for common use materials while the sputtering system supports the same plus a range of experimental or high risk materials. With this arrangement of deposition system capa- bilities, there are very few limitations to the combination of materials that can be deposited providing a high degree of flexibility in the research environment.

Core Room 1532: Thermal Processing

A variety of high temperature systems have been included in the Integration Laboratory for annealing samples, and for the growth and deposition of high quality thin films. These systems include an Atomic Layer Deposition (ALD) reactor, a multi-tube, atmospheric pressure Thermal Oxidation (TOx) and Low Pressure Chemical Vapor Deposition (LPCVD) furnace, a Rapid Thermal Anneal (RTA) system, and a set of smaller ovens. Future capabilities include the addition of two vacuum ovens for low temperature lithography support and for high temperature experimental work. The tube furnace uses a steam generator to accelerate silicon dioxide growth, dichlorosilane and ammonia for low stress and stoichiometric silicon nitride deposition, silane for intrinsic poly-silicon and TEOS for low stress silicon dioxide deposition. The ALD reactor can be operated in thermal, plasma assist or a thermal-soak mode to support atomic precision high-K dielectric and highly conformal metal depositions. The RTA supports both argon and forming gas annealing processes that are typically used for improving interlayer contact resistance or to make controlled adjustments to a thin film's electro-mechanical properties.

Femtosecond Laser Direct Writing (FLDW) (Gateway Facility):

A turnkey, FLDW capability has been developed for the prototyping and fabrication of 2-D and 3-D structures. This is primarily a subtractive manufacturing (cutting) capability where ultrashort laser pulses are used to remove material from substrates while causing little to no heat affected zone (HAZ). A few highlights of the applications of FLDW in this regime are: microfluidic channel arrays were fabricated on surface glass and plastics;masks (< 100 microns thick) were cut out of glass and metals; and, thin-film patterns that required the selective removal of a metal from a glass or semiconductor substrate were fabricated. Other capabilities performed include cutting Cu-Nb nanolayered composites and writing patterns on reduced graphene oxide (RGO). In this cutting regime, single-shot ablated features range in size from a few hundred nm to < 10 microns (depth or width), depending on user-selectable laser parameters. In addition to FLDW-based cutting, this system can also be used in a non-subtractive manner where the intense laser pulses are used to modify material properties such as index of refraction. In this regime, fiber Bragg gratings (FBGs) have been successfully written into commercially available optical fibers, and the lab is currently exploring the ability to write waveguides and gratings into bulk glass samples.

6. Electron Beam Lithography

Associated CINT Scientist: John Nogan (Cleanroom Manager)

	FY 13	FY14	FY15
Available Operational hours (1)	4,500	4,500	4,500
Staff Availability for Users (2)	900	900	900
Delivered hours - External Users	2,200	2,000	2,419
Delivered hours - LANL/SNL Users	1,700	2,000	1,678

(1) Available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Availability depends upon user competence and is staffing-limited: 1 technologist

Core Room 1501: Electron Beam Lithography Lab

Electron beam lithography is a tool that enables nanoscience and engineering research because of its powerful ability to write nanometer-scale features on a variety of substrate materials. The capability to pattern fine structures in a deterministic, repeatable fashion is desirable in virtually every field of science. CINT has offered electron beam lithography as a capability since the beginning of its User Program.

The JBX-6300FS electron beam lithography system (Figure 2.7) is a state-of-the-art tool capable of field emission operation at 100kV acceleration voltage. With a minimum spot size of less than 3nm, the system is capable of line widths less than 8nm in resist. A 19-bit beam deflection amplifier allows beam steps down to 1.25 Å at 100kV. Overlay and field stitching accuracy is better than 20nm in high resolution writing mode. Various holders can accommodate small pieces from 10 to 25 mm in side length and full wafers from 2 to 6 inches in diameter. To support the continued advancement of EBL technology at CINT, BEAMER an electron- beam lithography support software is utilized as a design aid to identify and minimize potential process effects that could result in a non-ideal pattern transfer. BEAMER carefully analyzes a design file and then fine tunes each structure's geometries to optimize beam positioning and dosing parameters to achieve high accuracy pattern transfer. Design aberrations that once took days to identify through assessment and experimentation, can now be identified and corrected within a few minutes prior to uploading the file into the JBX-6300FS for processing. This instrument, in association with etch and deposition tools in the CINT cleanroom, provides apowerful nanofabrication capability applicable to a wide variety of materials and devices.

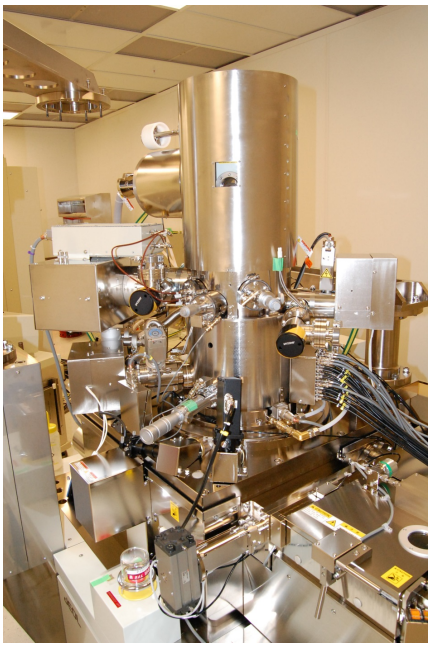


Figure 2.7 JEOL e-Beam Writer

7. Transmission Electron Microscopy

Associated CINT Scientist: Katie Jungjohann

	FY 13	FY14	FY15
Available Operational hours (1)	4,500	4,500	4,500
Staff Availability for Users (2)	1,400	1,400	1,400
Delivered hours - External Users	1,696	1,136	784
Delivered hours - LANL/SNL Users	216	920	664

(1) Available operating hours (18 hours/day, 5 days/week, 50 weeks/year); extended instrument availability including weekend time without any technical support would be 5850 hours/year.
(2) Staffing limited: 1 scientist (+ 0.50 contractor in FY15)

Core Room 1122: Transmission Electron Microscopy Lab

This lab operates an FEI Tecnai G(2) F30 S-Twin, 300 kV transmission electron microscope (Figure 2.8). The instrument has a resolution in TEM mode of 0.20 nm at 300 kV, and is configured to also operate at 200 kV and 100 kV with resolutions of 0.25 and 0.32 nm, respectively. The microscope may operate in scanning mode, with a resolution of 0.14 nm using the high-angle annular dark-field (HAADF) detector. Furthermore, the instrument has an EDAX ECON energy-dispersive x-ray detector for analyzing characteristic x-rays for elemental analysis, and a Gatan GIF Tridiem electron energy-loss spectrometer for characterizing the electronic structure for energy-filtered imaging.

The TEM is used for the structural and compositional characterization of materials at the nanometer-scale and for in-situ experimentation of nanostructure materials such as mechanical testing or electrochemical reactions. In-situ specimen stages are compatible with this electron microscope which uses a scanning probe to allow AFM, STM and nanoindentation while imaging. It also serves stages for MEMs heating, double tilt cryo, and liquid flow/electrochemical control.

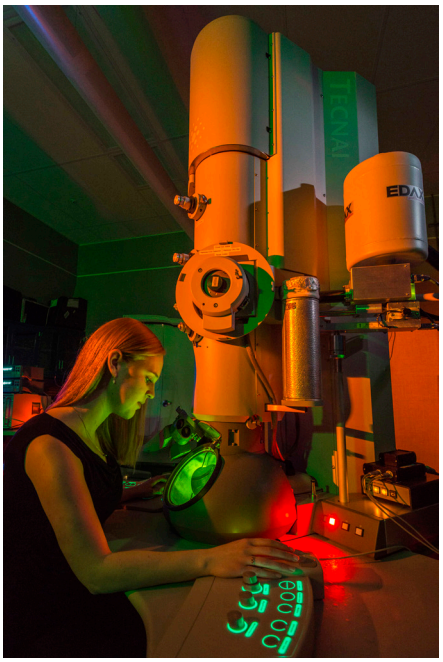


Figure 2.8 FEI Techni F30 TEM

Core Room 1123: TEM Sample Prep Laboratory

An adjacent laboratory is equipped to prepare specimens for TEM examination, with instruments for mechanically polishing, dimple-thinning, ion milling, or to microtome materials to produce ultrathin electron-transparent sections. The probes for the in-situ AFM, STM and nanoindentation stages are prepared within the fume hood in this laboratory.

8. Quantum Transport

Associated CINT Scientist: Mike Lilly, Tom Harris

	FY 13	FY14	FY15
Available Operational hours (1)	9,000	9,000	9,000
Staff Availability for Users (2)	667	667	667
Delivered hours - External Users	2,088	1,264	312
Delivered hours - LANL/SNL Users	4,928	3,024	5,256

(1) 2 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 2 scientists

Core Room 1111 and 1112: Quantum Transport Laboratory

The electronic properties of nanoelectronic structures exhibit quantum mechanical and interaction effects at low temperatures and high magnetic fields. At this lab, devices designed to explore these effects can be fabricated on compound semiconductor heterostructures using standard microfabrication techniques. The primary capabilities for transport characterization of nanoelectronic devices is a rapid turn-around 3 He system for 0.3 K to 300 K and two dilution refrigerators for reaching 0.02 K. One dilution refrigerator is a wet system with a high homogeneity 3 inch bore 13 Tesla magnet and the other is a dry system with a 2 inch bore 8 Tesla magnet. Also, for density characterization at the lab, a Hall system can be operated from 4 Kelvin to 300 Kelvin with a magnetic field of 0.17 Tesla. Semiconductor devices can be bonded with a ball/wedge Westbond wirebonder.

Core Room 1127: Transport Phenomena Laboratory

The Transport Phenomena Laboratory is equipped with instrumentation for measuring electron and phonon transport in nanoscale structures. The key capabilities of the laboratory include:

- Multiple closed-systems cryostats capable of operating from 10K-340K, with a temperature stability of 10mK. These cryogenic systems have been designed with custom sample holders and are coupled to numerous high-resolution source-measurement units that facilitate measurements of electron and phonon transport in single nanostructures.
- A variable temperature insert (VTI) with an operational range of ~1K-325K. This system is equipped with an 8Tesla superconducting magnet with a 3-inch bore.
- Variable temperature ultra-high vacuum atomic force microscope and scanning tunneling microscope (AFM/STM). This system consists of an RHK UHV 3000 system with a temperature range from 100 K to more than 1200 K. Open architecture controllers permit the use of customized AFM tips for the exploration of novel scanning methodologies.

9. Optical Characterization & Spectroscopy

Associated CINT Scientists: Igal Brener, Ryan Camacho, HouTong Chen, Steve Doorn, Anatoly Efimov, Han Htoon, Willie Luk, Rohit Prasankumar.

	FY 13	FY14	FY15
Available Operational hours (1)	31,500	31,500	31,500
Staff Availability for Users (2)	3,750	3,750	3,750
Delivered hours - External Users	5,776	7,152	9,048
Delivered hours - LANL/SNL Users	8,256	13,416	8,944

(1) 7 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staff limited: 8 scientists + 1.5 technologist

Gateway Room 1201: Ultrafast Optical Spectroscopy and Nanophotonics Lab

The lab provides a suite of ultrafast optical excitation, control and diagnostic capabilities, spanning wavelengths from the ultraviolet to the mid-infrared region, pulse durations down to 30fs and pulse energies up to 1mJ. Various experimental configurations are possible, including pump-probe, and time-synchronized multibeam configurations. Spectral measurements can be made using spectroscopic equipment available featuring regular and intensified CCDs, linear detector arrays and Fourier-transform infrared setups. Time- resolved and phase-sensitive measurements of ultrashort pulse dynamics in photonic nanostructures, waveguides and fibers are possible with frequency-resolved optical gating (FROG), cross-correlation FROG (X-FROG) and supercontinuum-based spectral interferometry setups. Pulse shaping capabilities for coherent quantum control experiments are available near 800 nm and 1500 nm using a liquid-crystal spatial light modulator mask and a one-dimensional deformable mirror. Various laser options offered at the lab make it possible to focus beams to the transform limit, allowing efficient excitation of single-mode waveguides, nanostructures and scanning imaging with ~μm resolution. Laser microscope setups are available for incoherent, coherent and ultrafast illumination, including dark-field coupled to spectroscopic detection. Additionally, a femtosecond, laser micromachining system can processmaterials in three dimensions. Materials can be processed at the laser's fundamental wavelength, 1552 nm, or at 776 nm or 388 nm through the use of frequency conversion optics. Typical applications of this system include the rapid prototyping of microfluidic devices, THz and IR metamaterials and fiber Bragg gratings.

Specific laboratory facilities and capabilities include:

- Multiple Ti:Sapphire femtosecond lasers.
- 82 MHz tunable optical parametric oscillator system delivering few nJ 100 fs pulses in the 1300-1600nm wavelength region.
- 1kHz Ti:Sapphire laser amplifier system delivering 1 mJ, 100 fs pulses.
- 1kHz white-light seeded parametric amplifier delivering sub-20 fs pulses at the μJ pulse energy range in the 250-1000nm wavelength span.
- 250kHz Ti:Sapphire laser amplifier system delivering 4 μJ pulses at 800 nm with subsequent stages of visible and IR parametric amplifiers and difference frequency generators covering the 400-4000nm wavelength region.
- 1Hz-500kHz amplified fiber laser capable of delivering 5 μJ, 800 fs pulses, at 1550 nm.
- Femtosecond pulse shapers at 800 and 1500 nm wavelengths.
- XFROG system for studying nonlinear dynamics of ultrashort pulses in photonic and nanostructured materials and waveguides featuring >30dB dynamic range, high sensitivity and ultrawide bandwidth.
- Dual-wavelength 800/1500 nm FROG/autocorrelator system.
- Z-scan system.
- Supercontinuum-based (1350-1850 nm) spectral interferometry system for measurement of linear parameters of nanophotonic structures and waveguides.
- Suite of fiberoptic capabilities for telecom wavelength range (single- and multi-mode fibers, amplifiers, electrooptic modulators, optical spectrum analyzers, lasers, broadband sources, APD and ultrafast

detectors, optomechanic components).
- Femtosecond laser micromachining system at 800 and 1550nm.
- FTIR microscope with polarized excitation/detection, step-scan, transmission/reflection modes and electrical sample probes.
- CARS microscope operating in the visible wavelength range.
- Various spectroscopic tools (CCD-based, linear array-based, scanning and FTIR spectrometers).

The lab provides a range of capabilities for the preparation, chemical manipulation, and spectroscopic characterization of carbon nanomaterials (including carbon nanotubes, graphene, and graphene oxide) and other optical nanomaterials, with a focus on measurements made in the near-infrared wavelength range. Capabilities include instrumentation for near-IR fluorescence spectroscopy, imaging, lifetime, and correlation spectroscopy. This system offers both single-line laser and broad wavelength-selectable lamp excitation for fluorescence and photoluminescence excitation spectroscopy on solution and solid bulk samples. For characterization at the single-nanostructure level, CW and tunable (from 480 to 600 nm) picosecond excitation (2-3 ps pulsewidths) sources are integrated to a microscope, which allows confocal and wide area direct fluorescence imaging and spectroscopy. Imaging detectors include 2D InGaAs and EM-CCD arrays for broad spectral coverage and they allow direct imaging of individual nanostructures and assemblies in real time. The complementary wavelength ranges of the two detector arrays enble simultaneous two-color imaging of samples. Sample emission is also coupled into a time-correlated single photon counting system with 2 silicon avalanche photo-diodes as detectors, allowing single-element lifetime and correlation measurements. Capability also exists for 785 nm Raman spectroscopy and standard UV-Vis-near-IR absorption spectroscopy. In addition to the lab's spectroscopic instrumentation, facilities include the resources required for preparation of carbon nanotube suspensions (using surfactant, DNA, and other polymer coatings), chemical functionalization (covalent and noncovalent), ultracentrifugation, separations (using gel chrotography, density gradient, and aqueous two-phase system approaches).

Specific capabilities include:
- Kaiser 785 nm Raman spectrometer.
- Varian UV-Vis-near-IR absorption spectrometer.
- Near-IR photoluminescence and photoluminescence excitation spectroscopy.
- Fluorescence imaging and microspectroscopy.
- Simultaneous 2-color large area imaging (with 2D InGaAs and EM-CCD detector arrays).
- Single nanostructure and single site spectroscopy with confocal excitation.
- Time correlated single photon counting and correlation spectroscopy (PicoQuant Hydra Harp system).
- 568 nm CW diode laser excitation (to 100 mW).
- 785 nm CW diode laser excitation (to 100 mW).
- Tunable (480 to 640 nm) pulsed (40 MHz, 3 ps pulsewidths) fiber laser excitation (1.5 mW average power).
- Ultracentrifuge.
- Density gradient maker.
- Ultrasonication apparatus.

Gateway Room 1203: Nanoscale Optical Probes and Spectroscopy Laboratory

The optical microscopy and spectroscopy lab provides tools to explore the optical properties of nanoenabled materials. This is achieved through high-resolution imaging microscopes, which measure the optical response of individual nanoscale materials such as carbon nanotubes, and a host of nanocrystal structures including dots, rods, and wires. The lab is equipped with 2 home-built inverted confocal optical microscopes, a laser scanning Raman microscope, and a combined AFM-confocal microscopy system capable of apertureless NSOM operation. Several microscopes can perform cryogenic measurements down to 4K. These microscopy systems, together with variety of lasers and photo detectors covering over both visible to NIR spectral ranges allow investigation on a highly diverse range of energetic and temporal photo-physical properties of nanoscale materials. Moreover, the lab is designed to be maximally flexible which allows experiments to be tailored for nearly any modern optically

active nanoscale material. Recent optical experiments include: single nanocrystal time resolved spectro-electrochemistry that unravel the mystery of nanocrystal blinking and 2nd order photon correlation spectroscopy studies that demonstrate the plasmonic manipulation on photon emission statistics of individual nanocrystals.
Specific capabilities include:

- Far-field optical microscopy.
- Fluorescence and Raman spectroscopy.
- Single-nanostructure fluorescence detection, imaging and spectroscopy.
- Single nanostructure spectro-electrochemistry.
- Single nanostructure time-resolved photoluminescence and photo-correlation spectroscopy.
- Direct correlation of optical and structural properties. (e.g. correlated Raman-TEM and TRPL-AFM studies).
- Simultaneous electrical-optical characterization of individual nano devices.
- Aperture and apertureless near-field scanning optical microscopy (NSOM) and atomic force microscopy.

Excitation and Detection Systems
Laser systems:

- Coherent Chameleon Ti: sapphire oscillator + OPO (150 fs pulses).
- Coherent Cube SS diode laser: 400 nm CW to 150 MHz.
- DPSS Nd:YAG: 532 nm CW.
- Picoquant picosecond diode lasers for 400 and 440 nm.

Spectrometers:

- Acton SP-2358 imaging spectrographs with < 0.5 Å resolution.
- Acton Trivista triple spectrometer in subtraction mode.
- Cooled array detectors for low light level spectroscopy applications.
- SPEC 10-2KB (2048x512) CCD (range: 200–1000 nm).
- PyLoN 100BR_eXcelon (1340x100) CCDs (range: 200-1050nm).
- OMAV 1024 InGaAs linear diode array (range: 800–1700 nm).
- NIRvana 2D InGaAs diode array (range: 800–1700 nm).
- Time correlated single photon counting systems for fluorescence lifetime studies.
- B&H SPC-630 and SPC-138 TCSPC PCI-cards.
- Picoquant HydraHarp TSCPC system.
- ID Quant ID 100 APDs (jitter 40ps, range 400-800 nm).
- Perkin Elmer SPCM-AQR-14 APDs (jitter 400 ps; range 400-950 nm).
- Hamamatsu H9170-45 NIR PMT (jitter 300 ps; range: 950–1400 nm).
- Single Quantum Eos 210, 4 channel superconducting nanowire single photon detector (jitter <60ps; range: 1000-1500nm).

Core Rooms 1128/1131: Ultrafast Spectroscopy Laboratory

Ultrafast spectroscopy provides important information about the excitation and relaxation dynamics occurring in nanostructured materials. This lab offers a suite of ultrafast excitation and diagnostic capabilities, spanning wavelengths from ultraviolet to far-infrared, for dynamic nanoscale characterization (Figure 2.9).

The available capabilities include:

- Femtosecond broadband transient absorption spectroscopy (mid-infrared to ultraviolet).
- Optical pump/terahertz probe spectroscopy.

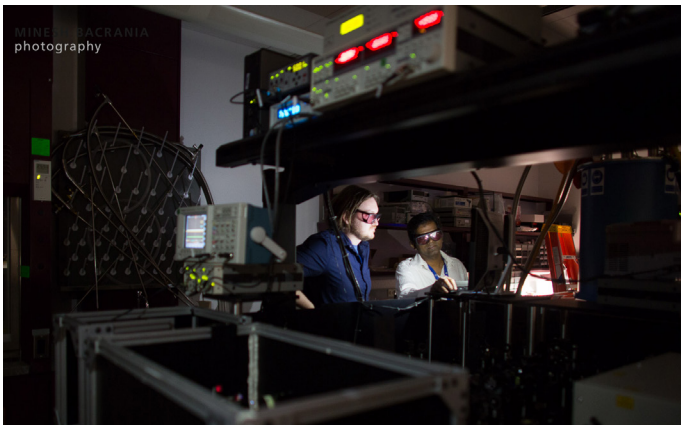


Figure 2.9 The Ultrafast Spectroscopy Laboratory

- Terahertz time-domain spectroscopy.
- Ultrafast optical characterization at photonic wavelengths (1.55 microns).
- Cryogenic capabilities (temperatures down to 1.5 K) in combination with all ultrafast optical and THz experiments.

In the lab, optical pump/THz probe and THz time-domain spectroscopy can be performed from ~0.1-10 THz in magnetic fields up to 8 T. Ultrafast optical spectroscopy can be done with independently tunable pump and probe wavelengths from 267 nm-3.4 μm. Facilities also include high sensitivity pump-probe spectroscopy at 400 and 800 nm. Experiment capabilities include ultrafast optical microscopy and single nanoparticle spectroscopy, light propagation in metamaterials, and time-resolved photoluminescence with ~ 1 picosecond time resolution. Specific instruments include a Spectra-Physics Spitfire Ti:sapphire amplifier (6 mJ, 35 fs pulses at 800nm, 1 kHz repetition rate), KML Cascade Ti:sapphire oscillator (40 nJ, 15 fs at 800 nm, 2 MHz repetition rate), a Coherent Chameleon Ti:sapphire oscillator, and a Coherent system consisting of a RegA regenerative amplifier (50 fs, 10 uJ, 100 kHz), 9450 OPA and 9850 OPA.

Core Rooms 1106 and 1108: Nanophotonics Laboratories

These laboratories are flexible optical characterization labs. There is a variety of compact mobile micro-pho- to-luminescence (micro-PL), -transmissivity and -reflectivity apparatus with excitation sources from 0.27 to 1.6 um region and detection capabilities from 0.35-1.6um region with a spatial resolution of about 1 micron. They can be integrated with a probe station to perform electro-luminescence measurements. In addition, small samples can be cooled to liquid nitrogen temperatures. Lab 1106 is also equipped with angular dependent thermal emission from heat samples up to 1000K. And, Lab 1108 is equipped with an infrared spectral ellipsometer for thin film characterization, a femtosecond fiber laser and a variety of bench top optical systems that use infrared lasers (Co2 lasers and similar) and infrared detectors (MCT, InSb, etc).

Core Room 1332: Opto-nanomechanics Laboratory

This new laboratory has built up capabilities for testing integrated photonics devices for classical and quantum information processing. There are four custom optical probe stations for a variety of fiber-chip coupling scenarios, a suite of tunable lasers ranging from 776nm to 1630 nm, single photon sources, detectors, counters and other high speed electronics useful for a variety of quantum and classical photonics experiments. The lab also has a new custom fiber-taper pulling setup capable of drawing fiber tapers with sub-micron diameters.

Gateway Room 1201: Photovoltaic Characterization Laboratory

It is not appropriate to use standard characterization tools for commercially available devices to investigate the performance of nanodevices because the sizes of devices fabricated in a laboratory with nanomaterials are much smaller than industry devices. This facility offers a photovoltaic measurement system (PV Measurements, Inc.) for solar cell in laboratory scale with the sizes ranging from 100 μm×100 μm to several cm2. The labis sample stage equipped with probes and clips that enable mounting small samples. Additionally, a NIST-traceable calibrated photovoltaic reference cell ensures accurate simulated sun light settings.

10. Scanning Probe Techniques & Imaging

Associated CINT Scientists: Brian Swartzentruber, Nate Mara, Jinkyoung Yoo, Taisuke Ohta/Gary Kellogg*

	FY 13	FY14	FY15
Available Operational hours (1)	27,000	27,000	27,000
Staff Availability for Users (2)	3,150	3,150	3,150
Delivered hours - External Users	4,400	6,672	5,224
Delivered hours - LANL/SNL Users	4,992	8,760	9,376

* Part-time CINT Scientist during reporting period.
(1) 6 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staff limited: 3.5 scientists + 0.5 technologist

Core Room 1102: Nanomanipulation Laboratory

This laboratory contains a two-probe nanomanipulator inside of a JEOL field-emission scanning electron microscope for manipulation and electrical characterization of nano-scale structures. Nanowires can be isolated and interrogated in their "as grown" configuration without additional processing to disperse them onto secondary substrates. Furthermore, selected nanostructures can be picked and placed over predefined electrical or MEMS-like contacts for integration into micro-scale structures.

Core Room 1103: Scanning Probe Microscopy Laboratory

A suite of scanning probe instrumentsare housed in ths lab for characterizing surfaces and nanoscale structures. A Veeco NanoScope IVa Atomic Force Microscope (AFM) enables topography, phase imaging, scanning capacitance, and conducting-tip (TUNA) microscopy. The lab also has one ultra-high vacuum variable-temperature STM instrument (RHK) and a custom-made UHV STM. Additionally, the lab provides two helium closed-cycle cryostats for variable-temperature measurements of nanowire thermoelectric properties, electrical conductivity of thin films, and device characterization.

Core Room 1504 Integration Laboratory: Ultra High Resolution SEM and Focused Ion Beam

Two FEI field-emission source SEMs are based in the Integration Lab. Frist, for sample analysis, the Nova 600 Nanolab from FEI Company combines the following capabilities all in one machine: ultrahigh resolution (SEM), Focused Ion Beam (FIB), Electron Dispersion Spectroscopy (EDS), Nabity Electron Beam Lithography (EBL) patterning, 2D and 3D machining, prototyping, and submicron litho-graphic processing. The resolution of 1.1 nm at 15 kV in secondary electron mode is further enhanced when using the STEM detector on the Nova 600. This dual-beam machine also allows for electron and ion induced deposition of metals from gas source precursors (currently, Pt) with line widths of 50 nm (ion beam) and 20 nm (electron beam). Also, an auto FIB, auto TEM, and pattern generation module is available for ion milling to provide automation of many tasks. The second machine, an FEI Nova NanoSEM 450, is a high resolution SEM for general surface analysis that includes a Nabity EBL patterning capability.

Gateway Room 1206: Nanoscale Characterization Laboratory

The ability to interrogate structure, composition, morphology, and transport properties across length-scales stretching from the macroscopic world to the nano-scopic world is critical to the integration of nano-enabled structures. To realize characterization in nanoscale, this lab's electron microscopes, single nanodevice fabrication and characterization facilities uniquely provide such capabilities that are essential assets for characterization of nanoscale systems. The Nanoscale Characterization Laboratory has scanning electron microscopes for imaging of nano-structures with high resolution and e-beam lithography capability (FEI Magellan 400 XHR-SEM for extreme high resolution and FEI Quanta 400FEG ESEM for imaging under environmental mode). Additionally, it provides a probe station for electrical device characterization capabilities down to single nanodevices.

The FEI Magellan 400 SEM provides sub-nanometer spatial resolution from 1kV to 30 kV (0.8 nm at 1 kV). Using

low voltages, only the surface of the sample interacts with the electron beam; thus, insulators/beam sensitive samples are imaged without the need for conductive coatings and the amount of surface data is maximized. The capabilities of this tool are ideal for investigations of nanotubes, nanowires, nanocomposites, and other materials when alternative equipment does not have the low-voltage resolution required for sensitive surface imaging.

This system features:

- Schottky thermal emission source to give a highly coherent beam (<0.2 eV energy spread).
- Energy Dispersive Spectroscopy detector for elemental analysis.
- Electron Backscatter Diffraction detector for crystallographic orientation determination.
- Nabity electron beam lithography patterning capability.
- Annular STEM detector (spatial resolution of 0.7 nm).

The FEI Quanta 400FEG operates in three modes: high-vacuum, low vacuum and an environmental mode. High-vacuum mode is used for high-resolution imaging of conductive samples, whereas low-vacuum mode is suitable for charging specimens. The ability to image samples that otherwise degrade in a high-vacuum environment is crucial in biological sciences. Additionally, the machine's energy dispersive spectroscopy allows for microscopic elemental spectroscopy and mapping. A Raith Elphy Quantum electron beam lithography attachment is utilized for fabrication of structure with critical dimensions >40nm.

The lab's electron beam induced current (EBIC) measurement system provides researchers with the capabilities to perform spatially-resolved electrical characterizations of materials and devices at nano/mesoscales with concurrent acquisition of morphological information. The recently purchased EBIC system has 0.76 fA sensitivity with a wide dynamic range of 108 dB. Electrical bias can be applied to nanomaterials/devices under observation. The EBIC system expands CINT's nanocharacterizations capability significantly from materials to devices in single nanostructure level. The EBIC system also works synergistically with CINT's nanofabrication suite which enables reserchers to fabricate nanodevices and to isolate single nanostructures, including quantum dot, nanowire, and two-dimensional materials.

The probe station is common electrical characterization equipment for micro/nanodevices. Additional features of this probe station expand such characterization capabilities. Temperature is one of the most fundamental parameters to control the characteristics of nanomaterials and nanodevices. Recently, the lab installed a temperature-dependent microprobe station in which sample temperatures can be continuously controlled in the range of 80 to 580 K via a Joule-Thomson refrigerator and a resistive heater. The microprobe station has a 4 probe configuration apt to field effect transistor measurements and resistivity measurements. The temperature-dependent microprobe station can be also connected to CINT's electrical characterization suite including a semiconductor parameter analyzer and a capacitance-voltage measurement system. The flexibility of measurement configuration and temperature-dependent measurement provide researchers with the opportunity to monitor the performances of nano/microdevices at various temperatures, corresponding to conditions of the real device in operation. Furthermore, the quartz window on top of the probe station enables researchers to assess the stimulus of photons on a sample of interest.

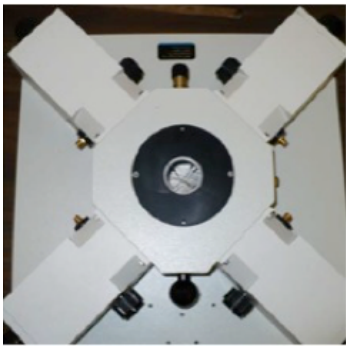


Figure 2.10 Probe station

SNL (Building 897 Room B212): LEEM-PEEM (low energy electron microscopy - photoemission electron microscopy) Laser LEEM-PEEM Laboratory

The LEEM-PEEM is a unique and versatile surface microscope that can be used to view dynamic processes on surfaces in real time with a spatial resolution of 5 nm (when using an electron gun) and a depth resolution of one atomic layer. LEEM provides high image contrast between regions on a surface with different atomic structures or chemical compositions. Because it is a non-scanning microscope, dynamic processes can be observed with a time resolution that is limited only by the video recording rate of the image acquisition system.

The sample temperature can be varied from ~100 K to 1800 K and images can be recorded with the sample at any temperature within this range. The instrument can also be operated while a flux of atoms or molecules impinges on the surface. The unique capability of this lab's LEEM-PEEM instrument is that it is equipped with an electron energy filter, and CW DUV and VUV light sources (pressurized xenon and helium discharge lamps). Thanks to the electron energy filter, electron energy loss spectroscopy and Auger electron spectroscopy can be carried out using this instrument. The LEEM-PEEM capability also allows the potential to directly study the surface behavior of integrated nano-structures which offers an unprecedented look into not only the collective behavior, but how individual nano-devices interact with each other, e.g. cross-talk.

SNL (Building 897 Room 2420): XPS Laboratory for X-ray and ultraviolet photoelectron spectroscopy (XPS and UPS)

The laboratory has XPS-UPS capability equipped with a hemispherical electron energy analyzer (Omicron NanoTechnology GmbH), a 5-axis sample manipulator (3 translational (x,y,z) and 2 angular (polar and azimuthal)), a magnesium/aluminum dual x-ray source, and a helium discharge lamp. The laboratory's 5-axis sample manipulator permits photoelectron diffraction mapping for interface atomic structure analysis and angle resolved photoemission spectroscopy. The system has a separate UHV chamber for sample processing/treatment and thin film deposition.

11. Nanomechanics

Associated CINT Scientists: : Nate Mara, Tom Harris, Wally Paxton

	FY 13	FY14	FY15
Available Operational hours (1)	13,500	13,500	13,500
Staff Availability for Users (2)	667	667	667
Delivered hours - External Users	1,136	720	1,096
Delivered hours - LANL/SNL Users	1,512	1,216	1,840

(1) 3 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 2 scientists

Gateway Rooms 1324 and Materials Science Laboratory C118: and Nanomechanics Laboratory

Ex-situ nanomechancial testing and behavior:

The nanomechanical characterization labs facilitate the testing of nanoscale material volumes and the discovery of differences between deformation at the nanoscale and the macroscale. Nanoscale materials include thin films, coatings, surface layers, included phases and nanostructured materials. These materials have enhanced strength, stiffness, wear, fracture, or fatigue properties but are typically synthesized with dimensions that make conventional testing impossible. The nanoindenter first scans the specimen surface to pinpoint the nanoscale region of interest. Testing uses instrumented, feedback controlled loading and displacement to determine a variety of properties including hardness, modulus, strain rate sensitivity, creep, damping, fracture toughness and tribological properties. Deformation at the nanoscale can produce bursts of dislocations or twins that are not observed in bulk measurements. In ceramics and other hard materials, the high pressure during indentation can lead to phase changes, which can introduce new slip systems or new modes of deformation. In addition, deformation at nanoscale dimensions has been found to involve material length scales, which has led to new mechanistic theories of strengthening. Nanoindentation can also be used to control the placement of defects, which causes localized effects in optical and electrical properties. Recent advancements in sample fabrication techniques, especially Focused Ion Beam (FIB) milling, have enabled new test methods such as micropillar compression to obtain the full stress-strain response and fracture behavior of nanoscale materials. Major workhorse instruments are a Hysitron Triboindenter 900 and an Agilent Nano XP nanoindenter with complementary capabilities including:

- Instrumented fully feedback controlled indentation
- Load resolution of 1 nN and displacement resolution 0.2 pm
- Surface scanning and nanopositioning
- Continuous stiffness measurement up to 2 N
- NanoDMA – dynamic mechanical analysis from 0.1-300 Hz
- NanoECR—Electrical contact resistance from 0-10V
- Temperature range from -10° to 240° C
- 3D lateral force measurement
- AFM contact or non-contact surface measurements
- Micropillar and other micromechanical testing

CINT's latest acquisition is the Hysitron TriboIndenter 950 (Figure 2.11), which is Hysitron's latest nanoindenter. It has three transducers including high load (up to 5 Newtons), low load and scratch; all of which are run with the Performech controller. The nanoDMA III option for both high and low loads is capable of testing at frequencies from 0.1 to 300 Hz. It is able to continuously monitor mechanical properties as a function of depth, frequency and time using CMX algorithms. This indenter is also equipped with the xSol 800 High Temperature stage for both high and low load options

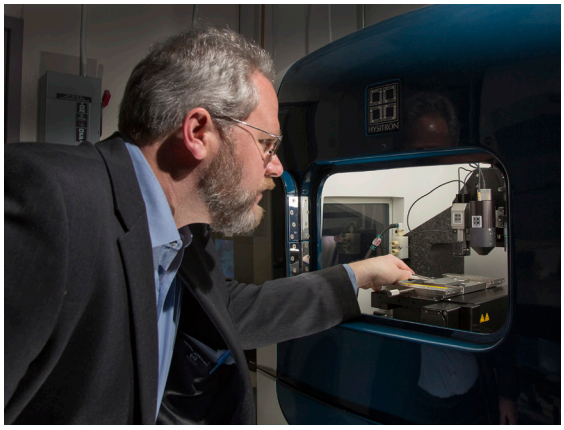


Figure 2.11 The Hysitron TriboIndenter 950

that allows for testing at temperatures from 22 ˚C to 800 ˚C depending on tip/sample compositional limitations in inert environments. The xSol stage is also compatible with all nanoDMA III techniques.

Gateway Room 1206: Nanoscale Characterization Laboratory

Nanoscale plasticity and fracture: In-situ deformation of small structures in the SEM:

In recent years, the ability to image localized plasticity events during small-scale mechanical testing has become critical to understanding nanomechanical behavior. These events include the onset of shear banding or fracture and anomalies in stress state such as buckling of compression samples and pile-up around nanoindents. In-situ mechanical measurements in the SEM provide an ideal combination of sufficient spatial and temporal resolution of these events, but require specialized mechanical test stages to deform the material under the appropriate imaging conditions. CINT has a Hysitron PI-85 SEM Picoindenter that provides the capability to deform materials via nanoindentation, tension, compression, or bending. This equipment excels in testing small samples or volumes with critical dimension <1 μm, and is equipped with a 400°C hot stage and Electrical Contact Resistance (ECR) capabilities for 4-point probe measurements. For larger samples of high-strength materials, the load capacity of commercially available in-situ deformation stages is inadequate. At CINT, we have designed and built a custom nanomechanical deformation stage to address these needs. By combining this information, along with using Digital Image Correlation techniques, the macroscopic stress-strain, as well as local stress-strain behavior, can give the complete deformation behavior of the material in question.

Core Room 1307: Holographic Optical Trapping and Force Measurement

The capability is comprised of a modular optical trapping fluorescence microscope that enables the non-contact 3-dimensional manipulation of trapped objects and a force measurement module capable of measuring interaction forces on the order of 0.1-900 pN, allowing one to observe the unfolding of supramolecular structures, the action of molecular motors, and measure the surface adhesion forces of biological cells. This laser trapping system complements the suite of top down and bottom up fabrication and manipulation methods at CINT, and fills a gap in the mechanical characterization in fluidic environments of soft structures composed of nanocomponents, such as biological and biomimetic materials and nanoparticles. We expect that the versatility of the system will be of great benefit to members of our user community interested in addressing the challenges of manipulating and interrogating the interaction between hard and soft nanomaterials in their native environments and integrating these components into composite nanomaterials and functional devices.

12. Discovery Platforms

Associated CINT Scientists: Tom Harris, Dale Huber

	FY 13	FY14	FY15
Available Operational hours (1)	9,000	9,000	9,000
Staff Availability for Users (2)	334	334	334
Delivered hours - External Users	2,744	2,272	2,752
Delivered hours - LANL/SNL Users	1,240	1,136	776

(1) 2 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)

(2) Staffing limited; Available user time is an estimate based upon 2 CINT scientists, part-time in support of Discovery Platform design, development, and user project support. The estimate includes non-CINT personnel time devoted to Discovery Platform™ support for user projects.

Core Room 1132: Energy Storage Systems Laboratory

The Energy Storage Systems Laboratory is equipped with instrumentation for studying nanoscale electrochemical systems. This lab is also equipped for measuring and analyzing phenomena associated with the motion, displacement, or vibration of micromechanical and nanomechanical structures. The key capabilities of the laboratory include:

- Numerous potentiostats (and bi-potentiostats) with ~10fA current resolution. These systems have been outfitted to perform electrochemical impedance spectroscopy from 5_Hz-5MHz with load impedances of ~1TOhm. These potentiostats also possess high-voltage (30V) sources for studying electrochemical behavior in solid electrolytes.
- A Desert Cryogenics probe station outfitted with 6 probes that have an operating range of 4K-325K.
- Custom laser interferometer for measuring vibrations in structures down to sub-nanometer amplitude, with a focused laser spot size of approximately 1 micron and a frequency range from KHz to 100 MHz. The system includes a sample chamber capable of 10-7 Torr vacuum up to ambient or special gas environments, piezoelectric actuation of the structures, and electrical feedthroughs for actuation or sensing.
- Scanning laser Doppler vibrometer (LDV) for mapping 2D resonance modes of complex structures with a spatial resolution of approximately 1 micron and at frequencies up to 1.5 MHz. The LDV system includes a Polytec MSA-400 LDV system coupled with a high vacuum chamber having electrical feedthroughs for MEMS actuation as well as a piezoelectric sample holder for achieving sample vibration. This system is capable of imaging complex mode shapes in micromechanical structures.

Core Room 1305: Soft Fabrication and Microfluidics Laboratory:

This laboratory houses CINT's Microfluidic Discovery Platform workstations where four sets of independent microfluidic synthesis experiments can be run simultaneously. The systems are modular and reconfigurable. They include computer controlled fluid pumping and temperature, real time UV, visible, and NIR spectroscopies, inline fluid mixing, droplet formation, variable magnetic fields, and custom software to integrate these functions. This laboratory also houses substantial soft fabrication capabilities, some of which are used to produce microfluidic components. Soft fabrication capabilities include additive manufacturing, laser cutting, as well as workstations for silicone microfluidics and other related techniques.

13. Nanostructure Analysis

Associated CINT Scientists: John Reno, Dale Huber, Sergei Ivanov, Millie Firestone

	FY 13	FY14	FY15
Available Operational hours (1)	13,500	13,500	13,500
Staff Availability for Users (2)	1,167	1,167	1,167
Delivered hours - External Users	3,496	3,280	4,376
Delivered hours - LANL/SNL Users	1,272	1,560	2,468

(1) 3 Labs, available operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 2 scientists

Core Room 1124: High-resolution X-ray Diffraction System Laboratory

The XRD instrument is comprised of a high-precision XRD platform with small-angle x-ray scattering, and variable temperature/pressure, thin-film, and micro-diffraction accessories. It is capable of variable-temperature and pressure crystal phase identification and quantification; size, size-distribution, and shape analysis of nanocrystals and crystalline domains; film thickness in single and multilayer films together with core and shell thickness determination in heterogeneous core/shell nanocrystals; stress analysis in films and hetero- geneous nanomaterials; and quality control of epitaxial films and superlattices.

Core Room 1302: Nanoparticle Characterization Laboratory

This lab hosts two fluorimeters, Horiba Jobin Yvon Fluorolog-3 (Nanolog) spectrofluorimeter with CCD detector (visible range)/InGaAs detector (1-1.8um) and PTI instrument with time-resolved luminescence capability; an Anasazi 90MHz multinuclear FT NMR spectrometer; a simultaneous Netzsch STA 449 Jupiter TGA/DSC analyzer; a Cary UV-vis-NIR spectrophotometer, a Bruker FT-IR spectrometer, and a 300W microwave chemical reactor by CEM. Thermogravimetric Analysis and Differential Scanning Calorimetry (TGA/DSC) are complementary techniques to investigate a material's response to different temperatures: mass change (e.g., decomposition or sublimation temperatures) and thermal changes often unaccompanied by the mass change as a function of temperature (e.g., melting, glass transition, second order phase transition, enthalpy and heat capacity measurements). Both techniques have become indispensable in the design of new metal precursors and understanding the structure/composition of nanocomposites.

Gateway Room 1208: Instrumentation Laboratory

This laboratory houses a Rigaku Ultima III X-ray Diffraction System, a critical piece of equipment for nanoparticle, nano-organic, semiconductor, metal, ceramic, etc. structural analysis. It has the versatility to analyze liquids and solids, powders and thin films. The XRD provides the ability to determine phase, conduct particle size and particle size distribution analyses, long-periodicity analysis (superlattice structures), and pore size distribution, etc. Further, this Rigaku instrument is uniquely suited for nanoscience research as it features a unique Crossed Beam Optical (CBO) Technology that allows easy use of both optics geometries - Bragg Brentano (Para-focusing) and parallel beam, where each geometry provides certain experimental advantages. Bragg Brentano provides high intensity and high resolution, critical for weakly diffracting and/or low symmetry samples (typical for many nanoscale materials). Parallel beam is used for thin-film analysis and for eliminating sample morphology errors in peak position that are common in samples having rough or curved surfaces (the standard situation in nanomaterials samples). Additionally, the instrument is fitted with a high-resolution small-angle X-ray scattering (SAXS) attachment and a thin-film attachment. The former is useful for measuring pore and particle size distributions, long periodicities (e.g., nanoparticle superlattices), and conducting nanoparticle modeling in both liquid and solid samples. The study of phase transitions between the various solid states is important to the pharmaceutical and other industries. X-ray diffraction (XRD) and differential scanning calorimetry (DSC) have proven to be two of the most useful techniques for this research. Since these methods are complementary to one another, measurements using both XRD and DSC have become a popular way of studying the thermal reactions of solids. The usual approach is to perform the two measuremetns sequentially; however, this can cause problems, as exact experimental conditions may be difficult to replicate. Such problems can be overcome by

simultaneously performing XRD and DSC on samples. The instrument can be used to do GXRD(Glazing-Angle X-ray Diffraction doing depth penetration scan on thin-films giving information at different depths to determine crystalline or amorphous nature from 50-300nm. Finally, for user convenience, the instrument features analysis software and the latest structure database (ICDD PDF-2).

14. Optical Microscopy

Associated CINT Scientists: Peter Goodwin, Jim Werner, Gabe Montano, Jen Hollingsworth

	FY 13	FY14	FY15
Available Operational hours (1)	13,500	13,500	13,500
Staff Availability for Users (2)	1,333	1,333	1,333
Delivered hours - External Users	3,720	3,864	4,680
Delivered hours - LANL/SNL Users	3,272	4,816	3,808

(1) 1 Lab, operating hours (18 hours/day, 5 days/week, 50 weeks/year)
(2) Staffing limited: 2 scientists

Gateway Room 1210: Optical Microscopy Laboratory

The Optical Microscopy Laboratory is a stateof-the-art user facility, with instrumentation for single- and multi-photon confocal fluorescence microscopy and atomic force microscopy. This laboratory has combined single-molecule atomic force microscopy (AFM) with single molecule fluorescence imaging for correlated studies of fluorescence and topography. CINT Scientists working with this facility have significant experience in single molecule spectroscopy by laser-induced fluorescence (both in optical imaging and flow cytometry). Standard fluorescence characterization techniques, such as time-correlated single photon counting, single pair fluorescence resonance energy transfer, and fluorescence correlation spectroscopy are used to study nanoscale fluorescence dynamics. This laboratory provides advanced optical and atomic force microscopy capabilities. It also houses the R&D 100 Award winning 3-D Tracking Microscope capability that can track the three-dimensional motion of fluorescent nanoparticles or other fluorophores in real time. This system can also perform Nipkow spinning disk microscopy (either as a stand-alone capability or during 3D tracking).

Specific laboratory capabilities include:

- Olympus IX81 inverted microscope with DP-71 color digital camera for conventional, wide-field optical (transmitted light, differential interference contrast (DIC), mercury-lamp excited epi-fluorescence) microscopy.
- An Olympus FV-300 confocal scanning unit coupled to the IX81 inverted microscope for laser scanned confocal microscopy with continuous-wave visible (457, 488, 514, 543, 594, and 633nm) lasers for one-photon excitation of samples and a tunable (710-990 nm), mode-locked pulsed laser for two-, and three-photon excitation of samples.
- An Olympus IX71 inverted microscope modified for single-fluorophore sensitivity with two single-photon counting silicon avalanche photodiode detectors useful for sample scanned confocal microscopy and fluorescence correlation spectroscopy, plus a variety of continuous-wave and pulsed laser sources are available for one-, and multi-photon excitation of samples. This system can perform fluorescence correlation spectroscopy (FCS) and is being upgraded for two-focus and scanning FCS.
- VEECO Bioscope and Enviroscope scanned probe microscopes for atomic force microscopy (AFM) imaging of samples. The Enviroscope provides AFM imaging capabilities under environmentally controlled (temperature, pressure) conditions. The Bioscope AFM head is mounted on an Olympus IX71 inverted microscope for combined optical and atomic force microscopy. This setup can acquire spatially registered atomic force and single-molecule fluorescence images.

Core Room 1331: Self-assembly Chemistry and Membrane Biochemistry Laboratory

In addition to the biomaterials synthesis capabilities, this laboratory has a Multi-Photon Laser Scanning Confocal Microscope (Olympus FV1000) with a Fluorescence Lifetime Imaging Attachment (Becker & Hickl). It is among the most advanced, commercially available optical imaging systems, and gives CINT a world-class capability for optical characterization of any array of biological, synthetic, and hybrid nanomaterials. Techniques enabled by this system include Fluorescence Recovery After Photobleaching (FRAP), and Fluorescence Resonance Energy Transfer (FRET). The FLIA module will enable spatial mapping of fluorescence lifetimes. MCP-PMT detector allows for lifetime resolution imaging in near-IR.

Gateway Room 2204: NanoSight – Nanoparticle Characterization

The system and associated Nanoparticle Tracking Analysis (NTA) software suite automatically tracks, sizes and counts nanoparticles on an individual basis. Through direct observation of particle motion and scattering behavior, particles are simultaneously sized and different materials identified by their disparate scattering intensities. Results are displayed as a frequency size distribution graph and output to spreadsheet, and concentration is directly determined. The high-sensitivity (HS) camera affords a lower detection limit of ~10 nm (upper detection limit ~2000 nm), and an added fluorescence measurement capability allows facile assessment of dark/bright nanoparticle fractions (total number of nanoparticles determined under light-scattering mode and bright particles determined under fluorescence mode). Polydisperse populations can be accurately and quantitatively assessed without the "intensity-biasing" that is characteristic of DLS because size is calculated on a particle-by-particle basis. Ideal for time-dependent studies of particle aggregation (aqueous and non-aqueous-solvent compatible).

15. Theory, Modeling & Simulation

Associated CINT Scientists: Normand Modine, Amalie Frischknect, Gary Grest, Mark Stevens, Sergei Tretiak, Stuart Trugman, JianXin Zhu, Sasha Balatsky (FY13 only)

	FY 13	FY14	FY15
Available Operational hours	N/A	N/A	N/A
Staff Availability for Users (1)	3,500	3,500	3,500
Delivered hours - External users	5,200	5,336	5,120
Delivered hours - LANL/SNL users	976	568	888
CPU hours used on SNL Cluster	0	63,000,000	101,000,000
Delivered CPU hours	864,000	864,000	864,000

(1) 7 scientists

CINT scientist and users have benefited from being able to run on SNL's institutional computing clusters at no cost to BES. SNL provided over 63 million-core hours in FY2014 and 101 million-core hours in FY2015 of computing time for CINT projects. The CINT has secured an institutional commitment for computing support from LANL, which startined in FY16. While the transition to LANL institutional computing is being completed it is expected that the existing CINT Linux cluster will be kept in service.

This computing capability offers a wide variety of analysis techniques to CINT users including:

- TRAMONTO, a parallel, classical density functional theory code for inhomogeneous atomic and polymeric fluids.
- Theory of complex fluids including polymer nanocomposites, and inhomogeneous charged fluids using classical density functional theory for fluids, self-consistent field theory.
- SOCORRO, a parallel quantum density functional theory code for investigating the electronic structure and predicting ground state and dynamical properties of systems containing up to 1000 atoms.
- First-principles quantum and multi-scale modeling of the structure and properties of surfaces, interfaces, and defects using Kohn-Sham density functional theory, time-dependent density functional theory, the cluster expansion approach, kinetic and statistical Monte Carlo method.
- LAMMPS (Large-scale Atomic/Molecular Massively Parallel Simulator), Sandia's highly parallel molecular dynamics code for classical atomistic and coarse grained level simulations.
- Atomistic or coarse-grained molecular dynamics simulations of nanoparticles assembly, charged polymers and polymer nanocomposites
- TURBOMOLE, an ab initio molecular dynamics package.
- RSPt, an LANL-developed FP-LMTO ab initio electronic structure code enabled with DMFT.
- Wien2k, a FP-LAPW ab initio electronic structure code enabled with a DMFT module.
- Computational modeling of nonlinear optical responses (e.g. two-photon absorption, second and third harmonic generations) in organic and organo-metallic chromophores with a quasi-particle density matrix response formalism in combination with time-dependent density functional theory.
- Quantum-chemical simulation of photoinduced adiabatic and non-adiabatic excited state dynamics in conducting polymers and (bio)organic chromophores, using CEO, a LANL-developed parallel molecular dynamics code based on semiempirical approaches.
- Theory and models of multi-particle excitations and energy/charge transport phenomena in semi-conductor nanocrystals and their assemblies using density functional theory and solid-state (e.g. tight-binding) approaches.
- Theory of quantum dynamics of coupled systems, including inelastic tunneling dynamics and fast optical probes of correlated systems by exact diagonalization, Lanczos, and numerical quantum dynamics in a large many-body Hilbert space.

- Theory of ultrafast optical probes of correlated systems, primarily the interpretation of experimental ultrafast data and exact quantum dynamics simulations.
- First-principles quantum many-body theory to strongly correlated electronic systems involving first
- –principles simulations of electronic, magnetic, optical properties in complex metal oxides; dynamical mean-field theory in combination of density functional theory in local density approxi- mation for bulk d-electron and f-electron materials; first-principles quantum many-body simulations of quantum impurity embedded in metallic host; and construction of low-energy models based on the Wannier functions.
- Numerical simulations and modeling of quantum criticality and local electronic structure in strongly correlated electronic systems using extended dynamical mean-field theoretical study of Kondo lattice models; cluster dynamical mean-field theory for periodic Anderson lattice models; simulation of single and multiple impurity problem in fermonic and bosonic media; simulation of local electronic structure around Kondo hole and Kondo stripes in Kondo and Anderson lattice models; Numerical Renormalization Group method; Hirsch-Fye Quantum Monte Carlo Method, Continuous Quantum Monte Carlo Method; Large-N based approach; Gutzwiller approximation; Slave-boson mean-field method.
- Theory of electrical and thermal transport through unconventional junctions out of equilibrium using Keldysh non-equilibrium Green's function; scattering theory based on transfer matrix and Blonder-Tinkham-Klapwij theory.
- Local electronic structure and bulk properties in inhomogeneous superconductors (including the presence of magnetic field) via Bogoliubov-de Gennes theory in tight-binding model.
- Theory of ultrafast optical probes of correlated systems by slave-boson mean-field modeling and Gutzwiller variational wavefunction approach.

2.d Leveraged Facilities

In addition to the laboratories in the Core Facility and Gateway Facility, CINT leverages capabilities available at both SNL and LANL to support its users. These facilities are described below.

Ion Beam Materials Laboratory (IBML) at LANL

IBML supports nanoscale materials research and user interactions through the use of energetic ion beams in a number of ways: (1) Synthesis of novel phase and nanostructured materials through ion implantation; (2) Irradiation response and stability of nanoscale structures, materials, and systems by ion irradiation; and (3) Characterization (stoichiometry, thickness/density, crystallinity etc.) of thin films and other nanostructures using ion beam analysis techniques.

Ion beam synthesis methods, such as ion implantation, are well known for their unique ability to produce novel materials. The principal advantage of synthesis methods such as ion implantation is that virtually any element can be implanted into any substrate independent of thermodynamic factors, thus making it possible to obtain impurity concentrations and distributions that would not be attainable by traditional alloying methods. Thereby, ion implantation makes it possible to introduce immiscible elements into a substrate to produce concentrations well above the solubility limit. Further ion irradiation or thermal treatment can transform such metastable alloys into more thermodynamically stable configurations, such as nano precipitates embedded in an inert matrix. Ion beams are used to simulate and study irradiation environments, such as those in a fission/fusion nuclear reactors or space environments. Recent work has shown that nanostructured materials are highly tolerant to radiation damage. Ion beam analysis techniques such as Rutherford backscattering spectrometry (RBS), particle induced X-ray emission (PIXE), nuclear reaction analysis (NRA), and elastic recoil detection (ERD) provide fast, non-destructive and quantitative means to measure elemental composition (up to ~1% accuracy), thickness/density determination (up to a few nm depth resolution), and trace elements detection (up to ppm) in thin films and bulk materials. These techniques in conjunction with ion channeling also provide a unique and sensitive means to probe various types of defects in crystalline materials.

The major instruments and capabilities at the IBML include: (1) NEC 3.0 MV Pelletron® tandem ion accelerator, equipped with two ion sources (RF Plasma source and Ion sputter source) and five beam lines attached to different experimental stations that support various research programs. Common ion species and their maximum energies are 6 MeV protons, 9 MeV alphas, 12 MeV C ions, 15 MeV Ni ions, and 18 MeV Au ions. Comprehensive ion beam analysis techniques include RBS, ERD, PIXE, NRA, and Ion Channeling. The high energy irradiation/implantation area can be as large as 1-square-inch with fluences ranging from 1E10 to 1E16 ions/cm2 under temperatures up to 1100°C. (2) Danfysik 200 kV high current ion implanter, equipped with a tri-mode (gas, oven, and sputter) high current ion source that enables the production of ions with multiple charged states. More than 60 ion species from the PT with energies ranging from 10 keV to 800 keV. Implantation/Irradiation fluences from 1E12 to 1E18 atoms/cm2. Sample sizes up to 8 inch wafers. Target temperature control: LN2 to 1100°C. (3) Unique dual-beam irradiation/implantation/analysis capability. The joint chamber between the Tandem Accelerator and a 200 kV Varian Implanter exposes samples to either sequential or simultane- ous high energy self-ion irradiation from Tandem and/or He (or H) ion implantations from the implanter. This capability allows for the study of synergistic effects between electronic and nuclear interactions in nanoscale materials, and the emulation of nuclear reactor radiation environments (displacement damage and He or H incorporation) or actinide decay process where alpha emissions are companied with heavy recoils.

Laboratory for Ultrafast Materials and Optical Science (LUMOS) at LANL

The LUMOS facility is equipped with multiple ultrafast laser systems covering broad spectral range spanning from the far-infrared (FIR) to soft X-Ray (~100 eV) region of the electromagnetic spectrum. These systems enable a multitude of ultrafast pump-probe and emission spectroscopies, where both pump and probe frequencies can be tuned in a wide (far-infrared to soft X-Ray) range. This specifically includes:

- Two regenerative amplifiers (1 kHz, up to 7.5 mJ, 1.5 eV, 30 fs) configured for optical-pump terahertz

(THz)-probe spectroscopy, where terahertz fields are generated by mixing in nonlinear crystals or a gas plasma, respectively. In addition, three oscillator-based THz-TDS systems are available for transmission and reflection (ranging) studies.

- Two high-repetition rate regenerative amplifier (100-250 kHz, >4 μJ, 1.5 eV, 50 fs) with visible and infrared optical parametric amplifiers (OPAs), second/third harmonic UV generation (SHG/THG), and difference frequency generation (DFG) modules provide spectral coverage from 267 nm – 8 μm and are configured for tunable UV-to-THz pump-probe, THz emission, time-resolved (TR) SHG, and TR-Kerr rotation (KR) spectroscopies.
- Multiple oscillator-based optical pump-probe systems with output pulsewidth ranging from 10 fs up to 100 fs are used to achieve better than ~10-7 sensitivity to transient reflectivity or transmission changes.
- Two newly developed systems for selective low-energy mode excitation: (i) A regenerative amplifier (1 kHz, 6 mJ, 1.5 eV, 30 fs) with a TOPAS OPA and DFG covering 1.1-20 μm is used for mid-IR/THz pump- broadband (THz, optical, TR-SHG, TR-KR) probe spectroscopy; (ii) A regenerative amplifier (1 kHz, 4.5 mJ, 1.5 eV, 100 fs) configured for high energy THz pulse generation using both the tilted pulse-front technique (~1 MV/cm at ~1 THz), and mixing the outputs of two tunable OPAs in a nonlinear crystal (up to ~1 MV/cm from 10-70 THz). In this system, a variety of photon energies and techniques can be used to selectively probe the dynamics of different degrees of freedom after low-energy mode excitation: THz or optical probes for lattice and charges, TR-SHG and TR-KR for (anti) ferromagnetic spin ordering.
- Novel time-resolved optical pump – X-Ray magnetic linear/circular absorption dichroism (XMLD/XMCD) probe spectroscopy system: A regenerative amplifier (1 kHz, 4.5 mJ, 1.5 eV, 35 fs) produces polarized soft X-Ray 'probe' pulses with photon energy in 30-100 eV range through high-harmonic generation process in gas jet. XMLD/XMCD signal appears as a change in the X-ray absorption at the element-specific 3p -> 3d (M2,3-edges) transition energy as a function of X-ray polarization and the angle between X-Ray beam and the magnetization/magnetic anisotropy direction. Available 20-100 eV spectral range provides direct access to the M2,3 absorption edges of a variety of relevant magnetic ions, e.g. 47 eV for Mn, and 53 eV for Fe. Pump pulses at 1.5, 3.0 and 4.5 eV photon energies can be generated by standard nonlinear conversion procedures. In addition, the lab is currently developing a new XMLD coherent x-ray diffraction imaging (XMLD-CXDI) capability to probe spin ordering dynamics with 10 fs temporal and ~ 50 nm spatial resolutions.
- Quantum coherent control systems feature pulsewidths as short as 10 fs as well as the ability to precisely control and measure the pulse envelope and phase on a femtosecond timescale. Every system has its unique features and specialization, however, they can be easily combined or extended to probe new materials and processes should the need arise. The common element of all of our experimental setups is an extensive utilization of evolutionary feedback algorithms for adaptive femtosecond pulse shaping. This approach relies on the fact that quantum system can "teach" the algorithm to find the optimal pulse characteristics for desired experimental outcome. The systems characteristics are as follows: (i) high sensitivity near-IR oscillator-based setup where the pulse (82 MHz, 1.5 eV, 10-100 fs) is shaped with an SLM phase and/or amplitude mask (128/640 pixels, 12bit). Pulse evolutions in the sample are extracted by means of spectral interferometry or SHG-FROG. Cooled PMT single-photon detector allows measurement of the sample response in broad spectral region down to several photons level. (ii) mid-IR oscillator based setup where the pulse (82 MHz, 1.5 eV, 100 fs) pumps optical parametric oscillator and generate mid-IR pulses (0.75 eV, 100 fs). The output is shaped with SLM (128 pixels, 12 bit) and SHG-XFROG is used for monitoring of the output pulse characteristics and their evolution upon propagation through the sample.

All these experiments can be performed as a function of temperature from 4K to 700K using available cryostats. Two split-coil magnets (0-8 T) are available with temperature coverage of 4-300 K, enabling field tuning of interactions, as well as permitting spin sensitive ultrafast spectroscopic probes such as TR-KR spec- troscopy. Additional characterization tools include a Fourier Transform Infrared Spectrometer (4-400K, 10
45,000 cm-1), a spectroscopic ellipsometer, and a suite of scanning probe microscopies (AFM, MFM, STM).

Nanoscale scanned probes: This laboratory is equipped with a full range of static and dynamics scanning probes for investigation of various aspects of material properties and surface effects:

- UHV750 STM from RHK Technologies. The sample environment can be varied from ambient to UHV (< 3x10-10 Torr), and sample temperature adjusted within T=25-600 K range with 0.1 K stability. Multiple sample preparation methods can be used to ensure reliable imaging: ion bombardment, thermal annealing, in situ cleaving and injection of the liquid solutions, and thermal evaporation for monolayer deposition. The system can be operated in a majority of scanning probe microscopy/ spectroscopy modalities including STM, contact/noncontact AFM, MFM, Kelvin probe, and Scanning Thermal Microscopy. Moreover, there is an optical setup coupled to the system for ultrafast scanning tunneling microscopy (USTM) experiments. The USTM has temporal resolution of less than 20 ps, and is capable of probing surface dynamics at the nanometer scales.
- Recently, another system was added that is based on ultrastable Pan-head STM design where both tip and sample are located inside a UHV cryostat that is capable of UHV greater than ~10-10 Torr and sample/tip temperature range of T=5-300 K with <0.01 K stability. The instrument is equipped with a bi-directional superconducting magnet providing magnetic fields of up to 1.2 T. As in the first system, various sample cleaning methods are available such as thermal annealing, ion sputtering, and in situ cleaving. The possibility exists for coupling this system to an ultrafast laser system.
- Room-temperature NSOM combined with an AFM and inverted optical microscope. NSOM uses a tuning fork approach to distance control and can be configured for operation in both reflection and transmission modes. AFM capabilities include various contact and non-contact techniques.
- An essential tool for examining nanoscale inhomogeneities is our apertureless reflection terahertz scanning near-field optical microscope (THz-SNOM) with temperature control from 77 K to 300 K. It covers 0.1-1.5 THz frequency range and has 50 nm spatial resolution. An optical pump pulse can be added for material dynamics studies with ultrafast temporal and nanometer spatial resolution. The instrument is based on STM/AFM setup and allows simultaneous acquisition of topographic information for comparison with terahertz maps.

<u>In-situ Ion Irradiation Transmission Electron Microscopy (I3TEM) Facility at SNL:</u>
The I3TEM Facility combines a 200 kV JEOL 2100 high-contrast TEM (2.5 Å point resolution) with a 10 kV Colutron and a 6 MVTandem accelerator. The facility can permit a wide breath of combined experiments in high temperature, flowing liquid, gas exposure, mechanical loading, displacement damage, gas implantation, and numerous sequential or simultaneous combinations thereof to evaluate the structural evolution that occurs during ion beam modification or overlapping combinations of extreme environments.

Specific capabilities of the I3TEM Facility include:

- Single electron sensitive 4k x4k camera
- Video rate 1k x1k camera
- Microfluidic mixing using a Protochips two channel fluid stage
- High temperature and gas flow experiments using a custom Protochips stage
- High temperature experiments using an 2.3 mm Hummingbird heating stage
- Classical TEM straining experiments using a Gatan 654 ST qualitative strain stage
- Quantitative straining environments using a Hysitron PI-95 with heating options
- Detailed 3D tomographic reconstructions of samples using either a Gatan 925 DT double tilt-rotate

stage or a Hummingbird high tilt (±81°) tomography stage
- A custom built stage with four electrical probes is available
- Large variety of ion species in the range between protons and gold
- Ion beam currents from single ion strikes up to 100 nA (Tandem) and 10 μA (Colutron)
- Direct photoluminescence, cathodoluminescence, and ion beam luminescence from the entire TEM sample
- Detailed orientation imaging microscopy (OIM) of texture and grain boundary information via the Nanomegas and ASTAR systems.

Co-Located Major Facility: National High Magnetic Field Laboratory (NHMFL) at LANL

Prospective CINT users whose nanoscience research could benefit from access to CINT facilities and high-magnetic-field experimental techniques are encouraged to consider submitting a joint proposal that includes CINT and the National High Magnetic Field Laboratory (NHMFL). These joint user proposals receive special handling by the CINT User Program Office to ensure a coordinated review by CINT and NHMFL. To date, few CINT users have availed themselves of these co-located facilities; and, joint user requests have been accomodated through the informal coordination of CINT use and the more formal NHMFL scheduling requirements.

The Pulsed Magnetic Field Facility at Los Alamos National Laboratory in Los Alamos, New Mexico (figure 2.12), is one of three campuses of the National High Magnetic Field Laboratory (NHMFL), the other two are located at Florida State University, Tallahassee, FL (continuous fields, magnetic resonance, and general headquarters) and the University of Florida, Gainesville, FL (ultra-low temperatures at high magnetic fields). The NHMFL is sponsored primarily by the National Science Foundation, Division of Materials Research, with additional support from the State of Florida and the U.S. Department of Energy.

Figure 2.12 National High Magnetic Field Lab at Los Alamos

Co-Located Major Facility: Microsystems Engineering and Science Applications (MESA) Complex at SNL

Sandia National Laboratories plays a significant role in advancing state-of-the-art microsystems research and development, and in introducing microsystems into the nuclear stockpile. Microsystems incorporate radiation-hardened microelectronics as well as other advanced components such as micromachines, optoelectronics, and photonic systems. The MESA Complex is designed to integrate the numerous scientific disciplines necessary to produce functional, robust, integrated microsystems and represents the center of Sandia's investment in microsystems research, development, and prototyping activities. This suite of facilities encompasses approximately 400,000 ft^2 and includes cleanroom facilities, laboratories and offices. CINT currently leverages this National Nulcear Security Administration (NNSA) resource by partnering with MESA staff in the design, development and production of sophisticated CINT Discovery Platforms. CINT plans to further leverage MESA facilities by bringing selected compound semiconductor synthesis capabilities into the CINT user program.

3 User Access

3.a User Program Policy

The CINT user program is designed to provide the international scientific community access to the CINT Core and Gateway facilities. User access can include use of capabilities, i.e., instrumentation and/or CINT scientist staff expertise, in either or both of our facilities. In accordance with the NSRC guidelines (appendix), there are two modes of user access: General user access and partner user access, each with variable scope and the ability to conduct non-proprietary or proprietary research.

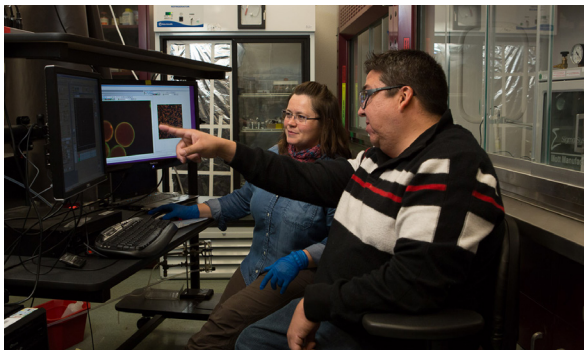


Figure 3.1 CINT Scientist Gabe Montano works with a user.

General users are individuals or groups who need access to the CINT facilities to carry out their research using one or more CINT capabilities. Access is requested through a semi-annual, peer-reviewed proposal process. The proposal is a two-page statement of work that succinctly describes the scientific problem, research tasks to be conducted, and expected impact.

One proposal may include multiple users, from one or more institutions, and may request access to multiple CINT capabilities and staff scientists (Table 3.6, Figure 3.9). The scope of a user proposal can vary from a single interaction to a several visits using a range of capabilities.

Upon acceptance of the user proposal, the CINT users make arrangements to conduct their project via on-site/off-site interactions. For foreign national visitors from sensitive countries, the required visit approval process may require a much longer time before the user visit is approved by the U.S. Department of Energy. Each approved user project is valid for 18 months, after which the results of non-proprietary projects should be submitted for publication in a peer-reviewed professional journal. Continuation of a productive project is encouraged via submission of a continuation proposal. CINT does not operate as a fee-for-service facility but rather as a nanoscale science research center where users and staff engage in cutting-edge research. CINT cannot provide funding to users.

Partner users are individuals/groups/institutions who not only carry out research at CINT but also enhance the capabilities or contribute to the operation of the center through new facility instrumentation or the support of personnel. These contributions must be made available to the general users and therefore benefit the overall user program as well as the facility. In recognition of their investment, partner users are provided negotiated access to one or more capabilities over several years. CINT has not yet entered into any partner user agreements.

Approved CINT users may conduct either non-proprietary (pre-competitive research to be published) or proprietary research. Prospective users must designate if any/all of their user proposal involves proprietary information and if any of the user project, if accepted, would contain proprietary work. User proposals containing proprietary information will be reviewed via a separate process to maintain confidentiality under protection of an executed Non-Disclosure Agreement between CINT (Los Alamos National Laboratory and Sandia National Laboratories) and the prospective user's institution(s).

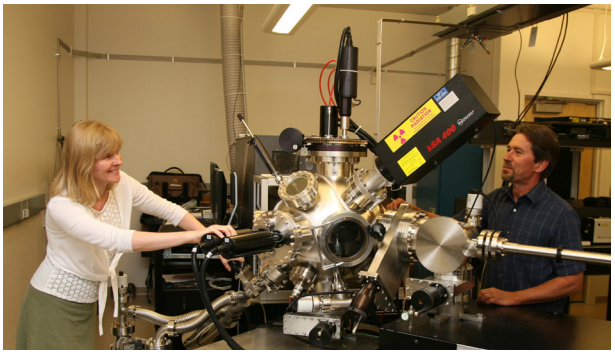


Figure 3.2 CINT User Judith Driscoll works with CINT Technologist Paul Dowden.

Upon acceptance of a user proposal for non-proprietary research, the user's institution is required to execute a CINT user agreement. In addition to defining the terms and conditions for intellectual property created during the user project, the agreement confirms that the user will publish the results in the open technical literature in return for no-fee access to CINT. The user is responsible for his/her own costs (such as travel, food, lodging, etc.) to conduct the approved project at CINT but will not be charged for instrument use, CINT personnel time, or temporary office space while at CINT.

For proprietary work at CINT, federal law requires full-cost recovery from the user's institution. The CINT Proprietary User Agreement (PUA) contains the terms and conditions, including intellectual property rights for proprietary users. CINT is engaged in proprietary proposal(s) with industrial user(s).

CINT users may conduct their approved research projects in collaboration with one or more CINT scientists or may choose to access CINT capabilities independently. User proposals are evaluated on the merits of the science without preference for collaborative/independent access. Users working independently are properly trained and supervised by technical personnel. Some CINT capabilities cannot be operated independently for safety or complexity reasons, and therefore, user availability is limited. See section 3.c. for time allocation procedures.

3.b User Proposal Submission & Review Process

The user proposal submission process is designed to acquire the information necessary for an initial feasibility/ safety screening and an objective external and independent technical review. User proposals consist of a two-page (maximum) document in pdf format that is uploaded via the website (https://cint.sandia.gov), along with user information entered on-line. Prior to submitting a proposal, prospective users are advised to read the published Call for User Proposals (http://cint.lanl.gov/user_call.shtml) or Rapid Access web page, identify the relevant CINT scientists and capabilities needed for their research project, and contact the CINT personnel to confirm feasibility. Although not required, advance consultation with the CINT scientist(s) with whom they would work can help the prospective user understand the feasibility, safety, and training issues, level of effort required, and other pragmatic aspects of the intended research project. The semi-annual proposal cycle from 2013 to 2015 is shown in Table 3.1.

Table 3.1 User proposal cycle

Proposal Cycle	Call for User Proposals	Project Start Date	Project End Date*	Eligible to submit Continuation Proposal
Fall 2012	09/01/12 – 09/30/12	01/01/13	06/30/14	Spring 2014
Spring 2013	03/01/13 – 03/31/13	07/01/13	12/31/14	Fall 2014
Fall 2013	09/01/13 – 09/30/13	01/01/14	06/30/15	Spring 2015
Spring 2014	03/01/14 – 03/31/14	07/01/14	12/31/15	Fall 2015
Fall 2014	09/01/14 – 09/30/14	01/01/15	06/30/16	Spring 2016
Spring 2015	03/01/15 – 03/31/15	07/01/15	12/31/16	Fall 2016

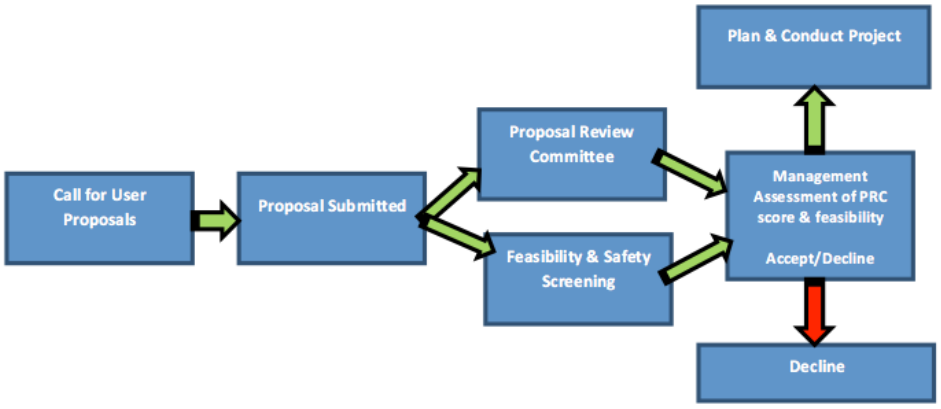


Figure 3.3 The steps in the User Proposal Review process.

Figure 3.3 schematically illustrates the proposal review process. All user proposals undergo a feasibility/safety screening by the CINT technical staff who would be involved with the project.

The technical peer review is conducted by an external Proposal Review Committee (PRC) that reflects the four CINT scientific thrusts. A list of the current PRC members is provided in the appendix. Each user proposal is read and scored by up to three individual PRC members. The scoring system is shown in Table 3.2. Reviewers are also asked to provide the strengths and weaknesses of each proposal to support their score. Sample guidance provided to the PRC is shown in the appendix.

Table 3.2 Proposal Review Scoring

Nominal Score	**Allowed Range**	**Relative Priority**	**Qualitative Assessment** (Supported by reviewer comments)
0.0	0.0 – 0.9	Decline	Seriously flawed proposal or other disqualifier.
1.0	1.0 –1.5	Low	Minimally acceptable proposal, not well-matched to CINT capabilities, little expected impact.
2.0	1.6 – 2.5	Medium	Good-to-excellent proposal, well-matched to CINT capabilities, significant anticipated impact.
3.0	2.6 – 3.0	High	Superior proposal, excellent use of CINT capabilities, potentialy very high impact.

The CINT management uses the PRC scores and comments as well as CINT scientists' feasibility and safety screening to prioritize access to CINT's capabilities. Prospective users are notified by the User Program Manager of the decision (accept/decline) via email and given the feedback comments from the reviewers. Once the proposal has been accepted, the user's institution executes the umbrella User Agreement (if one is not already in force), schedules visits to CINT, and conducts work. At the conclusion of the proposal, the user is expected to promptly publish the scientific/technological results in the peer-reviewed technical literature.

User Agreements

The U.S. Department of Energy Office of Science, Office of Basic Energy Sciences, requires that a User Agreement be executed for every accepted project at its national user facilities such as CINT. These agreements stipulate the terms and conditions under which users may conduct work at CINT (Los Alamos and Sandia National Laboratories). Important issues such as intellectual property and liability are addressed in the User Agreement.

To expedite this process, the DOE/SC/BES has created standard agreements for use at all of its national user facilities. These agreements are available in 5-year umbrella versions that, once executed by all parties, apply

to the current and all future CINT user proposals submitted from the signatory institutions within that 5-year period.

The agreement must be signed by a person from the user's institution who is legally authorized to enter into contractual obligations for the user's institution. Note: The user himself/herself is generally NOT authorized to make these contractual obligations. If users from multiple institutions are participating in one user project, User Agreements are required from each institution before work can begin at CINT.

Authorized representatives of CINT management, Los Alamos National Laboratory, Sandia National Laboratories, the National Nuclear Security Administration, and the DOE Office of Science must approve any change in the terms and conditions requested by the user institution. This change process can be lengthy (6 months or more). The duration of a CINT user project is 18 months; it will not be extended because of delays in negotiating changes to the User Agreement.

Nonproprietary research is conducted under the DOE Office of Science NSRC Umbrella Non-Proprietary User Agreement (UNPUA). A modified version, the Federal Umbrella Non-Proprietary User Agreement (FUNPUA) should be executed by users who are federal employees. If CINT accepts a user proposal from an institution not having an umbrella user agreement in place, CINT will enter the appropriate information into the UNPUA or FUNPUA and send it to the user to be authorized by his/her institution. If an umbrella agreement is already in place, any user proposal submitted from that institution and accepted by CINT is automatically included in that umbrella agreement.

Proprietary research at CINT may be conducted under other DOE/NNSA agreements, including but not limited to a Cooperative Research and Development Agreement (CRADA), Strategic Partnership Agreements, or the NNSA Designated User Facility Agreement.

At the conclusion of the project, the user completes a User Satisfaction Survey and reports related publications/ presentations to CINT.

Continuation Proposals
CINT recognizes that a productive user project may require more than 18 months to fully achieve its objectives or to perform subsequent research motivated by previous results. Therefore, before the end of the 18-month performance period of the user project, the user may choose to submit a CINT continuation proposal to continue the current project rather than submit a new user proposal. If the research problem has significantly changed in scope or technical direction, then it is more appropriate for the investigator(s) to submit a new user proposal rather than a continuation proposal.

A continuation proposal must be submitted in response to a semi-annual Call for User Proposals. The user must formally apply for continued access to CINT via the web-based submission process. The proposal becomes a "Continuation" by checking the appropriate box and by providing the currently approved proposal number (e.g., U20015A0250) on the web submission page prior to uploading the two-page continuation proposal.

In addition to providing the motivation and background information to establish the scientific impact of the proposed research, a successful continuation proposal is required to

- report the progress made in the current project; and
- report prior accomplishments of the project including publications and presentations based on the current results.

Continuation proposals compete with new proposals for access to CINT. Access to CINT is based on the scientific

quality of the proposed research. Through the submission of continuation proposals, a user project may continue for multiple years provided that it remains competitive. The CINT management will monitor the balance between new and continuation proposals to ensure equal access, and appropriate use of CINT capabilities. In FY13–FY15 CINT accepted 571 regular proposals. Approximately 39% of these regular accepted proposals were continuation proposals. (Table 3.4 and Figure 3.4).

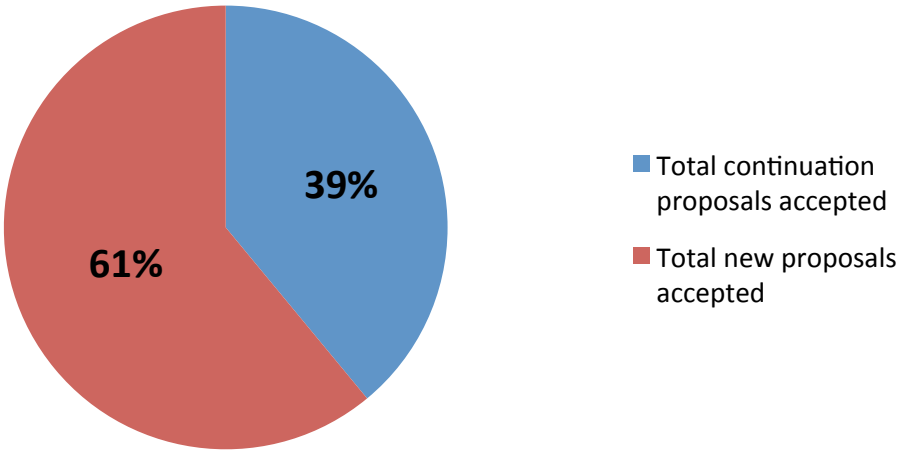


Figure 3.4 FY13-FY15 percentage of new and continuation proposals accepted

Rapid Access

CINT accepts user proposals via its website (http://CINT.lanl.gov) in response to semi-annual (March/September) published calls for CINT user proposals. User proposals submitted while the call is open compete, using the aforementioned process, for access to CINT capabilities. In contrast, a Rapid Access proposal can be submitted via the CINT website at any time that regular user proposals are not being accepted. This process provides a mechanism for a prospective user to have brief, limited access to CINT capabilities in advance of the next available semi-annual call for user proposals that are time critical, small in scope, and high-impact research.

Approval of a Rapid Access proposal is conditional upon passing the feasibility screening, subject to the availability of the requested capability, and at the discretion of CINT management.

If a Rapid Access proposal is approved, the project is given up to—but no more than—3 months to complete the proposed research. Rapid Access projects cannot be renewed.

To continue the research initiated under an approved Rapid Access proposal, the user must submit a regular User Proposal for full peer review during the next available, semi-annual User Proposal submission cycle. The user is certainly encouraged to include relevant results obtained via a Rapid Access proposal as background information in a regular CINT User Proposal.

Rapid Access Proposals must be submitted online (https://cint.sandia.gov/). The prospective user completes the online form (contact information, etc.) and uploads a two-page (maximum) pdf document, which is the formal Rapid Access Proposal.

The Rapid Access proposal must provide the motivation and background information to establish the time-critical need for CINT capabilities to produce high-impact science. A request to conduct preliminary or exploratory research alone is insufficient justification for rapid access.

The two-page document should succinctly explain the following:

- CINT staff involvement (http://cint.lanl.gov/contacts.php);
- CINT capabilities needed (http://cint.lanl.gov/capabilities/index.php);
- specific work to be performed, expected outcome, and scientific impact;
- justification for time urgency; and
- users who would perform the work.

Rapid Access proposals undergo an expedited feasibility screening and technical review. Approval is at the discretion of the CINT management. In most cases, a decision is returned to the prospective user within two weeks of application. If approved, the Rapid Access project may begin any time after the CINT User Agreement is executed.

Table 3.3 Rapid access proposals submitted and accepted

Rapid Access (RA) Proposals	2012B	2013A	2013B	2014A	2014B	2015A
Submitted RA	30	31	20	31	14	36
Accepted RA	26	25	15	27	9	31

In FY13-FY15 CINT accepted 727 total regular and rapid access proposals. Of those, 133 (18%) were rapid access proposals.

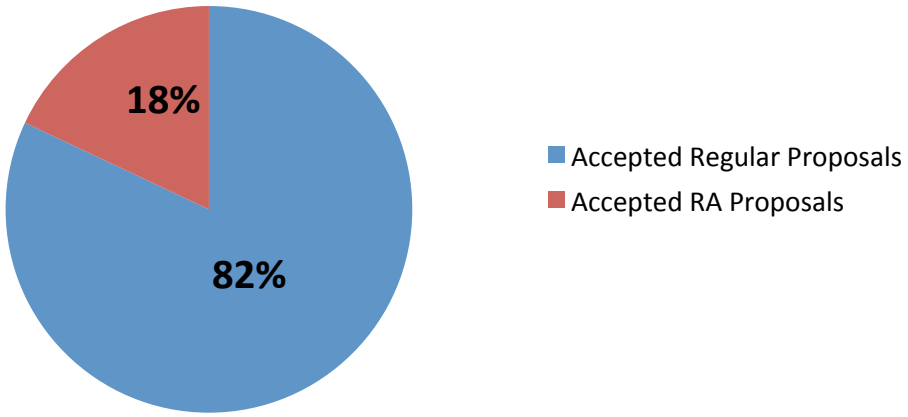


Figure 3.5 FY13-FY15 Percentage of regular and rapid access proposals accepted

3.c Capability time allocation

Approved proposals are granted an 18-month maximum duration. Capability access is based on a number of criteria, including PRC score, proposal scope, and current capability utilization. Certain capabilities that are at capacity or oversubscribed may set specific time allotments as part of the acceptance of the proposal. These time allotments are based on scope of approved project and who will be completing a majority of the proposed work, either CINT staff or the user.

For example, the capability owner for the oversubscribed Tecnai F30 TEM allots specific amounts of time to the instrument once the proposal has been marked for approval. The owner will balance PRC score and the skill of the worker who will be expected to perform a majority of the work. If the proposal requests that the CINT scientists or technologists perform the work, then they look at how many days it takes to complete the number of samples requested. One day of time would be two 4-hour sessions; this amount of time is then spread out

in monthly sessions over the 18-month proposal duration. If the user will be completing the work, they will consider how much experience the user has with the TEM/technique. In this case, they factor in amount of time needed for training and practice, iterative sample preparation, and TEM imaging. Once all of these factors have been considered, the owner will assign a set number of sessions per month that the user will be allotted. This allotment is sent out to the PI in their proposal acceptance letter. Users can be trained and granted access to the capability during the full facility operational hours (7 days a week, 6 a.m. to midnight). If a user is traveling to the facility, monthly time allocations may be grouped together during their visit time. When allocating time, CINT capability owners do not take a user's institution into consideration.

Another oversubscribed capability is the JEOL E-Beam Lithography tool in the Core Integration Lab (IL). To manage user access, the IL staff has developed a Utilization Policy for the instrument (found in the appendix). The policy for the tool divides time/availability into three categories: 10% maintenance, 20% CINT science, 70% user proposals. The time allotted per proposal varies with the number of active projects being requested. Based on 100% utilization, the policy is designed to give each project a 1 block/session of 3–4 hours per week. This amount of time varies depending on when the representative of the user proposal is onsite. The time block allocation is in addition to the time required for tool training (average 3–7 days over 4–8 weeks). The tool is scheduled via an online system that can schedule activity 2–4 weeks in advance. Guidelines for tool scheduling are identified and suggested to maximize tool efficiency, such as image processing and exposure run durations in excess of 4 hours are to be scheduled within the low-demand periods, preferably as an overnight write. The capability owner monitors feedback and project progress and can adjust the time allotments if issues arise.

Other scheduling limitations outside of specific time allocation have been implemented in oversubscribed capabilities such as our Integration Lab. The IL requires a large amount of training, both written and hands-on performed by IL staff, which could cause a bottleneck. The IL currently limits the number of users per proposal who can access the IL. The maximum number of IL users who will be granted access per proposal is limited to two people, with a limit of four people per group when multiple proposals come from the same PI. Also, to ensure an effective user of training resources, a minimum term limit for a user working in the IL is 3 months. If an IL user who is supporting a proposal leaves within the 3-month period, the maximum two-person per proposal (four per multi-proposal group) limit still applies until the 3-month period has elapsed for the departed individual.
For projects accessing capabilities that are not at capacity, scheduling is granted through the lab/capability owner. Priority scheduling is considered when granting resource time and is based on

1. Proposal Review Committee score,
2. traveling external users who have limited visit dates, and
3. time-sensitive deliverables provided in the approved proposal.

The lab owner and CINT management reserve the right to revoke laboratory and capability access at any time if a user is found to be working outside of any laboratory safety and security procedures or in violation of the terms and conditions set forth by the Institutional User Agreement. User will be responsible and held accountable for following the safety and security rules established by SNL and LANL while conducting R&D work at Core and Gateway facilities.

3.d User Program Statistics

3.d.1 User Proposal Statistics
Interest in CINT is significant as evidenced by the large number of proposal submissions and the actual number of users each year. Through careful planning, CINT has been able to achieve a high acceptance rate of proposals judged to be meritorious by the external Proposal Review Committee.

Once approved, User proposals have an 18-month duration for work to be completed. Based on project start and

end date (Table 3.1), CINT approves approximately 190 new regular projects each year. Because proposals span multiple calendar years, CINT has more than 370 active projects throughout each year (Table 3.4 and Figure 3.6).

Table 3.4 User proposal statistics

FY13-FY15	2012B	2013A	2013B	2014A	2014B	2015A
Proposals Submitted	98	126	148	91	122	108
Proposals Accepted	84	107	114	73	105	88
Acceptance Rate	86%	85%	77%	80%	86%	81%
Total accepted, internal	20	28	34	25	27	20
Total accepted, internal (%)	24%	26%	30%	34%	26%	23%
Continuation proposals (accepted)	30	51	45	21	49	28
New proposals (accepted)	54	56	68	52	56	60

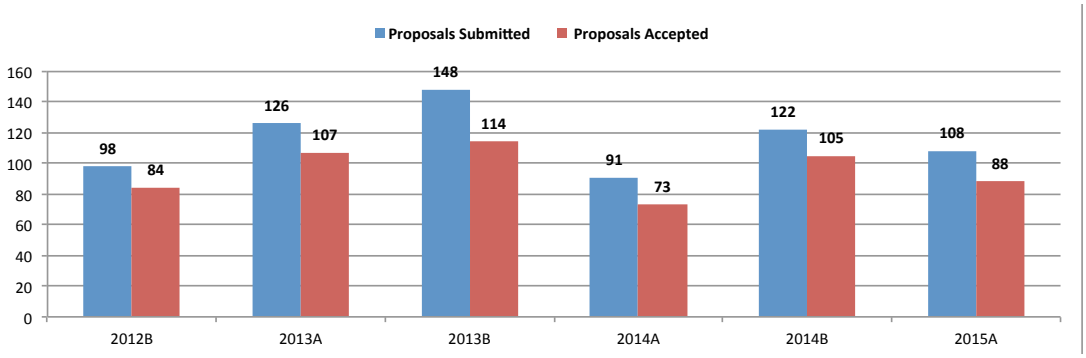


Figure 3.6 User proposal submissions and acceptances (*does not include rapid access proposals)

Table 3.5 and Figure 3.7 show the distribution of accepted proposals by institution type. Although the majority of proposals received are from academic institutions, proposals from non-academic institutions do comprise a significant fraction of the CINT user activities.

Table 3.5 Accepted user proposals by institution type.

Accepted Proposal by Institution Type	2012B	2013A	2013B	2014A	2014B	2015A
US Academic	47	61	60	30	57	52
Host DOE laboratory	20	28	34	25	27	20
Other DOE laboratories	1	4	3	1	4	3
Industry	1	6	3	5	10	4
Foreign	15	8	14	12	7	9
NSRC	0	0	0	0	0	0

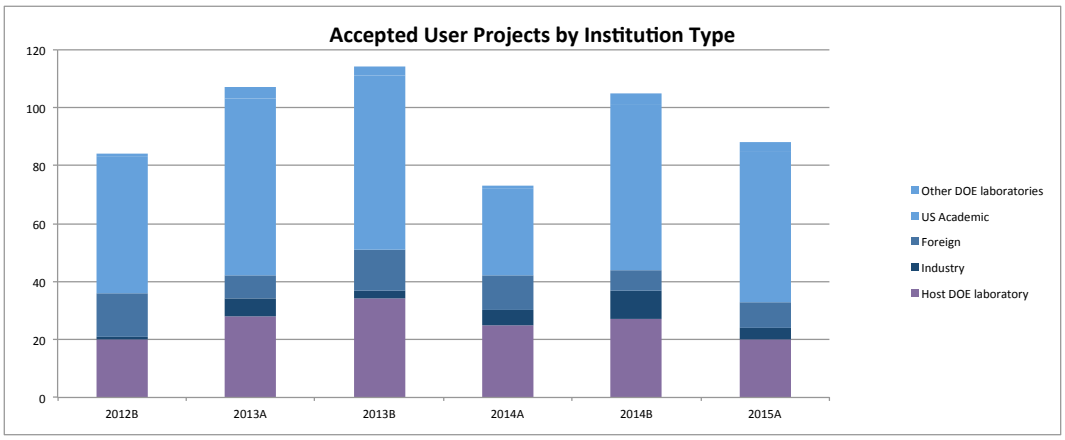


Figure 3.7 Accepted user proposals by institution type.

When submitting a proposal, we ask the PI to identify the main subject of the research based on the BES annual reporting categories. Although a proposal can often span multiple subject areas, we report to BES based on a 1:1 proposal to subject ratio. Figure 3.8 shows the distribution of accepted proposals by subject of experiment.

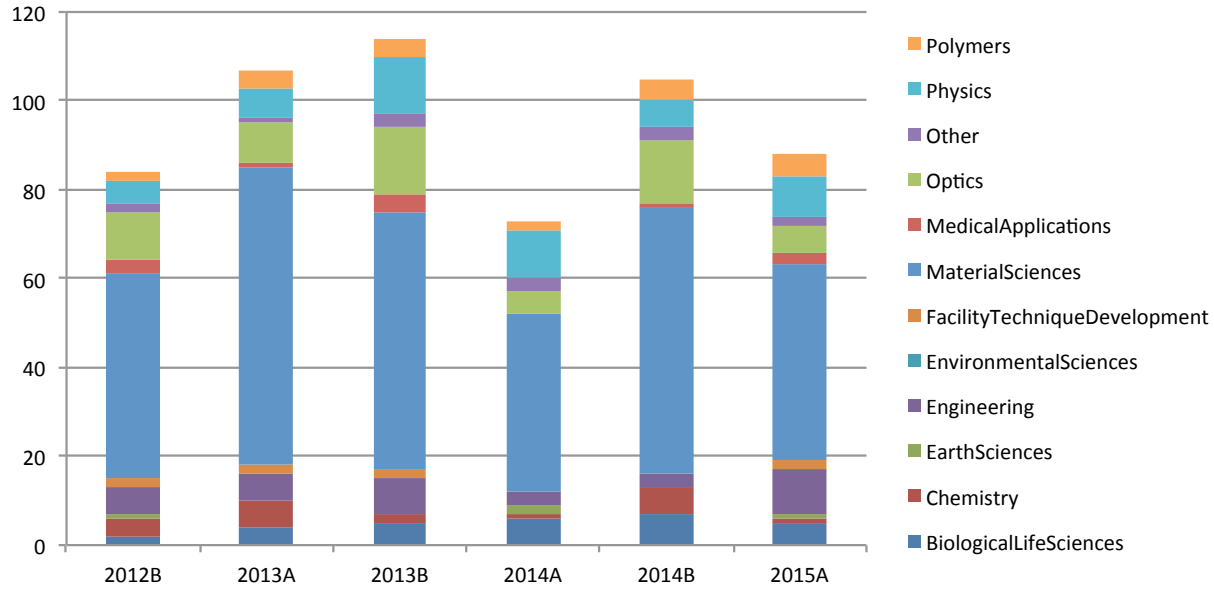


Figure 3.8 Accepted Proposals by Research Subject

Integration is the cornerstone of CINT's research mission. Unlike traditional user facilities, CINT user projects are highly collaborative. A continuing trend that we have seen over the last 6 years is half of our accepted user projects are requesting multiple CINT scientists and capability engagement per proposal. During FY13–FY15, 50% of our accepted user projects requested two or more CINT scientists to collaborate on a single proposal, and 149 proposals requested scientists and/or capabilities across multiple thrusts (Tables 3.6 and 3.7 and Figures 3.9 and 3.10).

Table 3.6 FY13-FY15 number of staff selected per accepted proposal per round

FY13-FY15 regular call accepted proposals	**1 Scientist**	**2 Scientists**	**3 Scientists**	**4 Scientists**	**5+ scientists**
2012B	44	33	4	2	1
2013A	60	33	12	1	1
2013B	52	47	9	5	1
2014A	34	22	12	1	4
2014B	47	26	18	11	3
2015A	46	24	13	3	2
TOTAL	283	185	68	23	12

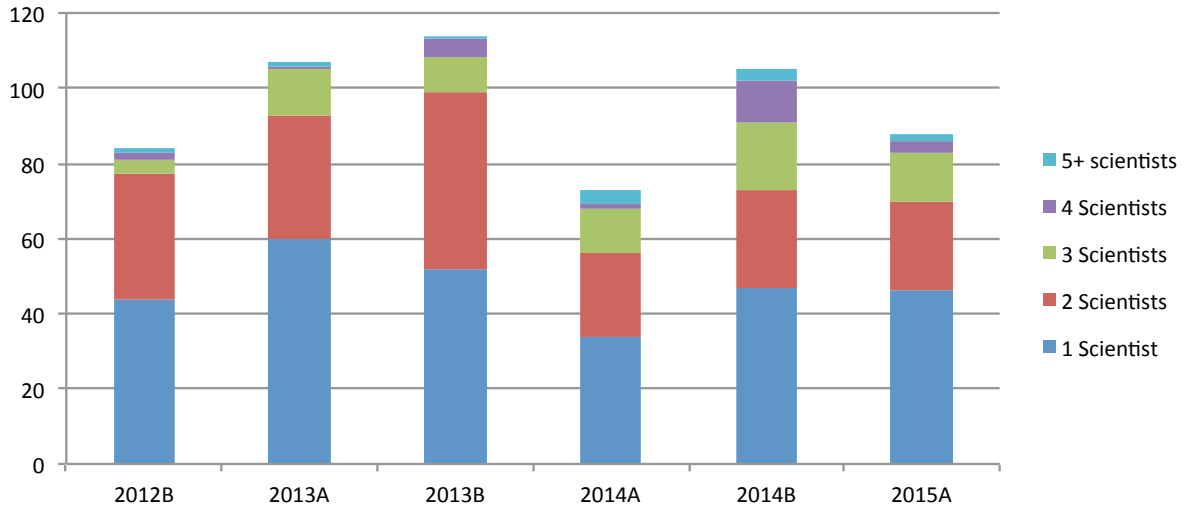


Figure 3.9 FY13-FY15 number of staff selected per accepted proposal per round.

Table 3.7 FY13-FY15 number of thrusts selected per accepted proposal per round.

FY13-FY15 regular call accepted proposals	1 thrust	2 thrusts	3 thrusts
2012B	67	17	0
2013A	86	20	1
2013B	83	27	4
2014A	49	24	0
2014B	63	38	4
2015A	74	14	0
Total	422	140	9

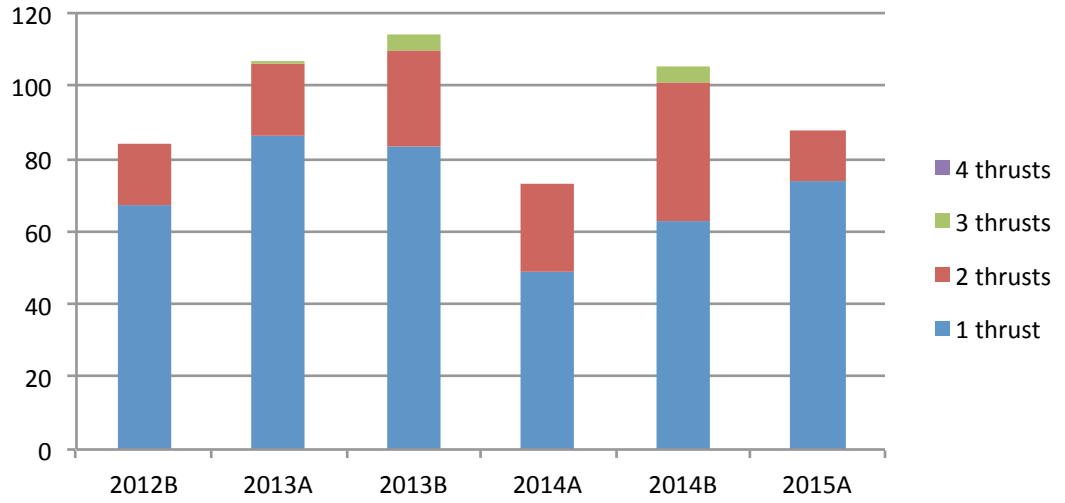


Figure 3.10 FY13-FY15 number of thrusts selected per accepted proposal per round.

3.d.2 User Statistics

From FY13–FY15, CINT hosted 1425 users, which is a ~34% increase over the previous triennial period. Table 3.8 and Figure 3.11 illustrate the number of both badged and offsite users by fiscal year. The geographic distribution of users (Figure 3.12) over the 3-year period indicates that CINT has not only the expected strong regional participation due to proximity but also a national presence, attracting users from virtually all states with a high density of research institutions. Overall, 38 states are represented among the 1314 users from domestic institutions (FY13–FY15). An additional 111 users are from institutions in 21 unique international countries including Argentina, Australia, Austria, Belgium, Canada, China, Czech Republic, France, Germany, Israel, Italy, Japan, Mexico, Netherlands, Singapore, Slovenia, South Korea, Spain, Sweden, Ukraine, and the United Kingdom. A roster of users can be found in the Appendix.

Table 3.8 Total badged and other users per fiscal year

	FY13	**FY14**	**FY15**
Total Number of Users	447	465	513
Badged User	356	373	430
Other User	91	92	83
Remote	0	0	4
Offsite	91	92	79

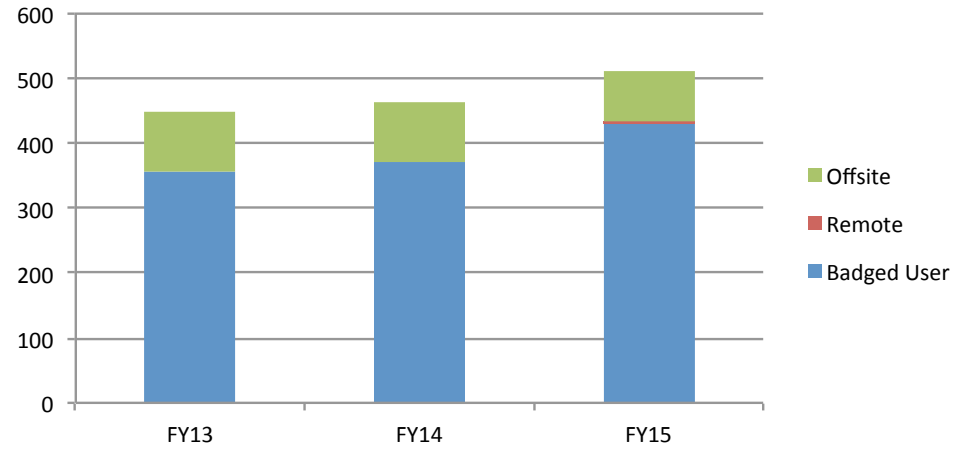


Figure 3.11 Badged and other users per fiscal year.

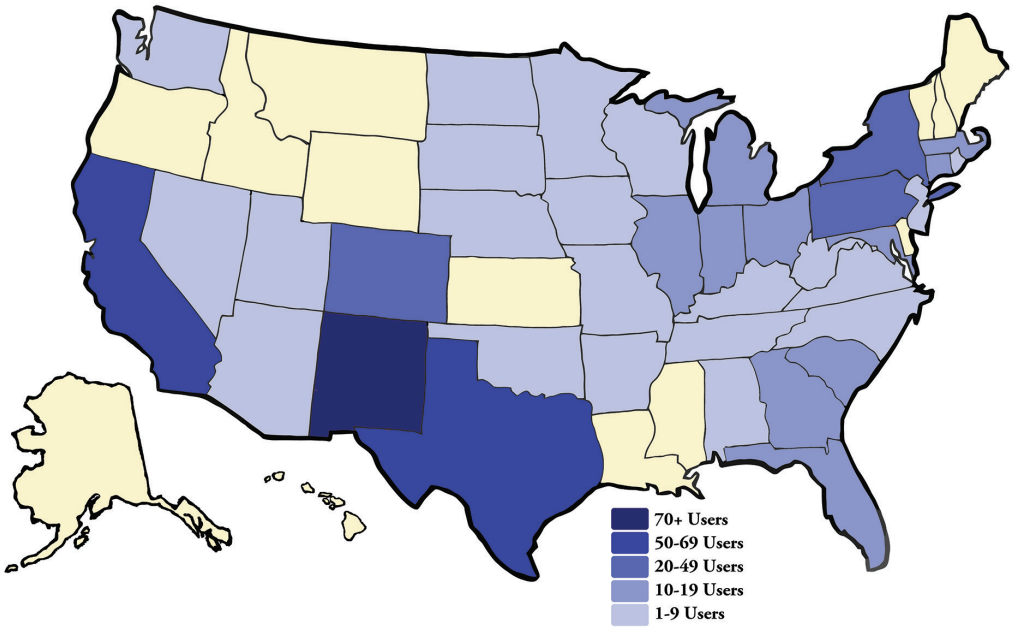


Figure 3.12 Geographic distribution of FY13-FY15 users within the USA.

While we highly value our academic users, we are encouraged by the growth we have seen in the non-academic user populations at CINT, as shown in Table 3.9 and Figure 3.13. We are particularly encouraged by the significant increase in industrial users (almost double from the previous triennial assessment) we have seen throughout the three year period. Through deliberate communication and outreach efforts, such as our recent industrial seminar series, we anticipate further increases in the industrial and other non-academic members of the CINT user community in the years ahead.

Table 3.9 Total number of users by research institution per fiscal year

Employer (User's Research Institution)	FY13	FY14	FY15
Academic (US & Foreign)	240	215	203
NSRC	0	0	21
Host DOE laboratory	154	202	240
Other DOE laboratories	3	3	2
Non-DOE federally funded institution	6	7	10
Industry	40	37	35
Foreign National Laboratory	1	0	1
Foreign Industry	3	0	1
Foreign Other	0	1	0

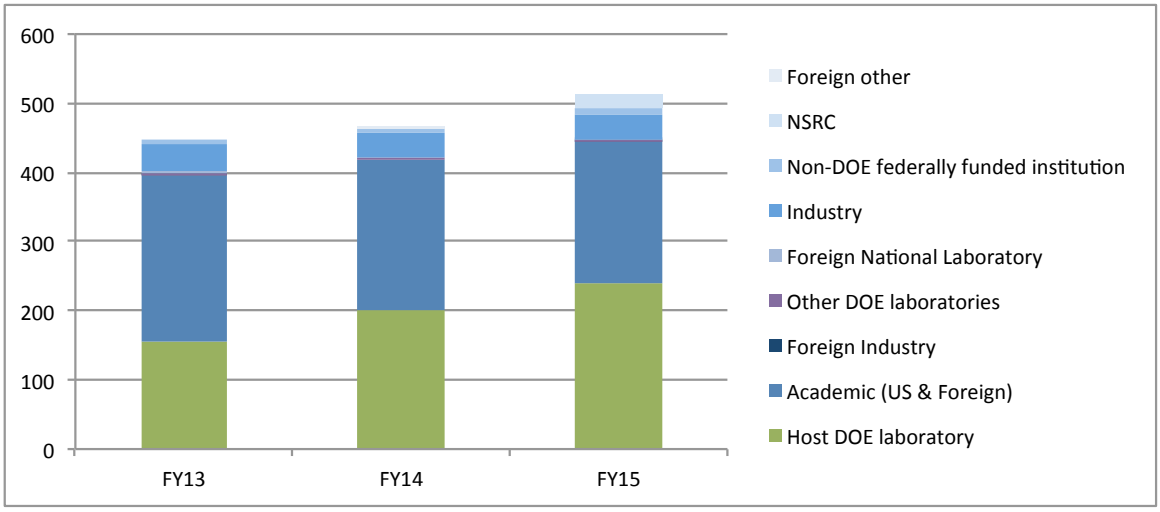


Figure 3.13 Total number of users by research insitution per fiscal year.

CINT users have increased their response rate to the BES annual users' satisfaction mini survey (Figure 3.14). With over 85% of all surveys responses falling in the highly satisfied or satisfied divisions, and only 1% of all responses falling in the dis-satisfied division, CINT is proving that it is serving and enabling a highly productive and satisfied user community (Figure 3.15).

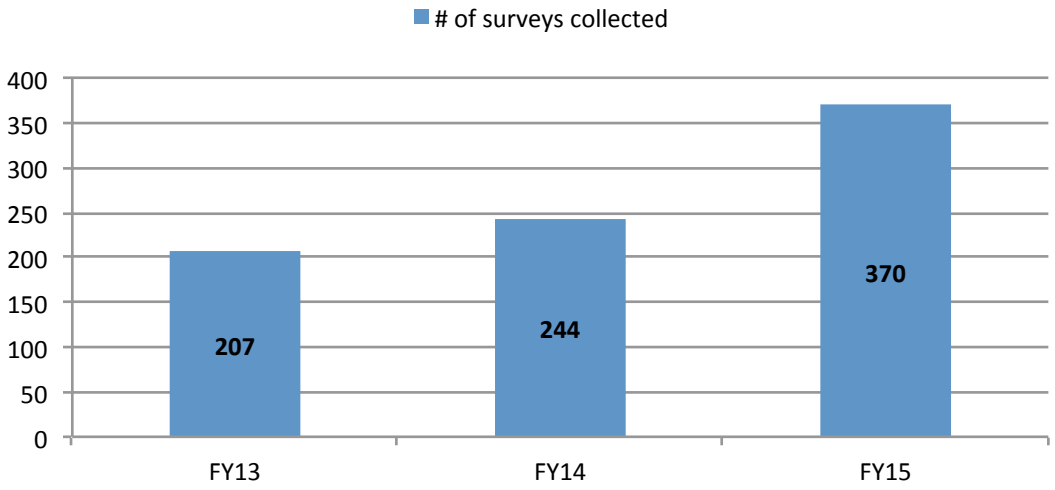


Figure 3.14 Total annual user survey responses collected

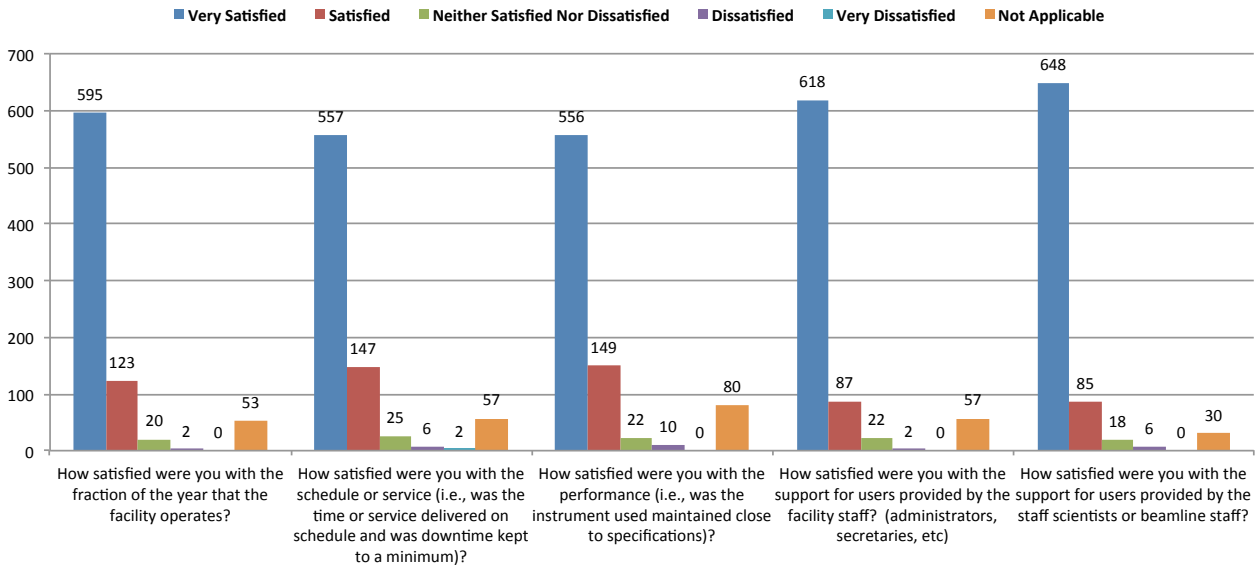
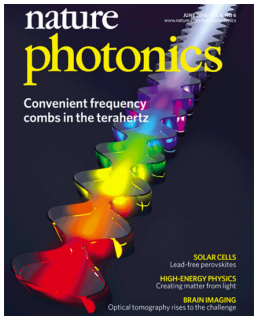


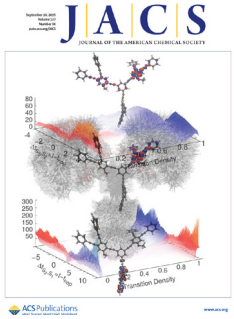
Figure 3.15 Annual user survey response per question, per fiscal year.

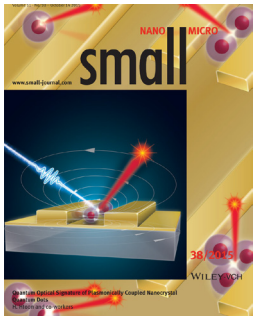
4. Impact

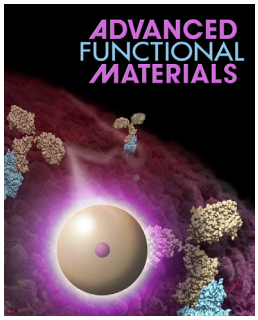
4.a. Highlights

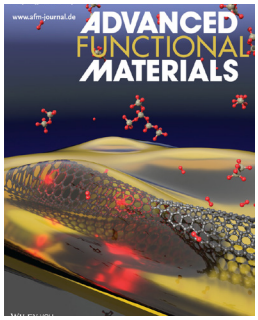
Two important indicators of the impact and success of a User Facility are the quality and quantity of publications that derive from the User and internal science research. We are particularly gratified by our ongoing high level of performance against this criterion in the FY 13 – FY 15 review period. In this section we provide research highlights that have been selected from among the body of work that has appeared in the archival journal literature since our last review. The NSRC community a list of the top 20 High Impact Journals against which our publication records are measured (see Section 4.b.2). We are proud to note that almost all of the research highlights provided in this section are derived from publications from this high impact list of journals. The highlights are a distribution of user science and internal science. The format for these highlights closely parallels that use in the Science Highlights that we provide on a monthly basis to BES with slight reformatting to accommodate the portrait (vs. landscape) format of this document. We note in particular that the user affiliations are readily evident from the presence of the logo of their home institution(s) on the highlight.

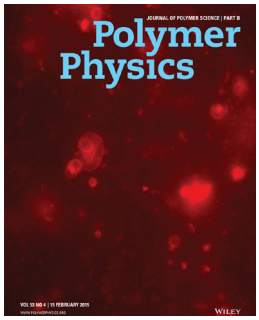


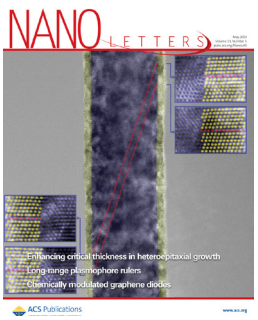


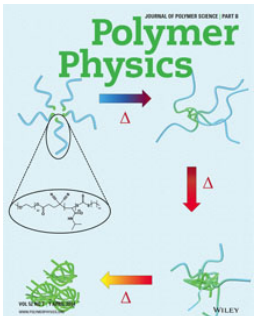


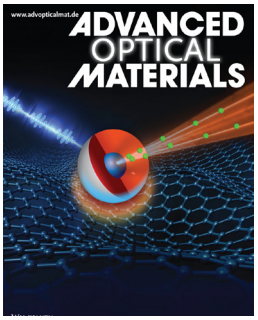


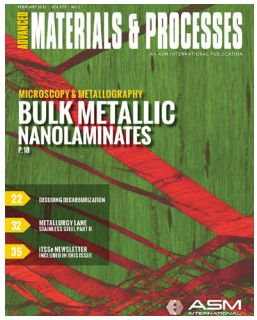


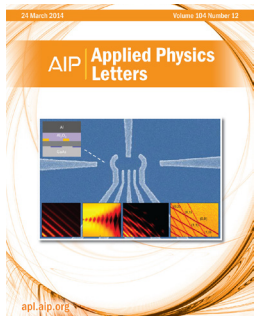


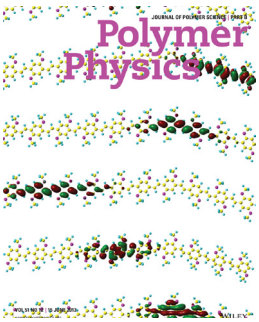


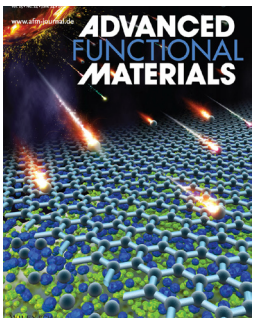


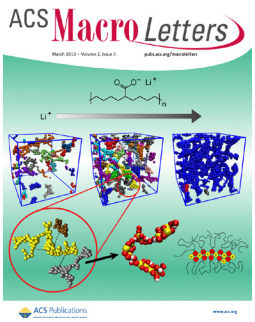












In the last three years, CINT Science was featured on the covers of 19 journals.

Table of Contents for Technical Highlights

Size Effects on the Kinetics and Structure of Nickelide Contacts to InGaAs Fin Structures

Scientific Achievement

We found that the reaction kinetics during the formation of compound contacts to indium gallium arsenide fin-like channels to be strongly dependent on size and orientation.

Significance and Impact

InGaAs fin channels are touted as the most serious candidate for replacing Si in sub-10nm technology nodes. Developing a self-aligned contact using nickelide (compound alloy between Ni and InGaAs) can pave the way for understanding and controlling the structural and electrical contact properties that become extremely important for overall device performance in atomic scale devices.

Research Details

Systematic studies of thermal annealing of Ni contacts on <100> and <110> oriented InGaAs fins with fin widths in the range of 30 – 500 nm have shown strong size-dependent growth mechanism and incubation times.

Detailed analysis revealed a surface-dominant diffusion at small fin sizes, which is different from a volume-dominant diffusion for the large fin width.

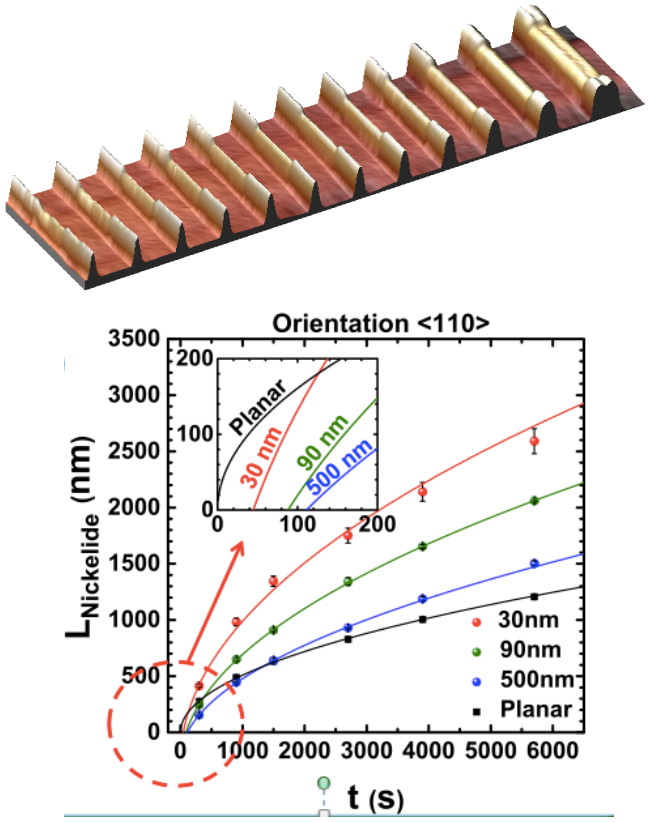


Figure 4.1. Top - Atomic force topography image showing unusual uniaxial volume expansion in [001] orientation and size-dependent extension into the InGaAs channel. Bottom- Size-dependent diffusion into InGaAs channels. Inset shows incubation time at different sizes.

Reference

S.A. Dayeh, R. Chen, Nano Letters 2015 doi: 10.1021/acs.nanolett.5b00327

Hierarchical Nanoporous Copper with Ten-fold Increase in Hardness

Scientific Achievement

We synthesized nanoporous (NP) copper with nanograined and nanotwinned ligaments (struts). This system exhibits more than order of magnitude greater hardness than other NP Copper systems. The enhancement is traced to a combination of geometry and material effects.

Significance and Impact

NP metals are finding increasing number of applications. The significance of this study is twofold. First, we demonstrate the synthesis of an exceptionally strong NP Copper that could be functionalized in a number of ways to yield cheap and reliable battery electrodes, catalysts, etc. Second, this is one of the first studies to probe mechanical properties of hierarchical NP metals, where macroscopic properties depend both on the geometrical structure of the 3D ligament network and on the internal structure of individual ligaments.

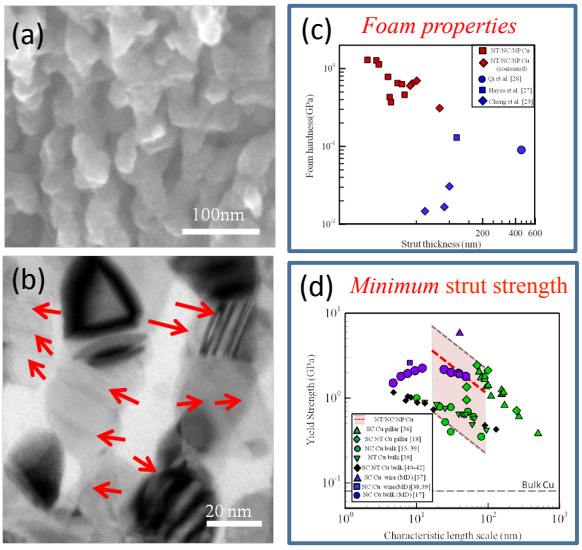


Figure 4.2. (A) Tilt view Scanning Electron micrograph of NP Copper. (B) Transmission Electron micrograph of NP Cu struts. Arrows show nanotwin boundaries. (C) Foam hardness as a function of strut diameter. NP Cu from this study (red data) have one order of magnitude higher hardness. (D) Region marked in pink is the range of strength of individual struts that contribute to enhancement in (B). Individual strut strength compares well with strength of other nanostructured copper systems.

Research Details

- The NP metal synthesized in this study has an additional layer of complexity --- the ligaments themselves are nanostructured, e.g. they have grains with same size as the ligament diameter. Moreover, twin boundaries are present within each grain. It is known from the work on large-scale (bulk) metals that when the size of grains or twin boundaries approaches the nm range, the mechanical properties can be significantly enhanced (smaller is stronger paradigm). Therefore, it may be expected that hierarchical NP metals have even better properties compared to other "simple" NP metals. Indeed, the NP Cu synthesized in this work is approximately 10 stronger than comparable "simple" Cu systems reported in literature.
- Using dimensional analysis, we trace the enhancement of strength to a combination of geometric and material effects. We place a lower bound estimate of the individual strut strength (D) and find it is comparable to other nanostructured copper systems and greater than bulk metal.

Reference

Liu R, Zheng S, Kevin Baldwin J, Kuthuru M, Mara N, Antoniou A. Synthesis and mechanical behavior of nanoporous nanotwinned copper. Applied Physics Letters 2013;103(24)

CINT User Project Highlight | Nanoscale Electronics and Mechanics

Lithium Electrodeposition Dynamics in Aprotic Electrolyte Observed in Situ via Transmission Electron Microscopy (TEM)

Scientific Achievement

We show the first in-situ observations at sub-μm resolution of controlled-rate Li electrodeposition & dissolution in standard battery electrolyte.

Significance

For high-capacity Li metal battery electrodes, the microstructure evolution during cycling reveals critical degradation mechanisms that are governed by passivating interfacial layers.

Research Details

- Sandia-microfabricated TEM liquid cell with multiple electrodes enabled multiple experiments under identical chemical conditions.
- Applied current induced Li deposition within field of view from carbonate/LiPF6–containing electrolyte.
- Interfacial films on the Li led to more pronounced dendrite formation, and electron-beam exposure altered surface film properties.

Reference

Leenheer, A.J., Jungjohann, K.L., Zavadil, K.R., Sullivan, J.P., Harris, C.T. (2015) "Lithium electrodeposition dynamics in aprotic electrolyte observed in situ via transmission electron microscopy"

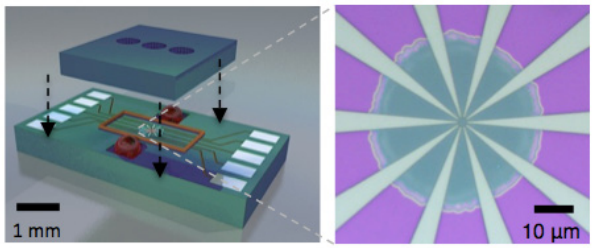


Figure 4.3. Custom TEM cell encapsulates a thin liquid layer between electron transparent membranes with multiple electrodes.

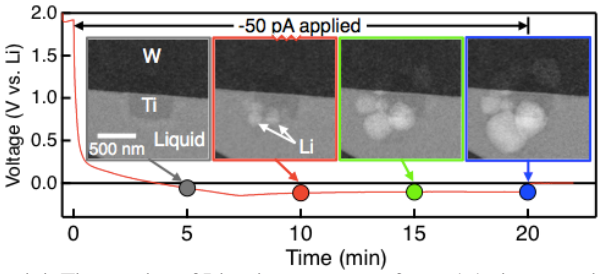


Figure 4.4. Time series of Li microstructures formed during quantitative, current-controlled electrodeposition

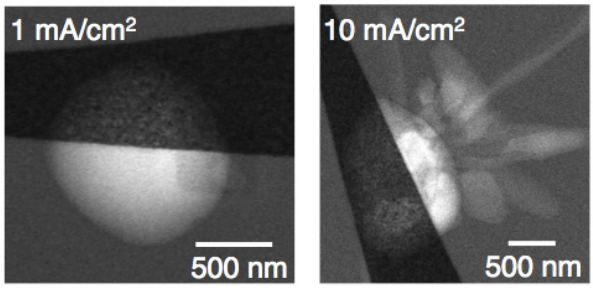


Figure 4.5. Dendritic Li formation occurs depending on the applied current density.

Relieving Stress: A Failure Mode Limiting Storage in Sodium Ion Batteries

Scientific Achievement

When sodium ions penetrate an antimony battery anode, the compressive stress leads to bulk horizontal fracture and buckling, relieving the stress in the anode material but degrading the anode.

Significance and Impact

Compared to lithium-ion batteries, sodium is both inexpensive and highly distributed, presenting an attractive alternative. Since graphite, a common anode material, does not store sodium ions, materials such as antimony have emerged as potential anodes.

This in-situ transmission electron microscopy (TEM) study provides unique in-depth mechanistic insight into sodium alloying with antimony and provides essential information for next generation anode materials design.

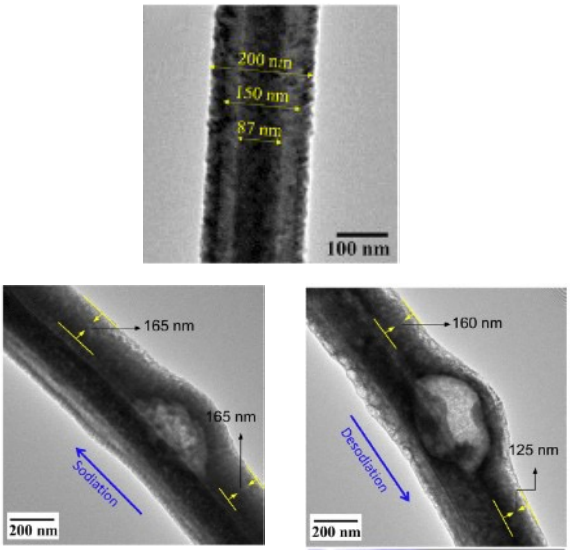


Figure 4.6. In-situ transmission electron microscopy (TEM) images of a single, 100 nm antimony nanowire. (top) "as-synthesized," (left) after 10 hours of sodiation, and (right) in the desodiated state.

Research Details

- Terminal sodiation of Sb thin-films was observed to result in buckling on the current collector due to high stress concentration.
- Anode buckling leads to the disconnection of sodiated material from the current collector, causing capacity loss in the battery.

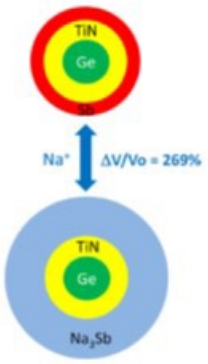


Figure 4.7. Cross-sectional illustration of changes in the Sb thin film anode (with a Ge substrate and TiN current collector) during sodiation. The volume change is 269%.

Reference

Z. Li, X. Tan, P. Li, P. Kalisvaart, M. Janish, W. Mook, E. Luber, K. Jungjohann, C. B. Carter, and D. Mitlin, Nano Lett. 15, 6339 (2015).

Compact Terahertz Laser Frequency Combs Using THz QCL

Scientific Achievement
Demonstrated compact terahertz laser frequency combs based on terahertz quantum cascade laser (QCL)!

Significance and Impact
Frequency combs are powerful tools for high-precision metrology and spectroscopy (2005 Nobel Prize in physics).

Research Details

- The comb spans over 550 GHz with ~70 equally spaced lines with a total power of 5mW
- Linewidth is 1.8 MHz (similar to free-running THz QCLs). Linewidth ≤10MHz needed.
- Integrated dispersion compensators used to generate the comb.

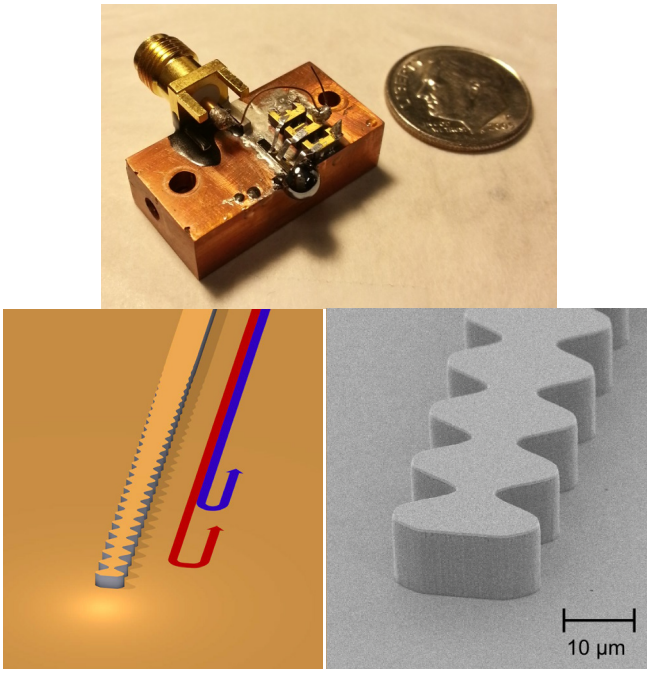


Figure 4.8. Top: Picture of actual device. Bottom left: Cartoon of double-chirped mirrors used. Bottom right: SEM of them.

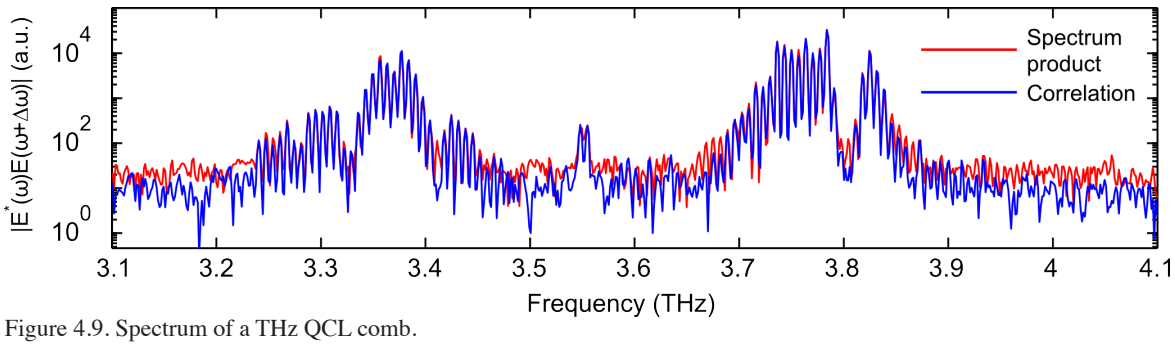


Figure 4.9. Spectrum of a THz QCL comb.

Reference
D. Burghoff,et al., "Terahertz laser frequency combs", Nature Photonics 8, 1462 (2014).

Synthesizing Graphene by Ion Implantation

Scientific Achievement

The precise control of graphene layer thickness by ion implantation has been achieved by taking advantage of the dual metal substrate of the Nickel (Ni)-coated Copper (Cu) foils. We created high quality layers of graphene that strictly correlate with predetermined layer numbers.

Significance and Impact

Graphene is a promising material in nanoelectronics and flexible electronic devices due to its unique 2D hexagonal lattice. However, synthesis of layer-tunable graphene by using traditional chemical vapor deposition method still remains a great challenge. Since our technique is compatible with large-scale microelectronics processing, it is expected that this approach will expedite the application of high-quality graphene to graphene-based nanoelectronic devices.

Research Details

- The Ni/Cu bilayer is implanted with 60 keV C ions. The samples were then annealed at 950°C. During this process, the inter-diffusion of Ni and Cu forms a Cu-Ni alloy. Because the carbon (C) solubility is moderate in Ni and extremely low in Cu, the implanted C ions are expelled to the surface and transformed into graphene.
- Raman, scanning tunneling microscopy (STM) and electrical measurements indicate that both monolayer and bilayer graphene films possess excellent crystalline quality.

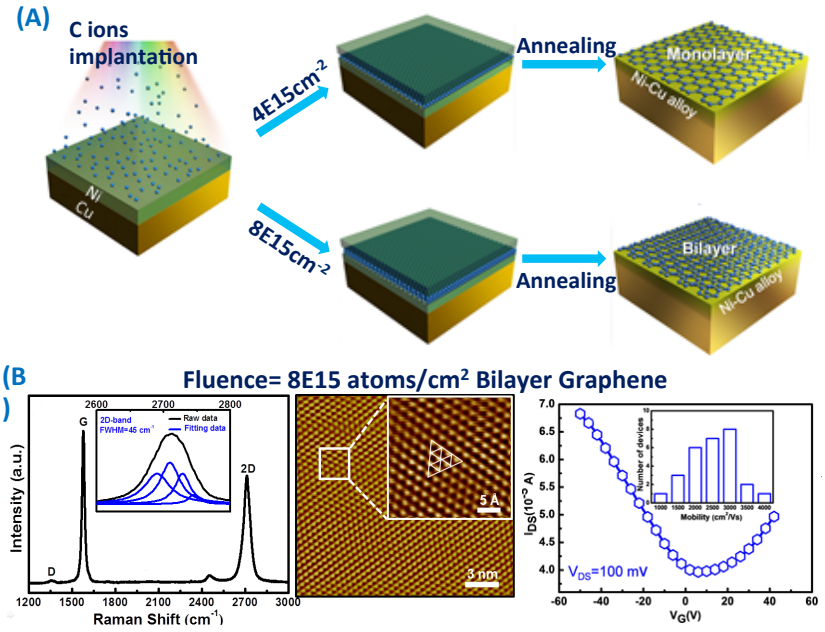


Figure 4.10. (A) Schematic diagrams of monolayer and bilayer graphene synthesized by C ion implant into the Ni/Cu bilayer substrate. (B) Characterization of bilayer graphene by Raman, STM and electrical measurement.

Reference

G. Wang, M. Zhang, S. Liu, X. M. Xie, G. Q. Ding, Y. Q. Wang, P. K. Chu, G. Heng, W. Ren, Q. H. Yuan, P. H. Zhang, X. Wang and Z. F. Di. "Synthesis of Layer-Tunable Graphene: A Combined Kinetic Implantation and Thermal Ejection Approach", Adv. Funct. Mater. DOI: 10.1002/adfm.201500981

Tiny "match-head" wires boost solar energy efficiency at nanoscale and microscale levels

Scientific Achievement

Controlled silicon crystal growth on the tops of silicon nanowires creates a "match-head" structure. The match-head acts as a light concentrator and is the first large structure grown on a nanowire tip. Radiant-light absorbance was increased by 36%, and photovoltaic efficiency was increased by 20%. The match-head structure creates a completely new architecture for controlling light-energy properties.

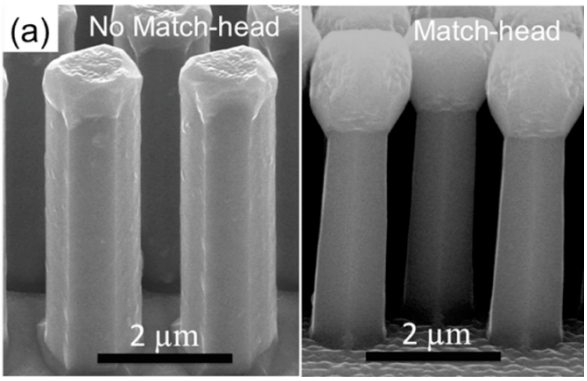


Figure 4.11. Cylindrical silicon wires without a match-head structure and with a match-head structure.

Significance

Match-head nanowires are optical focusing elements that can be used for solar energy. They have an advantage over other solar energy sunlight concentrators: they do not require construction of the light-concentrator system because the silicon growths are naturally formed. These match-head nanowires are attractive candidates for electronic devices because the ability to control the shape of the nanostructure is essential for manufacturing next-generation semiconductor devices such as photodetectors and light emitters. This method of crystal growth can be applied to all nanostructures and microstructures.

Research Details

- Surface energy minimization causes layered crystal growth of silicon at the tips of nanowires.
- The match-head structure improves light absorption of silicon when measured in a photovoltaic cell. Finite-difference time-domain (FDTD) simulation reveals that the match-head acts as a built-in light concentrator.
- When studying an array of nanowires, smaller-diameter nanowires that are densely packed optimize photovoltaic performance.

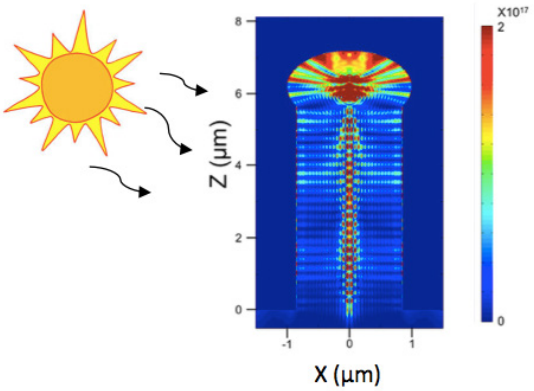


Figure 4.12. Light absorption cross-section profile of silicon match-head wire at 476 nm

Reference

Jinkyoung Yoo, Binh-Minh Nguyen, Ian H. Campbell, Shadi A. Dayeh, Paul Schuele, David Evans, S. Tom Picraux, *ACS Nano* 2015, *9,* 5154.

Induced Magnetization in $La_{0.7}Sr_{0.3}MnO_3/BiFeO_3$ Superlattices

Scientific Achievement

Through an integrated effort, we quantitatively evaluated the interface magnetism throughout the thickness of $La_{0.7}Sr_{0.3}MnO_3/BiFeO_3$ and explained its origin using density functional theory together with an effective exchange field model.

Significance

Our work provides the framework to address the key challenges in understanding of emergent behaviors at oxide interfaces.

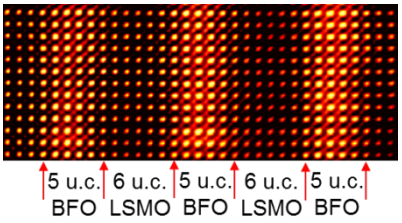


Figure 4.13. High angle annular dark field image of the superlattice.

Research Details

- CINT's capability of laser-MBE enabled the growth of chemically and structurally well-defined superlattices (Figure 4.13).
- Using polarized neutron reflectivity, we observed an induced magnetization in the superlattice extending from the interface through several atomic layers of $BiFeO_3$ (Figure 4.14).
- The induced magnetization in $BiFeO_3$ is explained by both density functional theory (Figure 4.15.) and classical exchange field theory (Figure 4.16).

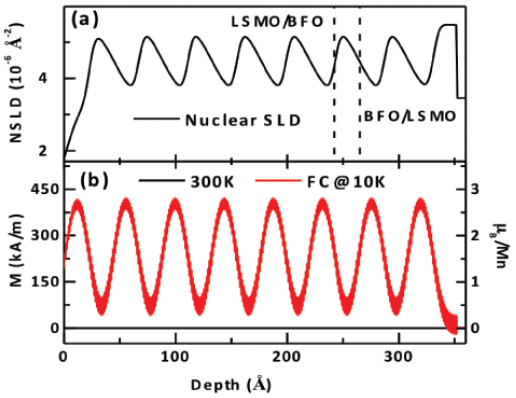


Figure 4.14. The depth profile of the characteristic parameters of the superlattice.

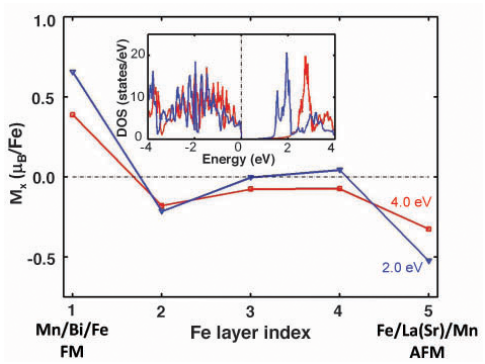


Figure 4.15. Induced magnetization from the density functional theory.

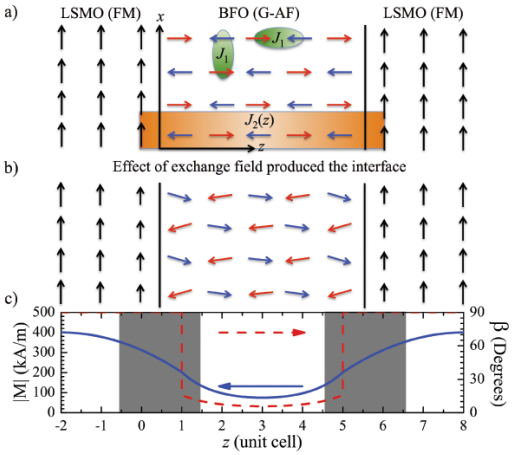


Figure 4.16. Effective exchange-coupling modeling of the magnetization across the interface.

Reference

S. Sing, J. H. Haraldsen, J. Xiong, E. M. Choi, P. Lu, D. Yi, X. D. Wen, J. Liu, H. Wang, Z. Bi, P. Yu, M. R. Fitzsimmons, J. L. MacManus-Driscoll, R. Ramesh, A. V. Balatsky, J. X. Zhu, and Q. X. Jia, Phys. Rev. Lett. 113, 047204 (2014).

Metallic Glass Nanostructures Exhibit Enhanced Radiation Damage Tolerance

Scientific Achievement

Mechanical testing of metallic glass nanostructures shows that helium irradiation actually enhances ductility with no sacrifice in strength.

Significance

This study reveals an improvement in the mechanical properties of $Ni_{73}P_{27}$ metallic glass upon high levels of helium implantation, which suggests that metallic glasses may be well-suited for irradiation-intensive applications, such as nuclear reactors.

Research Details

- $Ni_{73}P_{27}$ metallic glass nanostructures were fabricated and implanted with helium to create a uniform helium concentration throughout the sample volume.
- Transmission electron microscope imaging reveals the presence of ~2 nm helium bubbles as a result of the helium implantation.
- Tension testing on helium-implanted and as-fabricated nanostructures shows that helium implantation increases ductility by a factor of two with no sacrifice in strength.

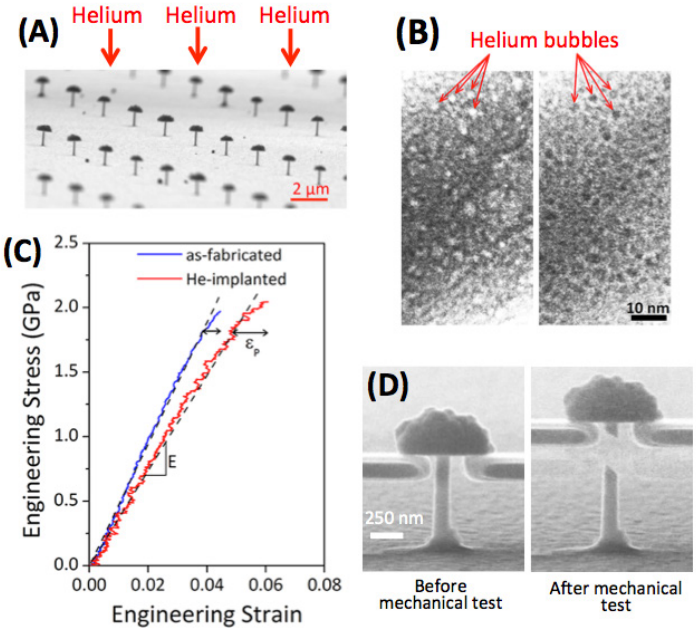


Figure 4.17. (A) Array of "mushroom-shaped" metallic glass nanostructures with the vertical direction of helium implantation indicated. (B) Helium bubbles resulting from the helium implantation. (C) Mechanical data from representative as-fabricated and helium-implanted samples. (D) Typical sample images before and after tension testing

Reference

R. Liontas, X. W. Gu, E. Fu, Y. Wang, N. Li, N. Mara, and J. R. Greer, "Effects of Helium Implantation on the Tensile Properties and Microstructure of $Ni_{73}P_{27}$ Metallic Glass Nanostructures", Nano *Lett*. **2014**, DOI 10.1021/nl502074d

CINT Staff Science Highlight

Nanoscale Electronics and Mechanics

Coupled Hole Quantum Dots in GaAs/AlGaAs

Scientific Achievement

Coupled hole quantum dots in a GaAs/AlGaAs heterostructure have been demonstrated with an interdot coupling that can be tuned from a large single dot to two well-isolated quantum dots.

Significance

The device should allow for control of individual hole spins. This device is a promising candidate for a solid-state quantum bit due to the increased coherence time of hole spins over electron spins.

Research Details

- Charge sensing was used to detect and control the charge occupation of the dots
- The number of holes in the dots was controlled from completely empty to the few-hole regime
- An undoped enhancement-mode device was used in this work.

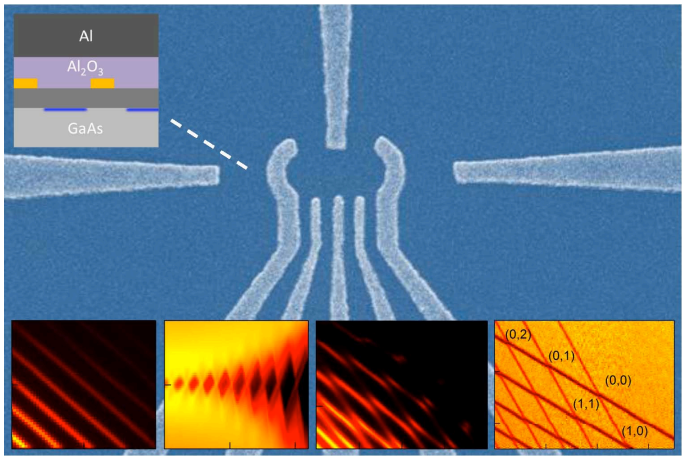


Figure 4.18. Top: An SEM micrograph along with a sketch of the cross-section of the device showing the metallic control gates. Bottom: On the left, charge conductance through the device operating as a large single dot. On the right, demonstration of of the device working as two separate dots and the control of the number of holes on each dot.

Reference

Tracy, L. A., Reno, J. L., Hargett, T., "Few-Hole Double Quantum Dot in an Undoped GaAs/AlGaAs Heterostructure", Applied Physics Letters, 104 (12) 123101, March 24, 2014.

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

Mechanism and Enhancement of an Aqueous Two-Phase Approach to Carbon Nanotube Separations

Scientific Achievement

Aqueous two phase (ATP) separations are emerging as a rapid approach to high-quality carbon nanotube separations, but require many sequential steps. We demonstrate a one-pot process with only a single or two steps. Higher yields and reproducibility result. Our mechanistic study demonstrates that nanotube surface hydrophobicity is defined by interacting surfactants and not by the tube itself.

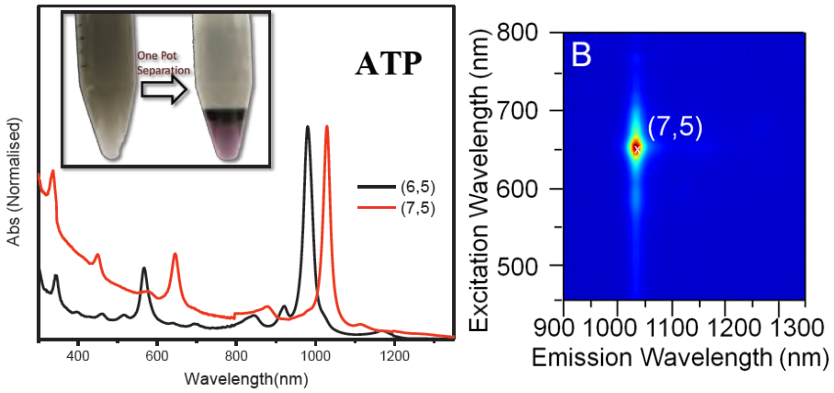


Figure 4.19. Absorbance spectra (left) and photoluminescence excitation map (right) demonstrating high degree of enrichment in (6,5) and (7,5) nanotube structures via ATP separations (illustrated in inset).

Significance

Carbon nanotube synthesis results in a variety of different forms called "chiralities". Enriched samples of individual chirality are required to advance applications, but current approaches introduce significant damage to the tube surface and require extensive processing times (~24 hours). Our 2-step ATP approach is rapid, highly scalable, and mild. Our mechanistic understanding of this process will enable further process enhancements.

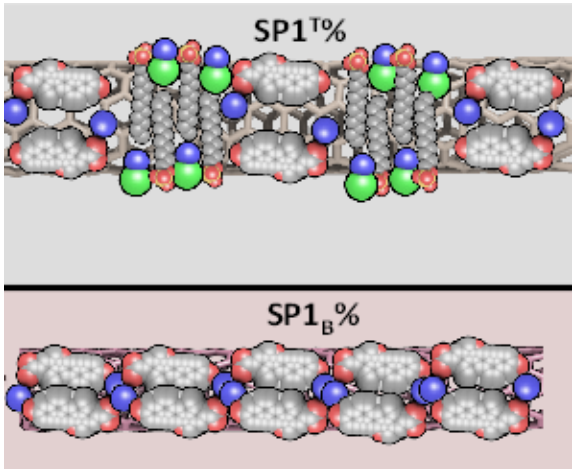


Figure 4.20. Mechanistic studies demonstrate chirality dependent surface chemistry resulting in different mixed-micelle surfactant compositions and structures that determine relative hydrophobicities.

Research Details

- ATP separations are carried out in a system consisting of relative hydrophilic and hydrophobic phases. Chirality-dependent nanotube surface chemistry defines the tube's relative hydrophobicity.
- By appropriately tuning surface compositions, we generated a highly efficient separations approach.
- The simple well-defined process enabled an easy parameter study that provides a mechanistic understanding of ATP separation.

Reference

N. Subbaiyan, et al., ACS Nano, 8, 1619 (2014).

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

Nanowire Synthesis in Motion: New Flow-based Solution-Liquid-Solid Technique

Scientific Achievement

A new technique for solution-phase nanowires synthesis was developed called "flow" solution-liquid-solid growth or flow-SLS. The versatile microfluidics-based approach affords unprecedented control over the parameters that govern catalyzed semiconductor nanowire nucleation and growth in a liquid environment.

Significance

Flow-SLS combines the solution-processibility of flask-synthesized nanowires with a capacity for dynamic control over the introduction of reactants and removal of by-products that heretofore was limited to gas-phase methods. By transforming SLS into a continuous technique, we have established a versatile platform for conducting mechanistic studies and growing novel nanowire heterostructures.

Research Details

- It was revealed for the first time that a combined-growth model - Gibbs–Thomson and diffusion-limited growth - governs SLS nanowire synthesis.
- Reaction parameters were tuned to influence supersaturation and shift the minimum diameter that supports nanowire growth to smaller or larger sizes; in this way ultra-small sub-10 nm wires were accessed.
- Reactant introduction/removal was dynamically controlled to synthesize CdSe/ZnSe superlattice nanowires of unprecedented complexity.

Reference

R. Laocharoensuk, K. Palaniappan, N. A. Smith, R. M. Dickerson, D. J. Werder, J. K. Baldwin and J. A. Hollingsworth, Nature Nanotechnology 2013 8, 660-666.

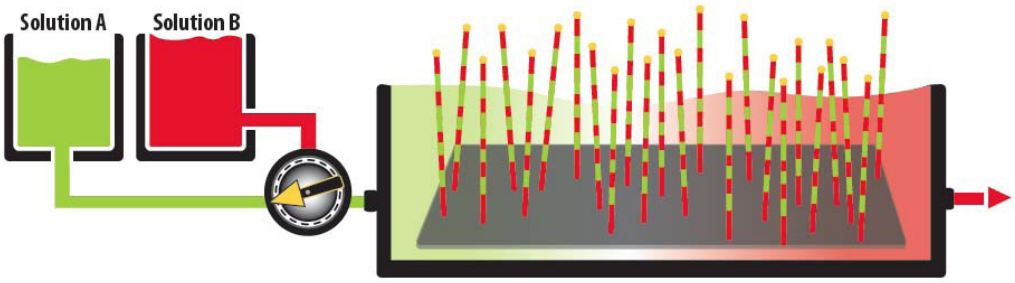


Figure 4.21. SLS Flow technique

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

Doped Carbon Nanotubes: New building blocks for quantum information technologies

Scientific Achievement

Single photons were generated from oxygen-doped carbon nanotubes in SiO_2 at room temperature.

Significance

New, doped nanotubes meet requirements for on-demand single-photon sources that function at room temperature and telecommunications wavelengths, requirements that are essential for quantum photonic devices and quantum information processing.

Research Details

- Incorporation of carbon nanotubes into a SiO_2 matrix leads to solitary oxygen dopant states capable of emission in the 1100-1300 nm wavelength range. The emission could be extended to 1500 nm.
- Nanotubes shows complete photon antibunching (i.e. single photon emission) at room temperature.
- Nanotubes emit strong photoluminescence that is free from fluctuations for long periods of time under continuous, intense laser irradiation.

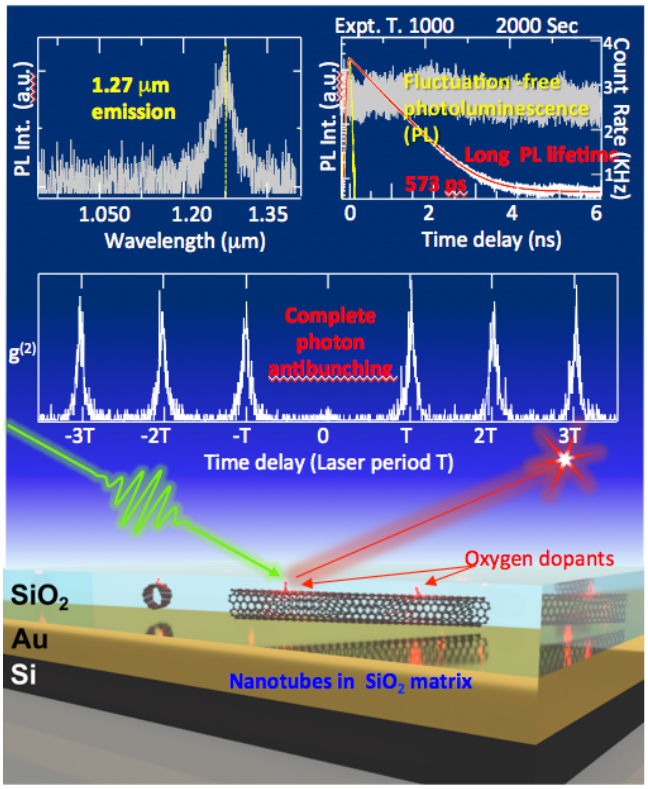


Figure 4.22. Photon antibunching and carrier dynamic properties of SWCNTs embedded in a SiO_2 matrix (top panel); Schematic representation of SWCNTs incorporated into a SiO_2 matrix (bottom panel).

Reference

Ma, X., Hartmann, N. F., Baldwin, J. K. S., Doorn, S. K. & Htoon, H. Nature Nanotechnology, DOI: 10.1038/NNANO.2015.1136, (2015)

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

Quantum Dot Molecules Formed in a Plasmonic Gap: A New Building Block for Quantum Information Networks

Scientific Achievement

An enhanced electromagnetic field (plasmonic field) couples quantum dots (QDs) together, forming quantum dot molecules.

Significance

Quantum dot molecules form key building blocks for quantum plasmonic devices (such as single-photon transistors) and quantum communication networks.

Research Details

- Small clusters of 2-3 silica-coated quantum dots "couple" under the influence of a plasmonic field and exhibit photon antibunching, normally a characteristic of single quantum emitters.
- Photon antibunching is observed by separating photons emitted by single-excitons from those produced by bi-excitons.
- Plasmon-enhanced charge interactions cause quantum dot clusters to behave as a single emitter.

Reference

Wang, F., Karan, N. S., Nguyen, H. M., Ghosh, Y., Sheehan, C. J., Hollingsworth, J. A., Htoon, H., Small, DOI:10.1002/smll. 201500823, (2015).

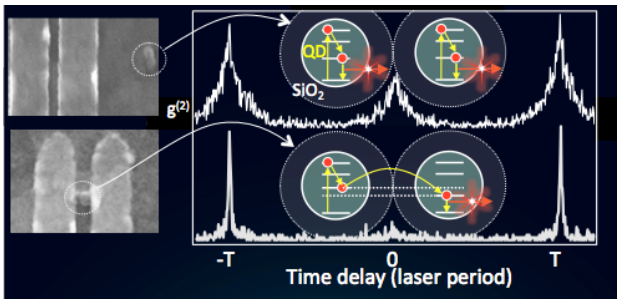


Figure 4.23. While two QDs clustered far from the plasmonic field (top row) behave as two independent quantum emitters, two QDs clustered inside the plasmonic (bottom row) behave as a single quantum emitter and exhibit complete antibunching ($g^{(2)}$ traces, right).

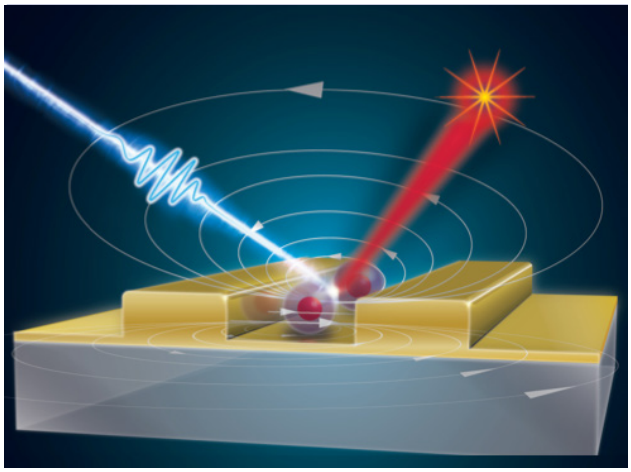


Figure 4. 24. Illustration of excitation and emission of QDs formed between a gold plasmonic gap-bar antenna structure.

Toward a Low-Cost, Efficient, and Ubiquitous Photovoltaic Material

Scientific Achievement

Achieved previously elusive alloying of germanium with a high concentration of tin (as high as 42%) at the nanoscale level using a new synthetic approach and tested its light absorption properties.

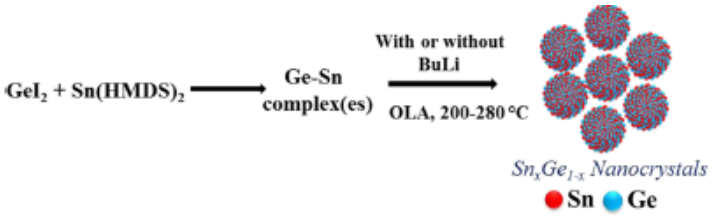


Figure 4. 25. Synthesis of Sn/Ge nanocrystals

Significance

The inefficient light absorption of germanium and silicon complicates their use in photovoltaic applications (solar energy capture), but it is significantly improved by adding tin. Nanoalloys of germanium and tin are also a potential replacement for pure germanium as an electrode material in lithium battery cells because germanium is brittle.

Research Details

- Developed a new synthesis to incorporate tin into germanium at the nanoscale level
- Observed a ten-fold increase in absorption compared with pure germanium
- Nanocrystals are solution-processable, making them ideal for solar energy capture applications

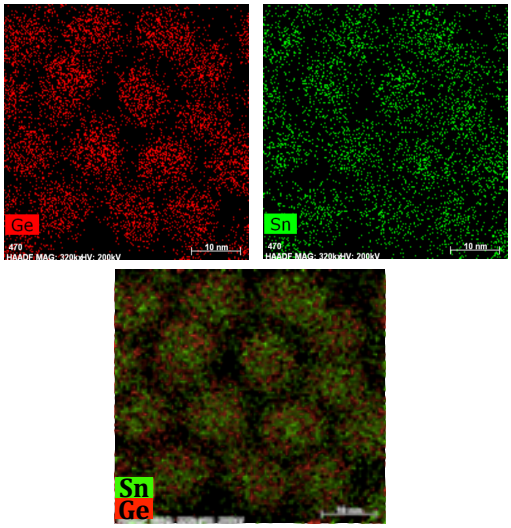


Figure 4. 26. Uniform distribution of Ge and Sn in the nanocrystals

Reference

K. Ramasamy, P. G. Kotula, A. F. Fidler, M. T. Brumbach, J. M. Pietryga, and S. A. Ivanov, Chem. Mater. 27, 4640 (2015)

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

MoS_2 as a Powerful Catalyst for Hydrogen Fuels Production and Clean Energy

Scientific Achievement

Theoretical and experimental methods were used to create different MoS_2 structures, a catalyst for artificial photosynthesis and hydrogen (H_2) fuel production. Both methods revealed that the octahedral structure (1T′ phase) of MoS_2 enhances H_2 yields by four-fold compared with other MoS_2 structures.

Significance

The 1T′ phase of MoS_2 is energetically favorable for a catalytic reaction that produces H_2. Using this phase as a catalyst produced the highest amount of H_2 yet reported for MoS_2. High-yielding H_2 production is vital toward developing hydrogen fuels that use only solar energy and water (clean energy).

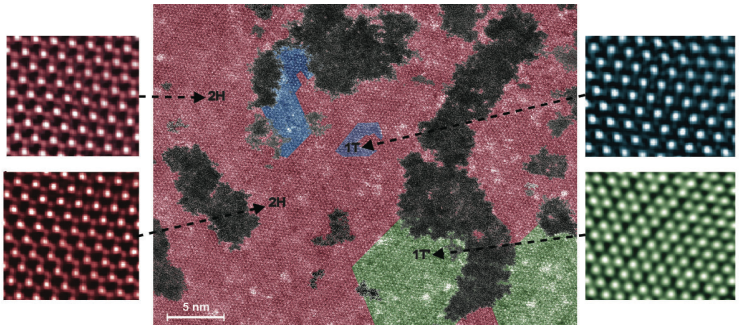


Figure 4. 27. Typical polymorphic MoS_2 sheet exfoliated and intercalated with Li.

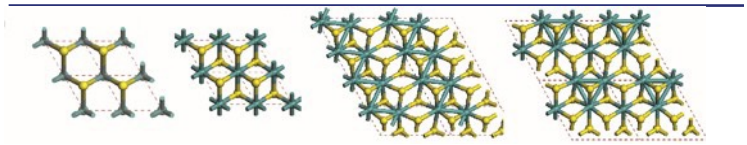


Figure 4. 28. Different structures of MoS_2 based on computational designs (DFT simulations).

Research Details

- Using advanced microscopy and chemical methods, achieved direct visualization of different atomic arrangements in the MoS_2 monolayer
- Used density functional theory (DFT) calculations to predict and rank the most energetically favorable phases/structures of MoS_2
- Reacted MoS_2 with Li to create primarily 1T′ phases of MoS_2 and experimentally tested H_2 production by investigating the charge transfer between the fluorescent molecule Eosin Y (EY) and the Li-reacted MoS_2.

Reference

S. S. Chou, N. Sai, P. Lu, E. N. Coker, S. Liu, K. Artyushkova, T. S. Luk, B. Kaehr, and C. J. Brinker, Nat. Comm., 6, 8311 (2015).

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

Using Light to Couple Electricity and Magnetism within a Few Trillionths of a Second

Scientific Achievement
Ultrashort optical pulses were used to explore and optically manipulate the coupling between ferroelectric (FE) and ferromagnetic (FM) order in an oxide heterostructure, revealing the microscopic mechanisms that limit the speed of the response.

Significance
Materials in which electric and magnetic order coexist, known as multiferroics, have great potential for applications in areas including data storage and magnetic sensing. Many of these applications require a high-speed response, making it critical to understand and control the timescales governing the coupling between magnetism and electricity in multiferroic devices.

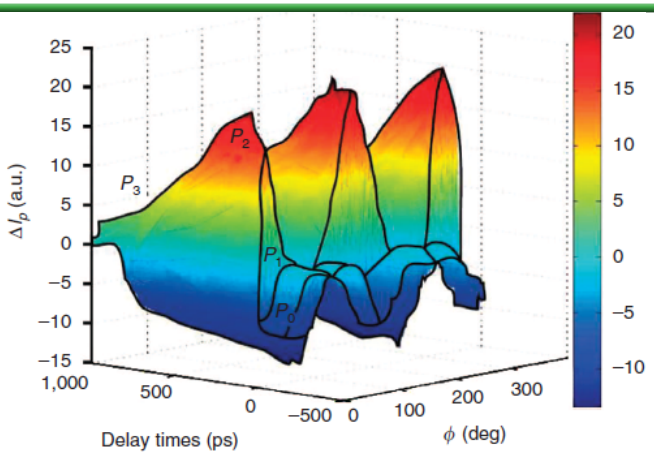


Figure 4. 29. Time-and-polarization dependent response of the FE layer after optically perturbing magnetic order in the FM layer. The timescale taken for the response to reach its peak, as well as the detailed polarization dependence, reveals the microscopic mechanisms underlying ME coupling.

Research Details

- Using femtosecond optical pulses to manipulate the coupling between FE and FM order in a complex oxide heterostructure
- Optically perturbing the magnetization in FM layer and selectively probing the associated change in the FE properties of FE layer
- Coupling between FE and FM order induced within tens of picoseconds, mediated through elastic coupling between the FE and FM layers

Reference
Y. M. Sheu, S. A. Trugman, L. Yan, Q. X. Jia, A. J. Taylor, and R. P. Prasankumar, "Ultrafast optical manipulation of magnetoelectric coupling at a multiferroic interface," Nat. Commun. 5, 5832 (2014)

Metamaterial flexible sheets could transform optics

Scientific Achievement

Using ultrafast optical microscopy, carrier relaxation and New ultrathin, planar, lightweight, and broadband polarimetric photonic devices and optics could result from recent research by CINT Scientist Hou-Tong Chen and his team. The advances would boost security screening systems, infrared thermal cameras, energy harvesting, and radar systems. (Members of the metamaterials team, from left: Nathaniel K. Grady, Hou-Tong Chen, Jane E. Heyes)

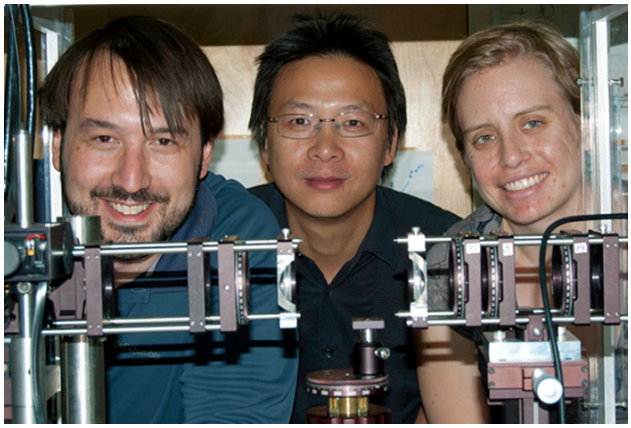


Figure 4. 30. Members of the metamaterials team, from left: Nathaniel K. Grady, Hou-Tong Chen, Jane E. Heyes

Significance

This development is a key step toward replacing bulky conventional optics with flexible sheets that are about the thickness of a human hair and weighing a fraction of an ounce. The advance is in the design of artificially created materials, called metamaterials, that give scientists new levels of control over light wavelengths.

The research was reported online in Science magazine, "Terahertz Metamaterials for Linear Polarization Conversion and Anomalous Refraction." The team demonstrated broadband, high-performance linear polarization conversion using ultrathin planar metamaterials, enabling possible applications in the terahertz (THz) frequency regime. Their design can be scaled to other frequency ranges from the microwave through infrared.

Reference

Terahertz Metamaterials for Linear Polarization Conversion and Anomalous Refraction," Science, published online in Science Express, May 16, DOI: 10.1126/science.1235399, by Nathaniel K. Grady, Jane E. Heyes, Dibakar Roy Chowdhury, Yong Zeng, Matthew T. Reiten, Abul K. Azad, Antoinette J. Taylor, Diego A. R. Dalvit and Hou-Tong Chen of Los Alamos National Laboratory.

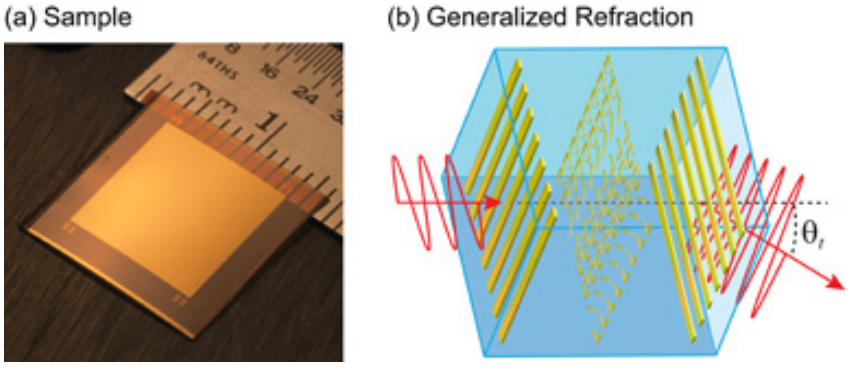


Figure 4. 31. (a) Photograph of an ultrathin (72 μm thick) metamaterial sample (b) Illustration of how the metamaterial redirects an electromagnetic wave, which would not happen for a normal thin film. The structure is not drawn to scale.

CINT User Project Highlight | Nanophotonics and Optical Nanomaterials

Metamaterials Coupled to Semiconductor Heterostructures: Giant Nonlinearities in a Highly Coupled System

Scientific Achievement

Metamaterial nanocavities coupled to highly nonlinear semiconductor heterostructures enhance second harmonic generation (SHG) by orders of magnitude. Arrays of these coupled systems act like a collection of phased array sources.

Significance and Impact

This is the first time that metamaterial nanocavities coupled to semiconductors have been used to generate light at new wavelengths and manipulate the resulting beams. New theory is being developed to describe resonant nonlinearities in a strongly coupled system.

Research Details

- Fabricated doubly resonant metamaterial arrays on top of a semiconductor heterostructure designed to have a large second order nonlinearity (using intersubband transitions)
- Through measurements of the SHG radiation far-field (at 5um), we proved that the metamaterial resonators were emitting in a phase coherent manner.
- Used arrays with different phase response at the second harmonic wavelength to create new functionality.

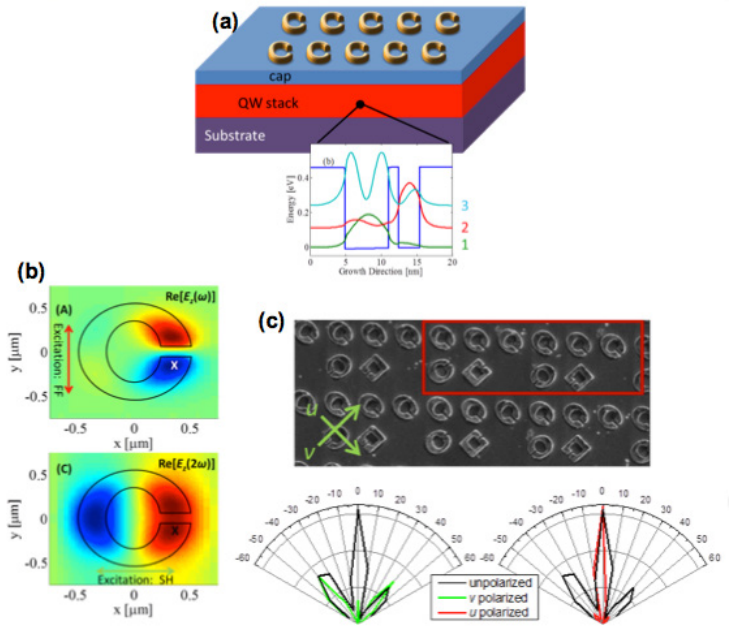


Figure 4. 32. (a) The coupled, nonlinear system: Metamaterial resonators are fabricated directly on III-V heterostructures, designed to have a resonant c(2) using intersubband transitions (inset: band structure). (b) Electric field mode patterns of metamaterial nanocavities at the fundamental (top) and second harmonic (bottom) frequencies (c) Far-field SH radiation pattern for a polarized beam splitter: two output lobes are observed polarized in the v-direction, and only one polarized in the u-direction.

Reference

"Phased-Array Sources Based on Nonlinear Metamaterial Nanocavities", O. Wolf, S. Campione, A. Benz, A. Ravikumar, S. Liu, T. Luk, E. Kadlec, E. Shaner, J. Klem, M. Sinclair, and I. Brener, Nature Communications 6, 7667 (2015)

Nanoscale Silicon Metadevices for Optical Beam Control

Scientific Achievement

Using silicon-nanostructuring, an ultra-thin, polarization-insensitive optical device was fabricated that can impart a complete, 0° to 360° phase change with small pixel sizes, a requirement for generating vortex beams.

Significance and Impact

The silicon metadevices are Huygens' scatterers (reflectionless) at resonance frequencies and are useful for beam control, such as laser beam shaping and beam steering. Flat, space-saving optical devices can be designed for holographic components.

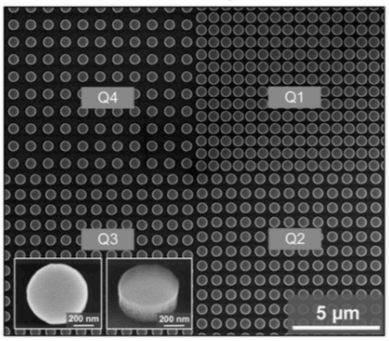


Figure 4. 33. Scanning electron micrograph of four quadrants of different silicon nanodisks.

Research Details

- Developed a metasurface consisting of silicon nanocylinder arrays
- The magnetic and electric dipole resonances overlap (Huygens' scatterer) to create a reflectionless surface
- The nanocylinder spacing was adjusted to provide a phase shift
- Four quadrants were created (Q1, Q2, Q3, Q4) using four optical phase values; the samples were made using ebeam lithography and etching
- A vortex beam was created and measured using interferometry

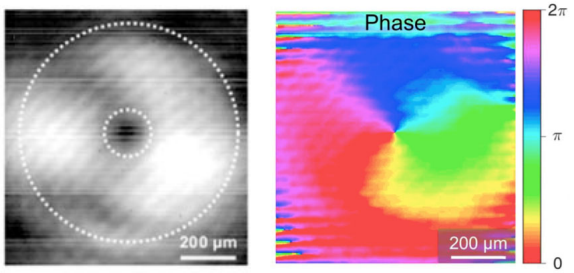


Figure 4. 34. Map of the generated vortex beam showing a center minimum (left) and phase image showing the gradual phase change (right).

Reference

K. E. Chong, I. Staude, A. James, J. Dominguez, S. Liu, S. Campione, G. S. Subramania, T. S. Luk, M. Decker, D. N. Neshev, I. Brener, and Y. S. Kivshar, Nano Lett. 15, 5369 (2015).

Nano-Enabled, Microfluidic Detection of *Bacillus anthracis*

Scientific Achievement

Using the unique optical properties and ability to surface functionalize gold nanoparticles (AuNPs), a microfluidic lateral flow assay (LFA) was developed in CINT for the selective detection of *Bacillus anthracis*, the causal agent responsible for anthrax infections. The LFA component was integrated into a larger architecture to create a credit card-sized detection system (called BaDx - *Bacillus anthracis* Diagnostics) for use in low resource environments.

Significance

Integrated device enables the rapid, inexpensive detection of virulent *B. anthracis* in a manner that does not require technical expertise or specialized equipment, and reduces the risk of unintentional exposure and malfeasant use.

Research Details

- On-chip microfluidic culture using selective growth medium permitted target amplification over 6-24 hr
- AuNPs surface functionalized with antibodies selective for two virulence factors, protective antigen (PA) and lethal factor (LF), expressed by *B. anthracis*
- LFA with functionalized AuNPs (right) enabled rapid visual detection of virulence factors without specialized instrumentation
- Self-decontamination rendered all components of the chip and assay free of infectious agents following detection

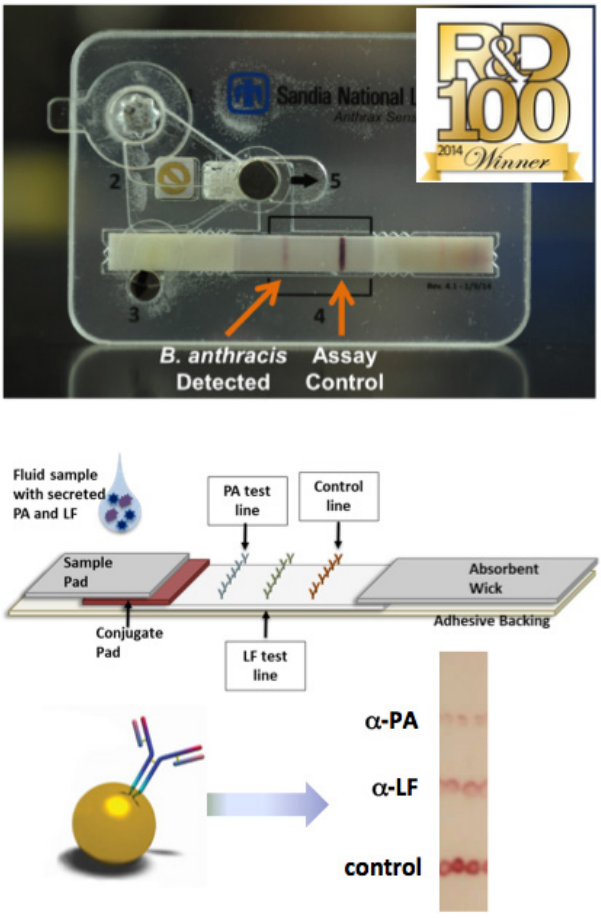


Figure 4.35. Photo and Schematic of magnetic-adhesive based valve operations.

Reference

Harper, J.C., Carson, B.D., Bachand, G.D., Arndt, W.D., Finley, M.R., Brinker, C.J., and Edwards, T.L. (2015) Laser machined plastic laminates: Towards portable diagnostic devices for use in row resource environments. Electroanalysis 27: 2503-2512

Ozonated Graphene Oxide Film as a Proton-Exchange Membrane

Scientific Achievement

Enhanced proton conductivity was achieved by the chemical modification of graphene oxide (GO) by ozone to form ozonated graphene oxide (OGO).

Significance and Impact

Modification of dispersed GO presents a powerful opportunity for optimizing this nanoscale material for proton exchange membranes that may be useful in fuel cell applications.

Research Details

- Ozonation resulted in an increase in both oxygenated functional groups and pinholes, which enhance the proton conductivity of the material.
- OGO and GO films were demonstrated as potential fuel cell membranes, with OGO showing improved performance and stability over GO.

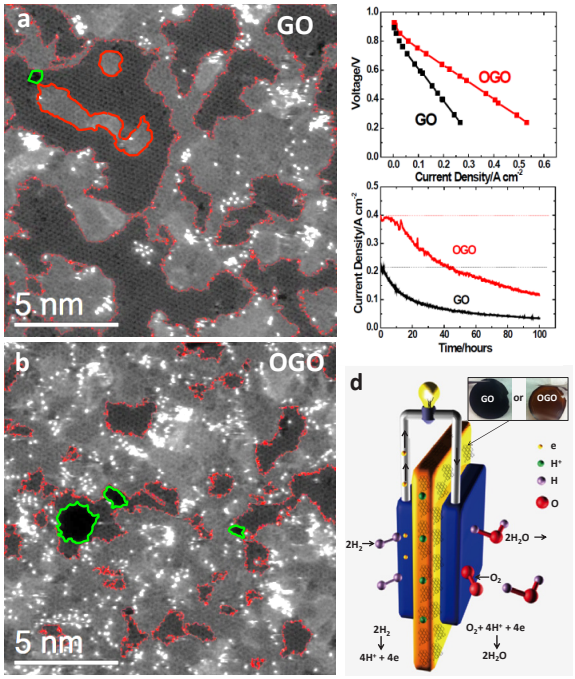


Figure 4.36. Z-contrast STEM images of (a) GO and (b) OGO showing differences in pore density and functional group surface coverage. (c) Hydrogen-air fuel cell tests showing improved performance and long-term stability of OGO membranes. (d) Schematic of a GO/OGO membrane incorporated into a fuel cell.

Reference

W. Gao, G. Wu, M.T. Janicke, D.A. Cullen, R, Mukundan, J.K. Baldwin, E.L. Brosha, C. Galande, P.M. Ajayan, K.L. More, A.M. Dattelbaum, and P. Zelenay, Angewandte Chemie 53, 1 (2014). DOI: 10.1002/anie.201310908

"One Pot" Cascade Synthesis of Nanoparticle Network Polymer Hydrogel Composites

Scientific Achievement

A durable, gold nanoparticle-polymer composite that exhibits solvent-induced color tuning is prepared using a "one pot" cascade synthesis.

Significance and Impact

Developed a facile, inexpensive approach for harnessing the inherent properties of individual inorganic nanoparticles within a polymer scaffold using reaction step economy. The synthesized composite exhibits plasmonic optical tuning, useful for the development of new materials and devices.

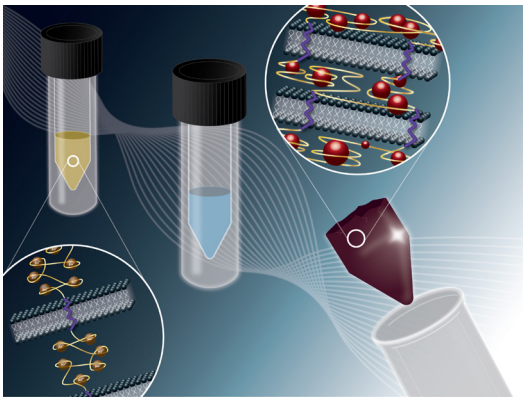


Figure 4.37. Illustration of the synthesis of gold nanoparticles and polymers to form composites. There is a distinct color and phase change following the reduction of gold and the formation of a hydrogel

Research Details

- Combined a phospholipid, acrylate-terminated polymers and hydroxyl-terminated polymers, a surfactant, and aqueous gold in a cascade reaction to generate hydrogel composites
- Hydrogel exhibited reversible swelling with water
- Solvent-triggered modulation of gold nanoparticle composite structure leads to changes in its optical properties

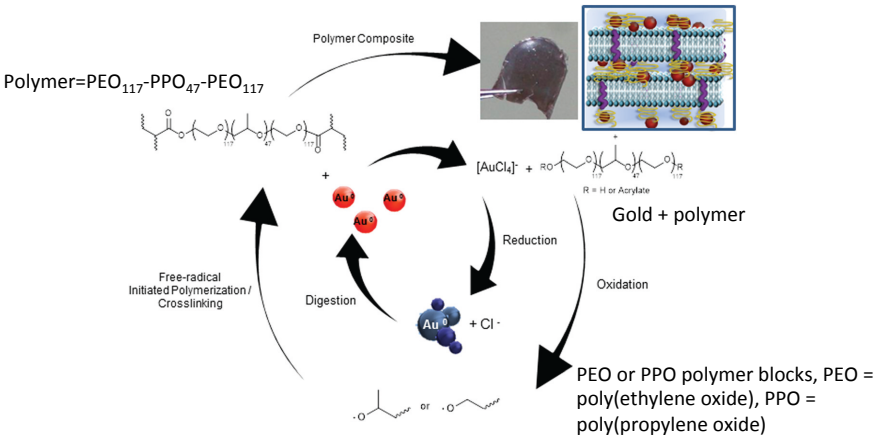


Figure 4.38. Schematic illustration of the cascade reaction that generates gold-nanoparticle composites. A redox reaction occurs in tandem.

Reference

S. Grubjesic, B.S. Ringstrand, K.L. Jungjohann, S.M. Brombosz, S. Seifert, and M.A. Firestone, Nanoscale, 8, 2601 (2016).

A Hybrid DNA-Templated Gold Nanocluster for Fuel Cells

Scientific Achievement

When assembled with carbon nanotubes (CNTs) and a bilirubin oxidase (BOD, a fuel cell enzyme), DNA-templated gold nanoclusters (AuNCs) significantly improve the oxygen reduction reaction (ORR), a reaction that takes place in fuel cells.

Significance and Impact

The AuNC could be used for clean energy fuel cell development, significantly lowering the electrochemical energy waste in the ORR, and removes a substantial barrier to fuel cell efficiency.

Research Details

- Synthesized and characterized DNA-templated AuNC
- The AuNC has 7 Au atoms and is ~1 nm in diameter
- The AuNC was assembled with carbon nanotubes and a fuel cell enzyme, bilirubin oxidase. The ORR was studied using this composite material.

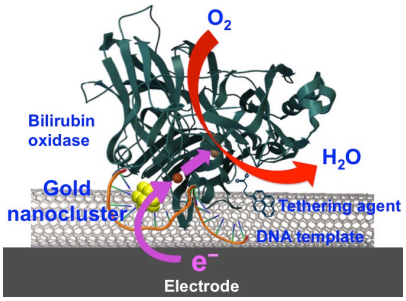


Figure 4.39. DNA-AuNC complex enhances ORR by mediating efficient electron transfer.

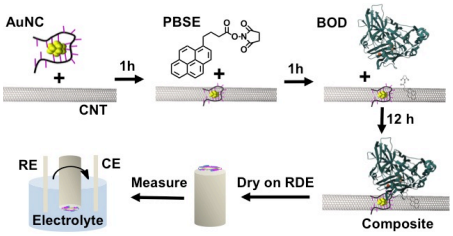


Figure 4.40. Assembly of the AuNC with a CNT and fuel cell enzyme, BOD (PBSE = 1-pyrenebutanoic acid succinimidyl ester, RDE = rotating disk electrode, RE = reference electrode, CE = counter electrode).

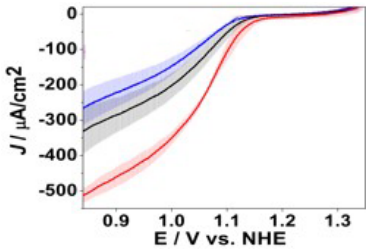


Figure 4.41. A linear sweep voltammetry scan shows that the AuNC enhances the kinetics and thermodynamics of electrocatalytic ORR.

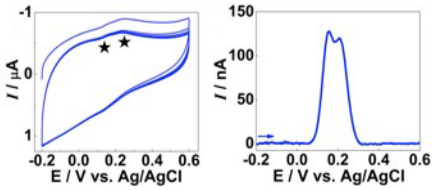


Figure 4.42. The AuNC is electrochemically unique, shown by its cyclic voltammetry scan (left) and differential pulse voltammetry scan (right).

Reference

S. Chakraborty, S. Babanova, R.C. Rocha, A. Desireddy, K. Artyushkova, A.E. Boncella, P. Atanassov, and J.S. Martinez, J. Am. Chem. Soc. 137, 11678 (2015).

CINT Staff Science Highlight

Soft, Biological & Composite Nanomaterials

Biomolecular Machines Assemble Complex Polymer Networks

Scientific Achievement

Kinesin, one of nature's biomolecular machines, is shown to both deform and dynamically reorganize highly-ordered polymer nanostructure networks.

Significance and Impact

Creates rapid and continuous assembly of nanostructures, which may enable a new class of self-healing electronic/photonic composite materials. Polymer networks display enhanced stability over lipid networks (24 hours vs. 4-5 hours).

Research Details

- Kinesin/microtubule biomolecular machines exert sufficient mechanical force on polymer micelles to remove polymer nanotubes from micelle. Polymer networks were formed within 30 minutes.
- Polymer network morphology and size increased with the addition of lipid, serving as a fluidizing agent.
- Polymer mobility in the network is different from lipid analogs.

Reference

Paxton, WF, Bouxsein, NF, Henderson, IM, & Bachand, GD., Nanoscale 7, 10998 (2015).

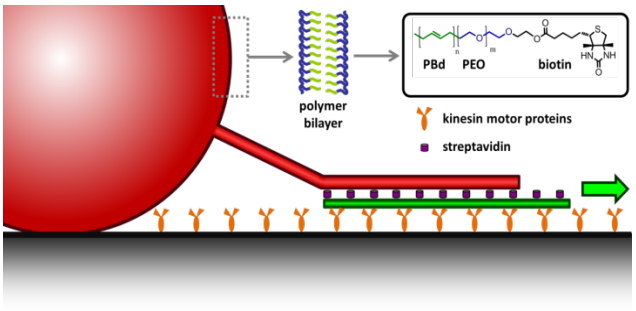


Figure 4.43. Illustration of the biomolecular polymer assembly system. Block copolymer is PBd PEO. Biotin on end of polymer binds to streptavidin.

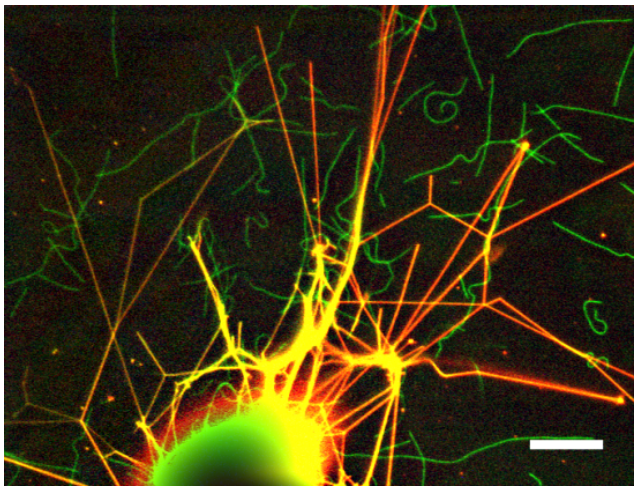


Figure 4.44. Fluorescence image of dyed polymer nanotubes (red) and microtubules (green)

3-Dimensional Tracking of Non-blinking 'Giant' Quantum Dots in Live Cells

Scientific Achievement

We have been able to follow individual allergy receptors in live cells for several minutes, discovering hetergeneous diffusive transport that may aid cell signaling pathways.

Significance and Impact

Single particle tracking is a powerfull tool to explore problems in cell biology, but blinking of the probe used as a label or movement of the molecule out of the image plane of the microscope limits measured trajectories to < 10 seconds. The techniques and probes described here enable following single molecule motion for minutes throughout entire cell volumes.

Research Details

This work combines novel probes, non-blinking "giant" CdSe/CdS core/thick-shell nanocrystal quantum dots (gQDs) with an advanced 3D confocal tracking microscope that uses active feedback to follow 3D molecular motion to measure single molecule motion in live cells for minutes. Hidden Markov modeling of measured trajectories classifies 3 states of receptor motion: (10^{-2} $\mu m^2/s$, assigned to antigen-cross linked immobile receptors), membrane diffusion (10^{-1} $\mu m^2/s$), and fast endocytotic transport (10^{0} $\mu m/s$).

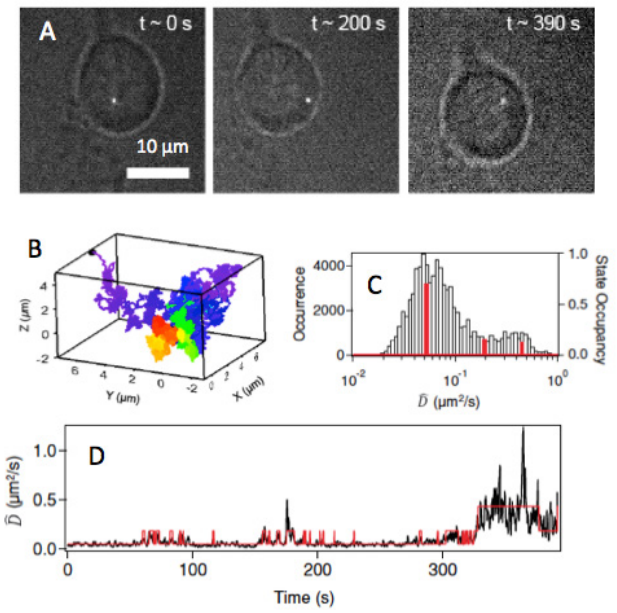


Figure 4.45. (A) 2D images of quantum dot labeled allergy receptor in a live cell at various times (B) A 3D representation of the measured single molecule trajectory. (C) Histograms of diffusion coefficients obtained by a mean squared displacement analysis (black) and by hidden Markov modeling (red). (D) Motion of molecule switches from immobile to slow to fast diffusion during trajectory.

Reference

Keller, AM, Ghosh, Y, DeVore, MS, Phipps, ME, Stewart, MH, Wilson, BS, Lidke, DS, Hollingsworth, JA and Werner, JH, Advanced Functional Materials 24, 4796-4803, (2014).

CINT User Project Highlight | Soft, Biological & Composite Nanomaterials

All-Star Nanocrystals

Tiny semiconducting crystals show promise for solar cell architectures and light-emitting devices.

Scientific Achievement

CINT users from Ames Laboratory discovered semiconducting nanocrystals that function not only as stellar light-to-energy converters but also as stable light emitters.

Significance

Honing methods to fine-tune optimal characteristics of materials that convert light to energy may lead to more efficient materials, as performance depends critically on composition, crystallinity, and morphology. These perovskites could be used in the construction of new solar cell architectures, as well as for light-emitting devices and single particle imaging and tracking.

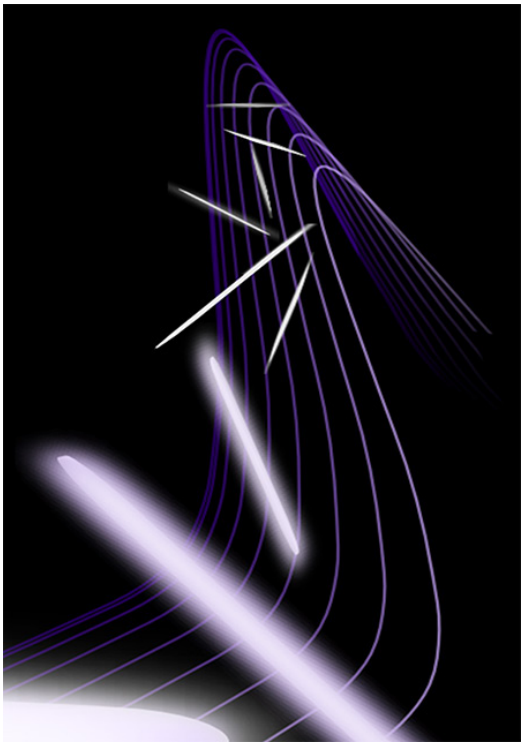


Figure 4.46. Perovskite nanowires have been found to function as shape-correlated stable light emitters.

Research Details

Perovskite materials, such as $CH_3NH_3PbX_3$ (X = I, Br), are known to display intriguing electronic, light-emitting, and chemical properties. Researchers at the Ames Laboratory synthesized a series of perovskite nanocrystals with different morphologies (i.e., dots, rods, wires, plates, and sheets) by using different solvents and capping ligands. The Ames Laboratory team tested the nanocrystals to explore their morphology, growth, properties, and stability under various conditions. Characterization studies of photoluminescence, like that seen with glow-in-the-dark paint, found that the rods and wires showed higher photoluminescence and longer photoluminescence lifetimes compared to other shapes. Perovskite nanocrystals with bromine were found to be particularly unstable when exposed to an electron beam during transmission electron microscopy analysis, "melting" to form smaller dot-like particles of unknown composition. Further optical studies revealed that the nanocrystals with iodine are shape-correlated stable light emitters at room temperature.

Reference

F. Zhu, L. Men, Y. Guo, Q. Zhu, U. Bhattacharjee, P.M. Goodwin, J.W. Petrich, E.A. Smith, J. Vela, "Shape evolution and single particle luminescence of organometal halide perovskite nanocrystals." ACS Nano, 9, 2948 (2015). [DOI: 10.1021/nn507020sExternal link]

CINT Staff Science Highlight

Soft, Biological & Composite Nanomaterials

Effect of Seed Age on Gold Nanorod Yield: A Microfluidic, Real-Time Study

Scientific Achievement

We performed a series of microfluidic experiments that point out the role of seed age in the seed mediated growth of gold nanorods. A continuous synthesis of rods with seeds that are aging as they await injection into the microfluidic chip show a constant decrease in rod yield. We discovered that diluting seeds 30 fold immediately after synthesis leads to sustained high yield of rods.

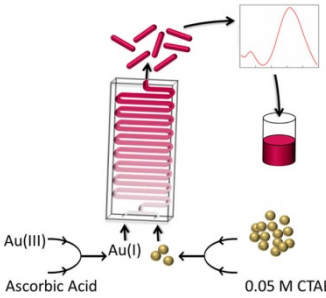


Figure 4.47. Schematic of apparatus

Significance

While seed mediated growth of gold nanorods is exceptionally popular in the literature, the effect of seed aging is largely unstudied. We show that seed age has an enormous effect on rod yield and the aging effects can be easily avoided by immediate dilution of the seeds. This will serve to make gold nanorod synthesis much more reproducible, an important advance for continued research and potential commercial applications.

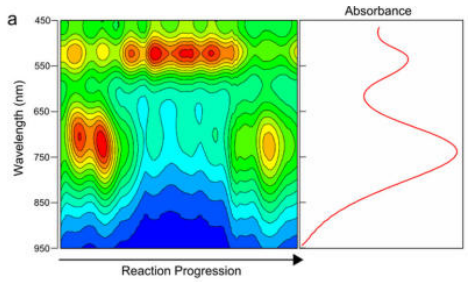


Figure 4.48. 3-D graph of visible absorption as reaction progresses showing dramatic loss of rod absorption near 700 nm and recovery of peak upon adding newly made seeds made seeds.

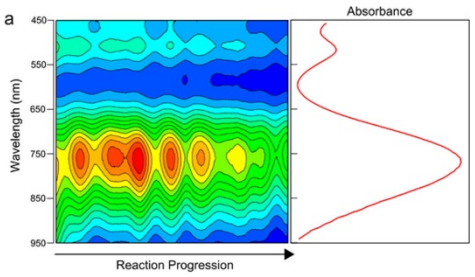


Figure 4.49. 3-D graph of visible absorption using pre-diluted seeds. Yield of rods is constant, as dilution dramatically slows aging of the seeds.

Research Details

- On chip, microfluidic synthesis of gold nanorods was monitored in real time with Visible Spectroscopy, allowing both the rod aspect ratio (by peak position of the higher wavelength absorption) and relative rod yield (by the ratio of the high wavelength to low wavelength peak height)
- Constant aging of seeds yield constant decrease in rod yield.
- The effect of seed age, previously unexplored in the literature, likely explains much of the difficulty reproducing published syntheses.

Reference

Watt, J., Hance, B.G., Anderson, R.S., and Huber, D.L., Chemistry of Materials, 2015. 27(18): p. 6442-6449

CINT User Project Highlight | Soft, Biological & Composite Nanomaterials

Salt, Shake, Fuse –
Giant Hybrid Polymer/Lipid Vesicles via Mechanically-Activated Fusion

Scientific Achievement

We developed a convenient mechanical activation method for fusing PEO-bearing polymer vesicles 1) with each other and 2) with lipid vesicles (DOPC) to prepare hybrid polymer/lipid vesicles.

Significance and Impact

Vesicles used as nanoreaction flasks and nanoreactors (e.g. to model and mimic biological processes) require control over membrane reorganization events such as fission and fusion. Robust polymer vesicles expand the nanoreactor reaction space, but they do not readily fuse. Our system uses simple conditions (salt, agitation) to fuse polymer vesicles readily. While liposomes do not fuse under the same conditions, they readily fuse with polymersomes to create hybrid vesicles. Our research enables easy resizing of vesicles and combining of polymer/lipid vesicles and will expand biomimetic nanoreactor research.

Research Details

Polymersomes were prepared by rehydrating dried films of poly(ethylene oxide):poly(butadiene) (MW=900:1800 Da). Vesicles were extruded to 200 nm and, when subjected to 10 mM NaCl and agitation at 20 Hz for 1 h, formed aggregates and giant vesicles >5 μm. Fusion was characterized by dynamic light scattering (DLS) and fluorescence microscopy. Hybrid vesicles were characterized by dye colocalization and FRET. Vesicle size had no impact on fusion, while increasing polymer chain length dramatically reduced the ability to fuse.

Reference

I. M. Henderson, W. F. Paxton, Angew. Chem. Int. Ed. 2014, 53, 3372

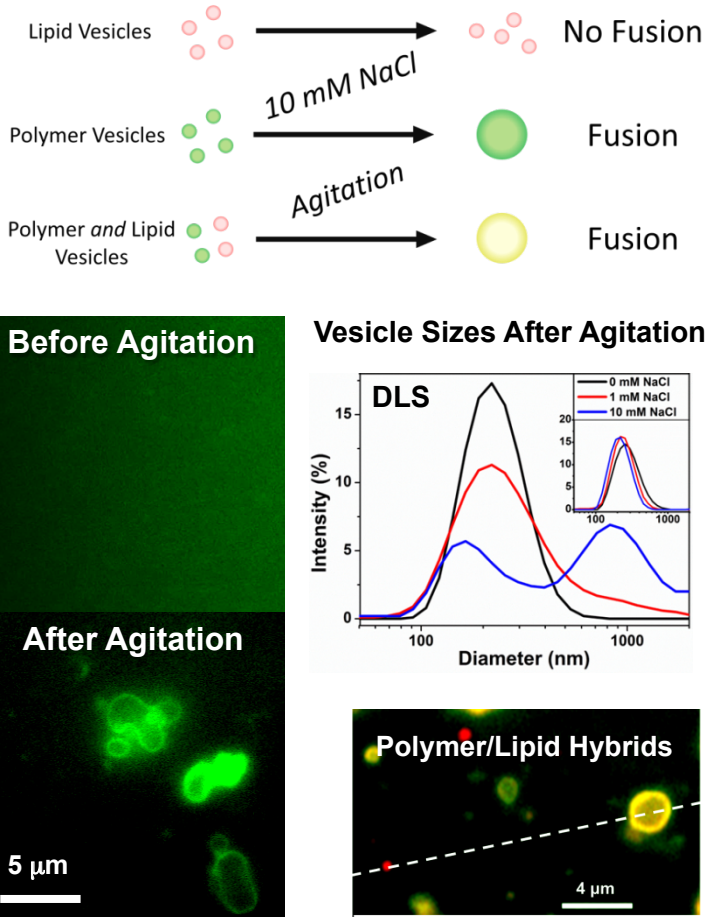


Figure 4.50. Visual representations and fluorescence microscopy images of vesicle fusion of polymersomes composed of poly(ethylene oxide).

Artificial Light-Harvesting Nanoparticles

Scientific Achievement

Energy-capturing polymer nanoparticles capture and transfer energy at efficiencies comparable to natural photosynthetic systems (>95% efficiency).

Significance and Impact

Light-harvesting nanospheres are inexpensive to manufacture, are amenable to large-scale assembly, can be adapted to control the amount of energy absorbed, and can be integrated with other materials for energy collection.

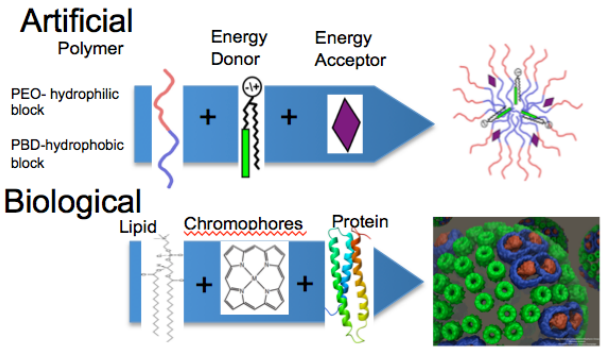


Figure 4.51. Self-assembly drives the formation of photonic nanocomposites into micelles and membranes. Biological systems driven by coordinated and directed assembly.

Research Details

- Nanoparticles form micelles in aqueous solution, and monolayer and bilayer films on solid supports.
- The energy transfer efficiency (ETE) depends on whether nanocomposites are in aqueous solution or on film.
- There is an excellent fit between experimental data and a theoretical model, making these nanoparticles useful for predicting and designing photonic material response.

Reference

Adams, P.G., Collins, A.M., Sahin, T., Subramanian, V., Urban, V.S., Vairaprakash, P., Tian, Y., Evans, D.G., Shreve, A.P., and Montaño, G.A., Nano Lett., 15, 1959 (2015).

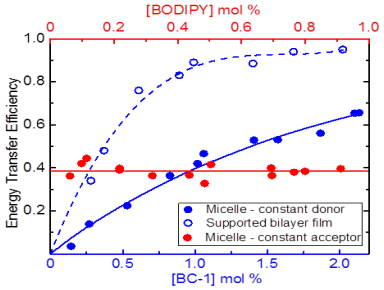


FIgure 4.52. Micelles exhibit modular energy transfer dependent on acceptor concentration up to ~60% ETE. Polymer films exhibit modular energy transfer >95% ETE. Demonstration of potential for scalable, modular photonic polymer platforms.

CINT User Project Highlight

Theory and Simulation of Nanoscale Phenomena

Computer Simulation Guide for Design of Polymeric Nanoparticles: A New Paradigm in Soft Nanoparticles

Scientific Achievement

Internal structure of soft highly luminescent nanoparticles was resolved by molecular dynamics simulations. Insight is the first ever obtained, overcoming the challenge of probing structure within very small volumes.

Significance and Impact

Work has opened the way to explore internal structures of soft nanoparticles that in turn will impact the design of new nanoparticles with well-defined luminescent characteristics.

Research Details

- Fully atomistic molecular dynamics simulations with an innovative method to controllably collapse an inherently rigid polymer used to determine internal structure and stability of polydots made of dialkyl-paraphenylene ethynylene.
- Nanoparticles remain predominantly spherical and compact in water, while their interface became significantly rough.
- No internal correlations were observed between the aromatic rings on the polymer within the nanoparticle, consistent with the experimental luminescence of nanoparticles.

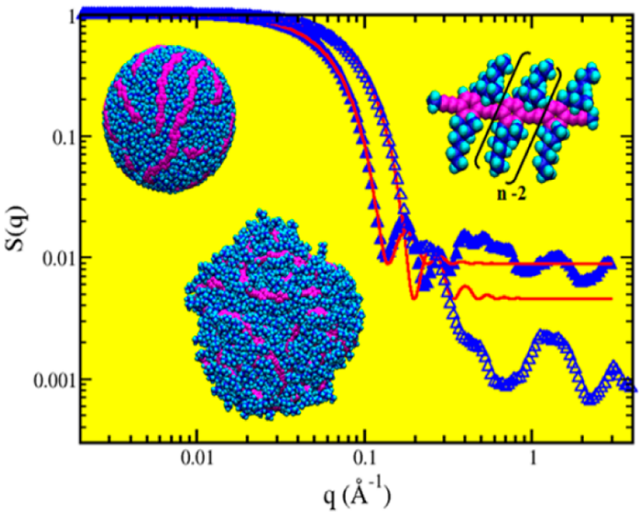


Figure 4.53. Monomer chemical structure (top right), the nanoparticle, as made (top left) and in equilibrium in water. The curves in the center correspond to the static structure factor S(q) as the function of q for polymer substituted (solid triangles) and without (open triangles) side chains in water with best fit to a fuzzy spherical form factor (solid lines).

Reference

Sabina Maskey, Naresh C. Osti, Dvora Perahia, and Gary S. Grest, ACS Macro Letters 2, 700 (2013)

CINT User Project Highlight

Theory and Simulation of Nanoscale Phenomena

Designing High Strength Thin Nanoparticle Membranes

Scientific Achievement

Because of their unusual strength, thin nanoparticles membranes have a number of potential applications from sensor arrays to nanoscale filtration. Current study resolved the fundamental mechanisms underlying their unique mechanical strength.

Significance and Impact

Simulations provided unprecedented molecular detail that cannot be obtained experimentally, and the resulting insights can be used to design nanoparticle membranes with more finely tailored properties.

Research Details

- Multi-million atom molecular dynamics simulations of alkanethiol-coated gold nanoparticle membranes were carried out to simultaneously measure nanoscale interactions while directly comparing membrane properties to experiment.
- By replicating experimental conditions, nanoparticle membranes at a water-vapor interface were made and then water removed to form free-standing membranes.
- Mechanical tests of the resulting membranes were then made and compared to experiment

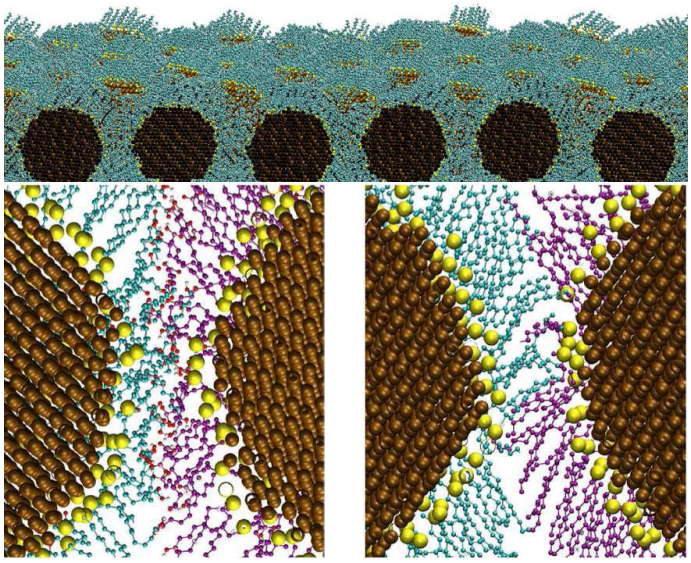


Figure 4.54. Top image is angled side view of CH_3-terminated dry membrane prior to deformation. Hydrogen atoms are represented in white, carbon in cyan, gold in brown, and sulfur in yellow. Bottom images show a close-up of COOH terminated (left) and CH_3-terminated (right) nanoparticles. Hydrogen atoms have been omitted except in the COOH end group. In both cases carbon atoms on the left NP are colored cyan while those on the right are colored purple.

Reference

K. Michael Salerno, Dan S. Bolintineanu, J. Matthew D. Lane, and Gary S. Grest, "High strength, molecularly thin nanoparticle membranes," Phys. Rev. Lett. 113, 258301 (2014)

Simulations Predict Surprising Variety of Morphologies in Ionomers

Scientific Achievement

We performed fully atomistic molecular dynamics (MD) simulations of melts of lithium-neutralized precise ionomers (ion-containing polymers) that reveal the structural features of the nanoscale ionic aggregates in unprecedented detail. We observe a rich variety of aggregate morphologies depending on neutralization level and ionic content, including string-like and percolated aggregates.

Significance

In the quest to make better batteries, determining the morphology of ionomers is essential, but is beyond the capability of present measurements. Our simulations determined the atomistic structure and have revealed a rich variety of morphologies that match experimental X-ray data, but were unsuspected. These revelations imply new strategies for designing ionomers with better conductivity.

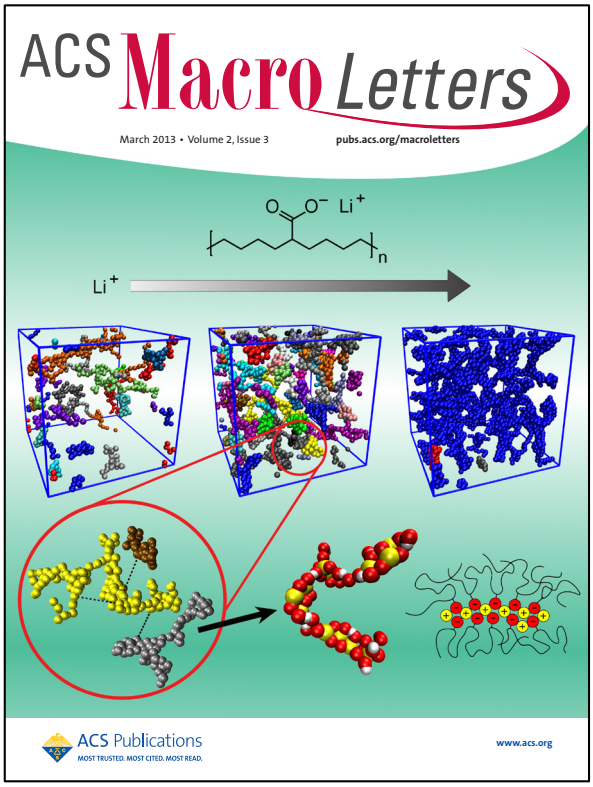


Figure 4.55. Representative snapshots of ionic aggregates in simulations of ionomer melts with increasing Li+ content (left to right). Details of the aggregates show "stringy" structures.

Research Details

- MD simulations revealed a variety of ionic aggregates, from compact, isolated clusters, to "stringy" aggregates, to fully percolated aggregates, depending on neutralization level and spacing between ionic groups on the polymer backbone.
- The scattering structure factor calculated from the simulations displays the low-wavevector ionomer peak in the same location as observed in X-ray scattering of these materials, and follows the experimental trends (data from K. I. Winey, U Penn).

Reference

D. S. Bolintineanu, M.J. Stevens, A. L. Frischknecht, ACS Macro Lett. 2, 206 (2013).

Creating Efficient and Tunable Molecular EmittersUsing Architectural Principles

Scientific Achievement
Size-dependent optical and electronic properties of a new class of molecules were studied computationally.

Significance and Impact
Our simulations provide valuable insights into the photophysics of this family of molecules and guidelines for future synthetic efforts in circular nanostructure systems aiming to control light-induced dynamics and energy/charge transfers.

Research Details
Computer simulations using advanced electronic structure codes provide important detailed information on quantum-mechanical processes and dynamics at the nanoscale, thus complementing and guiding experimental studies which lead to scientific and technological advancements in materials design. Our simulations provide valuable insights into photophysics and guidelines for future synthetic efforts in circular nanostructure systems aiming to control light-induced dynamics and energy/charge transfers.

Reference
L. Adamska, I. Nayyar, H. Chen, A. K. Swan, N. Oldani, S. Fernandez-Alberti, M. R. Golder, R. Jasti, S. K. Doorn, and S. Tretiak, "Self-Trapping of Excitons, Violation of Condon Approximation, and Efficient Fluorescence in Conjugated Cycloparaphenylenes," Nano Lett. 14, 6539-6546 (2014).

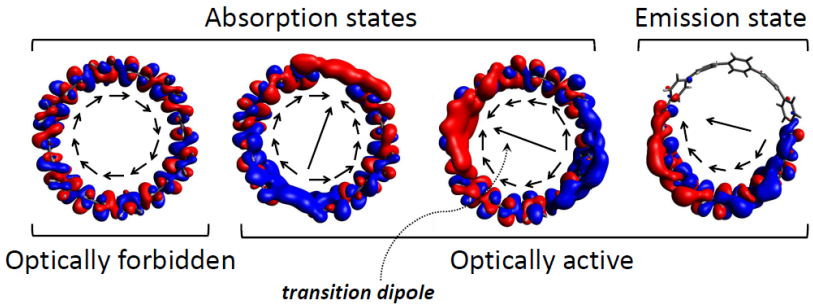


Figure 4.56. Real-space map of the light-induced charges for several excited states. Red/blue color corresponds to negative/positive light-induced charges.

Nonadiabatic Excited State Molecular Dynamics (NA-ESMD) of Organic Conjugated Materials

Scientific Achievement

The NA-ESMD offers a computationally feasible approach for simulating photo-excited electron-vibrational dynamics involving multiple coupled electronic excited states in organic conjugated materials with 100s of atoms on picosecond timescales.

Significance and Impact

These simulations allow us to study fundamental non-radiative processes including energy/charge transfer, internal conversion, and exciton localization that occur in natural biological complexes and tailor-designed optical materials such as solar cells. We have identified vibrational modes that couple to electronic relaxation suggesting that quantum control of relaxation pathways can be used to achieve desired material properties.

Research Details

- The NA-ESMD methodology improves on previous surface hopping approaches. We have developed techniques to correctly describe "trivial unavoided crossings" and to incorporate electronic decoherence.
- Configuration Interactions Singles (CIS) combined with model Hamiltonian for excited-state calculations. On-the-fly trajectory propagation using analytical excited-state gradients and couplings.
- State-specific gradients eliminate the classical path approximation and allow us to observe effects of differential nuclear motion.

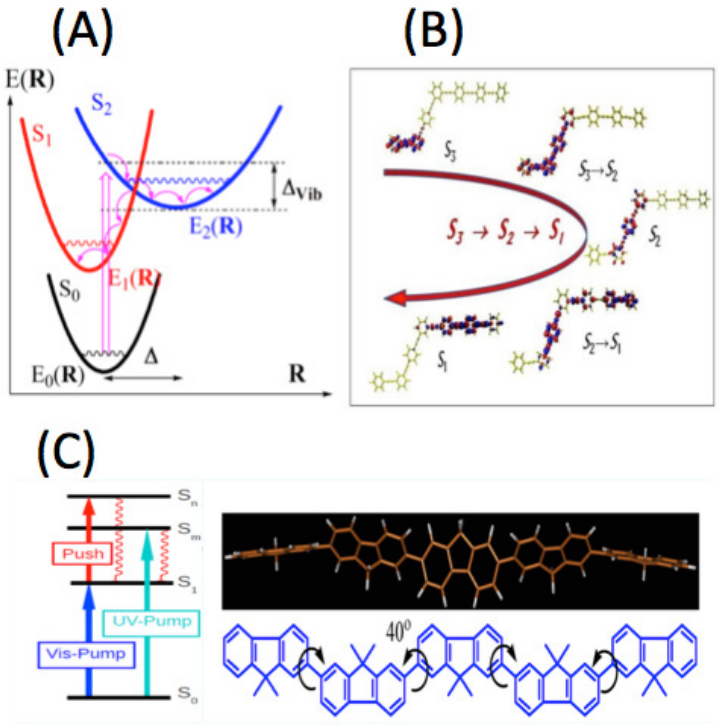


Figure 4.58. (A) Surface hopping approach used in NA-ESMD: Nuclei evolve on the native excited-state potential energy surfaces (PES) and transition between coupled excited states. (B) 2 → 3 → 4 ring unidirectional energy transfer mechanism in phenyl-ethylene chromophores revealed through transition density analysis. (C) Ultrafast torsional relaxation in polyfluorenes can be optically controlled by accessing different excited state relaxation pathways.

Reference

T. Nelson, S. Fernandez-Alberti, A. E. Roitberg, S. Tretiak, Acc. Chem. Res. 2014 47, 1155 (and about 20 other pubs)

Simulations of Polymer Welding: Strength from Interfacial Entanglements

Scientific Achievement

Large-scale molecular dynamics (MD) simulations of thermal welding of polymers were performed to investigate the rise of mechanical strength at the polymer-polymer interface with welding time t. We find that the interfacial strength saturates at the bulk shear strength long before the polymer chain at the interface diffuse their own size. We demonstrate the critical role of entanglements in strengthening polymer interface.

Significance

Thermal welding is at the core of integrating polymeric elements into devices as well as in the thermal induced healing of polymers, processes that require the development of interfacial strength equal to that of the bulk. Our simulations show that as the strength increases, the dominant failure mode changes from chain pullout at the interface to chain scission and that a sufficient number of entanglements across the interface is required to arrest catastrophic chain pullout at the interface.

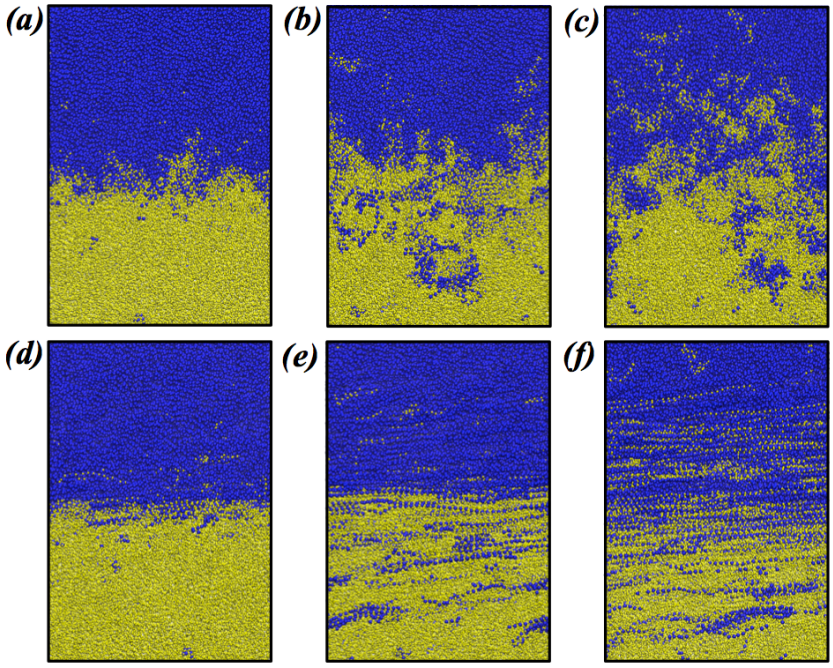


Figure 4.59. Snapshots of the interface between two flexible polymer films. Beads are colored based on their position at t=0: $z > 0$ (blue) and $z < 0$ (yellow). Only a portion of the sample, 40σ in horizontal direction which is the direction of the shear and 60σ in vertical direction, is shown, where σ is the diameter of a polymer monomer. Snapshots (a)-(c) depict the interface at interdiffusion time $t = 0.01M$, $0.5M$ and $7M\tau$, while (d)-(f) show the corresponding states at large shear strain $= 12$.

Research Details

- MD simulations were used to follow the interdiffusion of two polymer films above the glass transition temperature Tg. After welding for a time t, the systems were quenched rapidly below Tg and shear applied to measure the mechanical strength of the interface.
- Evolution of entanglements during welding is tracked using a primitive path analysis algorithm and compared to that of a bulk sample.

Reference

T. Ge, F. Pierce, D. Perahia, G. S. Grest, and M. O. Robbins, Physical Review Letters 110, 098301 (2013) (Editor's Choice)

Investigating Effective Light-Harvesting at the Atomic Level

Scientific Achievement

A combined experimental and computational study of energy transfer reveals the relationship between electronic and nuclear forces during light-harvesting processes in dendrimers, a synthetic light-harvesting molecule that can be used in optical-electronic applications.

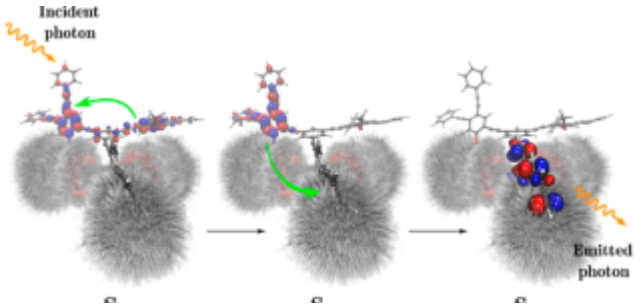


Figure 4.60. Transitions over different energy states ($S_n \rightarrow S_2 \rightarrow S_1$) after light irradiation. Model structures of dendrimers are colored. The dendrimer in 1000 different conformations is in gray.

Significance and Impact

Dendrimers contain chromophores and have enormous potential for achieving efficient light capture and transport. This study helps develop improved organic photovoltaics and other solar energy conversion technologies with a new type of dendrimer.

Research Details

Electronic energy-transfer involves the ultrafast collapse of the photoexcited wave function due to nonadiabatic electronic transitions (no heat energy required)

Computer simulations provide detailed information on quantum-mechanical processes at the nanoscale

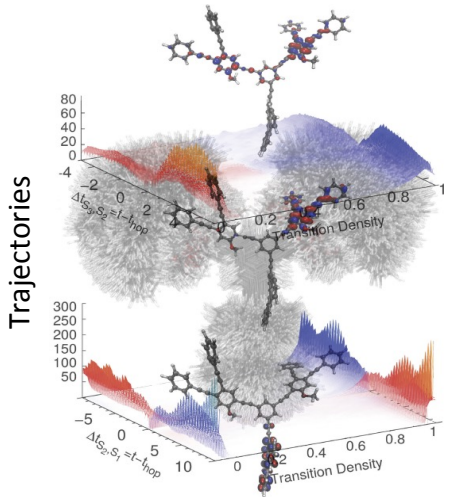


Figure 4.61. Excited state electron localization/delocalization across the dendrimer molecule in ultrafast energy transfers. The electron transition density changes after t=0 between different "branches" of the dendrimer.

Reference

J. F. Galindo, E. Atas, A. Altan, D. G. Kuroda, S. Fernandez-Alberti, S. Tretiak, V. Kleiman, and A. E. Roitberg, J. Am. Chem. Soc. 137, 11637 (2015).

CINT Staff Science Highlight

Theory and Simulation of Nanoscale Phenomena

Photoexcited Dynamics of Molecular Donor used in Organic Photovoltaics

Scientific Achievement

Our computer modeling provides detailed information on molecular dynamics (i.e. materials heating and wave-function evolution) after light absorption, a primary relaxation step in the photoexcited material of the solar cell followed by charge separation.

Significance and Impact

Organic solar cells fabricated using a recently synthesized molecular donor p-DTS(PTTh2)2 exhibited high power conversion efficiencies (6.7%), thus revealing potential of small donor molecular materials. Our simulations deliver a critical knowledge necessary for future improvements of light-harvesting capabilities in organic solar cells.

Research Details

- Our modeling use LANL-developed Non-Adiabatic Excited States Molecular Dynamics (NA-ESMD) approach;
- After photoexcitation to its broad high-energy peak in the 3-4 eV range, associated with multiple excited states, the molecule undergoes efficient ultrafast internal conversion to its lowest excited state.
- Our simulations do not detect possible bond-breaking or decomposition of the system, suggesting minimal molecular photo-damage.

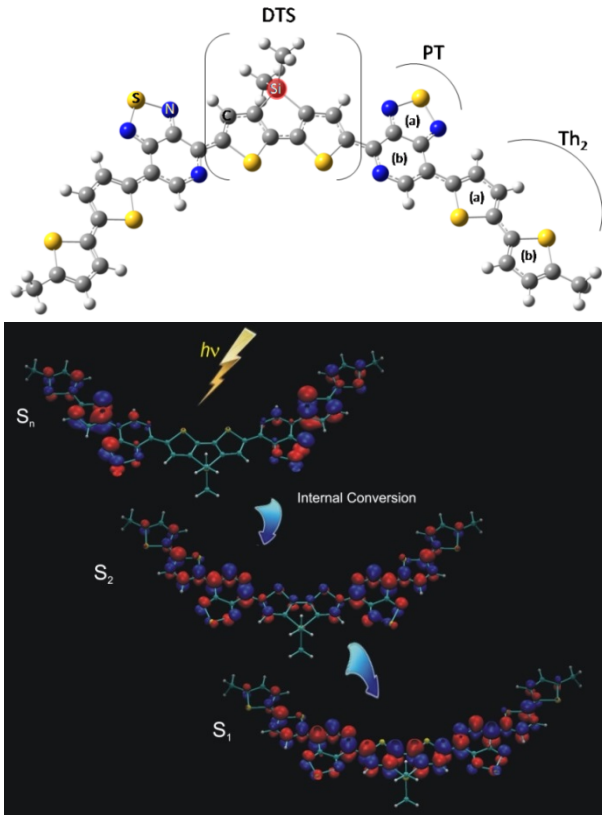


Figure 4.62. Top: Chemical structure of p-DTS(PTTh2)2 molecule (DTS is dithienosilole and PT is pyridalthiadiazole) showing high promise for organic solar cells. Bottom: Calculated time-dependent evolution of the electronic wave-function illustrating photoexcited molecular dynamics involving multiple electronic states

Reference

N. Oldani, S. Tretiak, G. Bazan and S. Fernandez-Alberti, Energy & Env. Sci., 7, 1175-1184 (2014)

CINT Staff Science Highlight

Theory and Simulation of Nanoscale Phenomena

Superconductivity at the Border of Electron Localization and Itinerancy

Scientific Achievement

We have demonstrated that, by incoporating the so-called bad metal states of iron pnictides, a strong-coupling approach provides a unified understanding of superconducting pairing in diverse iron-based superconductors.

Significance and Impact

Our study reveals an important principle that superconductivity is optimized at the border between itinerancy and electronic localization. This principle should apply beyond the context of iron pnictides and chalcogenides, and is expected to guide the search for superconductors with even higher transition temperatres.

Research Details

- We have applied a strong-coupling approach to reveal the comparable pairing strength in the alkaline iron selenides and iron pnictides.
- We have found the superconducting pairing amplitides are enhanced near the Mott transition.
- Our results uncover a univerality in the exitsing and emerging iron-based high-temperature superconductors with very diverse materials and Fermi-surface characteristics.

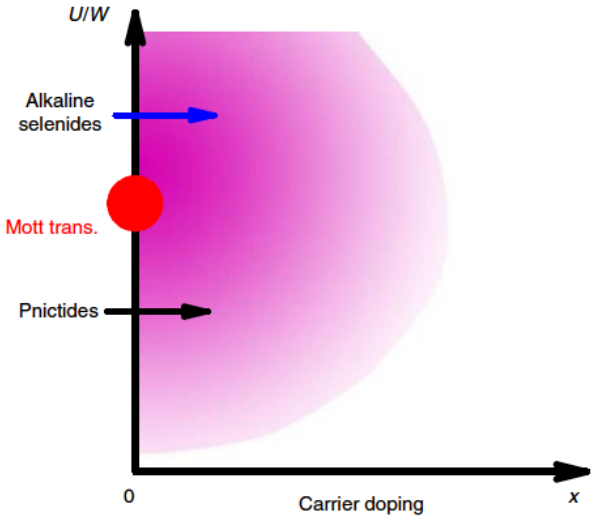


Figure 4.63. Above drawing shows a schematic phase diagram near a Mott transition. In this zero-temperature phase diagram, the red point located on the *U/W* axis referes to the point of the Mott transition, whereas the purple shading illustrates the regime that has strong anti-ferromagnetic correlations. The parent compounds of alkaline iron selenides and iron pnictides are located in the vicinity of, albeit on the two sides of, the Mott transition. Superconductivity occurs at non-zero carrier doping, with the optimal doping located in the region indicated by the arrows.

Reference

R. Yu, P. Goswami, Q. Si, P. Nikolic, and J.-X. Zhu, Nat. Commun. 4, 2733 (2013).

CINT User Project Highlight | Theory and Simulation of Nanoscale Phenomena

Interface-induced Magnetic Coupling in Multiferroic/Ferromagnetic Bilayer

Scientific Achievement

We have demonstrated that, by placing a multiferroic manganite $TbMnO_3$ (TMO) and ferromagnetic manganite $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) in close proximity to each other, interfacial coupling induces ferromagnetism on the multiferroic side, and antiferromagnetism on the manganite side, of the bilayer thin film.

Significance and Impact

Our work points to the possibility of using TMO/LSMO bilayer for the next generation of spintronic devices, by taking advantage of multiferroic properties of TMO, half metallicity and colossal magnetoresistance of LSMO, and the magnetic coupling between them to control magnetism with electric field.

Research Details

- We performed all-optical pump-probe measurements of the TMO/LSMO bilayer thin film.
- We found that the relaxation dynamics of the individual layers are the result of the interplay between the intrinsic magnetic order and the induced interfacial effect.

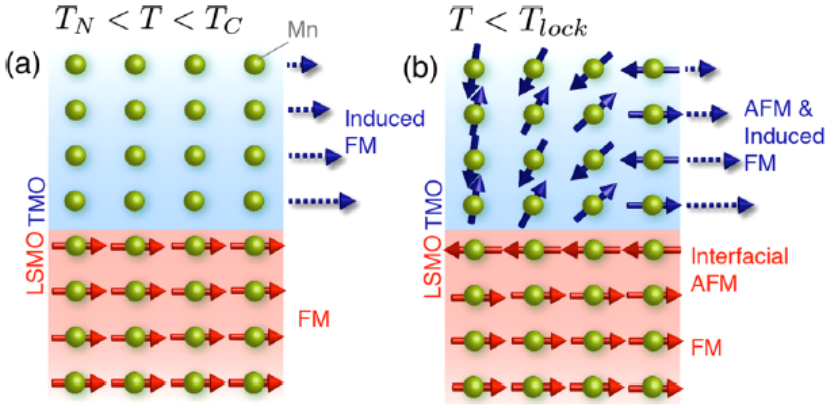


Figure 4.64. A possible spin configuration of Mn ions inferred from our pump-probe data at the temperature (a) between T_N and T_C and (b) below T_{lock}. Below T_C, a ferromagnetic order (FM) is induced into the TMO layer due to the proximity effect (blue), while below T_{lock}, an interface effect induces an interfacial antiferromagnetic (AFM) order inside LSMO (red). The dashed arrows on the right side of the figure illustrate the induced ferromagnetism.

Reference

C. La-o-vorakiat, Y. Tian, T. Wu, C. Panagopoulos, J.-X. Zhu, H. B. Su, Elbert E. M. Chia, Appl. Phys. Lett. 104, 141602 (2014)

4.b. Publications

4.b.1a. 20 highly cited publications from CINT during 2013-2015, based on data from Web of Science and Google Scholar:

1. W. Nie, T. Hsinhan, R. Asadpour, J.C. Blancon, R. Kappera, M. Chhowalla, A. Neukirch, S. Tretiak, G. Gupta, J. Crochet, M.A. Alam, H.L. Wang, A.D. Mohite, (2015) "High-efficiency solution-processed perovskite solar cells with millimeter-scale grains" *Science*: 347, 522. User Project: U2014B0093.
   Times Cited: 210 (Web of Sci.), 329 (Google Scholar)

2. N.K. Grady, J.E. Heyes, R. D. Chowdhury, Y. Zeng, M.T. Reiten, A.K. Azad, A.J. Taylor, D.A.R. Dalvit, H.T. Chen, (2013) "Terahertz metamaterials for linear polarization conversion and anomalous refraction" *Science*: 340, 1304.
   Times Cited: 168 (Web of Science), 222 (Google Scholar)

3. I. Staude, A. E. Miroshnichenko, M. Decker, N. T. Fofang, S. Liu, E. Gonzales, J. Dominguez, T. S. Luk, D. N. Neshev, I. Brener, and Y. Kivshar, (2013) "Tailoring directional scattering through magnetic and electric resonances in subwavelength silicon nanodisks" *ACS Nano*: 7, 7824. User Project: U2012A0053.
   Times Cited: 104 (Web of Sci.), 153 (Google Scholar)

4. J.W.Wang, Y. He, F. Fan, X.H. Liu, S. Xia, Y. Liu, C.T. Harris, H. Li, J.Y. Huang, S.X. Mao, T. Zhu, (2013) "Two-phase electrochemical lithiation in amorphous silicon" *Nano Letters*: 13, 709. User Project: C2012A0045.
   Times Cited: 93 (Web of Science), 132 (Google Scholar)

5. F. Shafiei, F. Monticone, L.Q. Khia, X.X. Liu, T. Hartsfield, A. Alu, X. Li, (2013) "A subwavelength plasmonic metamolecule exhibiting magnetic based optical Fano resonance" *Nature Nanotechnology*: 8, 95.
   Times Cited: 82 (Web of Science), 100 (Google Scholar)

6. L. Zhong, R.R. Mitchell, Y. Liu, B.M. Gallant, C.V. Thompson, J.Y. Huang, S.X. Mao, Y. Shao-Horn, (2013) "In situ transmission electron microscopy observations of electrochemical oxidation Li_2O_2" *Nano Letters:* 13, 2209. User Project: C2010B1063.
   Times Cited: 76 (Web of Science), 97 (Google Scholar)

7. W. Liang, H. Yang, F. Fan, Y. Liu, X.H. Liu, J.Y. Huang, T. Zhu, S. Zhang, (2013) "Tough germanium nanoparticles under electrochemical cycling" *ACS Nano*: 7, 3427. User Project: C2012A0033.
   Times Cited: 55 (Web of Science), 72 (Google Scholar)

8. S. Zheng, I.J. Beyerlein, J.S. Carpenter, K. Kang, J. Wang, W.Z. Han, N.A. Mara, (2013) "High strength and thermally stable bulk nanolayered composites due to twin-induced interfaces" *Nature Communications*: 4, 1696. User Project: U2011B27.
   Times Cited: 51 (Web of Science), 71 (Google Scholar)

9. I.J. Beyerlein, J.A. Caro, M.J. Demkowicz, N.A. Mara, A. Misra, B.P. Uberuaga, (2013) "Radiation-damage-tolerant nanomaterials" *Materials Today*: 16, 443. User Project: U2011A1071.
   Times Cited: 44 (Web of Science), 67 (Google Scholar)

10. J.W.Wang, F. Sansoz, J.Y. Huang, Z. Zhang, T. Zhu, S.X. Mao, (2013) "Near-ideal theoretical strength in gold nanowires containing angstrom scale twins" *Nature Communications*: 4, 1742. User Project: C2010B1063.
    Times Cited: 43 (Web of Science), 74 (Google Scholar)

11. S. Lei, L. Ge, S. Najmaei, A. George, R. Kappera, J. Lou, M. Chhowalla, H. Yamaguchi, G. Gupta, R. Vajtai, A.D. Mohite, P.M. Ajayan, (2014) "Evolution of the electronic band structure and efficient photo-detection in atomic layers of InSe" *ACS Nano*: 8, 1263. User Project: U2012B0028.
Times Cited: 42 (Web of Science), 54 (Google Scholar)

12. C. Wu, N. Arju, G. Kelp, J.A. Fan, J. Dominguez, E. Gonzales, E. Tutuc, I. Brener, G. Shvets, (2014) "Spectrally selective chiral silicon metasurfaces based on infrared Fano resonances" *Nature Communications*: 5, 3892. User Project: C2012A0095.
Times Cited: 36 (Web of Science), 48 (Google Scholar)

13. M. Decker, I. Staude, M. Falkner, J. Dominguez, D.N. Neshev, I. Brener, T. Pertsch, Y.S. Kivshar, (2015) "High-efficiency dielectric Huygens' surfaces" *Advanced Optical Materials*: 3, 813.
Times Cited: 34 (Web of Science), 61 (Google Scholar)

14. I. J. Beyerlein, N.A. Mara, J.S. Carpenter, T.R. Nizolek, K. Kang, S. Zheng, J. Wang, T.M. Pollock, (2013) "Interface-driven microstructure development and ultra high strength of bulk nanostructured Cu-Nb multilayers fabricated by severe plastic deformation" *Journal of Materials Research*: 28, 1799. User Project: U2011B27.
Times Cited: 34 (Web of Science), 48 (Google Scholar)

15. T. Nelson, S. Fernandez-Alberti, A.E. Roitberg, S.Tretiak, (2014) "Nonadiabatic excited-state molecular dynamics: modeling photophysics in organic conjugated materials" *Account of Chemical Research*: 47, 1155. User Project: C2012A0016.
Times Cited: 33 (Web of Science), 40 (Google Scholar)

16. X. Han, Y. Liu, Z. Jia, T.C. Chen, J. Wan, N. Weadock, K.J. Li, T. Gaskell, L.Hu, (2014) "Atomic-layer-deposition oxide nano-glue for sodium ion batteries" *Nano Letters*: 14, 139. User Project: U2012A0007.
Times Cited: 32 (Web of Science), 54 (Google Scholar)

17. A. Chen, Z. Bi, Q. X. Jia, J. L. MacManus-Driscoll, and H. Wang, (2013) "Microstructure, vertical strain control and tunable functionalities in self-assembled vertically aligned nanocomposite thin films," *Acta Materialia* 61, 2783.
Times Cited: 31 (Web of Science), 39 (Google Scholar)

18. D. Burghoff, T.Y. Kao, N.R. Han, C.W.I. Chan, X.W. Cai, Y. Yang, D.J. Hayton, J.R. Gao, J.L. Reno, Q. Hu, (2014) "Terahertz laser frequency combs" *Nature Photonics*: 8, 462. User Project: C2013A0020.
Times Cited: 29 (Web of Science), 48 (Google Scholar)

19. K. Appavoo, N.F. Brady, B. Wang, M. Seo, J. Nag, R.P. Prasankumar, S.T. Pantelides, D.J. Hilton, R.F. Haglund Jr., (2014) "Ultrafast phase transition via catastrophic phonon collapse driven by plasmonic hot-electron injection" *Nano Letters*: 14, 1127. User Project: C2011A1037.
Times Cited: 28 (Web of Science), 34 (Google Scholar)

20. S. Berciaud, X. Li, H. Htoon, L.E. Brus, S.K. Doorn, T.F. Heinz, (2013) "Intrinsic line shape of the Raman 2D-mode in freestanding graphene monolayers" *Nano Letters*: 13, 3517. User Project: C2012A0080.
Times Cited: 26 (Web of Science), 35 (Google Scholar)

4.b.1b. 20 highly cited publications from CINT during 2006-2015, based on data from Web of Science and Google Scholar:

1. H.-T. Chen, W. J. Padilla, J. M. O. Zide, A. C. Gossard, A. J. Taylor, R. D. Averitt, "Active terahertz metamaterial devices", *Nature* 444, 597 (2006). User Project: P2003107.
Times Cited: 831 (Web of Science), 1139 (Google Scholar)

2. V. I. Klimov, S. A. Ivanov,; J. Nanda, M. Achermann, I. Bezel, J. A. McGuire, A, Piryatinski, "Single-exciton optical gain in semiconductor nanocrystals", *Nature* 447, 441 (2007).
Times Cited: 493 (Web of Science), 630 (Google Scholar)

3. J. Y. Huang, L. Zhong, C. M. Wang, J. P. Sullivan, W. Xu, L. Q. Zhang, S. X. Mao, N. S. Hudak, X. H. Liu, A. Subramanian, H. Y. Fan, L. A. Qi, A. Kushima, J. Li, "In situ observation of the electrochemical lithiation of a single SnO_2 nanowire electrode", *Science* 330, 1515 (2010). User Project: C2009A052.
Times Cited: 474 (Web of Science), 621 (Google Scholar)

4. M. M. Qazilbash, M. Brehm, B.-G. Chae, P. C. Ho, G. O. Andreev, B. J. Kim, S. J. Yun, A. V. Balatsky, M. B. Maple, F. Keilmann, H. T. Kim, D. N. Basov, "Mott transition in VO_2 revealed by infrared spectroscopy and nano-imaging", *Science* 318, 1750 (2007).
Times Cited: 472 (Web of Science), 614 (Google Scholar)

5. A. V. Balatsky, I. Vekhter, J.-X. Zhu, "Impurity-induced states in conventional and unconventional superconductors", *Review of Modern Physics* 78, 373 (2006).
Times Cited: 434 (Web of Science), 575 (Google Scholar)

6. W. J. Padilla, A. J. Taylor, C. Highstrete, M. Lee, R. D. Averitt, "Dynamical electric and magnetic meta-material response at terahertz frequencies", *Physical Review Letters* 96, 107401 (2006).
Times Cited: 411 (Web of Science), 587 (Google Scholar)

7. Y. Chen, J. Vela, H. Htoon, J. L. Casson, D. J. Werder, D. A. Bussian, V. I. Klimov, J. A. Hollingsworth, "'Giant' multishell CdSe nanocrystal quantum dots with suppressed blinking", *Journal of the American Chemical Society* 130, 5026 (2008).
Times Cited: 382 (Web of Science), 546 (Google Scholar)

8. H.-T. Chen, J. F. O'Hara, A. K. Azad, A. J. Taylor, R. D. Averitt, D. B. Shrekenhamer, W. J. Padilla, "Experimental demonstration of frequency agile terahertz metamaterials", *Nature Photonics* 2, 295 (2008).
Times Cited: 338 (Web of Science), 394 (Google Scholar)

9. X. H. Liu, L. Zhong, S. Huang, S. X. Mao, T. Zhu, J. Y. Huang, "Size dependent fracture of silicon nanoparticles during lithiation", *ACS Nano* 6, 1522 (2012).
Times Cited: 313 (Web of Science), 444 (Google Scholar)

10. Y. Huang, J. Wu, K. C. Hwang, "Thickness of graphene and single-wall carbon nanotubes," *Physical Review B* 74, 245413 (2006). User Project: P2005069.
Times Cited: 305 (Web of Science), 447 (Google Scholar)

11. H.-T. Chen, W. J. Padilla, M. J. Cich, A. K. Azad, R. D. Averitt and A. J. Taylor, "A metamaterial solid-state terahertz phase modulator", *Nature Photonics* 3, 148 (2009). User Project: U2007A030.
Times Cited: 302 (Web of Science), 418 (Google Scholar)

12. K. Y. Kim, A. J. Taylor, J. H. Glownia, G. Rodriguez, "Coherent control of terahertz supercontinuum generation in ultrafast laser-gas interactions", *Nature Photonics* 2, 605 (2008).
Times Cited: 259 (Web of Science), 332 (Google Scholar)

13. C. Galland, Y. Ghosh, A. Steinbruck, M. Sykora, J. A. Hollingsworth, V. I. Klimov, H. Htoon, "Two types of luminescence blinking revealed by spectroelectrochemistry of single quantum dots", *Nature* 479, 203 (2011).
Times Cited: 250 (Web of Science), 307 (Google Scholar)

14. H. C. Yeh, J. Sharma, J. J. Han, J. S. Martinez, J. H. Werner, "A DNA- silver nanocluster probe that fluoresces upon hybridization", *Nano Letters* 10, 13308 (2010). User Project: U2008A132.
Times Cited: 238 (Web of Science), 282 (Google Scholar)

15. J. M. Pietryga, J. D. Werder, D. J. Williams, J. L. Casson, R. D. Schaller, V. I. Klimov, J. A. Hollingsworth, "Utilizing the lability of lead selenide to produce heterostructured nanocrystals with bright, stable infrared emission", *Journal of the American Chemical Society* 130, 4879 (2008).
Times Cited: 233 (Web of Science), 284 (Google Scholar)

16. X. H. Liu, H. Zheng, L. Zhong, S. Huan, K. Karki, L. Q. Zhang, Y. Liu, A. Kushima, W. T. Liang, J. W. Wang, J. H. Cho, E. Epstein, S. A. Dayeh, S. T. Picraux, T. Zhu, J. Li, J. Sullivan, J. Cummings, C. Wang, S. X. Mao, Z. Z. Ye, S. Zhang, J. Y. Huang, "Anisotropic swelling and fracture of silicon nanowires during lithiation", *Nano Letters* 11, 3312 (2011).
Times Cited: 229 (Web of Science), 298 (Google Scholar)

17. T. N. Lambert, C. A. Chavez, B. Hernandez-Sanchez, P. Lu, N. S. Bell, A. Ambrosini, T. Friedman, T. J. Boyle, D. R. Wheeler, D. L. Huber, "Synthesis and characterization of titania-graphene nanocomposites", *Journal of Physical Chemistry C* 113, 19812 (2009).
Times Cited: 223 (Web of Science), 258 (Google Scholar)

18. F. Terenziani, C. Katan, E. Badaeva, S. Tretiak, M. Blanchard-Desce, "Enhanced two-photon absorption of organic chromophores: Theoretical and experimental assessments", *Advanced Materials* 20, 4641 (2008).
Times Cited: 218 (Web of Science), 258 (Google Scholar)

19. A. E. Aliev, J. Y. Oh, M. E. Kozlov, A. A. Kuznetsov, S. L. Fang, A. F. Fonseca, R. Ovalle, M. D. Lima, M. H. Haque, Y. N. Gartstein, M. Zhang, A. A. Zakhidov, R. H. Baughman, "Giant-Stroke, superelastic carbon nanotube aerogel muscles", *Science* 323, 1575 (2009). User Project: U2007A053.
Times Cited: 208 (Web of Science), 291 (Google Scholar)

20. S. A. Ivanov, A. Piryatinski, J. Nanda, S. Tretiak, K. R. Zavadil, W. O. Wallace, D. Werder, V. I. Klimov, "Type-II core/shell CdS/ZnSe nanocrystals: Synthesis, electronic structures, and spectroscopic properties", *Journal of the American Chemical Society* 129, 11708 (2007).
Times Cited: 206 (Web of Science), 269 (Google Scholar)

4.b.2 CINT Publications in NSRC High Impact Journals – 2013-2016

	CINT Publication Count			
NSRC High Impact Journals	**2013**	**2014**	**2015**	**Total**
ACS Nano	5	5	10	**20**
Advanced Functional Materials	1	5	4	**10**
Advanced Materials	2	1	1	**4**
Angewandte Chemie International Edition	0	2	0	**2**
Applied Physics Letters	29	23	17	**69**
Chemistry of Materials	3	0	2	**5**
Journal of the American Chemical Society	1	1	4	**6**
Nano Letters	11	12	14	**37**
Nanoscale	1	2	7	**10**
Nature	0	0	0	**0**
Nature Chemistry	0	0	0	**0**
Nature Communications	4	5	5	**14**
Nature Materials	0	0	1	**1**
Nature Nanotechnology	3	1	2	**6**
Nature Photonics	2	1	0	**3**
Nature Physics	0	0	0	**0**
Physical Review Letters	4	6	2	**12**
Proceedings of the National Academy of Sciences USA	0	0	0	**0**
Science	1	1	1	**3**
Small	1	2	1	**4**
TOTAL:	68	67	71	**206**

4.b.3 CINT Publication List

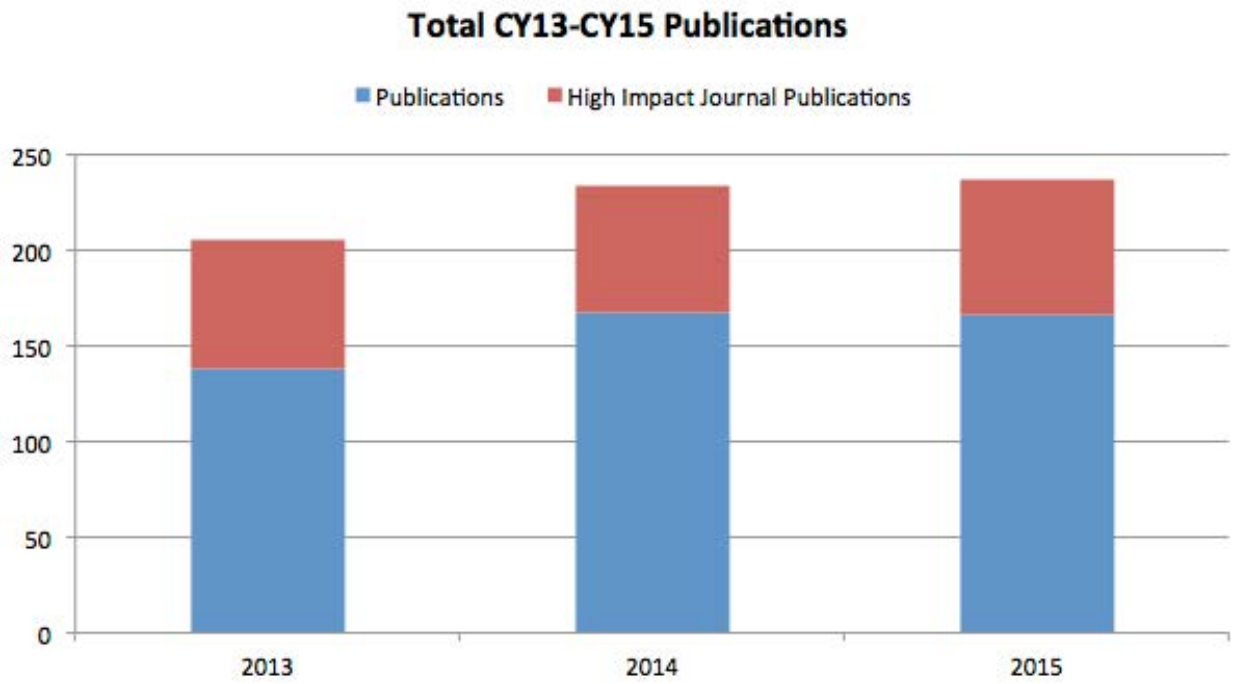


Figure 4.b.1 CINT has maintained a ratio of high-impact journl publications to total publications of ~ 30 % for the entire review period.

Note: CINT Scientist authors are indicated in red; CINT User authors are indicated in green (external) and orange (internal).

Citations for 2013 (206 total)

CINT Science (38)

Benz, A., Campione, S., Liu, S., Brener, I. (2013) "Monolithic metallic nanocavities for strong light-matter interaction to quantum-well intersubband excitations" Optics Express: 21, 32572

Benz, A., Campione, S., Liu, S., Brener, I. (2013) "Strong coupling in the sub-wavelength limit using metamaterial nanocavities" Nature Communications: 4, 2822

Benz, A., Montano, I., Klem, J.F., Brener, I. (2013) "Tunable metamaterials based on voltage controlled strong coupling" Applied Physics Letters: 103, 263116

Berciaud, S., Li, X., Htoon, H., Brus, L.E., Doorn, S.K., Heinz, T.F. (2013) "Intrinsic Lineshape of the Raman 2D Mode in Freestanding Graphene Monolayers" Nano Letters: 13, 3517. C2012A0080

Bolintineanu, D.S., Stevens, M.J., Frischknecht, A.L. (2013) "Influence of Cation Type on Ionic Aggregates in Precise Ionomers" Macromolecules: 46, 5381

Bolintineanu, D.S., Stevens, M.J., Frischknecht, A.L. (2013) "Atomistic Simulations Predict a Surprising Variety of Morphologies in Precise Ionomers" ACS Macro Letters: 2, 206-210

Brady, N.K., Perkins Jr., B.G., Hwang, H.Y., Brandt, N.C., Torchinsky, D., Singh, R., Yan, L., Trugman, D., Trugman, S.A., Jia, Q.X., Taylor, A.J., Nelson, K.A., Chen, H.T. (2013) "Nonlinear high-temperature superconducting terahertz metamaterials," New Journal of Physics: 15, 105016

Caviezel, A., Staub, U., Johnson, S.L., Mariager, S.O., Mohr-Vorobeva, E., Ingold, G., Milne, C.J., Garanourakis, M., Scagnoli, V., Huang, S.W., Jia, Q.X., Cheong, S.W., Beaud, P. (2013) "Femtosecond dynamics of the structural transition in mixed valence manganites" Physical Review B: 86, 174105

Chen, D., Zhang, M., Liu, S., Wang, Y.Q., Nastasi, M., Wang, X., Di, Z.F. (2013) "Sharp crack formation in low fluence hydrogen implanted Si0.75Ge0.25/B doped Si0.70Ge0.30/Si heterostructure" Applied Physics Letters: 103, 142102

Chen, J., Meng, Q., Inerbaev, T., Tretiak, S., Schmitz, A., Kilin, D.S. (2013) "First-principles study of p-n-doped silicon quantum dots: charge transfer, energy dissipation, and time-resolved emission" Journal of Physical Chemistry Letters: 4, 2906-2913

Conradson, S.D., Durakiewicz, T., Espinosa-Faller, F.J., An, Y., Anderson, D.A., Bishop, A.R., Boland, K.S., Bradley, J.A., Byler, D.D., Clark, D.L., Conradson, D.R., Conradson, L.L., Costello, A.L., Hess, N.J., Lander, G.H., Llobett, A., Martucci, M.B., Mustre de Leon, J., Nordlund, D., Lezama-Pacheco, J.S., Proffen, T.E., Rodriguez, G., Schwarz, D.E., Seidler, G.T., Taylor, A.J., Trugman, S.A., Tyson, T.A., Valdez, J.A. (2013) "Possible Bose-condensate behavior in a quantum phase originating in a collective excitation in the chemically and optically doped Mott-Hubbard system UO_2+x" Physical Review B: 88, 115135

Driben, R., Yulin, A.V., Efimov, A., Malomed, B.A. (2013) "Trapping of light in solitonic cavities and its role in the supercontinuum generation" Optics Express: 21, 19091-19096

Efimov, A. (2013) Lateral-sheering, delay-dithering Mach-Zehnder interferometer for spatial coherence measurement" Optics Letters: 38, 4522-4525

Fofang, N.T., Luk, T.S., Okandan, M., Nielson, G.N., Brener, I. (2013) "Substrate-modified scattering properties of silicon nanostructures for solar energy applications" Optics Express: 21, 4, 4774-4782

Guo, Q., Landau, P., Hosemann, P., Wang, Y.Q., Greer, J.R. (2013) "Helium implantation effects on the compressive response of Cu nano-pillars" Small: 9, 691-696

Grady, N.K., Perkins Jr., B.G., Hwang, H.Y., Brandt, H.Y., Torchinsky, D., Singh, R., Yan, L., Trugman, D., Trugman, S.A., Jia, Q.X., Taylor, A.J., Nelson, K.A., Chen, H.T. (2013) "Nonlinear high temperature superconducting terahertz metamaterials" New Journal of Physics: 15, 105016 C2011B23

Hollingsworth, J.A. (2013) "Heterostructuring nanocrystal quantum dots toward intentional suppression of blinking and auger recombination" Chemical Materials: 25, 1318-1331

Hollingsworth, J.A. (2013) "Nanoscale engineering facilitated by controlled synthesis: From structure to function" Coordinated Chemical Review: 263-264

Huang, L., Chen, H.T. (2013) "A brief review on terahertz metamaterial perfect absorbers" International Journal of Terahertz Science and Technology: 6, 26-39

Jilek, R.E., Bauer, E., Burrell, A.K., McCleskey, T.M., Jia, Q.X., Scott, B.L., Beaux, B.F., Duakiewicz, T., Joyce, J.J., Rector, K.D., Xiong, J., Gofryk, K., Ronning, F., Martin, R.L. (2013) "Preparation of epitaxial uranium dicarbide thin films by polymer-assisted deposition," Chemical Materials: 25, 4373-4377

Kashinath, A., Wang, P., Majewski, J., Baldwin, J. K., Wang, Y. Q., et al. (2013) "Detection of helium bubble formation at fcc-bcc interfaces using neutron reflectometry" Journal of Applied Physics: 114, 4

Lu, P., Xiong, J., Van Benthem, M., Jia, Q.X. (2013) "Atomic-scale chemical quantification of oxide interfaces using energy dispersive x-ray spectroscopy" Applied Physics Letters: 102, 173111

McCleskey, T.M., Bauer, E., Jia, Q.X., Burrell, A.K., Scott, B.L., Conradson, S.D., Mueller, A., Roy, L., Wen, X.D., Scuseria, G.E., Martin, R.L. (2013) "Optical band gap of NpO_2 and PuO_2 from optical absorbance of epitaxial films," Journal of Applied Physics: 13, 013515

Nayyar, I., Batista, E., Tretiak, S., Saxena, A., Smith, D.L., Martin, R.L. (2013) "Effect of trans and cis isomeric defects on the localization of the charged excitations in pi-conjugated organic polymers" Journal of Polymer Physics B: 51, 935-942

Nayyar, I., Batista, E., Tretiak, S., Saxena, A., Smith, D.L., Martin, R.L. (2013) "Role of geometric distortion and polarization in localizing electronic excitations in conjugated polymers" Journal of Chemistry Theory and Computation: 9, 1144-1154

Nayyar, I.H., Masunov, A., Tretiak, S. (2013) "Comparison of TD-DFT methods for the calculation of two-photon absorption spectra of olygophenylvinylenes" Journal of Physical Chemistry C: 117, 18170-18189

Ren, F., Zhou, X.D., Liu, Y.C., Wang, Y.Q., Cai, G.X., Xiao, X.H., Dai, Z.G., Li, W.Q., Yan, S.J., Wu, W., Zhang, C., Ni, H.W., Jiang, C.Z. (2013) "Fabrication and properties of TiO2 nanofilms on different substrates by a novel and universal method of Ti-ion implantation and subsequent annealing" Nanotechnology: 24, 255603

Seo, M.A., Yoo, J., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P. (2013) "Mapping carrier diffusion in single silicon core-shell nanowires with ultrafast optical microscopy," Ultrafast Dynamics in Molecules, Nanostructures, and Interfaces, G. G. Gurzadyan, G. Lanzani, C. Soci, T. C. Sum eds, World Scientific: p. 128

Shepherd, D.P., Li, N., Micheva-Viteva, S., Munsky, B., Hong-Geller, E., Werner, J.H. (2013) "Counting small RNA in pathogenic bacteria" Analytical Chemistry: 85, 4938-4943

Sheu, Y.M., Trugman, S.A., Yan, L., Chuu, C.P., Bi, Z., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2013) "Photoinduced stabilization and enhancement of the ferroelectric polarization in $Ba_{0.1}Sr_{0.9}TiO_3/La_{0.7}Ca(Sr)_{0.3}MnO_3$ thin film heterostructures," Physical Review B: 88, 020101

Sheu, Y.M., Trugman, S.A., Park, Y.S., Lee, S., Yi, H.Y., Cheong, S.W., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2013) "Ultrafast carrier dynamics and radiative recombination in multiferroic BiFeO3 single crystals and films" 18th International Conference on Ultrafast Phenomena, M. Chergui, A. J. Taylor eds., Oxford University Press: p. 03018

Sheu, Y.M., Trugman, S.A., Park, Y.S., Lee, S., Yi, H.Y., Cheong, S.W., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2013) "Ultrafast carrier dynamics and radiative recombination in multiferroic BiFeO3 single crystals and films" European Physical Journal: 41, 03018

Sheng, C.X., Singh, S., Gambetta, A., Drori, T., Tong, M., Tretiak, S., Vardeny, Z.V. (2013) "Ultrafast intersystem-crossing in platinum containing pi-conjugated polymers with tunable spin-orbit coupling" Surface Science Reports: 3, 2653

Ting, C.L., Frischknecht, A.L. (2013) "Activated pathways for the directed insertion of patterned nanoparticles into polymer membranes" Soft Matter: 9, 9615-9623

Zeng, Y., Chen, H.-T., Dalvit, D. A. R. (2013) "The role of magnetic dipoles and non-zero-order Bragg waves in metamaterial perfect absorbers" Optics Express: 21, 3540-3546

Zhu, L., Sandhu, S., Otey, C., Fan, S., Sinclair, M.B., Luk, T.S. (2013) " Temporal coupled mode theory for thermal emission from a single thermal emitter supporting either a single mode or an orthogonal set of modes" Applied Physics Letters: 102, 103104

Zhu, L., Zhu, J.X. (2013) "Singularity in self-energy and composite fermion excitations of interacting electrons" Physical Review B: 87, 085120. C2011A1070

Zou, X., Shang, J., Leaw, J., Luo, Z., La-o-vorakiat, C., Cheng, L., Cheong, S.A., Su, H., Zhu, J.X., Liu, Y., Loh, K.P., Castro Neto, A.H., Yu, T., Chia, E.E.M. (2013) "Terahertz conductivity of twisted bilayer graphene" Physical Review Letter: 110, 067401

CINT User Science - Internal (51)

Alexandrov, B.S., Phipps, M.L., Alexandrov, L.B., Booshehri, L.G., Erat, A., Zabolotny, J., Mielke, C.H., Chen, H.T., Rodriguez, G., Rasmussen, K.O., Martinez, J.S., Bishop, A.R., Usheva, A. (2013) "Specificity and heterogeneity of terahertz radiation effect on gene expression in mouse mesenchymal stem cells" Scientific Reports: 3, 1184. C2012A0078

Anderoglu, O., Zhou, M.J., Zhang, J., Wang, Y.Q., Maloy, S., Baldwin, J.K., Misra, A. (2013) "He+ ion irradiation response of Fe-TiI2 multilayers" Journal of Nuclear Materials: 435, 96. C2011B83

Arnold, M.S., Blackburn, J.L., Crochet, J.J., Doorn, S.K., Duque, J.G., Mohite, A., Telg, H. (2013) "Recent Developments in the Photophysics of Single-Wall Carbon Nanotubes for Active and Passive Material Elements in Thin Film Photovoltaics" Physical Chemistry Chemical Physics: 15, 14896 . C2011B7

Azad, A.K., O'Hara, J.F., Singh, R., Chen, H.-T., Taylor, A. J. (2013) "A review of terahertz plasmonics in subwavelength holes on conducting films" IEEE Journal of Selected Topics in Quantum Electronics: 19, 8400416

Beyerlein, I.J., Caro, J.A., Demkowicz, M.J., Mara, N.A., Misra, A., Uberuaga, B.P. (2013) "Radiation-damage-tolerant Nanomaterials" Materials Today: 16, 443-449. U2011A1071

Beyerlein, I.J., Wang, J., Kang, K., Zheng, S.J., Mara, N.A. (2013) "Twinnability of bimetal interfaces in nanostructured composites" Materials Research Letters: 1, 89-95 U2012B0018

Bi, Z., Uberuaga, B.P., Fu, E.G., Wang, Y.Q., Li, N., Wang, H.Y., Misra, A., Jia, Q.X. (2013) Radiation damage in heteroepitaxial $BaTiO_3/SrTiO_3$ thin films under Ne ion irradiation," Journal of Applied Physics: 113, 023513

Bronkhorst, C.A., Mayeur, J.R., Beyerlein, I.J., Mourad, H.M., Hansen, B.L., Mara, N.A., Carpenter, J.S., McCabe, R.J., Sintay, S.D. (2013) "Meso-scale modeling the orientation and interface stability of Cu/Nb-Layered Composites by Rolling" Journal of Materials: 65, 431 U2011B27

Carpenter, J.S., McCabe, R.J., Beyerlein, I.J.,Wynn, T.A., Mara, N.A. (2013) "A wedge-mounting technique for nanoscale electron backscatter diffraction" Journal of Applied Physics: 113, 9 RA2012B0013

Carpenter, J.S., Zheng, S.J., Zhang, R.F., Vogel, S.C., Beyerlein, I.J., Mara, N.A (2013) "Thermal stability of Cu-Nb nanlamellar composites fabricated via accumulative roll bonding" Philos. Magazine: 93, 718 U2011B27

Cheaito, R., Duda, J.C., Beechem, T.E., Piekos, E.S., Ihlefeld, J. F., et al. (2013) "The effect of ballistic electron transport on copper-niobium thermal interface conductance" ASME 2013 Heat Transfer Summer Conf. Collocated with the ASME 2013 7th Int. Conf. on Energy Sustainability and the ASME 2013 11th Int. Conf. on Fuel Cell Science, Engineering and Technology 1,V001T03A009

Chowdhury, D.R., Singh, R., Taylor, A.J., Chen, H.T., Azad, A.K. (2013) "Ultrafast manipulation of near field coupling between bright and dark modes in terahertz metamaterial" Applied Physics Letters: 102, 011122 U2011A1082

Grady, N.K., Heyes, J.E., Chowdhury, D.R.., Zeng, Y., Reiten, M.T., Azad, A.K., Taylor, A.J., Dalvit, D.A.R., Chen, H.T. (2013) "Terahertz metamaterials for linear polarization conversion and anomalous refraction" Science: 340, 1304-1307

Dayal, P., Bhattacharyya, D., Mook, W.M., Fu, E.G., Wang, Y.Q., Carr, D.G., Anderoglu, O., Mara, N.A., Misra, A., Harrison, R.P., Edwards, L. (2013) "Effect of double ion implantation and irradiation by Ar and He ions on nano-indentation hardness of metallic alloys" Journal of Nuclear Materials: 438, 108-115 C2011A1105

Gilbertson, S.M., Durakiewicz, T., Dakovski, G.L., Li, Y., Zhu, J.X., Conradson, S.D., Trugman, S.A., Rodriguez, G. (2013) "Ultrafast photoemission spectroscopy of the uranium dioxide UO2 Mott insulator: Evidence for a robust energy gap structure" Physical Review Letters: 112, 87402. C2011A1070

Han, W.Z., Fu, E.G., Demkowicz, M.J., Wang, Y.Q., Misra, A. (2013) "Irradiation damage of single crystal, coarse-grained and nano-grained copper under helium bombardment at 450C" Journal of Material Resources: 28, 2763-2770 U2008A119

Hansen, B.L., Carpenter, J.S., Sintay, S.D., Bronkhorst, C.A., McCabe, R.J., Mayeur, J.R., Mourad, H.M., Beyerlein, I.J., Mara, N.A., Chen, S.R., Gray III, G.T. (2013) "Modeling the texture evolution of Cu/Nb layered composites during rolling" International Journal of Plasticity: 89, 71-84 U2011B27

Hollingsworth, J.A., Laocharoensuk, R., Palaniappan, K., Smith, N.A., Dickerson, R.M., et al. (2013) "Flow solution-liquid-solid nanowire synthesis: New platform for understanding growth mechanisms and advancing axial heterostructuring" Abstracts of Papers of the American Chemical Society: 246

Lakshminarayana, G., Weis, E., Lira, A., Caldino, U., Williams, D., Hehlen, M. (2013) "Cross relaxation in rare-earth-doped oxyfluoride glasses" Journal of Luminescence: 139, 132 U2008A165

Laocharoensuk, R., Palaniappan, K., Smith, N.A., Dickerson, R.M., Werder, D., Baldwin, J.K., Hollingsworth, J.A. (2013) "Flow-based solution-liquid-solid nanowire synthesis" Nature Nanotechnology: 8, 660-666 U2010A1007

Lee, J., Trugman, S.A., Batista, C.D., Zhang, C.L., Talbayev, D., Xu, X.S., Cheong, S.W., Yarotski, D.A., Taylor, A.J., Prasankumar, R.P. (2013) "Probing the interplay between charge fluctuations and magnetic ordering in LuFe2O4" Surface Science Reports: 3, 2654 U2010A952

Liu, S., Ihlefeld, J.F., Dominguez, J., Gonzales, E.F., Bower, J.E., Burckel, D.B., Sinclair, M.B., Brener, I. (2013) "Realization of Tellurium-based all Dielectric Optical Metamaterials using a Multi-cycle Deposition-etch Process" Applied Physics Letters: 102, 161905

Liu, S., Mahony, T.S., Bender, D.A., Sinclair, M.B., Brener, I. (2013) "Mid-infrared time-domain spectroscopy system with carrier-envelop phase stabilization" Applied Physics Letters: 103, 181111

Liu, Y.H., Xiong, J., Haraldsen, J.T., Yan, L., Balatsky, A.V., Jia, Q.X., Taylor, A.J., Yarotski, D. (2013) "Tuning the electronic properties of ultrathin $La_{0.7}Sr_{0.3}MnO_3$ films by interfacing with superconducting $EuBa_2Cu_3O_{7-\square}$," Physical Review B: 87, 165140

Luk, T.S., Kim, I., Campione, S., Howell, S.W., Subramania, G.S., Grubbs, R.K., Brener, I., Chen, H.T., Fan, S., Sinclair, M.B. (2013) "Near-infrared surface plasmon polariton dispersion control with hyperbolic metamaterials" Optics Express: 21, 11107-11114

Magedov, I.V., Frolova, L.V., Ovezmyradov, M., Bethke, D., Shaner, E.A., Kalugin, N.G. (2013) "Benzyne-functionalized graphene and graphite characterized by raman spectroscopy and energy dispersive X-ray analysis" Carbon: 54, 192-200 C2011B47

Mangum, B. D., Ghosh, Y., Hollingsworth, J. A., Htoon, H. (2013) "Disentangling the Effects of Clustering and Multi-exciton Emission in Second-Order Photon Correlation Experiments" Optics Express: 21, 6, 7419-7426 U2010A906

Mangum, B. D., Park, Y.S., Ghosh, Y., Hollingsworth, J. A. & Htoon, H. "New single nanocrystal spectroscopy approaches for investigation of emission efficiency and recombination dynamics of multi-excitons" in SPIE Defense, Security, and Sensing: 87270S-87270S-87214 U2010A906

Martinez, J.A., Cho, J.H., Liu, X., Luk, T.S., Huang, J., Picraux, S.T., Sullivan, J.P., Swartzentruber, B.S. (2013) "Contribution of radial dopant concentration to the thermoelectric properties of core-shell nanowires" Applied Physics Letters: 102, 103101

Montano, G.A., Adams, P.G., Xiao, X., Goodwin, P.M. (2013) "Scanning Probe Microscopy of Nanocomposite Membranes and Dynamic Organization" Advanced Functional Materials: 23, 2576-2591

Nagy, A., Hollingsworth, J.A., Hu, B., Steinbruck, A., Stark, P.C., Rios-Valdez, C., Vuyisich, M., Stewart, M., Atha, D.H., Nelson, B.C., Iyer, R. (2013) "Functionalization-dependent induction of cellular survival pathways by CdSe quantum dots in primary normal human bronchial epithelial cells" ACS Nano: 7, 8397-8411 U2010A979

Nguyen, K.T., Lilly, M.P., Nielsen, E., Bishop, N.C., Rahman, R., Young, R., Wendt, J., Dominguez, J., Pluym, T., Stevens, J., Lu, T.M., Muller, R., Carroll, M.S. (2013) "Charge sensed Pauli blockade in metal-oxide-semiconductor lateral double quantum dot" Nano Letters: 13, 5785 U2011A1066

Park, Y.S., Ghosh, Y., Xu, P., Mack, N.H., Wang, H.L., Hollingsworth, J.A., Htoon, H. (2013) "Single-nanocrytal photoluminescence spectroscopy studies of plamson-multiexciton interactions at low temperature" Journal of Physical Chemistry: 4, 1465-1470 U2009B062

Park, Y.S., Ghosh, Y., Chen, Y., Piryatinski, A., Xu, P., Mack, N.H., Wang, H.S., Klimov, V.I., Hollingsworth, J.A., Htoon, H. (2013) "Super-Poissonian Statistics of Photon Emission from Single CdSe-CdS Core-Shell Nanocrystals Coupled to Metal Nanostructures" Physical Review Letters: 110, 117401. U2011B72

Qi, J., Durakiewicz, T., Trugman, S.A., Zhu, J.X., Riseborough, P.S., Baumbach, R., Bauer, E.D., Gofryk, K., Meng, J.Q., Joyce, J.J., Taylor, A.J., Prasankumar, R.P. (2013) "Measurement of two low-temperature energy gaps in the electronic structure of antiferromagnetic USb2 ultrafast optical spectroscopy" Physical Review Letters: 111, 057402. C2011A1070

Ribaudo, T., Peters, D.W., Ellis, A.R., Davids, P.S., Shaner, E.A. (2013) "Highly directional thermal emission from two-dimensional silicon structures" Optics Express: Vol. 21, Issue 6, pp. 6837-6844 C2010A972

Sau, J.D., Crochet, J.J., Doorn, S.K., Cohen, M.L. (2013) "Multi-Particle Exciton Ionization in Shallow Doped Carbon Nanotubes" Journal of Physical Chemistry Letters: 4, 982 U2013A0132

Seo, M.A., Boubanga-Tombet, S., Yoo, J., Ku, Z., Gin, A.V., Picraux, S.T., Brueck, S.R.G., Taylor, A.J., Prasankumar, R.P. (2013) "Utrafast optical wide field microscopy" Optics Express: 21, 7, 8763 C2010A1011

Shafiei, F., Monticone, F., Khia, L.Q., Liu, X.X., Hartsfield, T., Alu, A., Li, X. (2013) "A subwavelength plasmonic metamolecule exhibiting magnetic based optical Fano resonance" Nature Nanotechnology: 8, 95

Shchegolkov, D.Y., Reiten, M.T., O'Hara, J.F., Azad, A.K. (2013) "Direct observation of electro-optic modulation in a single split-ring resonator" Applied Physics Letters: 102, 091109 U2010A985

Singh, R., Chowdhury, D.R., Xiong, J., Yang, H., Azad, A.K., Taylor, A.J., Jia, Q.X., Chen, H.T. (2013) "Influence of film thickness in THz active metamaterial devices: A comparison between superconductor and metal split-ring resonators" Applied Physics Letters: 103, 061117

Tracy, L.A., Lu, T.M., Bishop, N.C., Ten Eyck, G.A., Pluym, T., Wendt, J.R., Lilly, M.P., Carroll, M.S. (2013) "Electron spin lifetime of a single antimony donor in silicon" Applied Physics Letters: 103, 143115 U2011A1019

Wachtor, A.J., Mocko, V., Williams, D.J., Goertz, M.P., and Jebrail, F.F. (2013) "Buoyancy driven mixing of miscible fluids by volumetric energy deposition of microwaves" Journal of Microwave Power and Electromagnetic Energy: **47**(3), 210-223 U2011B51

Wynn, T., Bhattacharyya, D., Hammon, D., Misra, A., Mara, N. (2013) "Large strain deformation of bimodal layer thickness Cu/Nb Nanolamellar Composites" Materials Science and Engineering: 564, 213-218 C2011A1105

Xiao, X., Montaño, G.A., Edwards, T.L., Allen, A., Achyuthan, K.E., Polsky, R., Wheeler, D.R., Brozik, S.M. (2012) "Surface charge dependent nanoparticle disruption and deposition of lipid bilayer assemblies." Langmuir: 28, 17396. U2008B122

Xiao, X., Montano, G.A., Edwards, T.L., Allen, A., Achyuthan, K.E., Wheeler, D.R., Brozik, S.M. (2013) "Surface charge localized lipid bilayer membrane disruption and nanoparticle deposition" Langmuir: 28, 50

Zepeda-Ruiz, L.A., Martinez, E., Caro, M., Fu, E.G., Caro, A. (2013) "Deformation mechanisms of irradiated metallic nanofoams" Applied Physics Letters: 103, 031909 U2011A1071

Zhang, S.X., Li, Y., Dayeh, S.A., Crooker, S.A., Smith, D.L., Picraux, S.T. (2013) "Electrical spin injection and detection in silicon nanowires through oxide tunneling barriers" Nano Letters: 13 U2011A1004

Zheng, S., Beyerlein, I.J., Carpenter, J.S., Kang, K., Wang, J., Han, W.Z., Mara, N.A. (2013) "High strength and thermally stable bulk nanolayered composites due to twin-induced interfaces" Nature Communications: 4, 1696 U2011B27

Zhuo, M.J., Yan, L., Fu, E.G., Wang, Y.Q., Misra, A., Nastasi, M., Uberuaga, B.P., Jia, Q.X. (2013) "Phase transformations and defect clusters in single crystal $SrTiO_3$ irradiated at different temperatures," Journal of Nuclear Material: 442, 143-147

Zhuo, M.J., Uberuaga, B.P., Yan, L., Fu, E.G., Dickerson, R.M., Wang, Y.Q., Misra, A., Nastasi, M., Jia, Q.X. (2013) "Radiation damage at the coherent anatase TiO2/SrTiO3 interface under Ne ion irradiation" Journal of Nuclear Material: 429, 177

CINT User Science - External (117)

Appavoo, K., Brady, N.F., Seo, M.A., Nag, J., Prasankumar, R.P., Hilton, D.J., Haglund Jr., R.F. (2013) "Ultrafast Phase Transition in Vanadium Dioxide Driven by Hot-electron Injection" 18th International Conference on Ultrafast Phenomena, M. Chergui, A. J. Taylor eds, Oxford University Press: p. 03026 C2011A1037

Armijo, L.M., Akins, B.A., Plumley, J.B., Rivera, A.C., Withers, N.J., Cook, N.C., Smolyakov, G.A., Huber, D.L., Smyth, H.D.C., Osinki, M. (2013) "Highly efficient multifunctional MnSe/ZnSeS quantum dots for biomedical applications" Proceedings of SPIE: 8595, 859517

Beyerlein, I.J., Mara, N.A., Carpenter, J.S., Nizolek, T.R., Kang, K., Zheng, S., Wang, J., Pollock T.M. (2013) "Interface-driven microstructure development and ultra high strength of bulk nanostructured Cu-Nb multilayers fabricated by sever plastic deformation" Journal of Materials Research: 1-14 U2011B27

Bi, Z., Uberuaga, B.P., Vernon, L.J., Fu, E., Wang, Y., Li, N., Wang, H., Misra, A., Jia, Q.X. (2013) "Radiation Damage in Heteroepitaxial BaTiO3 Thin Films on SrTiO3 under Ne Ion Irradiation", Journal of Applied Physics: 113, 023513 C2013A0036.

Brady, N.F., Appavoo, K., Seo, M.A., Nag, J., Prasankumar, R.P., Haglund Jr., R.F., Hilton, D.J. (2013) "Ultrafast dynamics of the VO_2 insulator-to-metal transition observed by nondegenerate pump-probe spectroscopy," 18th International Conference on Ultrafast Phenomena, M. Chergui, A. J. Taylor eds, Oxford University Press: p. 03006 C2011A1037

Briscoe, J.L., Cho, S.Y., Brener, I. (2013) "Defect-assisted plasmonic crystal sensor" Optics Letters: 38, 2569-2571 U2010A919

Brons, J.G., Padilla II, H.A., Thompson, G.B., Boyce, B.L. (2013) "Cryogenic indentation-induced grain growth in nanotwinned copper" Scripta Materialia: 68 C2010A911

Bufford, D., Bi, Z., Jia, Q.X., Wang, H., Zhang, X. (2013) "Nanotwins and stacking faults in high-strength epitaxial Ag/Al multilayer films" Applied Physics Letters: 101, 223112 C2012A0017

Bufford, D., Liu, Y., Zhu, Y., Bi, Z., Jia, Q.X., Wang, H., Zhang, X. (2013) "Formation mechanisms of high-density growth twins in aluminum with high stacking-fault energy" Materials Research Letters: 1, 1, 51-60 C2010B1039

Butler, K.S., Lovato, D.M., Adolphi, N.L., Belfon, R., Fegan, D.L., Monson, T.C., Hathaway, H.J., Huber, D.L., Tessier, T.E., Bryant, H.C., Flynn, E.R., and Larson, R.S. "Development of antibody-tagged nanoparticles for detection of transplant rejection using biomagnetic sensors". Cell Transplant: 22, 10, 1943-54. C2011B103

Chan, C.W.I., Hu, Q., et al. (2013) "Tall-barrier terahertz quantum cascade lasers" Applied Physics Letters: 103, 15 C2010B1033

Chen, A., Bi, Z., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2013) "Strain-induced ferromagnetism and magnetoresistance in epitaxial thin films of $LaCoO_3$ prepared by polymer assisted deposition," Chemistry of Materials: 25, 55-58 U2011B3

Chen, A., Zhou, H., Bi, Z., Zhu, Y., Luo, Z., Bayraktaroglu, A., Phillips, J., Choi, E.M., McManus-Drisoll, J.L., Pennycook, S.J., Narayan, J., Jia, Q.X., Zhang, X., Wang, H. (2013) "A new class of room-temperature multiferroic thin films with bismuth-based supercell structure" Advanced Materials: 10, 201203051 U2011B3

Chen, A., Zhang, W., Jian, J., Wang, H., Tsai, C.F., Su, Q., Jia, Q.X., MacManus-Driscoll, J.L. (2013) "Role of boundaries on low-field magnetotransport properties of $La_{0.7}Sr_{0.3}MnO_3$-based nanocomposite thin films," Journal of Material Resources: 28, 1707-1714 U2011B3

Chen, A., Zhang, W., Khatkatay, F., Su, Q., Tsai, C.F., Chen, L., Jia, Q.X., MacManus-Driscoll, Wang, H. (2013) "Magnetotransport properties of quasi-one-dimensionally channeled vertically aligned heteroepitaxial nanomazes" Applied Physics Letters: 102, 093114 U2011B3

Chen, J., Schmitz, A., Inerbaev, T., Meng, Q., Kilina, S., Tretiak, S., Kilin, D. (2013) "First-principles study of p-n doped silicon quantum dots: Charge transfer, energy dissipation, and time-resolved emission" Journal of Physical Chmistry Letters: 4, 2906-2913 U2010B1108

Chan, C.W.I, Hu, Q., Reno, J.L. (2013) "Tall-Barrier Terahertz Quantum Cascade Lasers," Applied Physics Letters: 103, 151117 C2010B1033

Chowdhury, D.R., Azad, A.K., Zhang, W., Singh, R. (2013) "Near field coupling in passive and active terahertz metamaterial devices," IEEE Transactions on Terahertz Science and Technology: 3, 6, 783-790 C2010A954

Crochet, J.J., Duque, J.G., Werner, J.H., Lounis, B., Cognet, L., Doorn, S.K. (2013) "Disorder Limited Exciton Transport in Colloidal Single-Wall Carbon Nanotubes". Nano Letters: 12, 5091−5096 C2011B102

Cui, M., Hovenier, J.N., Ren, Y., Vercruyssen, N., Gao, J.R., Kao, T.Y., Hu, Q., Reno, J.L. (2013) "Beam and phase distributions of a terahertz quantum cascade wire laser" Applied Physics Letters: 102, 111113

Demming, A., Tonouchi, M., et al. (2013) "Terahertz nanotechnology" Nanotechnology: 24, 21

Dumont, E.L.P., Belmas, H., Hess, H. (2013) "Observing the mushroom-to-brush transition for kinesin proteins", Langmuir: 29(49), 15142-15145. U2012A0018

Duque, J.G., Oudjedi, L., Crochet, J.J., Tretiak, S., Lounis, B., Doorn, S.K., Cognet, L. (2013) "Mechanism of Electrolyte-Induced Brightening in Single-Wall Carbon Nanotubes". Journal of the American Chemical Society: 135, 3379−3382 U2010A946

Duzik, A., Thomas, J.C., Van der Ven, A., Millunchik, J.M. (2013) "Surface reconstruction stability and configurational disorder on Bi-terminated GaAs(001)." Physical Review B: 87**:** 035313. U2008B054

Dyer, G.C., Aizin, G.R., et al. (2013) "Induced transparency by coupling of Tamm and defect states in tunable terahertz plasmonic crystals" Nature Photonics: 7, 11 U2013B0053

Dyer, G.C., Nordquist, C.D., et al. (2013) "Position and mode dependent coupling of terahertz quantum cascade laser fields to an integrated diode" Applied Physics Letters: 103, 16 U2013B0053

Dyer, G.C., Nordquist, C.D., et al. (2013) "Rectified diode response of a multimode quantum cascade laser integrated terahertz transceiver" Optics Express: 21, 4 U2013B0053

Fang, K., Fernando, G.W., Kocharian, A.N. (2013) "Local electronic nematicity in the two-dimensional one-band hubbard model" Journal of Physics: Condensed Matter: 25, 205601. U2011A1109

Field III, R.L., Jin, Y., Dannecker, T., Jock, R.M., Goldman, R.S., Cheng, H., Kurdak, C., Wang, Y. (2013) "Influence of N incorporation on persistent photoconductivity in GaAsN alloys" Physical Review B: 8, 87 C2010B1038

Frischknecht, A.L., Hore, M.J.A., Ford, J., Composto, R.J. (2013). "Dispersion of Polymer-Grafted Nanorods in Homopolymer Films: Theory and Experiment". Macromolecules: 46, pp.2856–2869. C2012A0112.

Fu, E.G., Wang, H., Carter, J., Shao, L., Wang, Y.Q., Zhang, X. (2013) "Fluence –dependent radiation damage in helium (He) ion-irradiated Cu/V multilayers" Philosophical Magazine: 93, 883-898 C2012A0017

Gamaski, A.D., Perea, D.E., Yoo, J., Li, N., Olszta, M.J., Colby, R., Screiber, D.K., Ducati, C., Picraux, S.T., Hofmann, S. (2013) "Catalyst composition and impurity-dependent kinetics of nanowire heteroepitaxy" ACS Nano: 7, 7689-7697 C2011A1005

Gan, Z., Perea, D.E., Yoo, J., Picraux, S.T., Smith, D.J., McCartney, M.R. (2013) "Mapping electrostatic profiles across axial p-n junctions in Si nanowires using off-axis electron holography" Applied Physics Letters: 103, 153108 C2011A1005

Ge, T., Grest, G.S., Robbins, M.O. (2013) "Structure and Strength at Immiscible Polymer Interfaces" ACS Macro Letters: 2, 882 U2010A927

Ge, T., Pierce, F., Perahia, D., Grest, G.S., Robbins, M.O. (2013) "Molecular Dynamics Simulations of Polymer Welding: Strength from Interfacial Entanglements" Physical Review Letters: 110, 098301 C2011B75

Gram, M.D., Carpenter, J.S., Payzant, E.A., Misra, A., Anderson, P.M. (2013) "Forward and reverse plastic flow in nanoscale layers: results from heated diffraction studies" Material Resources Letters: C2010B1062

Gregorczyk, K.E., Liu, Y., Sullivan, J.P., Rubloff, G.W. (2013) "In situ transmission electron microscopy study of electrochemical lithiation and delithiation cycling of the conversion anode RuO2" ACS Nano: 7, 6354 U2011A1061

Haberkorn, N., Zhang, Y.Y., Kim, J., McCleskey, T.M., Burrell, A.K., DePaula, R.F., Tajima, T., Jia, Q.X., Civale, L. (2013) "Upper critical magnetic field and vortex-free state in very thin epitaxial □-MoN films grown by polymer-assisted deposition," Superconductor Science and Technology: 26, 105023 C2011B101

Hagmann, M.J., Henage, T.E., Azad, A.K., Taylor, A.J., Yarotski, D.A. (2013) "Frequency comb from 500 Hz to 2 THz by optical rectification in zinc telluride" Electronics Letters: Vol. 49 1459-1460. U2008A056

Hagmann, M.J., Stenger, F.S., and Yarotski, D.A. (2013) "Linewidth of the harmonics in a microwave frequency comb generated by focusing a mode-locked ultrafast laser on a tunneling junction" Journal of Applied Physics: Vol. 114 223107 (6 pp). U2010B1103

Haroz, E.H., Duque, J.G., Tu, X., Zheng, M., Walker, A.R., Hauge, R.H., Doorn, S.K., Kono, J. (2013) "Fundamental Optical Processes in Armchair Carbon Nanotubes" Nanoscale: 5, 1411 U2013B0085

Harriman, T.A., Bi, Z., Jia, Q.X., Lucca, D.A. (2013) "Frequency shifts of E_2^{High} Raman mode due to residual stress in epitaxial ZnO thin films," Applied Physics Letters: 103, 121904 U2013A0076

Hayton, D.J., Khudchencko, A., Pavelyev, D.G., Hovenier, J.N., Baryshev, A., Gao, J.R., Kao, T.Y., Hu, Q., Reno, J.L., Vaks, V. (2013) "Phase locking of a 3.4 THz third-order distributed feedback quantum cascade laser using a room-temperature superlattice harmonic mixer" Applied Physics Letters: 103, 051115 C2010B1033

Hedrick, M., Mayo, M.L., Badaeva, E., Kilina, S. (2013) "Studies of the ground and excited state properties of quantum dots functionalized by Ru(II)-Polybipyridine" Journal of Physical Chemistry: 117, 18216 U2010B1108

Huang, J.Y., Lo, Y.C., Jun, J.N., Kushima, A., Qian, X., Zhong, L., Mao, S.X., Li, J. (2013) "Nanowire liquid pumps" Nature Nanotechnology: 8, 277 C2010B1063

Hur, S.-M., Frischknecht, A. L., Huber, D. L., Fredrickson, G. H. (2013) "Self-assembly in a mixed polymer brush with inhomogeneous grafting density composition" Soft Matter: 9**,** 5341–5354. C2011A1029.

Hurtado, A., Xu, H., Wright, J.B., Liu, S., Wang, G., Brener, I. (2013) "Polarization Switching in GaN Nanowire Lasers" Applied Physics Letters: 103, 251107 C2012A0024

Hwang, Y., Nguyen, B.M., Dayeh, S. (2013) "Atomic Layer Deposition of Platinum with Enhanced Nucleation and Coalescence by Trimethylaluminum Pre-Pulsing". Applied Physics Letters: 103, 263115

Jung, J., Sethi, A., Gaiotto, T., Han, J.J., Jeoh, T., Goodwin, P.M. (2013) "Binding and movement of individual Cel7A cellobiohydrolases on crystalline cellulose surfaces revealed by single-molecule fluorescence imaging" Journal of Biological Chemistry: 288, 24164-24172 U2012B0020

Jun, Y.C., Reno, J.L., Ribaudo, T., Shaner, E., Greffet, J.J., Vassant, S., Marquier, F., Sinclair, M., Brener, I., (2013) "Epsilon-near-zero strong coupling in metamaterial-semiconductor hybrid structures," Nano Letters: 13, 5391 C2010A972

Kilina, S., Dandu, N., Batista, E., Saxena, A., Smith, D.L., Martin, R.L., Tretiak, S. (2013) "Effect of packing on formation of deep carrier traps in amorphous conjugated polymers" Journal of Physical Chemistry: 4, 1453-1459 U2010B1108

Kim, I., Jiao, L., Khatkhatay, F., Martin, M.S., Lee, J., Shao, L., Zhang, X., Swadener, J.G., Wang, Y.Q., Gan, J., Cole, J., Wang, H. (2013) "Size-dependent radiation tolerance in ion irradiated TiN/AlN nanolayer films" Journal of Nuclear Materials: 441, 47-53

Kloosterman, J.L., Hayton, D.J., Ren, Y., Kao, T.Y., Hovenier, J.N., Gao, J.R., Klapwijk, T.M., Hu, Q., Walker, C.K., Reno, J.L. (2013) "Hot electron bolometer heterodyne receiver with a 4.7 THz quantum cascade laser as a local oscillator" Applied Physics Letters: 102, 011123 C2010B1033

Koecher, M., Yeager, J.D., Park, T., Fullwood, D., Colton, J.S., Mara, N., Hansen, N. (2013) "Characterization of nickel nanostrand nanocomposites through dielectric spectroscopy and nanoindentation" Polymer Engineering and Science: 53, 12, 2666-2673 C2010A915

Li, H., Wu, C., Malinin, S.V., Tretiak, S., Chernyak, V.Y. (2013) "Effective tight-binding models for

excitons in branched conjugated molecules" Journal of Chemical Physics: 139, 064109 C2011A1021

Li, W.W., Zhao, R., Wang, L., Tang, R.J., Zhu, Y.Y., Lee, J.H., Cao, H.X., Cai, T.Y., Guo, H.Z., Wang, C., Ling, L.S., Pi, L., Jin, K.J., Zhang, Y.H., Wang, H.Y., Wang, Y.Q., Ju, S., Yang, H. (2013) "Oxygen-vacancy-induced antiferromagnetism to ferromagnetism transformation in Eu0.5Ba0.5TiO32d multiferroic thin films" Scientific Reports: 3, 2618

Liang, W., Yang, H., Fan, F., Liu, Y., Liu, X.H., Huang, J.Y., Zhu, T., Zhang, S. (2013) "Tough Germanium Nanoparticles under Electrochemical Cycling" ACS Nano: 7, 3427 C2012A0033

Liu, R., Zheng, S., Baldwin, K.J., Kuthuru, M., Mara, N., Antoniou, A. (2013) "Synthesis and mechanical behavior of nanoporous nanotwinned copper" Applied Physics Letters: 103(24). U2012A0107

Liu, R., Antoniou, A. (2013) "A relationship between the geometrical structure of a nanoporous metal foam and its modulus". Acta Materialia: 61(7):2390-402. C2010B1054

Liu, Y., Liu, X.H., Nguyen, B.M., Yoo, J., Sullivan, J.P., Picraux, S.T., Huang, J.Y, Dayeh, S.A. (2013) "Tailoring Lithiation Behavior by Interface and Bandgap Engineering at the Nanoscale" Nano Letters: 13,4876 C2012A0014

Lotfian, S., Rodriguez, M., Yazzie, K.E., Molina-Aldareguia, J.M., Chawla, N., Lorca, J.L. (2013) "High Temperature Micropillar Compression of Al/SiC Nanolaminates" Acta Materialia: 61, 4439-4451 U2012B0013

Mann, J., Sun, D., Ma, Q., Chen, J.R., Preciado, E., Ohta, T., Diaconescu, B., Yamaguchi, K., Tran, T., Wurch, M.A., Magnone, K.M., Heinz, T.F., Kellogg, G.L., Kawakami, R., Bartels, L. (2013) "Facile growth of monolayer MoS2 on SiO2" European Phyical Journal B: 86, 226 C2011A1026

Mara, N.A., Crapps, J., Wynn, T., Clarke, K., Antoniou, A., Dickerson, P., Dombrowski, D.E., Mihaila, B. (2013) "Defining Strength of Metallic Bonded Interfaces via Microcantilever Bend Testing" Philosophical Magazine: 93, 2749-2758 C2010B1054

Martin, K.E., Tian, Y., Busani, T., Medforth, C.J., Franco, R., van Swol, F., Shelnutt, J.A. (2013) "Charge effects on the structure and composition of porphyrin binary ionic solids: ZnTPPS/SnTMePyP nanomaterials" Chemistry of Materials: 25, 441 U2012A0117

Maskey, S., Osti, N.C., Perahia, D., Grest, G.S. (2013) "Internal Correlations and Stability of Polydots, Soft Conjugated Polymeric Nanoparticles" ACS Macro Letters: 2, 700 U2010B1092

McCombe, B.D., Thomas, D., Einhorn, M., Reno, J.L., Strasser, G., Bird, J.P. (2013) "Terahertz detection with nanoscale semiconductor rectifiers" IEEE Sensors Journal: 13, 24 C2012A0038

Meng, D., Kumar, S.K., Cheng, S., Grest, G.S. (2013) "Simulating the Miscibility of Nanoparticles and Polymer Melts" Soft Matter: 9, 5417 C2010A900

Mitrofanov, O., Yu, W., Thompson, R.J., Jiang, Y., Brener, I., Pan, W., Berger, C., de Heer, W.A., Jiang, Z. (2013) "Probing terahertz surface plasmon waves in graphene structures" Applied Physics Letters: 103, 111105 RA2012A0025

Monclus, M.A., Zheng, S.J., Mayeur, J.R., Beyerlein, I.J., Mara, N.A., Polcar, T., Lorca, J., Molina-Aldareguia, J.M. (2013) "Optimum high temperature strength of two-dimensional nanocomposites" Applied Physics Letters Materials: 1, 5

Mook, W.M., Raghavan, R., Baldwin, J.K., Frey, D., Michler, J., Mara, N.A., Misra, A., Zheng, S. (2013) "Indentation fracture response of Al-TiN nanolaminates" Materials Research Letters: 1-7 RA2012A0023

Nelson, T., Fernandez-Alberti, S., Roitberg, A.E., Tretiak, S. (2013) "Artifacts due to trivial unavoided crossings in the modeling of photoinduced energy transfer dynamics in extended conjugated molecules" Chemical Physics Letters: 590, 208-213 U2010B1045

Nelson, T., Fernandez-Alberti, S., Roitberg, A.E., Tretiak, S. (2013) "Conformational Disorder in Energy Transfer: Beyond Forster Theory" Physical Chemistry Chemical Physics: 15, 9245-9256 U2010B1045

Nelson, T., Fernandez-Alberti, S., Roitberg, A.E., Tretiak, S. (2013) "Nonadiabatic Excited-State Molecular Dynamics: Treatment of Electronic Decoherence" The Journal of Chemical Physics: 138, 224111 U2010B1045

Neuner III, B., Wu, C., Ten Eyck, G., Sinclair, M., Brener, I., Shvets, G. (2013) "Efficient infrared thermal emitters based on low-albedo polaritonic meta-surfaces" Applied Physics Letters: 102, 2111111 C2012A0095

Nguyen, B.M., Yoo, J., Dayeh, S.A., Schuele, P., Evans, D., Picraux, S.T. (2013) "Design of Radial p–i–n Silicon Nanowires for High-Performance Solar Cells" The Wonder of Nanotechnology: Quantum Optoelectronic Devices and Applications M. Razeghi. L. Esaki, and K. von Klitzing, Eds., SPIE Press, Bellingham, WA, pp. 823-842 C2012A0014

Niu, X., Stagon, S.P., Huang, H., Baldwin, J. K., Misra, A. (2013) "Smallest Metallic Nanorods Using Physical Vapor Deposition" Physical Review Letters 110, 13

Obliosca, J.M., Liu, C., Batson, R.A., Babin, M.C., Werner, J.H., Yeh, H.C. (2013) "DNA/RNA detection using DNA-templated few-atom silver nanoclusters" Biosensors: 3, 185-200 U2010A916

Ou, Y., Sokoloff, J.B., Stevens, M.J. (2013) "Molecular dynamics simulation studies of two grafted polyelectrolyte polymer hydrogels pressed in contact" Journal of Chemical Physics: 139, 144902 C2010B1067

Paxton, W. F., Price, D., Richardson, N. J. (2013) "Hydroxide ion flux and pH-gradient driven ester hydrolysis in polymer vesicle reactors," Soft Matter, 9, 11295-11302. (SAND#2013-4575 J) User proposal RA2012A0003

Petty, J.T., Sergev, O.O., Nicholson, D.A., Goodwin, P.M., Giri, B., McMullan, D.R. (2013) "A silver cluster—DNA equilibrium" Analytical Chemistry: 85, 9868-9876 U2011B34

Prenzel, T., Mehner, A., Lucca, D.A., Qi, Y., Harriman, T.A., Mutlugünes, Y, Shojaee, S.A., Wang, Y.Q., Williams, D., Nastasi, M., Zoch, H.-W., Swiderek, P. (2013) "Chemical and mechanical properties of silica hybrid films from NaOH catalyzed sols for micromachining with diamond cutting tools" Thin Solid Films: 531, 208-216. C2010B1100

Qin, Q., Han, N., Kao, W., Reno, J.L., Hu, Q., (2013) "An effective mode selector for tunable terahertz wire-lasers," Optics Letters: 38, 407. C2010B1033

Ramani, S., Reiten, M.T., Colestock, P.L., Taylor, A.J., Azad, A.K., O'Hara, J.F. (2013) "Electromagnetic response of finite terahertz metafilm arrays excited on total internal reflection boundaries," IEEE Transactions on Terahertz Science and Technology: 3, 6, 709-720

Ramirez, J., Mayo, M.L., Tretiak, S., Kilina, S. (2013) "Electronic structure calculations and optical spectra of semiconducting carbon nanotube functionalized by diazonium systems" Chemical Physics: 413, 89-101 U2010B1108

Ran, L., Antoniou, A. (2013) "A relationship between geometrical structure of nanoporous metal foam and its modulus" Acta Materialia: 61, 7, 2390 U2012A0107

Rivadulla, F., Bi, Z.X., Bauer, E., Murias, B.R., Vila-Fungueirino, J.M., Jia, Q.X. (2013) "Strain-induced ferromagnetism and magnetoresistance in epitaxial thin films of $LaCoO_3$ prepared by polymer assisted deposition," Chemistry of Materials: 25, 55-58 U2011B104

Rui, C., Chen, R., Song, J., Jungwoo, S., et al. (2013) "Terahertz detection with nanoscale semiconductor rectifiers" IEEE Sensors Journal: 13, 1

Seo, M.A., Yoo, J., Perea, D.E., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P. (2013) "Tracking ultrafast dynamics in molecules, nanostructures, and interfaces" 18th International Conference on Ultrafast Phenomena, M. Chergui, A. J. Taylor eds, Oxford University Press: p. 04030

Shafiei, F., Wu, C., Putzke, P., Wu, Y., Singh, A., Li, X., Shvets, G. (2013) "Plasmonic nano-protractor based on polarization spectro-tomography" Nature Photonics: 7, 367 C2012A0095

Shelnutt, J.A., Tian, Y., Martin, K.M., Medforth, C.J. (2013) "Binary ionic porphyrin nanomaterials for energy from sunlight" Handbook of porphyrin science: 2 C2011A1013

Staude, I., Miroshnichenko, A.E., Decker, M., Fofang, N.T., Liu, S., Brener, I. (2013) "Tailoring Directional Scattering through Magnetic and Electric Resonances in Subwavelength Silicon Nanodisks" ACS Nano: 7, 7824 U2012A0053

Stevens, M.J., McIntosh, D.B., Saleh, O.A. (2013) "Simulations of Stretching a Strong, Flexible Polyelectrolyte: Using long chains to access the Pincus Scaling Regime" Macromolecules: 46, 636 C2011B66

Su, Q., Yoon, D., Sisman, Z., Khatkhatay, F., Jia, Q.X., Manthiram, A., Wang, H. (2013) "Vertically aligned nanocomposite $La_{0.8}Sr_{0.2}MnO_{3-\square}/Zr_{0.92}Y_{0.08}O_{1.96}$ thin films as electrode/electrolyte interfacial layer for solid oxide reversible fuel cells," International Journal of Hydrogen Energy: 38, 16320-16327 C2010B1039

Sun, C., Bufford, D., Chen, Y.X., Kirk, M., Wang, Y.Q., Li, M.M., Wang, H.Y., Maloy, S., Zhang, X.H. (2013) "In situ study of defect migration kinetics in nanoporous Ag with enhanced radiation tolerance" Scientific Reports: 4, 3737 C2013A0005

Sun, Y., Padbury, R.P., Akyildiz, H.I., Goertz, M.P., Palmer, J.A., Jur, J.S. (2013) "Influence of subsurface hybrid material growth on the mechanical properties of atomic layer deposited thin films on polymers" Chemical Vapor Deposition: 19, 134-141 U2011A1059

Tang, W., Dayeh, S.A., Picraux, S.T., Huang, J., Tu, K.N. (2013) "Nucleation and Atomic Layer Reaction in Nickel Silicide for Defect-engineered Si Nanochannels" Nano Letters: 13,2748 C2011A1023

Tang, W., Dayeh, S.A., Picraux, S.T., Liu, X., Huang, J., Tu, K.N. (2013) "Gold Catalyzed Ni Disilicide Formation in Si Nanowires: A New Solid-Liquid-Solid (SLS) Phase Growth Mechanism" Nano Letters:13, 6009 C2011A1023

Thomas, J.C., Van der Ven, A., Millunchick, J., Modine, N.A. (2013). "Considerations for surface reconstruction stability prediction on GaAs(001)." Physical Review B: 87: 075320 C2012A0028

Vanderhoef, Azad, A.K., Bomberger, C.C., Chowdhury, D.R.., Chase, D.B., Taylor, A.J., Zide, J.M.O., Doty, M.F. (2013) "Charge carrier relaxation processes in TbAs nanoinclusions in GaAs measured by optical-pump THz-probe transient absorption spectroscopy" Physical Review B: 89, 045418 C2010A950

Wang, J.W., He, Y., Fan, F., Liu, X.H., Xia, S., Liu, Y., Harris, C.T., Li, H., Huang, J.Y., Mao, S.X., Zhu, T. (2013) "Two-Phase Electrochemical Lithiation in Amorphous Silicon" Nano Letters: 13, 709 C2012A0045

Wang, J.W., Narayanan, S., Huang, J.Y., Liu, Y., Sun, S., Zhang, Z., Mao, S.X. (2013) "Atomic-scale dynamic process of deformation-induced stacking fault tetrahedral in gold nanocrystals" Nature Communications: 4, 2340 C2010B1063

Wang, J.W., Sansoz, F., Huang, J.Y., Zhang, Z., Zhu, T., Mao, S.X. (2013) "Near-ideal theoretical strength in gold nanowires containing angstrom scale twins" Nature Communications: 4, 1742 C2010B1063

Wright, J., Liu, S., Wang, G., Brener, I. (2013) "Multi-colour Nanowire Photonic Crystal Laser Pixels" Scientific Report: 3, 2982 C2012A0024

Xiao, S., Xiang, S., et al. (2013) "Talking through the continuum: new manifestations of Fano-resonance phenomenology realized with mesoscopic nanostructures" Fortschritte DerPhysik- Progress of Physics: 61, 2-3

Xu, Y., Chen, G., Fu, E., Zhou, M., Dunwell, M., Fei, L., Deng, S.G., Andersen, P., Wang, Y.Q., Jia, Q.X., Civale, L. (2013) "Nickel substituted $LiMn_2O_4$ cathode with durable high-rate capability for Li-ion batteries," Royal Society of Chemistry Advances: 3, 18441-18445 C2011B101

Yang, Z.B., Chen, T., He, R.X., Li, H.P., Lin, H.J., Li, L., Zou, G.F., Jia, Q.X., Peng, H.S. (2013) "A novel carbon nanotube/polymer composite film for counter electrodes of dye-sensitized solar cells," Polymer Chemistry: 4, 1680-1684 U2010A895

Yeager, J.D., Ramos, K.J., Pesce-Rodriguez, R.A., Piraino-Haynes, S. (2013) "Microstructural effects of processing in the explosive composition A-3" Materials Chemistry and Physics: 139, 1 C2011A1060

Yoo, J., Dayeh, S.A., Tang, W., Picraux, S.T. (2013) "Epitaxial growth of radial Si p-i-n junctions for photovoltaic applications" Applied Physics Letters: 102, 093113

Yoo, J., Ma, X., Tang, W., Yi, G.C. (2013) "Metal-lined semiconductor nanotubes for surface plasmon-mediated luminescence enhancement" Nano Letters: 13, 2134-2140

Yu, K. Y., Bufford, D., Chen, Y., Liu, Y., Wang, H., Zhang, X., (2013) "Basic criteria for formation of growth twins in high stacking fault energy metals." Applied Physics Letters: 103 (18), 181903. C2013B0013.

Yu, K., Liu, Y., Fu, E., Wang, Y., Myers, M., Wang, H., Shao, L., Zhang, X. (2013) "Comparisons of radiation damage in He ion and proton irradiated immiscible Ag/Ni nanolayers" Journal of Nuclear Materials: 440, 310 U2012A0032

Zaslavsky, A., Wan, J., Le, S.T., Jannaty, P., Cristoloveanu, S., Le Royer, C., Perea, D.E., Dayeh, S.A., Picraux, S.T. (2013) "Sharp-switching high-current tunneling devices" Electrochemical Society

Transcripts: 53, 5, 63-74 C2011A1067

Zhong, L., Mitchell, R.R., Liu, Y., Gallant, B.M., Thompson, C.V., Huang, J.Y., Mao, S.X., Shao-Horn, Y. (2013) "In situ Transmission Electron Microscopy Observations of Electrochemical Oxidation Li2O2" Nano Letters: 13, 2209 C2010B1063

Zhu, Y.Y., Chen, A., Zhou, H., Zhang, W., Narayan, J., MacManus-Driscoll, J.L., Jia, Q.X., Wang, H. (2013) "Research updates: Epitaxial strain relaxation and associated interfacial reconstructions: The driving force for creating new structures with integrated functionality," APL Materials: 1, 050702 U2011B3

Zhu, Y., Wang, J. W., Liu, Y., Liu, X., Kushima, A., Liu, Y., Xu, Y., Mao, S. X., Li, J., Wang, C., Huang, J. Y. (2013) "In Situ Atomic-Scale Imaging of Phase Boundary Migration in $FePO_4$ Microparticles During Electrochemical Lithiation" Advanced Materials: 25: 5461–5466. U2010B1073

Zhu, Z., Zhu, J (2013) "Singularity in self-energy and composite fermion excitations of interacting electrons" Physical Review B: Phys. Rev. B 87, 085120. C2011A1070

Zou, G.F., Zhao, J., Luo, H.M., McCleskey, T.M., Burrell, A.K., Jia, Q.X. (2013) "Polymer-assisted-deposition: a chemical solution route for a wide range of materials" Chemical Society Review: 42, 439 U2012B0011

Citations for 2014 (234 Total)

CINT Science (45)

Ahmed, T., Haraldsen, J., Zhu, J.X., Balatsky, A. (2014) "Next generation epigenetic detection technique: identifying methylated cytosine using graphene nanopore" Journal of Physical Chemistry Letters: 5, 2601

Benz, A., Campione, S., Moseley, M.W., Wierer, J.J., Allerman, A.A., Wendt, J.R., Brener, I. (2014) "Optical strong coupling between near-infrared metamaterials and intersubband transitions in III-nitride heterostructures" ACS Photonics: 1, 10

Bolintineanu, D.S., Grest, G.S., Lechman, J.B., Pierce, F., Plimpton, S.J., Schunk, P.R. (2014) "Particle dynamics modeling methods for colloid suspensions" Computational Particle Mechanics: 1, 321

Bolintineanu, D.S., Lane, J.M.D., Grest, G.S. (2014) "Effects of functional groups and ionization on the structure of alkanethiol coated gold nanoparticles" Langmuir: 30, 11075

Coughlin, J.E., Bakus, R.C., van der Poll, T.S., Welch, G.C., Zhugayevych, A., Teat, S.J., Bazan, G.C., Tretiak, S. (2014) "Polymorphism of crystalline molecular donors for solution-processed organic photovoltaics" Journal of Physical Chemistry C: 118, 15610

Dowden, P.C., Bi, Z., Jia, Q.X. (2014) "Method for controlling energy density for reliable pulsed laser deposition of thin films" Review of Scientific Instruments: 85, 025111

Efimov, A. (2014) "Intuitive model for the scintillations of a partially coherent beam" Optics Express: 22, 26

Efimov, A. (2014) "Spatial coherence at the output of multimode optical fibers" Optics Express: 22, 13

Efimov, A., Velizhanin, K., Gelikonov, G. (2014) "Simultaneous scintillation measurements of coherent and partially coherent beams in an open atmosphere experiment" Proceedings of SPIE: 8971 U2013A0032

Fransson, J., Ren, J., Zhu, J.X. (2014) "Electrical and thermal control of magnetic exchange interactions" Physical Review Letters: 113, 257201

Goodwin, P.M., Bartram, B.D., Gibson, L.L., Wu, M., Dattelbaum, D.M. (2014) "Non-invasive timing of gas gun projectiles with light detection and ranging" Journal of Physics: Conference Series: 500, 14

Henderson, I.M., Adams, P.G., Montano, G.A., Paxton, W.F. (2014) "Ionic effects on the behavior of thermoresponsive PEO-PNIPAAm block copolymers" Journal of Polymer Science Part B- Polymer Physics: 52, 7

Hendrickson, S.M., Foster, A.C., Camacho, R.M., Clader, B.D. (2014) "Integrated nonlinear photonics: emerging applications and ongoing challenges" Journal of the Optical Society of America B: 31, 3193

Hollingsworth, J.A. (2014) "Nanoscale engineering facilitated by controlled synthesis: From structure to function" Coordin. Chem. Review: 197, 263-264

Ji, Z., Wu, R., Adamska, L., Velizhanin, K., Doorn, S.K., Sykora, M. (2014) "In-situ synthesis of graphene molecules on TiO2. Application in sensitized solar cells" ACS Applied Materials and Interfaces: 6, 20473

Lane, J.M.D., Grest, G.S. (2014) "Aggregation of responsively-shaped coated nanoparticles at water/vapor interfaces" Nanoscale: 6, 5132

Lai, L.F., Love, J.A., Sharenko, A., Coughlin, J.E., Gupta, V., Tretiak, S., Nguyen, T.Q., Wong, W.Y., Bazan, G.C. (2014) "Topological considerations for the design of molecular donors with multiple absorbing units" Journal of the American Chemical Society: 136, 5591

Lee, J., Prasankumar, R.P. (2014) "Correlation between quantum charge fluctuations and magnetic ordering in multiferroic LuFe2O4" European Physics Journal B: 87, 267

Lei, Q.Y., Golalikhani, M., Yang, D., Withanage, W., Rafti, A., Qiu, J., Hambe, M., Bauer, E., Ronning, F., Jia, Q.X., Weiss, J., Hellstrom, E., Wang, X., Chen, X.H., Williams, F., Yang, Q., Temple, D., Xi, X.X. (2014) "Structural and transport properties of epitaxial Ba(Fe1-xCox)2As2 thin films on various substrates" Superconducting Science and Technology: 27, 115010

Leuth, C.A., Bolintineanu, D.S., Stevens, M.J., Frischknecht, A.L. (2014) "Hydrogen-bonded aggregates in precise acid copolymers" Journal of Chemical Physics: 140, 054902

McCleskey, T.M., Shi, P., Bauer, E., Highland, M.J., Eastman, J.A., Bi, Z.X., Fuoss, P.H., Baldo, P.M., Ren, W., Scott, B.L., Burrell, A.K., Jia, Q.X. (2014) "Nucleation and growth of epitaxial metal-oxide films based on polymer-assisted deposition" Chemical Society Review: 43, 2141

McGrane, S.D., Moore, D.S., Goodwin, P.M., Dattelbaum, D.M. (2014) "Quantitative tradeoffs between spatial, temporal, and thermoelectric resolution of nonresonant raman thermometry for dynamic experiments" Applied Spectroscopy: 68, 11

Pan, L., Li, J., Tai, Y.Y., Graf, M.J., Zhu, J.X., Ting, C.S. (2014) "Evolution of quasiparticle states without a Zn impurity in doped 122 iron pnictides" Physical Review B: 90, 134501

Paranthaman, M.P., Aytug, T., Stan, L., Jia, Q.X., Cantoni, C., Wee, S.H. (2014) "Chemical solution derived planarization layers for highly aligned IBAD-MgO templates" Superconducting Science and

Technology: 27, 022002

Pietryga, J.M., Hollingsworth, J.A. (2014) "Mid-infrared emitting lead selenide nanocrystal quantum dots" Inorganic Syntheses: 36, 198

Ren, J., Zhu, J.X. (2014) "Assymetric Andreev reflection induced Hall-like effects in metal/anisotropic superconductor junctions" Physics Review B: 89, 064512

Salerno, K.M., Bolintineanu, D.S., Lane, J.M., Grest, G.S. (2014) "High Strength, Molecularly Thin Nanoparticle Membranes" Physical Review Letters: 113, 258301

Salerno, K.M., Ismail, A.E., Lane, J.M.D., Grest, G.S. (2014) "Coating thickness and coverage effects on the forces between silica nanoparticles in water" Journal of Chemical Physics: 140, 194904

Sheu, Y.M., Trugman, S.A., Yan, L., Qi, J., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2014) "Polaronic transport induced by competing interfacial magnetic order in a La.7Ca.3MnO3/BiFeO3 heterostructure" Physical Review X: 4, 021001

Sheu, Y.M., Trugman, S.A., Yan, L., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2014) "Using ultrafast optical pulses to couple ferroelectric and ferromagnetic order in an oxide heterostructure" Nature Communications: 5, 5832

Sista, P., Ghosh, K., Martinez, J.S., Rocha, R.C. (2014) "Polythiophenes in biological applications" Journal of Nanoscience and Nanotechnology: 14, 1

Staruch, M., Cil, K., Silva, H., Xiong, J., Jia, Q.X., Jain, M. (2014) "Effect of Mn doping on the properties of sol-gel derived Pb0.3Sr0.7TiO3 thin films" Ferroelectrics: 470, 227

Sutter, E., Jungjohann, K., Bliznakov, S., Courty, A., Maisonhaute, E., Tenney, S., Sutter, P. (2014) "In situ liquid-cell electron microscopy of silver-palladium galvanic replacement reactions on silver nanoparticles" Nature Communications: 5, 4946

Van der Poll, T.S., Zhugayevych, A., Chertkov, E., Bakus, R.C., Coughlin, J., Teat, S.J., Bazan, G.C., Tretiak, S. (2014) "Polymorphism of crystalline molecular donors for solution-processed organic photovoltaics" Journal of Physical Chemistry Letters: 5, 2700

Wang, F., Wei, Q.H., Htoon, H. (2014) "Generation of steep phase anisotropy with zero-backscattering by arrays of coupled dielectric nano-resonators" Applied Physics Letters: 105, 12112

Watkins, E.B., Kashinath, A., Wang, P., Baldwin, J.K., Majewski, J., Demkowicz, M.J. (2014) "Characterization of a Fe/Y2O3 metal/oxide interface using neutron and x-ray scattering" Applied Physics Letters: 105, 041601

White, A.J., Gorshkov, V.N., Wang, R., Tretiak, S., Mozyrsky, D. (2014) "Semiclassical monte-carlo: A first principles approach to nonadiabatic molecular dynamics" Journal of Physical Chemistry: 141, 184101

Xiong, J., Matias, V., Tao, B.W., Li, Y.R., Jia, Q.X. (2014) " Ferroelectric and ferromagnetic properties of epitaxial BiFeO3-BiMnO3 films on ion-beam-assisted deposited TiN buffered flexible Hastelloy" Journal of Applied Physics: 115, 17

Zhang, J., Zhang, Y., Mara, N.A., Nicola, L., Lou, J. (2014) "Nanoimprinting of single crystalline gold: experiments and dislocation simulations" Applied Surface Science: 290, 301

Zhang, P., Goodwin, P.M., Werner, J.H. (2014) "Fast 3D imaging via confocal line scanning of a Bessel beam using a single galvo mirror" Proceedings of SPIE: 8947

Zhang, P., Goodwin, P.M., Werner, J.H. (2014) "Interferometric three-dimensional single molecule localization microscopy using a single high numerical-aperture objective" Applied Optics: 53, 31

Zhang, P., Goodwin, P., Werner, J. (2014) "Fast, super resolution imaging via Bessel-beam stimulated emission depletion microscopy" Optics Express: 22, 10

Zhang, P., Phipps, M., Goodwin, P., Werner, J. (2014) "Confocal line scanning of a Bessel beam for fast 3D imaging" Optics Letters: 39, 12

Zhernenkov, M., Gill, S., Stanic, V., DiMasi, E., Kisslinger, K., Baldwin, J.K., Misra, A., Demkowicz, M.J., Ecker, L. (2014) "Design of radiation resistant metallic multilayers for advanced nuclear systems" Applied Physics Letters: 104, 241906

Zhu, J.X., Janoschek, M., Rosenberg, R., Ronning, F., Thompson, J.D., Torrez, M.A., Bauer, E.D., Batista, C.D. (2014) "LDA+DMFT approach to magnetocrystalline anisotropy of strong magnets" Physics Review X: 4, 021027

CINT User Science - Internal (57)

Acharya, K.P., Ji, Z., Holesinger, T.G., Crisp, J.A., Ivanov, S.A., Williams, D.J., Casson, J.L., Sykora, M., Hollingsworth, J.A. (2014) "Layer-by-layer fabrication of nanowire sensitized solar cells: geometry-independent integration" Advanced Functional Materials: 24, 43. RA2013A0030

Aguiar, J.A., Dholabhai, P.P., Bi, Z., Jia, Q.X., Fu, E., Wang, Y., Aoki, T., Zhu, J. (2014) "Probing defect-boundary interactions at oxide interfaces" Journal of Materials Research: 29, 1699-1710

Aguiar, J.A., Dholobhai, P.P., Bi, Z., Jia, Q.X., Fu, E.G., Wang, Y.Q., Aoki, T., Zhu, J., Misra, A., Uberuaga, B.P. (2014) "Linking interfacial step structure and chemistry with locally enhanced radiation-induced amorphization at oxide heterointerfaces" Advanced Material Interfaces: 1, 1300142

Aguiar, J.A., Zhuo, M., Bi, Z., Fu, E., Wang, Y., Dholabhai, P.P., Misra, A., Jia, Q., Uberuaga, B.P. (2014) "Orientation-specific amorphization and intercalated recrystallization at ion-irradiated SrTiO3/MgO interfaces" Journal of Materials Research: 10, 1557

Ardeljan, M., Knezevic, M., Nizolek, T., Beyerlein, I.J., Zheng, S.J., Carpenter, J.S., McCabe, R.J., Mara, N.A., Pollock, T.M. (2014) "A multi-scale model for texture development in Zr/Nb nanolayered composites processed by accumulative roll bonding" Materials Science and Engineering: 63, 012170. U2011B27

Balog, E.R.M., Ghosh, K., Park, Y.I., Hartung, V., Sista, P., Rocha, R.C., Wang, H.L., Martinez, J.S. (2014) "Optical properties of a pH-sensitive and thermoresponsive hydrogel made from a genetically engineered polymer and phenylene vinylene oligomer" Journal of Physical Chemistry Letters C2013A0022

Beyerlein, I.J., Mayeur, J.R., McCabe, R.J., Zheng, S.J., Carpenter, J.S., Mara, N.A. (2014) "Influence of slip and twinning on the crystallographic stability of bimetal interfaces in nanocomposites under deformation" Acta Materialia: 72, 137-147

Branch, B., Dubey, M., Anderson, A.S., Artyushkova, K., Baldwin, J. K., et al. (2014) "Investigating phosphonate monolayer stability on ALD oxide surfaces" Applied Surface Science 288, 98-108

Bussmann, E., Rudolph, M., Subramania, G., Misra, S., Carr, S.M., Langlois, E., Dominguez, J., Ten Eyck, G., Pluym, T., Lilly, M., Carroll, M.S. (2014) "Scanning capacitance microscopy registration of buried atomic-precision donor devices" Nanotechnology: 26, 085701 U2013B0148

Campione, S., Benz, A., Sinclair, M.B., Capolino, F., Brener, I. (2014) "Second harmonic generation from metamaterials strongly coupled to intersubband transitions in quantum wells" Applied Physics Letters: 104, 131104 RA2013A0026

Caro, M., Mook, W.M., Fu, E.G., Wang, Y.Q., Sheehan, C., Martinez, E., Caro, A. (2014) "Radiation induced effects on mechanical properties of nanoporous gold foams" Applied Physics Letters: 104, 23

Carpenter, J.S., McCabe, R.J., Zheng, S.J., Wynn, T.A., Mara, N.A., Beyerlein, I.J. (2014) "Processing parameter influence on texture and microstructural evolution in Cu-Nb multilayer composites fabricated via accumulative roll bonding" Metallurgical and Materials Transactions A: 45, 4 RA2012B0013

Carpenter, J.S., Nizolek, T., McCabe, R.J., Zheng, S.J., Scott, J., Vogel, S.C., Mara, N.A., Pollock, T., Beyerlein, I.J. (2014) "The suppression of instabilities via biphase interfaces during bulk fabrication of nanograined Zr" Materials Research Letters: 10.1080 U2013B0110

Chowdhury, D.R., Su, X., Zeng, Y., Chen, X., Taylor, A.J., Azad, A. (2014) "Excitation of dark plasmonic modes in symmetry broken terahertz metamaterials" Optics Express: 22, 19401 U2011A1082

Chowdhury, D.R., O'Hara, J. F., Taylor, A. J., Azad, A.K. (2014) "Orthogonally twisted planar concentric split ring resonators towards strong near field coupled terahertz metamaterials" Applied Physics Letters: 104, 101105 U2011A1082

Cobb, J., Vachhani, S., Dickerson, R.M., Dickerson, P.O., Han, W.Z., Mara, N.A., Schneider, J. (2014) "Layer stability and material properties of friction stir welded Cu-Nb nanolamellar composite plates" Materials Research Letters: 1, 1-6 RA2014A0000

Coltrin, M.E., Armstrong, A.M., Brener, I., Chow, W.W., Crawford, M.H., Fischer, A.J., Kelley, D.F., Koleske, D.D., Lauhon, L.J., Martin, J.E., Nyman, M., Schubert, E.F., Shea-Rohwer, L.E., Subramania, G., Tsao, J.Y., Wang, G.T., Wierer, J.J., Wright, J.B. (2014) "Energy frontier research center for solid-state lighting science: exploring new materials architectures and light emission phenomena" Journal of Physical Chemistry C: 118, 13330

Crooker, S.A., Liu, F., Kelley, M.R., Martinez, N.J.D., Nie, W., Mohite, A., Nayyar, I.H., Tretiak, S., Smith, D.L., Ruden, P.P. (2014) "Spectrally-resolved hyper ne interactions between polaron and nuclear spins in organic light emitted diodes: Magneto-electroluminescence studies" Applied Physics Letters: 105, 153304

Dyer, G.C., Aizin, G.R., Allen, S.J., Grine, A.D., Bethke, D., Reno, J.L., Shaner, E.A. (2014) "Coherent phenomena in terahertz 2d plasmonic structures: strong coupling, plasmonic crystals, and induced transparency by coupling of localized modes" Terahertz physics, devices, and systems VIII: Advanced Applications in Industry and Defense: 9102 U2013B0053

Dyer, G.C., Aizin, G.R., Allen, S.J., Grine, A.D., Bethke, D., Reno, J.L., Shaner, E.A. (2014) "Interferometric measurement of far infrared plasmons via resonant homodyne mixing" Optics Express: 22, 13 RA2009B068

Eftink, B.P., Mara, N.A., Kingstedt, O.T., Safarik, D.J., Lambros, J., Robertson, I.M. (2014) "Anomalous deformation twinning in coarse-grained Cu in Ag60Cu40 composites under high strain-rate compressive loading" Materials Science & Engineering A: 618, 254

Ekiz, H.E., Lach, T., Averback, R.S., Mara, N.A., Beyerlein, I.J., Pouryazdan, M., Hahn, H., Bellon, P. (2014) "Microstructural evolution of nanolayered Cu-Nb composites subjected to high pressure torsion" Acta Materialia: 72, 178

Gao, Y., Roslyak, O., Dervishi, E., Karan, N.S., Ghosh, Y., Sheehan, C.J., Wang, F., Gupta, G., Mohite, A., Dattelbaum, A.M., Doorn, S.K., Hollingsworth, J.A., Piryatinski, A., Htoon, H. (2014) " Hybrid graphene-giant nanocrystal quantum dot assemblies with highly efficient biexciton emission" Advanced Optical Materials: 10.1002 U2013B0037

Ghosh, K., Balog, E.R.M., Sista, P., Williams, D.J., Kelly, D., Martinez, J.S., Rocha, R.C. (2014) "Temperature-dependent morphology of hybrid nanoflowers from elastin-like polypeptides" APL Materials: 2, 021101

Gilbertson, S.M., Durakiewicz, T., Dakovski, G.L., Li, Y., Zhu, J.X., Conradson, S.D., Trugman, S.A., Rodriguez, G. (2014) "Ultrafast photoemission spectroscopy of the uranium dioxide UO2 Mott insulator: Evidence for a robust energy gap structure" Physical Review Letters: 112, 87402

Guclu, C., Luk, T.S., Wang, G.T., Capolino, F. (2014) "Radiative emission enhancement using nano-antennas made of hyperbolic metamaterial resonators" Applied Physics Letters: 105

Han, J.J., Kunde, Y.A., Hong-Geller, E., Werner, J.H. (2014) "Actin restructuring during salmonella typhimurium infection investigated by confocal and super resolution micrscopy" Journal of Biomedical Optics: 19, 1

Hensley, J., Cederberg, J.G., Bethke, D.T., Grine, A.D., Shaner, E.A. (2014) "Heterogenous metasurface for high temperature selective emission" Applied Physics Letters: 105, 8

Kappera, R., Voiry, D., Yalcin, S.E., Jen, W., Acerce, M., Torrel, S., Branch, B., Lei, S., Chen, W., Najmaei, S., Lou, J., Ajayan, P.M., Gupta, G., Mohite, A.D., Chhowalla, M. (2014) "Metallic 1T phase source/drain electrodes for field effect transistors from chemical vapor deposited MoS2" APL Materials: 2, 092516 U2012B0055

Kaul, A.M., Ivanovsky, A.V., Atchison, W.L., Petrukhin, A.A., Duday, P.V., Griego, J.R., Salazar, M., Nadezhin, S.S., Tyupanova, O.A., Oro, D.M., Holtkamp, D.B., Rodriguez, G., Tabaka, L.J., Kraev, A.I., Skobelev, A.N., Westley, D.T., Anderson, B.G., Ivanov, V.A., Glybin, A.M., Kuzyaev, A.I., Stone, J.B., Payton, J.R., Goodwin, P.M., McCulloch, Q., Montoya, R.R., Dudin, V.I., Zimenkov, A.A., Randolph, R.B., Fierro, F., Reinovksy, R.E., Rousculp, C.L., Balandina, A.N., Podurets, A.M. (2014) "Damage growth and recollection in aluminum under axisymmetric convergence using a helical flux compression generator" Journal of Applied Physics: 115, 023516 RA2011A1268

Knezevic, M., Nizolek, T., Ardeljan, M., Beyerlein, I.J., Mara, N.A., Pollock, T.M. (2014) "Texture evolution in two-phase Zr/Nb lamellar composites during accumulative roll bonding" International Journal of plasticity: 57, 16-28

Lei, S., Ge, L., Najmaei, S., George, A., Kappera, R., Lou, J., Chhowalla, M., Yamaguchi, H., Gupta, G., Vajtai, R., Mohite, A.D., Ajayan, P.M. (2014) "Evolution of the electronic band structure and efficient photo-detection in atomic layers of InSe" ACS Nano: 8, 2 U2012B0028

Li, N., Hattar, K., Misra, A. (2013) "In situ Probing of the Evolution of Irradiation-Induced Defects in Copper", Journal of Nuclear Materials: 439, 185. C2013A0036.

Li, N., Wang, J., Wang, Y.Q., Serruys, Y., Nastasi, M., Misra, A. (2013) "Σ3 Grain Boundary Migration Induced by Ion Irradiation", Journal of Applied Physics: 113, 023508. C2013A0036.

Liontas, R., Gu, X.W., Fu, E., Wang, Y., Li, N., Mara, N.A., Greer, J.R. (2014) "Effects of Helium Implantation on the tensile properties and microstructure of Ni73P27 Metallic glass nanostructures" Nano Letters: 14, 5176

Luk, T.S., Fofang, N.T., Cruz-Campa, J.L., Frank, I., Campione, S. (2014) "Surface plasmon polariton enhanced ultrathin nano-structured CdTe solar cell" Optics Express: 22, 1372

Ma, X., Adamska, L., Yamaguchi, H., Yalcin, S.E., Tretiak, S., Doorn, S.K., Htoon, H. (2014) "Electronic structure and chemical nature of oxygen dopant states in carbon nanotubes" ACS Nano: 8, 10782

Ma, X., Wang, F., Roslyak, O., Duque, J.G., Piryatinski, A., Doorn, S.K., Htoon, H. (2014) "Influence of exciton dimensionality on spectral diffusion of single-walled carbon nanotubes" ACS Nano: 8, 10613 U2010A944 722

Mangum, B.D., Wang, F., Dennis, A.M., Gao, Y., Ma, X., Hollingsworth, J.A., Htoon, H. (2014) "Competition between auger recombination and hot-carrier trapping in Pl intensity fluctuations of type Li Nanocrystals" Small: 10, 14 U2012B0040 1287

Mara, N.A., Beyerlein, I.J. (2014) "Review: Effect of bimetal interface structure on the mechanical behavior of Cu/Nb nanolayered composites" Journal of Materials Science: 49, 6497 U2008B092 419

McCabe, R.J., Beyerlein, I.J., Carpenter, J.S., Mara, N.A., (2014) "The critical role of grain orientation and applied stress in nanoscale twinning" Nature Communications: 5, 3806

Modine, N.A., Wright, A.F., Lee, S.R. (2014) "Bounds on the range of density-functional-theory point-defect levels in semiconductors and insulators" Computational Materials Science: 92, 431 U2013B0025

Nizolek, T., Mara, N.A., Beyerlein, I.J., Avallone, J.T., Scott, J.E., Pollock, T.M. (2014) "Processing and deformation behavior of bulk Cu-Nb nanolaminates" Metallography, Microstructure, and Analysis: 3, 6

Park, Y.I., Postupna, O., Zhugayevych, A., Kyu, W.S., Park, Y.S., Park, B., Park, J., Martinez, J.S., Tretiak, S., Wang, H.L. (2014) "A new pH sensitive fluorescent and white light emissive material through controlled intermolecular charge transfer" Chemical Science: 6, 789-797

Pena-Rodriguez, O., Caro, M., Rivera, A., Olivares, J., Perlado, J.M., Caro, A. (2014) "Optical properties of Au-Ag alloys: An ellipsometric study" Optical Materials Express: 4, 2 C2012A0092

Quan, Z., Xu, H., Wang, C., Wen, X., Wang, Y., Zhu, J., Li, R., Sheehan, C.J., Wang, Z., Smilgies, D., Luo, Z., Fang, J. (2014) "Solvent-mediated self-assembly of nanocube superlattices" Journal of the American Chemical Society: 136, 1352-1359 RA2014A0006

Ribaudo, T., Taylor, A.J., Nguyen, B.M., Bethke, D., Shaner, E.A. (2014) "High Efficiency Reflective Wave Plates in the Midwave Infrared" Optics Express: 22, 3, 2821 C2013A0099

Rudolph, M., Carr, S.M., Subramania, G., Ten Eyck, G., Dominguez, J., Pluym, T., Lilly, M.P., Carroll, M.S., Bussmann, E. (2014) "Probing limits of STM field emission patterned Si:P-doped devices" Applied Physics Letters: 105, 163110 C2013B0052

Selby, N.S., Crawford, M., Tracy, L., Reno, J.L., Pan, W. (2014) "In-situ biaxial rotation at low-temperatures in high magnetic fields" Review of Scientific Instruments: 85, 9 U2012B0085

Small, L.J., Wolf, S., Spoerke, E.D. (2014) "Exploring Electrochromics: A series of eye-catching experiments to introduce students to multidisciplinary research" Journal of Chemical Education: 91, 12 U2013A0096

Tracy, L.A., Hargett, T.W., Reno, J.L. (2014) "Few-hole double quantum dot in an undoped GaAs/AlGaAs heterostructure" Applied Physics Letters: 104, 123101 U2011A1019

VanDelinder, V., Bachand, G.D. (2014) "Photodamage and the importance of photoreception in biomolecular-powered device applications" Analytical Chemistry: 86(1), 721-728

Wright, J.B., Figiel, J.J., Brener, I., Wang, G.T., Luk, T.S., Xu, H., Hurtado, A., Li, C., Liu, S., Brueck, S.R.J., Balakrishnan, G., Li, Q. (2014) "Polarization control in GaN nanowire lasers" Optics Express: 22, 16. C2013B0093

Xiao, X., Fischer, A.J., Wang, G.T., Lu, P., Koleske, D.D., Coltrin, M.E., Wright, J.B., Liu, S., Brener, I., Subramania, G.S., Tsao, J.Y. (2014) "Quantum-size-controlled photoelectrochemical fabrication of epitaxial InGaN quantum dots" Nano Letters: 14, 10 RA2010A1013

Yablinsky, C.A., Tippey, K.E., Vaynman, S., Anderoglu, O., Fine, M.E., Chung, Y.W., Speer, J.G., Findley, K.O., Dogan, O.N., Jablonski, P.D., Hackenberg, R.E., Clarke, A.J., Clarke, K.D. (2014) "Concepts for the development of nanoscale stable precipitation-strengthened steels manufactured by conventional methods" JOM: 66, 12 C2010A988

Zheng, S.J., Capenter, J.S., McCabe, R.J., Beyerlein, I.J., Mara, N.A. (2014) "Engineering stable interfaces in bulk nanostructured metals" Scientific Reports: 4, 4226 C2013A0022

Zheng, S.J., Wang, J., Carpenter, J.S., Mook, W.M., Dickerson, P.O., Mara, N.A., Beyerlein, I.J. (2014) "Plastic instability mechanisms in bimetallic nanolayered composites" Acta Materialia: 79, 282-291 C2013A0022

CINT User Science - External (132)

Adams, P.G., Lamoreux, L., Swingle, K.L., Mukundan, H., Montano, G.A. (2014) "Lipopolysaccharide-induced dynamic lipid membrane reorganization: Tubules, perforations, and stacks" Biophysical Journal: 106, 11

Adamska, L., Nayyar, I., Chen, H., Swan, A.K., Oldani, N., Fernandez-Alberti, S., Doorn, S.K., Tretiak, S. (2014) "Self-trapping of excitons, violation of the condon approximation and efficient fluorescence in conjugated cycloparaphenylenes" Nano Letters: 14, 6539 C2012A0016

Agrawal, A., Aryal, D., Grest, G.S., Perahia, D. (2014) "Interfacial response of semifluorinated multi-block co-polymers" Handbook of Fluropolymer Science and Technology: p. 43 C2012A0123

Ahmed, T., La-o-vorakiat, C., Salim, T., Lam, Y.M., Chia, E.M., Zhu, J.X. (2014) "Optical properties of organometallic perovskite: an ab initio study using relativistic GW correction and Bethe-saltpeter equation" Europhysics Letters: 108, 67015 U2013A0058

Alberi, K., Mialitsin, A.V., Fluegel, B., Crooker, S.A., Reno, J.L., Mascarenhas, A. (2014) " Magnetic field-induced direct-indirect crossover in AlxGa1-Xas" Applied Physics Express: 7, 11 C2012B0045

Appavoo, K., Brady, N.F., Wang, B., Seo, M., Nag, J., Prasankumar, R.P., Pantelides, S.T., Hilton, D.J., Haglund Jr., R.F. (2014) "Ultrafast Phase Transition via Catastrophic Phonon Collapse Driven by Plasmonic Hot-Electron Injection" Nano Letters: 14, 1127-1133 C2011A1037

Aquino, A.A.J., Borges, I., Nieman, R., Kohn, A., Lischka, H. (2014) "Intermolecular interactions and charge transfer transitions in aromatic hydrocarbon- tetracyanoethylene complexes" Physical Chemistry Chemical Physics: 16, 20586 C2013A0070

Armijo, L.M., Kopciuch, M., Olszowka, Z., Wawrzyniec, S.J., Rivera, A.C., Plumley, J.B., Cook, N.C., Brandt, Y.I., Huber, D.L., Smolyakov, G.A., Adolphi, N.L., Smyth, H.D.C., Osinski, M. (2014) "Delivery of tobramycin coupled to iron oxide nanoparticles across the biofilm of mucoidal pseudomonas aeruginosa and investigation of its efficacy" Proceedings of SPIE: 10.1117 C2012A0105

Aryal, D., Etampawala, T., Perahia, D., Grest, G.S. (2014) "Phase behavior of a single structured ionomer chain in solution" Macromolecular Theory Simulations: 23, 523 C2012A0123

Auge, W.K., Ganguly, K., Goodwin, P.M., Gadomski, A., Gehlert, R.J. (2014) "Lipid distribution in human knee and hip articular cartilage correlated to tissue surface roughness and surface active phospholipid layer presence: evidence of cooperative interfacial lipid delivery mechanisms" Osteoarthritis and Cartilage: 22, 312-313 RA2009A135

Benavidez, A.D., Burton, P.D., Nogales, J.L., Jenkins, A.R., Ivanov, S.A., Miller, J.T., Karim, A.M., Datye, A.K. (2014) "Improved selectivity of carbon-supported palladium catalysts for the hydrogenation of acetylene in excess ethylene" Applied Catalysis A: 482, 108 RA2011A1256

Bi, Z., Uberuaga, B.P., Vernon, L.J., Aguiar, J.A., Fu, E., Zheng, S., Zhang, S., Wang, Y., Misra, A., Jia, Q.X. (2014) "Role of the interface on radiation damage in the SrTiO3/LaAlO3 heterostructure under Ne2+ ion irradiation" Journal of Applied Physics: 115, 124315 U2013A0039

Browning, J.F., Baggetto, L., Jungjohann, K., Wang, Y., Tenhaeff, W., Keum, J.K., Wood, D.L., Veith, G.M. (2014) "In situ determination of the liquid/solid interface thickness and composition for the Li-Ion cathode LiMn1.5Ni0.5O4" ACS Applied Materials and Interfaces: 10.1021 U2013A0019

Bufford, D., Liu, Y., Wang, J., Wang, H., Zhang, X., (2014) "In situ nanoindentation study on plasticity and work hardening in aluminium with incoherent twin boundaries." Nature Communications: *5*. C2013B0013.

Burghoff, D., Kao, T.Y., Han, N.R., Chan, C.W.I., Cai, X.W., Yang, Y., Hayton, D.J., Gao, J.R., Reno, J.L., Hu, Q. (2014) "Terahertz laser frequency combs" Nature Photonics: 8, 6 C2013A0020

Cao, Z., Stevens, M.J., Dobrynin, A.V. (2014) "Adhesion and wetting of nanoparticles on soft surfaces" Macromolecules: 47, 3203 C2013B0036

Cao, Z., Stevens, M.J., Dobrynin, A.V. (2014) "Elastocapillarity: Adhesion and wetting in soft polymeric systems" Macromolecules: 47, 6515 C2013B0036

Chason, E. Shin, J.W., Chen, C-H., Engwall, A.M., Miller, C.M., Hearne, S.J., Freund, L.B. "Growth of patterned island arrays to identify origins of thin film stress" Journal of Applied Physics 115(12) 123519

Chen, A., Weigand, M., Bi, Z., Zhang, W., Lu, X., Dowden, P., MacManus-Driscoll, J.L., Wang, H., Jia, Q.X. (2014) "Evolution of microstructure, strain and physical properties in oxide nanocomposite films" Scientific Reports: 4, 5426 C2013A0005

Chen, A., Bi, Z., Zhang, W., Jian, J., Jia, Q.X., Wang, H. (2014) "Textured metastable VO2 (B) thin films on SrTiO3 substrates with significantly enhanced conductivity" Applied Physics Letters: 104, 071909 C2013A0005

Chen, Y., Jiao, L., Sun, C., Song, M., Yu, K. Y., Liu, Y., Kirk, M., Li, M., Wang, H., Zhang, X., (2014) "In situ studies of radiation induced crystallization in Fe/a-Y2O3 nanolayers." Journal of Nuclear Materials: 452 (1–3), 321-327. C2013B0013.

Cheng, L., La-o-vorakiat, C., Tang, C.S., Nair, S.K., Xia, B., Wang, L., Zhu, J.X., Chia, E.M. (2014) "Time-dependent ultrafast carrier and phonon dynamics of topologic insulator Bi1.5Sb0.5Te1.8Se1.2" Applied Physics Letters: 104, 211906 U2013A0058

Choi, E.M., Fix, T., Kursumovic, A., Kinane, C.J., Arena, D., Sahonta, S.L., Bi, Z., Xiong, J., Yan, L., Lee, J.S., Wang, H., Langridge, S., Kim, Y.M., Borisevich, A.Y., MacLaren, I., Ramasse, Q.M., Blamire, M.G., Jia, Q.X., MacManus-Driscoll, J.L. (2014) "Room temperature ferrimagnetism and ferroelectricity in strained, thin films of BiFe0.5Mn0.5O3" Advanced Functional Materials: 24, 7478 U2012B0069

Chong, K.E., Hopkins, B., Staude, I., Miroshnichenko, A.E., Dominguez, J., Decker, M., Neshev, D.N., Brener, I., Kivshar, Y.S. (20 14) "Observation of Fano Resonances in All-Dielectric Heptamers" Small: 10.1002 U2012A0053

Chul, X.L., Brenner, T.J.K., Chen, X.W., Ghosh, Y., Hollingsworth, J.A., Sandoghdar, V., Goetzinger, S. (2014) "Experimental realization of an optical antenna for collecting 99% of photons from a quantum emitter" Optical: 1, 203 RA2013A0008

Duzik, A., Millunchick, J.M. (2014) "Surface morphology and Bi incorporation in GaSbBi(As)GaSb films" Journal of Crystal Growth: 390, 5-11 C2013B0023

Fan, Z., Jian, J., Liu, Y., Chen, Y., Song, M., Jiao, L., Wang, H., Zhang, X., "In situ studies on superior thermal stability of bulk FeZr nanocomposites." Acta Materialia 101, 125-135. C2015A0021.

Fang, K., Fernando, G.W., Balatsky, A.V., Kocharian, A.N., Palandage, K. (2014) "Pairing modulations and phase separation instabilities in Bi2Sr2CaCu2O8" Physics Letters A: 378, 243-248 C2012B0074

Fransson, J., Kang, M.G., Yoon, Y., Xiao, S., Ochiai, Y., Reno, J.L., Aoki, N., Bird, J.P. (2014) "Tuning the Fano resonance with an intruder continuum" Nano Letters: 14, 788 C2012A0038

Fu, E.G., Fang, Y., Zhuo, M.J., Zheng, S.J., Bi, Z.X., Wang, Y.Q., Tang, M., Ding, X., Han, W.Z., Luo, H.M., Baldwin, J.K., Misra, A., Nastasi, M. (2014) "Interface structure of Nb films on single crystal MgO(100) and MgO(111) substrates" Acta Materialia: 64, 100-112 U2012B0011

Gao, W., Wu, G., Janicke, M.T., Cullen, D.A., Mukundan, R. (2014) "Proton conducting ozonated graphene oxide membrane" Angewandte Chemie International Edition: 53, 14 RA2012A0009

Gao, W., Wu, G., Janicke, M.T., Cullen, D.A., Mukundan, R et al. (2014) "Ozonated graphene oxide film as a proton-exchange membrane" Angewandte Chemie International Edition: 53, 14 RA2012A0009

Gao, X., Mamaluy, D., Nielsen, E., Young, R.W., Shirkhorshidian, A., Lilly, M.P., Bishop, N.C., Carroll, M.S., Muller, R.P. (2014) "Efficient self-consistent quantum transport simulator for quantum devices" Journal of Applied Physics: 115, 133707 U2011A1066

Ge, T., Grest, G.S., Robbins, M.O. (2014) " Tensile Fracture of Welded Polymer Interfaces: Miscibility, Entanglements, and Crazing" Macromolecules: 47, 6982-6989 C2011B75

Ge, T., Robbins, M.O., Perahia, D., Grest, G.S. (2014) "Healing of polymer interfaces: Interfacial dynamics, entanglements, and strength" Physical Review E: 90, 012602 C2012A0123

Habteyes, T. G., Staude, I., Chong, K.E., Dominguez, J., Decker, M., Miroshnichenko, A., Kivshar, Y., Brener, I. (2014) "Near-field mapping of optical modes on all-dielectric silicon nanodisk" ACS Photonics: 1, 9 U2012A0053

Han, N.R., de Geofroy, A., Burghoff, D.P., Chan, C.W.I., Lee, A.W.M., Reno, J.L., Hu, Q. (2014) "Broadband all-electronically tunable mems terahertz quantum cascade lasers" Optics Letters: 39, 12 C2012A0006

Han, X., Liu, Y., Jia, Z., Chen, T.C., Wan, J., Weadock, N., Gaskell, K.J., Li, T., Hu, L. (2014) "Atomic-layer-deposition oxide nano-glue for sodium ion batteries" Nano Letters: 14, 139

Han, Y., Tretiak, S., Kilin, D.S. (2014) "Dynamics of charge transfer at Au/Si metal-semiconductor nano-interface" Molecular Physics: 112, 474-484 U2013B0142

Hayton, D.J., Kloosterman, J.L., Ren, Y., Gao, J.R., Klapwijk, T.M., Hu, Q., Walker, C.K., Reno, J.L. (2014) "A 4.7 THz heterodyne receiver for a balloon borne telescope" Proceedings of SPIE: 9153 C2013A0020

Heyes, J. E., Withayachumnankul, W., Grady, N. K., Chowdhury, D. R., Azad, A. K., Chen, H.-T. (2014) "Hybrid metasurface for ultra-broadband terahertz modulation" Applied Physics Letters: 105, 181108 U2012B0061

Hong, M., Wang, Y., Ren, F., Zhang, H., Fu, D., Yang, B., Xiao, X., Jiang, C. (2014) "Helium release and amorphization resistance in ion irradiated nanochannel films" Europhysics Letters: 106, 12001 U2011B13

Huang, H.Y.S., Subramanian, A. (2014) "Special section on spectroscopy, scattering, and imaging, techniques for nanostructured materials" ASME Journal of Nanotechnology in Engineering and Medicine: 5, 2 C2012B0030

Ignatova, T., Blades, M., Duque, J.G., Doorn, S.K., Biaggio, I., Rotkin, S.V. (2014) "Formation and dynamics of 'waterproof' photoluminescent complexes of rare earth ions in crowded environment" Physical Chemistry Chemical Physics: 16, 26715 C2013A0101

Ji, Y., Zhang, Y., Gao, M., Yuan, Z., Xia, Y., Jin, C., Tao, B., Chen, C., Jia, Q.X., Lin, Y. (2014) "Role of microstructures on the M1-M2 phase transition in epitaxial VO2 thin films" Scientific Reports: 4, 4854 U2012B0070

Jun, Y.C., Luk, T.S., Ellis, A.R., Klem, J.F., Brener, I. (2014) "Doping-tunable thermal emission from plasmon polaritons in semiconductor epsilon-near-zero thin films" Applied Physics Letters: 105, 131109 RA2013A0012

Kalathi, J.T., Kumar, S.K., Rubinstein, M., Grest, G.S. (2014) "Rouse Mode Analysis of Chain Relaxation in Homopolymer Melts" Macromolecules: 47, 6925-6931 U2013A0057

Kalathi, J.T., Yamamoto, U., Schweizer, K.S., Grest, G.S., Kumar, S.K. (2014) "Nanoparticle diffusion in polymer nanocomposites" Physical Review Letters: 112, 108301 U2013A0057

Kao, T.Y., Cai, X., Hu, Q., Reno, J.L. (2014) "Microstrip-antenna-coupled distribute feedback terahertz quantum-cascade lasers" Quantum Sensing and Nanophotonic Devices: 8993 C2012A0006

Karl, N., Reichel, K., Chen, H.T., Taylor, A.J., Brener, I., Benz, A., Reno, J.L., Mendis, R., Mittleman, D.M. (2014) "An electrically driven terahertz modulator with over 20 dB of dynamic range" Applied Physics Letters: 104, 091115 C2013B0008

Kilina, S., Cui, P., Fischer, S.A., Tretiak, S. (2014) "Conditions for directional charge transfer in CdSe quantum dots functionalized by Ru(II) polypyridine complexes" Journal of Physical Chemistry Letters: 5, 20 C2012A0125

Keller, A.M., Ghosh, Y., Devore, M.S., Phipps, M.E., Stewart, M.H., Wilson, B.S., Lidke, D.S., Hollingsworth, J.A., Werner, J.H. (2014) "3-dimensional tracking of non-blinking 'giant' quantum dots in live cells" Advanced Functional Materials: 24, 30 C2013A0111

Khanal, S., Zhao, L., Reno, J.L., Kumar, S. (2014) "Temperature performance of terahertz quantum-cascade lasers with resonant-phonon active-regions" Journal of Optics: 16, 9 U2012A0041

Kocharian, A.N., Fang, K., Fernando, G.W., Balatsky, A.V. (2014) "Phase separation instabilities and magnetism in two dimensional square and honeycomb Hubbard model" Journal of Magnetism and Magnetic Materials: 383, 8-12 C2012B0074

Kormondy, K.J., Posadas, A.B., Slepko, A., Dhamdhere, A., Smith, D.J., Mitchell, K.N., Willet-Gies, T.I., Zollner, S., Marshall, L.G., Zhou, J., Demkov, A.A. (2014) "Epitaxy of polar semiconductor Co3O4 (110): Growth, structure, and characterization" Journal of Applied Physics: 115, 243708 C2012B0084

La-o-vorakiat, C., Tian, Y., Wu, T., Panagopoulos, C., Zhu, J.X., Su, H.B., Chia, E.M. (2014) "Interface-induced magnetic coupling in multiferroic/ferromagnetic bilayer: An ultrafast pump-probe study" Applied Physics Letters: 104, 141602 U2013A0058

Laroche, D., Gervais, G., Lilly, M.P., Reno, J.L. (2014) "1D-1D Coulomb Drag Signature of a Luttinger Liquid" Science: 343, 631 C2012B0019

Lee, J., Han, J.E., Xiao, S., Song, J., Reno, J.L., Bird, J.P. (2014) "Formation of a protected sub-band for conduction in quantum point contacts under extreme biasing" Nature Nanotechnology: 9, 101. C2013B0022

Lee, S., Sangle, A., Lu, P., Chen, A., Zhang, W., Lee, J.S., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L. (2014) "Novel electroforming-free nanoscaffold memristor with very high uniformity, tenability, and density" Advanced Materials: 26, 6284 U2012B0069

Li, H., Nieman, R., Aquino, A.J.A., Lischka, H., Tretiak, S. (2014) "Comparison of LC-TDDFT and ADC(2) methods in computations of bright and charge transfer states in stacked oligothiophenes" Journal of Chemical Theory and Computation: 10, 3280 C2013A0070

Li, H., Shi, T., Tretiak, S., Chernyak, V.Y. (2014) "How geometric distortions scatter electronic excitations in conjugated macromolecules" Journal of Physical Chemistry Letters: 5, 3946 C2012B0034

Li, J., Catanzaro, M.J., Tretiak, S., Chernyak, V.Y. (2014) "Excited-state structure modifications due to molecular substituents and exciton scattering in conjugated molecules" Journal of Physical Chemistry Letters: 5, 641-647 U2012A0008

Li, N., Wang, H., Misra, A., Wang, J. (2014) "In situ Nanoindentation Study of Plastic Co-deformation in Al-TiN Nanocomposites" Scientific Reports: 4, 6633 U2014A0085.

Liang, W., Li, Z., Bi, Z., Nan, T., Du., H., Nan, C., Chen, C., Jia, Q.X., Lin, Y. (2014) "Role of the interface on the magnetoelectric properties of BaTiO3 thin films deposited on polycrystalline Ni foils" Journal of Materials Chemistry C: 2, 708 U2012B0070

Lim, Y.S., Nugraha, A.R.T., Cho, S.J., Noh, M.Y., Yoon, E.J., Liu, H., Kim, J.H., Telg, H., Haroz, E.H., Sanders, G.D., Baik, S.H., Kataura, H., Doorn, S.K., Stanton, C.J., Saito, R., Kono, J., Joo, T. (2014) "Ultrafast generation of fundamental and multiple-order phonon excitations in highly enriched (6,5) single-wall carbon nanotubes" Nano Letters: 14, 1426-1432 C2013A0029

Liu, S., Sinclair, M.B., Mahony, T.S., Jun, Y.C., Campione, S., Ginn, J., Bender, D.A., Wendt, J.R., Ihlefeld, J.F., Clem, P.G., Wright, J.B., Brener, I. (2014) "Optical magnetic mirrors without metals" Optica: 1, 4, 250 RA2013A0012

Liu, Y., Jian, J., Chen, Y., Wang, H., Zhang, X., (2014) "Plasticity and ultra-low stress induced twin boundary migration in nanotwinned Cu by in situ nanoindentation studies." Applied Physics Letters: 104 (23), 231910. C2013B0013.

Liu, Y., Liu, X.H., Nguyen, B.M., Yoo, J., Sullivan, J.P., Picraux, S.T., Dayeh, S.A. (2014) "In-situ transmission electron microscopy (TEM) study on the lithium ion transport in Si-Ge heterostructures nanowires" Microscopy and Microanalysis: 20, 1534

Liu, Y., Ren, F., Cai, G., Zhou, X., Hong, M., Li, W., Xiao, X., Wu, W., Jiang, C. (2014) "Energy dependence on formation of TiO2 nanofilms by Ti Ion implantation and annealing" Materials Research Bulletin: 51, 376 C2013B0011

Liu, Y., Fan, F., Wang, J., Liu, Y., Chen, H., Jungjohann, K.L., Xu, Y., Zhu, Y., Bigio, D., Zhu, T., Wang, C. (2014) "In situ transmission electron microscopy study of electrochemical sodiation and potassiation of carbon nanofibers" Nano Letters: 14, 3445-3452 C2012B0038

Liu, Y., Zhang, S., Zhu, T. (2014) "Germanium-based electrode materials for lithium ion batteries" ChemElectroChem: 1, 706 C2012A0033

Loftian, S., Mayer, C., Chawla, N., Llorca, J., Misra, A., Baldwin, J.K., Molina-Aldareguia, J.M. (2014) "Effect of layer thickness on the high temperature mechanical properties of Al/SiC nanolaminates" Thin Solid Films: 10, 1016 U2012B0013

Lu, P., Romero, E., Lee, S., MacManus-Driscoll, J.L., Jia, Q.X. (2014) "Chemical quantification of atomic-scale EDS maps under thin specimen conditions" Microscopy and Microanalysis: 20, 1782 U2012B0069

Lu, Q., Hor, A., Fisher, J., Anderson, R.B., Liu, S., Luk, T.S., Paudel, H.P., Farrokh Baroughi, M., May, P.S., Smith, S. (2014) "Two-color Surface Plasmon Polariton Enhanced Upconversion in NaYF4:Yb:Tm Nanoparticles on Au Nanopillar Arrays" Journal of Physical Chemistry C: 118, 3251-3257 C2011B87

Lu, X., Wang, G., Howard, J.W., Chen, A., Zhao, Y., Daemen, L.L., Jia, Q.X. (2014) "Li-rich anti-perovskite Li3OCI films with enhanced ionic conductivity" Chemical Communications: 50, 11520-11522 C2012A0024

Luk, T.S., Campione, S., Kim, I., Feng, S., Jun, Y.C., Liu, S., Wright, J.B., Brener, I., Catrysse, P.B., Fan, S., Sinclair, M.B. (2014) "Directional perfect absorption using deep subwavelength low-permittivity films" Physical Review B: 90, 085411 RA2013A0012

Macfaden, A.J., Reno, J.L., Brener, I., Mitrofanov, O. (2014) "3UM aperture probes for near-field

terahertz transmission microscopy" Applied Physics Letters: 104, 011110 C2012B0064

Macfaden, A.J., Reno, J.L., Brener, I., Mitrofanov, O. (2014) "Terahertz near-field probe incorporating lambda/100 aperture for time-domain spectroscopy and imaging" Quantum Sensing and Nanophotonic Devices: 8993 C2012B0064

Mackay, D.T., Janish, M.T., Sahaym, U., Kotula, P.G., Jungjohann, K.L., Carter, C.B., Norton, M.G. (2014) "Template-free electrochemical synthesis of tin nanostructures" Journal of Materials Science: 49, 4 U2013A0103

Makarov, N.S., Lau, P.C., Olson, C., Velizhanin, K.A., Solntsev, K.M., Kieu, K., Kilina, S., Tretiak, S., Norwood, R.A., Peyghambarian, N., Perry, J.W. (2014) "Two-photon absorption in CdSe colloidal quantum dots compared to organic molecules" ACS Nano: 8, 12 C2012A0125

Mangum, B.D., Sampat, S., Ghosh, Y., Hollingsworth, J.A., Htoon, H., Malko, A.V. (2014) "Influence of the core size on biexciton quantum yield of giant Cdse/Cds Nanocrystals" Nanoscale: 6, 3712-3720 U2013A0134

Martin, K., Erdman, M., Quintana, H., Shelnutt, J., Nogan, J., Swartzentruber, B., Martinez, J., Lavrova, O., Busani, T. (2014) "Bio-hybrid integrated system for wide-spectrum solar energy harvesting" Organic Photonic Materials and Devices: 89831 C2011A1013

Mitrofanov, O., Dominec, F., Kuzel, P., Reno, J.L., Brener, I., Chung, U.C., Elissalde, C., Maglione, M., Mounaix, P. (2014) "Near-field probing of Mie resonances in single TiO2 microspheres at terahertz frequencies" Optics Express: 22, 19 C2012B0064

Nelson, T., Fernandez-Alberti, S., Roitberg, A.E., Tretiak, S. (2014) "Nonadiabatic excited-state molecular dynamics: modeling photophysics in organic conjugated materials" Account of Chemical Research: 47, 1155-1164 C2012A0016

Nguyen, B.M., Taur, Y., Picraux, S.T., Dayeh, S.A. (2014) "Diameter-independent hole mobility in Ge/Si core/shell nanowire field effect transistors" Nano Letters: 14, 2, 585 RA2013A0023

Oldani, N., Tretiak, S., Bazan, G., Fernandez-Alberti, S. (2014) "Modeling of internal conversion in photoexcited conjugated molecular donors used in organic conjugated materials" Energy and Environmental Science: 7, 1175 C2012A0016

Ondarse-Alvarez, D., Oldani, N., Tretiak, S., Fernandez-Alberti, S. (2014) "Computational study of photoexcited dynamics in bichromophoric cross-shaped oligofuorene" Journal of Physical Chemistry A: 118, 10742 C2012A0016

Palapati, N.K.R., Muth, A., Zhu, Y., Wang, C., Subramanian, A. (2014) "Elastic modulus measurements on large diameter nanowires using a nano-assembled platform" ASME Journal of Nanotechnology in Engineering and Medicine: 5, 2 C2012B0030

Paul, J., Dey, P., Tokumoto, T., Reno, J.L., Hilton D.J., Karaiskaj, D. (2014) "Exploring two-dimensional electron gases with two-dimensional fourier transform spectroscopy" Journal of Chemical Physics: 141, 13 U2013B0016

Perillo, E.P., De Haro, L., Phipps, M.E., Martinez, J.S., Yeh, H.C., Dunn, A.K., Shepherd, D.P., Werner, J.H. (2014) "Enhanced 3D localization of individual RNA transcripts via astigmatic imaging" Proceedings of SPIE: 8950 U2010A916

Perng, Y., Cho, J., Sun, Y., Membreno, D., Cirigliano, N., Dunn, B., Chang, J.P. (2014) "Synthesis of ion conducting LixAlySizO thin films by atomic layer deposition" Journal of Materials Chemistry A: 2, 9566 U2013B0077

Peteanu, L.A., Hong, J., Jeon, S., Kim, J., Devi, D., Wildeman, J., Sfeir, M.Y., Werner, J.H., Shreve, A.P. (2014) " The optical properties of conjugated materials and their aggregates: Towards imaging of films and devices" SPIE Nanoscience and Engineering: 13, 91650 C2011A1006

Ribaudo, T., Taylor, A., Nguyen, B.M., Bethke, D., Shaner, E.A. (2014) "High efficiency reflective waveplates in the midwave infrared" Optics Express: 22, 3 C2013B0114

Sanders, C. E., Zhang, C., Kellogg, G.L., Shih, C. K. (2014) "Role of thermal processes in dewetting of epitaxial Ag(111) film on Si(111)" Surface Science: 630, 168-173

Scherbakov, M.R., Neshev, D.N., Hopkins, B., Shorokhov, A.S., Staude, I., Melik-Gaykazyan, E.V., Decker, M., Ezhov, A.A., Miroshnichenko, A.E., Brener, I., Fedyanin, A.A., Kivshar, Y.S. (2014) "Enhanced third-harmonic generation in silicon nanoparticles driven by magnetic response" Nano Letters: 14, 6488-6492 U2012A0053

Schoeppner, R.L., Abdolrahim, N., Salehinia, I., Zbib, H.M., Bahr, D.F. (2014) "Elevated temperature dependence of hardness in tri-metallic nano-scale metallic multilayer systems" Thin Solid Films: 10.1016 U2013A0056

Scott, B.L., Joyce, J.J., Durakiewicz, T.D., Martin, R.L., McCleskey, T.M., Bauer, E., Luo, H., Jia, Q.X. (2014) "High quality epitaxial thin films of actinide oxides, carbides, and nitrides: Advancing understanding of electronic structure of f-element materials" Elsevier: 266-267, 137-154 U2012B0011

Sharma, Y.D., Jun, Y.C., Kim, J.O., Brener, I., Krishna, S. (2014) "Polarization-dependent photocurrent enhancement in metamaterial-coupled quantum dots-in-a-well infrared detectors" Optics Communications: 312, 31-34 U2011B90

Shu, J., Gao, W., Reichel, K., Nickel, D., Dominguez, J., Brener, I., Mittleman, D.M., Xu, Q. (2014) "High-Q terahertz Fano resonance with extraordinary transmission in concentric ring apertures" Optics Express: 22, 4 C2012A0030

Singh, S., Haraldsen, J.T., Xiong, J., Choi, E.M., Lu, P., Yi, D., Wen, X.D., Liu, J., Wang, H., Bi, Z., Yu, P., Fitzsimmons, M.R., MacManus-Driscoll, J.L., Ramesh, R., Balatsky, A.V., Zhu, J.X., Jia, Q.X. (2014) "Induced Magnetization in La .7 Sr.3MnO3/BiFeO3 Superlattices" Physical Review Letters: 113, 047204 U2013B0009

Soler, M.A., Nelson, T., Roitberg, A.E., Tretiak, S., Fernandez-Alberti, S. (2014) "Signature of nonadiabatic coupling in unique excited-state vibrational modes" Journal of Physical Chemistry A: 118, 10372 C2012A0016

Soni, S.K., Sheldon, B.W., Hearne, S.J (2014). "Origins of saccharin-induced stress reduction based on observed fracture behavior of electrodeposited Ni films" Journal of Materials Science 49 (3)1399-1407

Su, Q., Gong, W., Yoon, D., Jacob, C., Jia, Q.X., Manthiram, A., Jacobson, A.J., Wang, H. (2014) "Interlayer Effects on Oxygen Reduction Kinetics in Porous Electrodes of La.5Sr.5C0O3" Journal of the Electrochemical Society: 161, 398-404 C2013A0005

Subbaiyan, N.K., Cambre, S., Parra-Vasquez, N.G., Haroz, E.H., Doorn, S.K., Duque, J.G. (2014) "Role of surfactants and salt in aqueous two-phase separation of carbon nanotubes toward simple chirality

isolation" ACS Nano: 8, 1619-1628 U2012B0014

Subramanian, A., Hudak, N.S., Huang, J.Y., Zhan, Y., Lou, J., Sullivan, J.P. (2014) "On-chip lithium cells for electrical and structural characterization of single nanowire electrodes" Nanotechnology: 25, 265402 C2012B0030

Sun, C., Bufford, D., Chen, Y., Kirk, M.A., Wang, Y.Q., Li, M., Wang, H., Maloy, S., Zhang, X. (2014) "In situ study of defect migration kinetics in nanoporous Ag with enhanced radiation tolerance" Nature Scientific Report: 4, 3737 C2012A0017

Tang, W., Nguyen, B.M., Chen, R., Dayeh, S.A. (2014) "Solid-state reaction of nickel silicide and germanide contacts to semiconductor nanochannels" Semiconductor Science and Technology: 29, 5

Telg, H., Haroz, E.H., Duque, J.G., Tu, X., Khripin, C.Y., Fagan, J., Zheng, M., Kono, J., Doorn, S.K. (2014) "Diameter dependence of TO phonon frequencies and the Kohn anomaly in armchair metallic single-wall carbon nanotubes" Physical Review B: 90, 245422 C2011B100

Thomas, J.C., Mirecki Millunchick, J., Van der Ven, A., Modine, N.A. (2014) "Phase stability analysis of the InAs/GaAs (001) Wetting Layer from first principles" Physical Review B: 89, 205306 C2012A0028

Vanderhoef, L.R., Azad, A.K., Boomberger, C.C., Chowdhury, D.R., Chase, D.B., Taylor, A.J., Zide, J.M.O., Doty, M.F. (2014) "Charge carrier relaxation processes in TbAs nanoinclusions in GaAs measured by optical-pump THz-probe transient absorption spectroscopy" Physical Review B: 89, 045418 C2008A087

Vasilev, C., Johnson, M., Gonzales, E., Wang, L., Ruban, A., Montano, G.A., Cadby, A., Hunter, C.N. (2014) "Reversible switching between non-quenched and quenched states in nanoscale linear arrays of plant light harvesting antenna (LHCII) complexes" Langmuir: 30, 8481 U2011A1024

Vetterick, G., Baldwin, J.K., Misra, A., Taheri, M.L. (2014) "Texture evolution in nanocrystalline iron films deposited using biased magnetron sputtering" Journal of Applied Physics: 116, 233503

Wan, J., Bao, W., Liu, Y., Dai, J., Shen, F., Zhou, L., Cai, X., Urban, D., Li, Y., Jungjohann, K., Fuhrer, M.S., Hu, L. (2014) "Rapid first-cycle lithiation strategy for enhanced performance of Li-MoS2 batteries as identified by in situ studies" Advanced Energy Materials: 1401742 U2012A0007

Wang, J., Fan, F., Liu, Y., Jungjohann, K.L., Lee, S.W., Mao, S.X., Liu, X., Zhu, T. (2014) "Structural evolution and pulverization of tin nanoparticles during lithiation-delithiation cycling" Journal of Electrochemical Society: 161, 11 U2012B0018

White, A.J., Tretiak, S., Galperin, M. (2014) "Raman Scattering in Molecular Junctions: A Pseudoparticle Formulation" Nano Letters: 14, 699-703

Whitcomb, K.J., Geisenhoff, J.Q., Ryan, D.P., Gelfand, M.P., Van Orden, A.K. (2014) " Photon antibunching in small clusters of CdSe/ZnS core/shell quantum dots" Journal of Physical Chemistry B: 10.1021 C2012B0078

Wood, R.M., Saha, D., McCarthy, L.A., Tokarski, J.T., Sanders, G.D., Kuhns, P.L., McGill, S.A., Reyes, A.P., Reno, J.L., Stanton, C.J., Bowers, C.R. (2014) "Effects of strain and quantum confinement in optically pumped nuclear magnetic resonance in GaAs: Interpretation guided by spin-dependent band structure calculations" Physical Review B: 90, 15 U2013B0045

Wright, J.B., Campione, S., Liu, S., Martinez, J.A., Xu, H., Luk, T.S., Li, Q., Wang, G.T., Swartzentruber, B.S., Lester, L.F., Brener, I. (2014) "Distributed feedback gallium nitride nanowire lasers" Applied Physics Letters: 104, 041107 U2012A0040

Wu, C., Arju, N., Kelp, G., Fan, J.A., Dominguez, J., Gonzales, E., Tutuc, E., Brener, I., Shvets, G. (2014) "Spectrally selective chiral silicon metasurfaces based on infrared Fano resonances" Nature Communications: 5, 3892 C2012A0095

Wu, Y., Zhang, C., Zhao, Y., Kim, J., Zhang, M., Mohammadi, N., Liu, Z., Pribil, G., Alu, A., Shih, C., Li, X., (2014) "Intrinsic optical properties and enhanced plasmonic response of epitaxial silver" Advanced Materials: 26, 6106 U2013B0015

Xing, Z., Shen, S., Wang, M., Ren, F., Liu, Y., Zheng, X., Liu, Y., Xiao, X., Wu, W., Jiang, C. (2014) "Efficient enhancement of solar-water-splitting by modified 'Z-scheme' structural WO3-W-Si photoelectrodes" Applied Physics Letters: 105, 143902 C2013B0011

Yoo, J., Dayeh, S.A., Bartelt, N.C., Tang, W.Findikoglu, A.T., Picraux, S.T. (2014) "Size-dependent silicon epitaxy in mesoscale dimensions" Nano Letters: 14, 11

Zhao, R., Li, W., Lee, J.H., Choi, E.M., Liang, Y., Zhang, W., Tang, R., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L., Yang, H. (2014) "Precise Tuning of (YBa 2 Cu 3 O 7-δ) 1-x :(BaZrO 3) x Thin Film Nanocomposite Structures" Advanced Functional Materials: 24, 5240-5245 U2011B13

Zhang, B., Hendrickson, J., Esfahani, N. N., Chen, H.-T., Guo, J. (2014) "Metasurface optical antireflection coating" Applied Physics Letters: 105, 241113

Zhang, H., Ren, F., Hong, M., Xiao, X., Cai, G., Jiang, C. (2014) "Structure and growth mechanism of V/Ag multilayers with different period fabricated by magnetron sputtering deposition" Journal of Material Science & Technology: 30, 1012 C2013B0011

Zhang, H., Ren, F., Wang, Y., Hong, M., Xiao, X., Liu, D., Qin, W., Zheng, X., Liu, Y., Jiang, C. (2014) "Enhanced radiation tolerance of nanochannel V films through defects release" Nuclear Instruments and Methods in Physics Research B: 334, 1-7 U2011B13

Zhang, Q., Arikawa, T., Kato, E., Reno, J.L., Pan, W., Watson, J.D., Manfra, M.J., Zudov, M.A., Tokman, M., Erukhimova, M., Belyanin, A., Kono, J. (2014) "Superradiant decay of cyclotron resonance of two-dimensional electron gases" Physical Review Letters: 113, 4 C2010B1057

Zhang, W., Chen, A., Bi, Z., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2014) "Interfacial coupling in heteroepitaxial vertically aligned nanocomposite thin films: From lateral to vertical control" Elsevier: 18, 6-18 C2013A0005

Zhang, W., Jian, J., Chen, A., Jiao, L., Khathatay, F., Li, L., Chu, F., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2014) "Strain relaxation and enhanced perpendicular magnetic anisotropy in BiFeO3:CoFe2O4 vertically aligned nanocomposite thin films" Applied Physics Letters: 104, 062402 C2013A0005

Zheng, X.D., Ren, F., Cai, G.X., Hong, M.Q., Xiao, X.H., Wu, W., Liu, Y.C., Li, W.Q., Ying, J.J., Jiang, C.Z. (2014) "Formation of TiO2 Nanorods by Ion Irradiation" Journal of Applied Physics: 115, 184306 C2013B0011

Zhu, J.X., Wen, X.D., Haraldsen, J.T., He, M., Panagopoulos, C., Chia, E.M. (2014) "Induced ferromagnetism at BiFeO3/YBa2Cu3O7 interfaces" Scientific Reports: 4, 5368 U2013A0058

Zollner, C.J., Willett-Gies, T.I. Zollner, S., Choi, S. (2014) "Infrared to vacuum-ultraviolet ellipsometry studies of spinel (MgAl2O4)" Thin Solid Films: 571, 3 C2013A0028

Citations for 2015 (236 Total)

CINT Science (30)

Adams, P.G., Swingle, K.L., Paxton, W.F., Firestone, M.A., Mukundan, H., Montano, G.A. (2015) "Exploiting lipopolysaccharide-induced deformation of lipid bilayers to modify membrane composition and generate two-dimensional geometric membrane array patterns" Scientific Report: 5, 10331

Bolintineanu, D.S., Grest, G.S., Lechman, J.B., Silbert, L.E. (2015) "Diffusion in jammed particle packs" Physical Review Letters: 115, 088002

Chen, H.T. (2015) "Semiconductor activated terahertz metamaterials" Frontiers of Optoelectronics: 8, 27

Driben, R., Yulin, A., Efimov, A. (2015) "Resonant radiation from oscillating higher order solitons" Optics Express: 23, 19112

Efimov, A. (2015) "Scintillations of a partially coherent beam in a laboratory turbulence: Experiment and comparison to theory" Proceedings of the SPIE: 9354, 935404

Firestone, M.A., Hayden, S.C., Huber, D.L. (2015) "Greater than the sum: synergy and emergent properties in nanoparticle-polymer composites" MRS Bulletin: 40, 09

Ghosh, K., Balog, E.R.M., Sista, P., Martinez, J.S., Rocha, R.C. (2015) "Multicolor luminescence from conjugates of genetically encoded elastin-like polymers and terpyridine-lanthanides" Macromolecular Chemical Physics: 216, 18

Greenfield, M.T., McGrane, S.D., Bolme, C.A., Bjorgaard, J.A., Nelson, T.R., Tretiak, S., Scharff, R.J. (2015) "Photoactive high explosives: linear and nonlinear photochemistry of petrin tetrazine chloride" Journal of Physical Chemistry C: 119, 4846-4855

Hanson, C.J., Buck, M.R., Acharya, K., Torres, J.A., Kundu, J., Ma, X., Bouquin, S. Hamilton, C.E., Htoon, H., Hollingsworth, J.A. (2015) "Giant quantum dots: Matching solid-state to solution-phase photoluminescence performance for near-unity down-conversion efficiency" ACS Applied Material Interfaces: 7, 13125

Ji, Z., Doorn, S.K., Sykora, M. (2015) "Electrochromic Graphene Molecules" ACS Nano: 9, 4043

Kelly, J.C., Huber, D.L., Price, A.D., Roberts, M.E. (2015) "Switchable electrolyte properties and redox chemistry in aqueous media based on temperature-responsive polymers" Journal of Applied Electrochemistry: 45, 8

Leenheer, A.J., Sullivan, J.P., Shaw, M., Harris, C.T. (2015) "A sealed liquid cell for in-situ transmission electron microscopy of controlled electrochemical processes" Journal of Microelectromechanical Systems: 24, 4

Liang, L., Qi, M., Yang, J., Shen, X., Zhai, J., Xu, W., Jin, B., Liu, W., Feng, Y., Zhang, C., Lu, H., Chen,

H.T., Kang, L., Xu, W., Chen, J., Cui, T.J., Wu, P., Liu, S. (2015) "Anomalous terahertz reflection and scattering by flexible and conformal coding metamaterials" Advanced Optical Materials: 3, 1374

Li, J., Chen, S., Yang, H., Li, J., Yu, P., Cheng, H., Gu, C., Chen, H.T., Tian, J. (2015) "Simultaneous control of light polarization and phase distributions using plasmonic metasurfaces" Advanced Functional Materials: 25, 704

Liu, J., Adamska, L., Doorn, S.K., Tretiak, S. (2015) "Singlet and triplet exictons and charge polarons in cycloparaphenylenes: A density functional theory study" Physical Chemistry Chemical Physics: 17, 14613-14622

Nan, C.W., Jia, Q.X. (2015) "Obtaining ultimate functionalities in nanocomposites: Design, control, and fabrication" MRS Bulletin: 40, 719

Park, Y., Choi, J.S., Choi, T., Lee, M.J., Jia, Q.X., Park, M., Lee, H., Park, B.H. (2015) "Configuration of ripple domains and their topological defects formed under local mechanical stress on hexagonal monolayer graphene" Scientific Reports: 5, 9390

Paxton, W.F., Bouxsein, N.F., Henderson, I.M., Gomez, A., Bachand, G.D. (2015) "Dynamic assembly of polymer nanotube networks via kinesin powered microtube filaments" Nanoscale: 7, 25

Paxton, W.F., Sanchez, S., Nitta, T. (2015) "Editorial: Special issue micro- and nanomachines" Transactions on Nanobioscience: 14, 258-259

Salerno, K.M., Grest, G.S. (2015) "Temperature effects on nanostructure and mechanical properties of single-nanoparticle thick membranes" Faraday Discussions: 181, 339

Soh, D.B.S., Brif, C., Coles, P.J., Lütkenhaus, N., Camacho, R.M., Urayama, J., Sarovar, M., (2015). "Self-Referenced Continuous-Variable Quantum Key Distribution Protocol" Phys. Rev. X: 5, 041010

Talbayev, D., Lee, J., Trugman, S.A., Zhang, C.L., Cheong, S.W., Averitt, R.D., Taylor, A.J., Prasankumar, R.P. (2015) "Spin-dependent polaron formation dynamics in Eu.75Y.25MnO3 probed by femtosecond pump-probe spectroscopy" Physical Review B: 91, 064420

Ting, C.L., Stevens, M.J., Frischknecht, A.L. (2015) "Structure and dynamics of coarse-grained ionomer melts in an external electric field" Macromolecules: 48, 809 U2013A0037

Wang, F., Wei, Q.H., Htoon, H. (2015) "Switchable and non-switchable zero backscattering of dielectric nano-resonators" Optical Materials Express: 5, 668-675

Wang, Z., Li, R., Bian, K., Wang, X., Xu, H., Hollingsworth, J.A., Hanrath, T., Fang, J. (2015) "An obtuse rhomhohedral superlattice assembled by Pt nanocubes" Nano Letters: 15, 6254

Watt, J., Huber, D.L., Price, A.D., Roberts, M.E. (2015) "Effect of seed age on gold nanorod formation: a microfluidic, real-time investigation" Chemistry of Materials: 27, 18

White, A.J., Gorshkov, V.N., Tretiak, S., Mozyrsky, D. (2015) "Non-adiabatic molecular dynamics by accelerated semiclassical monte carlo" Journal of Chemical Physics: 143, 014115

Willey, M., Bagge-Hansen, M., Lauderbach, L., Hodgin, R., Hansen, D., May, C., VanBuuren, T., Gustavsen, R., Watkins, E., Firestone, M., Dattelbaum, D., Jensen, B., Graber, T., Bastea, S., Fried, L. (2015) "Measurement of carbon condensates using small-angle X-ray scattering during detonation of high explosives" APS Topical Conference on the Shock Compression of Matter: O1.003

Zhang, Y., Li, T., Chen, Q., Zhang, H., O'Hara, J.F., Abele, E., Taylor, A.J., Chen, H.T., Azad, A.K. (2015) "Independently tunable dual-band perfect absorber based on graphene at mid-infrared frequencies" Scientific Reports: 5, 18463

Zhu, J.X., Albers, R.C., Haule, K., Wills, J.M. (2015) "First-principles study of the Kondo physics of a single Pu impurity in Th host" Physical Review B: 91, 165126

CINT User Science - Internal (54)

Acharya, K. P., Nguyen, H. M., Paulite, M., Piryatinski, A., Zhang, J., Casson, J. L., Xu, H., Htoon, H., Hollingsworth, J. A. (2015) "Elucidation of Two Giants: Challenges to Thick-shell Synthesis in CdSe/ZnSe and ZnSe/CdS Core/Shell Quantum Dots" Journal of the American Chemical Society: *137*, 3755-3758. U2013B0037

Adamska, L., Nazin, G.V., Doorn, S.K., Tretiak, S. (2015) "Self-trapping of charge carriers in semiconducting carbon nanotubes: Structural analysis" Journal of Physical Chemistry Letters: 6, 3873 U2012B0055

Aguilar, R.V., Qi, J., Brahlek, M., Bansal, N., Azad, A., Bowlan, J., Oh, S., Taylor, A.J., Prasankumar, R.P., Yarotski, D.A. (2015) "Time-resolved terahertz dynamics in thin films of the topological insulator Bi2Se3" Applied Physics Letters: 106, 011901 U2013B0125

Ahmed, T., Modine, N.A., Zhu, J.X. (2015) "Bonding between graphene and MoS2 monolayers without and with Li intercalation" Applied Physics Letters: 107, 043903 U2013B0097

Benz, A., Campione, S., Klem, J.F., Sinclair, M.B., Brener, I. (2015) "Control of strong light-matter coupling using the capacitance of metamaterial nanocavities" Nano Letters: 15, 3 U2014A0057

Bjorgaard, J.A., Kuzmenko, V., Velizhanin, K.A., Tretiak, S. (2015) "Solvent effects in time-dependent self-consistent field methods I: optical response calculations" Journal of Chemical Physics: 142, 044103 U2013A0032

Bjorgaard, J.A., Nelson, T., Kalinin, K., Kuzmenko, V., Velizhanin, K.A., Tretiak, S. (2015) "Simulations of fluorescence solvatochromisms in substituted PPV oligomers from excited state molecular dynamics with implicit solvent" Chemical Physics Letters: 631, 66-69 U2013A0032

Bjorgaard, J.A., Velizhanin, K.A., Tretiak, S. (2015) "Solvent effects in time-dependent self-consistent field methods II: variational formulations and analytical gradients" Journal of Chemical Physics: 143, 054305 U2013A0032

Bowlan, J., Xu, X., Sinha, K., Trugman, S.A., Taylor, A., Prasankumar, R., Yarotski, D. (2015) "Ultrafast dynamics of multiferroic h-LuFeO3" Institute of Electrical and Electronics Engineers: Conference Proceedings, May 2015 U2013B0125

Bussmann, E., Rudolph, M., Subramania, G.S., Misra, S., Carr, S.M., Langlois, E., Dominguez, J., Pluym,

T., Lilly, M.P., Carroll, M.S. (2015) “Scanning capacitance microscopy registration of buried atomic-precision donor devices” Nanotechnology: 26, 085701

Campione, S., Luk, T.S., Liu, S., Sinclair, M.B. (2015) “Realizing high-quality, ultralarge momentum states and ultrafast topological transitions using semiconductor hyperbolic metamaterials” Journal of the Optical Society of America B: 32, 1809

Campione, S., Liu, S., Benz, A., Klem, J.F., Sinclair, M.B., Brener, I. (2015) “Epsilon-near-zero modes for tailored light-matter interaction” Physics Review Applied: 4, 044011

Carpenter, J.S., Nizolek, T., McCabe, R., Knezevic, M., Zheng, S., Eftink, B., Scott, J., Vogel, S., Pollock, T., Mara, N.A., Beyerlein, I.J. (2015) “Bulk texture evolution of nanolamellar Zr-Nb composites processed via accumulative roll bonding” Acta Materialia: 92, 97-108 C2013A0022

Chen, A., Poudyal, N., Xiong, J., Liu, J.P., Jia, Q.X. (2015) “Modification of structure and magnetic anisotropy of epitaxial CoFe2O4 films by hydrogen reduction” Applied Physics Letters: 106, 111907 U2014A0041

Chou, S.S., Huang, Y.K., Kim, J., Kaehr, B., Foley, B.M., Lu, P., Dykstra, C., Hopkins, P.E., Brinker, C.J., Huang, J., Dravid, V.P. (2015) “Controlling the metal to semiconductor transition of MoS2 and WS2 in solution” Journal of the American Chemical Society: 137, 5 U2014B0071

Curry, M.J., England, T.D., Bishop, N.C., Ten-Eyck, G., Wendt, J.R., Pluym, T.P., Lilly, M.P., Carr, S.M., Carroll, M.S. (2015) “Cryogenic preamplification of a single-electron-transistor using a silicon-germanium heterojunction-bipolar-transistor” Applied Physics Letters: 106, 203505 U2013B0148

Dai, Y., Bowlan, J., Li, H., Miao, H., Shi, Y.G., Trugman, S.A., Zhu, J.X., Ding, H., Taylor, A.J., Yarotski, D.A., Prasankumar, R.P. (2015) “Ultrafast carrier dynamics in the large magnetoresistance material WTe2” Physical Review B: 92, 161104 U2013B0125

Gao, Y., Roslyak, O., Dervishi, E., Karan, N.S., Ghosh, Y., Sheehan, C.J., Wang, F., Gupta, G., Mohite, A., Dattelbaum, A.M., Doorn, S.K., Hollingsworth, J.A., Piryatinski, A., Htoon, H. (2015) “Hybrid graphene-giant nanocrystal quantum dot assemblies with highly efficient biexciton emission” Advanced Optical Materials: 3, 39 RA2014A0017

Hartmann, N.F., Yalcin, S.E., Adamska, L., Haroz, E.H., Ma, X., Tretiak, S., Htoon, H., Doorn, S.K. (2015) “Photoluminescence imaging of solitary dopant sites in covalently doped single-wall carbon nanotubes” Nanoscale: 7, 20521 U2012B0055

Jain, P., Wang, Q., Roldan, M., Glavic, A., Lauter, V., Urban, C., Bi, Z., Ahmed, T., Zhu, J.X., Varela, M., Jia, Q.X., Fitzsimmons, M.R. (2015) “Synthetic magnetoelectric coupling in a nanocomposite multiferroic” Scientific Reports: 5, 9089 U2013B0097

Kamaraju, N., Pan, W., Ukenberg, U., Gvozdic, D.M., Boubanga-Tombet, S., Upadhya, P.C., Reno, J., Taylor, A.J., Prasankumar, R.P. (2015) “Terahertz magneto-optical spectroscopy of a two-dimensional hole gas” Applied Physics Letters: 106, 031902 U2012B0010

Kent, M.S., Avina, I.C., Rader, N., Busse, M.L., George, A., Sathitsuksanoh, N., Baidoo, E., Timlin, J., Giron, N.H., Celina, M.C., Martin, L.E., Polsky, R., Chavez, V.H., Huber, D.L., Keasling, J.D., Singh, S., Simmons, B.A., Sale, K.L. (2015) “Assay for lignin breakdown based on lignin films: insights into the

Fenton reaction with insoluble lignin" Green Chemistry: 17, 4830 C2014A0038

Lee, J., Trugman, S.A., Zhang, C.L., Talbayev, D., Xu, X.S., Cheong, S.W., Yarotski, D.A., Taylor, A.J., Prasankumar, R.P. (2015) "The influence of charge and magnetic order on polaron and acoustic phonon dynamics in LuFe2O4" Applied Physics Letters: 107, 042906 U2013B0125

Leenheer, A.J., Jungjohann, K.L., Zavadil, K.R., Sullivan, J.P., Harris, C.T. (2015) "Lithium electrodeposition dynamics in aprotic electrolyte observed in situ via transmission electron microscopy" ACS Nano: 9, 4

Liu, J., Adamska, L., Doorn, S.K., Tretiak, S. (2015) "Singlet and triplet excitons and charge polarons in cycloparaphenylenes: A density functional theory study" Physical Chemistry Chemical Physics: 17, 14613 U2012B0055

Ma, X., Baldwin, J.K.S., Hartmann, N.F., Doorn, S.K., Htoon, H. (2015) "Solid-state approach for fabrication of photostable oxygen-doped carbon nanotubes" Advanced Functional Materials: 25, 6157 U2012B0040

Ma, X. & Htoon, H. Tailoring the photophysical properties of carbon nanotubes by photonic nanostructures. Modern Physics Letters *B*, 1530004, (2015). U2012B0040

Ma, X., Roslyak, O., Duque, J.G., Doorn, S.K., Piryatinski, A., Dunlap, D.H., Htoon, H. (2015) "Influences of exciton-exciton annihilation on photon emission statistics of carbon nanotubes" Physical Review Letters: 115, 017401 U2012B0040

Mara, N.A., Beyerlein, I.J. (2015) "Interface-dominant multilayers fabricated by severe plastic deformation: Stability under extreme conditions" Current Opinions in Solid State and Materials Science: 19, 5 U2014A0085

Mayer, C., Li, N., Mara, N., Chawla, N. (2015) "Micromechanical and in situ shear testing of Al-SiC nanolaminate composites in a transmission electron microscope (TEM)" Materials Science and Engineering A: 621, 229 U2014A0085

Moore, S.G., Stevens, M.J., Grest, G.S. (2015) "``Liquid-vapor interface of the Stockmayer fluid in a uniform external field" Physical Review E 91, 022309

Nie, W., Gupta, G., Crone, B.K., Liu, F., Smith, D.L., Ruden, P., Kuo, C., Tsai, H., Wang, H.L., Li, H., Tretiak, S., Mohite, A.D. (2015) "Interface design principles for high efficiency organic semiconductor devices" Advanced Sciences: 2, 1500024 U2014B0093

Nie, W., Hsinhan, T., Asadpour, R., Blancon, J.C., Kappera, R., Chhowalla, M., Neukirch, A., Tretiak, S., Gupta, G., Crochet, J., Alam, M.A., Wang, H.L., Mohite, A.D. (2015) "High-efficiency solution-processed perovskite solar cells with millimeter-scale grains" Science: 347, 522-525 U2014B0093

Nizolek, T., Avallone, J., Pollock, T., Mara, N., Beyerlein, I. (2015) "High strength bulk metallic nanolaminates" Advanced Materials and Processes: 173, 2 C2013A0022

Nizolek, T., Avallone, J., Mara, N.A., Beyerlein, I.J. (2015) "Enhanced plasticity via kinking in cubic metallic nanolaminates" Advanced Engineering Materials: 17, 6 C2013A0022

Pathak, S, Kalidindi, S.R. (2015) “Spherical nanoindentation stress–strain curves” Materials Science and Engineering: R: Reports. 91, 1-36

Paulite, M., Acharya, K. P., Nguyen, H. M., Hollingsworth, J. A. & Htoon, H. “Inverting Asymmetric Confinement Potentials in Core/Thick-Shell Nanocrystals.” The Journal of Physical Chemistry Letters: 6, 706-711, (2015). C2013A0064

Ramasamy, K., Kotula, P.G., Fidler, A.F., Brumbach, M.T., Pietryga, J.M., Ivanov, S.A. (2015) “SnxGe1-x Alloy Nanocrystals: a First Step Toward Solution-Processed Group IV Photovoltaics” Chemical Materials: 27, 4640-4649 U2015B0017

Roehling, D., Perron, A., Fattebert, J-L, Coughlin, D.R, Gibbs, P.J., Gibbs, J.W., Imhoff, S.D., Tourret, D., Baldwin, J.K., Clarke, A.J., Turchi, P.E.A., McKeown, J.T. (2015) “Imaging the rapid solidification of metallic alloys in the TEM”, Microscopy and Microanalysis: 21(S3):469-470 U2014A0006.

Shirkhorshidian, A., Bishop, N., Dominguez, J., Wendt, J., Lilly, M.P., Carroll, M.S. (2015) “Transport spectroscopy of low disorder silicon tunnel barriers with and withour Sb implants” Nanotechnology: 26, 205703 U2013B0148

Subbaiyan, N.K., Doorn, S.K. (2015) “Nanotube micellar surface chemistry- surfactant surface structure, modification and application” Handbook of Carbon Nanomaterials: Volume 8, Chapter 1 U2013B0095

Subbaiyan, N.K., Parra-Vasquez, N.G., Cambre, S., Santiago Cordoba, M.A., Yalcin, S.E., Hamilton, C.E., Mack, N.H., Blackburn, J.L., Doorn, S.K., Duque, J.G. (2015) “Bench-top aqueous two-phase extraction of isolated individual single-walled carbon nanotubes” Nano Research: 10.1007 U2013A0024

Sun, C., Kirk, M., Li, M., Hattar, K., Wang, Y., Anderoglu, O., Valdez, J., Uberugga, B.P., Dickerson, R., Maloy, S.A. (2015), Microstructure, chemistry and mechanical properties of Ni-based superalloy Rene N4 under irradiation at room temperature, Acta Materialia, 95, 357-365. U2014A0061

VanDelinder, V., Wheeler, D.R., Small, L.J., Brumbach, M.T., Spoerke, E.D., Henderson, I., Bachand, G.D. (2015) “Simple, benign, aqueous-based animation of polycarbonate surfaces” Applied Material Interfaces: 10, 5643 C2014B0124

Wang, G., Zhang, M., Liu, S., Xie, X.M., Ding, G.Q., Wang, Y.Q., Chu, P.K., Heng, G., Ren, W., Yuan, Q.H., Zhang, P.H., Wang, X., Di, Z.F (2015) “Synthesis of layer-tunable graphene: A combined kinetic implantation and thermal ejection approach” Advanced Functional Materials: 25, 3666-3675 U2014A0013

Wang, F., Karan, N. S., Nguyen, H. M., Ghosh, Y., Sheehan, C. J., Hollingsworth, J. A. & Htoon, H. “Correlated structural-optical study of single nanocrystals in a gap-bar antenna: effects of plasmonics on excitonic recombination pathways.” Nanoscale **7**, 9387-9393, (2015). U2013B0037

Wang, F., Karan, N. S., Nguyen, H. M., Ghosh, Y., Sheehan, C. J., Hollingsworth, J. A. & Htoon, H. “Quantum Optical Signature of Plasmonically Coupled Nanocrystal Quantum Dots.” Small **11**, 5028-5034, (2015) (Back Cover) U2013B0037

Wang, F., Karan, N. S., Nguyen, H. M., Ghosh, Y., Hollingsworth, J. A. & Htoon, H. (2015) “Coupling Single Giant Nanocrystal Quantum Dots to the Fundamental Mode of Patch Nanoantennas through Fringe Field” Scientific reports: 5, 14313 U2013B0037

Wolf, O., Allerman, A.A., Ma, X., Wendt, J.R., Song, A.Y., Shaner, E.A., Brener, I. (2015) "Enhanced optical nonlinearities in the near-infrared using III-nitride heterstructures coupled to metamaterials" Applied Physics Letters: 107,151108

Wolf, O., Campione, S., Benz, A., Ravikumar, A.P., Liu, S., Luk, T.S., Kadlec, E.A., Shaner, E.A., Klem, J.F., Sinclair, M.B., Brener, I. (2015) "Phased-array sources based on nonlinear metamaterial nanocavities" Nature Communications: 6, 7667 C2014B0115

Wolf, O., Campione, S., Brener, I., Klem, J., Sinclair, M. (2015) "A smail-footprint IR source with beam control" Optics and Photonics News: 54

Wright, A.F., Modine, N.A. (2015) "Application of the bounds-analysis approach to arsenic and gallium antisite defects in gallium arsenide" Physical Review B: 91, 014110 U2013B0025

Gupta, G., Staggs, K., Mohite, A. D., Baldwin, J. K. ; Iyer, S., et al. (2015) "Irradiation-induced formation of a spinel phase at the FeCr/MgO interface" Acta Materialia ; 93, 87-94

Yalcin, S.E., Gallande, C., Kappera, R., Yamaguchi, H., Velizhanin, K.A., Doorn, S.K., Dattelbaum, A.M., Chhowalla, M., Ajayan, P.M., Gupta, G., Mohite, A. (2015) "Imaging charge transport pathways in progressively reduced graphene oxide using electrostatic force microscopy" ACS Nano: 9, 2981 U2012B0055

CINT User Science - External (152)

Adams, P.G., Collins, A.M., Sahin, T., Subramanian, V., Urban, V.S., Vairaprakash, P., Tian, Y., Evans, D.G., Shreve, A.P., Montano, G.A. (2015) "Diblock copolymer micelles and supported films with noncovalently incorporated chromosphores: A modular platform for efficient energy transfer" Nano Letters: 10.1021 U2015A0086

Adamska, L., Nazin, G.V., Doorn, S.K., Tretiak, S. (2015) "Self-trapping of charge carriers in semiconducting carbon nanotubes: structural analysis" Journal of Physical Chemistry Letters: 6, 3873-3879

Agrawal, A., Perahia, D., Grest, G.S. (2015) "Clustering effects in ionic polymers: Molecular dynamics simulations" Physical Review E: 92, 022601 U2015A0031

Aguiar, J.A., Anderoglu, O., Choudhury, S., Baldwin, J.K., Wang, Y., Misra, A., Uberuagapril, B.P. (2015) "Nanoscale morphologies at alloyed and irradiated metal-oxide bilayers" Journal of Materials Science: 50, 7 U2014B0058

Alfonso-Hernandez, L., Nelson, T., Tretiak, S., Fernandez-Alberti, S. (2015) "Photoexcited energy transfer in a weakly coupled dimer" Journal of Physical Chemistry B: 119, 7242-7252 C2013B0039

Aryal, D., Perahia, D., Grest, G.S. (2015) "Solvent controlled ion association in structured copolymers: Molecular dynamics simulations in dilute solutions" Journal of Chemical Physics: 143, 124905 U2015A0031

Bennaceur, K., Schmidt, B.A., Gaucher, S., Laroche, D., Lilly, M.P., Reno, J.L., West, K.W., Pfeiffer, L.N., Gervais, G. (2015) "Mechanical flip chip for ultra-high electron mobility devices" Scientific

Reports: 5, 13494 U2014A0003

Bilodeau, R.A., Fullwood, D.T., Colton, J., Yeager, J.D., Bowden, A.E., Park, T. (2015) "Evolution of nanojunctions in piezoresistive nanostrand composites" Composites Part B: 72, 45 C2013A0091

Bomberger, C.C., Vanderhoef, L.R., Rahman, A., Shah, D., Chase, D.B., Taylor, A.J., Azad, A.K., Doty, M.F., Zide, J.M.O (2015) "Determining the band alignment of TbAs:GaAs and TbAs:In0.53Ga.47As" Applied Physics Letters: 107, 10 C2012A0054

Bricker, W.P., Shenai, P.M., Ghosh, A., Enriquez, M.G.M., Lambrev, P.H., Liu, Z., Tan, H.S., Lo, C.S., Tretiak, S., Fernandez-Alberti, S., Zhao, Y. (2015) "Non-radiative relaxation of photoexcited chlorophylls: Theoretical and experimental study" Scientific Report: 5, 13625 C2013B0039

Briscoe, J.L., Cho, S.Y., Brener, I. (2015) "Part-per-trillion level detection of microcystin-LR using a periodic nanostructure" IEEE Sensors Journal: 15, 1366

Budiman, A.S., Narayanan, K.R., Li, N., Wang, J., Tamura, N., Kunz, M., Misra, A., (2015) "Plasticity evolution in nanoscale Cu/Nb single-crystal multilayers as revealed by synchrotron X-ray microdiffraction" Materials Science and Engineering: A: 635, 6 U2013B0018.

Buitrago, C.F., Bolintineanu, D.S., Seitz, M.E., Opper, K.L., Wagener, K.B., Stevens, M.J., Frischknecht, A.L., Winey, K.I. (2015) "Direct comparisons of X-ray scattering and atomistic molecular dynamics simulations for precise acid copolymers and ionomers" Macromolecules: 48, 1210 C2014B0023

Burghoff, D., Yang, Y., Hayton, D.J., Gao, J.R., Reno, J.L., Hu, Q. (2015) "Evaluating the coherence and time-domain profile of quantum cascade laser microcombs" Optics Express: 23, 1190 C2013B0004

Campione, S., Brener, I., Marquier, F. (2015) "Theory of epsilon-near-zero modes in ultrathin films" Physical Review B: 91, 121408 U2014B0064

Cao, Z., Carrillo, J.M., Stevens, M.J., Dobrynin, A.V. (2015) "Adhesion and Wetting of soft nanoparticles on textured surfaces: Transition between Wenzel and Cassie-Baxter states" Langmuir: 31, 1693 C2013B0036

Catanzaro, M.J., Shi, T., Tretiak, S., Chernyak, V.Y. (2015) "Counting the Number of Excited States in Organic Semiconductors Systems Using Topology" Journal of Chemical Physics: 142, 084113 C2013A0054

Chakraborty, S., Babanova, S., Rocha, R.C., Desireddy, A., Artyushkova, K., Atanassov, P. *, Martinez, J.S*.(2015) "A DNA-Hosted Gold Nanocluster Enhances Enzymatic Reduction of Oxygen by Facilitating Efficient Electron Transfer" Journal of the American Chemical Society: 137(36), 11678-11687 RA2015A0006

Chason, E. Engwall, A.M., Miller, C.M., Chen, C-H., Bhandari, A. Soni, S.K., Hearne, S.J., Freund, L.B., Sheldon, B.W. (2015) "Stress evolution during growth of 1-D island arrays: Kinetics and length scaling" Scripta Materialia 97, 33-36.

Cheaito, R., Hattar, K., Gaskins, J.T., Yadav, A.K., Duda, J.C., Beechem, T.E., Ihlefeld, J.F., Piekos, E.S., Baldwin, J.K., Misra, A., Hopkins, P.E. (2015) "Thermal flux limited electron Kapitza conductance in copper-niobium multilayers" Applied Physics Letters: 093114 U2014B0058

Chen, H., Golder, M.R., Wang, F., Doorn, S.K., Jasti, R., Tretiak, S., Swan, A.K. (2015) "Raman-active modes of even-numbered cycloparaphenylenes: Comparisons between experiments and density functional theory (DFT) calculations with group therapy arguments" Journal of Physical Chemistry C: 119, 2879-2887 U2011B69

Chen, L.Y., He, M., Shin, J., Richter, G., Gianola, D.S. (2015) "Measuring surface dislocation nucleation in defect-scarce nanostructures" Nature Materials: 10.1038 C2013A0009

Chen, R., Dayeh, S.A. (2015) "Size and orientation effects on the kinetics and structure of nickelide contacts to InGaAs fin structures" Nano Letters: 15, 6 U2013B0062

Chen, Y., Fu, E., Yu, K., Song, M., Liu, Y., Wang, Y., Wang, H., Zhang, X., (2015)"Enhanced radiation tolerance in immiscible Cu/Fe multilayers with coherent and incoherent layer interfaces." Journal of Materials Research: 30 (09), 1300-1309. C2015A0021.

Chen, Y., Liu, Y., Fu, E. G., Sun, C., Yu, K. Y., Song, M., Li, J., Wang, Y. Q., Wang, H., Zhang, X., (2015) "Unusual size-dependent strengthening mechanisms in helium ion-irradiated immiscible coherent Cu/Co nanolayers." Acta Materialia *84*, 393-404. C2015A0021.

Chen, Y., Yu, K.Y., Liu, Y., Shao, S., Wang, H., Kirk, M.A., Wang, J., Zhang, X., (2015)"Damage-tolerant nanotwinned metals with nanovoids under radiation environments." Nature Communications: 6. C2015A0021.

Cheng, F., Gao, J., Luk, T.S., Yang, X. (2015) "Structural color printing based on plasmonic metasurfaces of perfect light absorption" Scientific Reports: 5, 11045 C2014B0011

Chong, K.E., Staude, I., James, A., Dominguez, J., Liu, S., Campione, S., Subramania, G.S., Luk, T.S., Decker, M., Neshev, D.N., Brener, I., Kivshar, Y.S. (2015) "Polarization-independent silicon metadevices for efficient optical wavefront control" Nano Letters: 15, 5369 U2014A0030

Cole, W.T.S., Hlavacek, N.C., Lee, A.W.M., Kao, T.Y., Hu, Q., Reno, J.L., Saykally, R.J. (2015) "Terahertz Vrt spectrometer employing quantum cascade lasers" Chemical Physics Letters: 638, 144-148 C2013B0004

Creange, N., Constantin, C., Zhu, J.X., Balatsky, A., Haraldsen, J. (2015) "Computational investigation of the electronic and optical properties of planar Ga-doped graphene" Advanced Condensation Matter: 635019 U2013B0009

Crook, C.B., Constantin, C., Ahmed, T., Zhu, J.X., Balatsky, A.V., Haraldsen, J.T. (2015) "Proximity-induced magnetism in transition-metal substituted graphene" Scientific Reports: 5, 12322 U2013B0009

De Haro, L.P., Karaulanov, T., Vreeland, E.C., Anderson, B., Hathaway, H.J., Huber, D.L., Matlashov, A.N., Nettles, C.P., Price, A.D., Monson, T.C., Flynn, E.R. (2015) "Magnetic relaxometry as applied to sensitive cancer detection and localization" Biomed Tech: 60, 5 C2014B0127

Decker, M., Staude, I., Falkner, M., Dominguez, J., Neshev, D.N., Brener, I., Pertsch, T., Kivshar, Y.S. (2015) "High-efficiency dielectric Huygens' surfaces" Advanced Optical Materials: 3, 813

DeVore, M., Stich, D., Keller, A., Cleyrat, C., Phipps, M., Hollingsworth, J., Lidke, D., Wilson, B., Goodwin, P., Werner, J. (2015) "Time-gated 3D single quantum dot tracking with simultaneous spinning disk imaging" Review of Scientific Instruments: 86, 12 C2013A0111

DeVore, M., Stich, D.G., Keller, A.M., Ghosh, Y., Goodwin, P.M., Phipps, E., Stewart, M.H., Cleyrat, C., Wilson, B.S., Lidke, D.S., Hollingsworth, J., Werner, J. (2015) "Three dimensional time-gated tracking of non-blinking quantum dots in live cells" SPIE BiOS: 933812-933815 C2013A0111

Dhara, S., Mele, E., Agarwal, R. (2015) "Voltage-tunable circular photogalvanic effect in silicon nanowires" Sciencexpress: 10, 1126 U2013B0054

Dumont, E.L.P., Do, C., Hess, H. (2015) "Molecular wear of microtubules propelled by surface-adhered kinesins" Nature Nanotechnology: 10.1038 U2012A0018

Fagan, J.A., Haroz, E.H., Ihly, R., Gui, H., Blackburn, J.L., Simpson, J.R., Lam, S., Hight Walker, A.R., Doorn, S.K., Zheng, M. (2015) "Isolation of >1 nm diameter single-wall carbon nanotube species using aqueous two phas extraction" ACS Nano: 9, 5377 RA2015A0027

Fluegel, B., Mialitsin, A.V., Beaton, D.A., Reno, J.L., Mascarenhas, A. (2015) "Electronic Raman Scattering as an ultra-sensitive probe of strain effects in semiconductors" Nature Communications: 6 C2012B0045

Fluegel, B., Alberi, K., Reno, J., Mascarenhas, A. (2015) "Spectroscopic determination of the bandgap crossover composition in Mbe-grown AlxGa1-Xas" Japanese Journal of Applied Physics: 54, 4 C2012B0045

Frolova, L.V., Magedov, I.V., Harper, A., Jha, S.K., Ovezmyradov, M., Chandler, G., Garcia, J., Bethke, D., Shaner, E.A., Vasiliev, I., Kalugin, N.G. (2015) "Tetracyanothylene oxide-functionalized graphene and graphite characterized by Raman and Auger spectroscopy" Carbon: 81, 216 C2013A0099

Galindo, J.F., Atas, E., Altan, A., Kuroda, D.G., Fernandez-Alberti, S., Tretiak, S., Kleiman, V., Roitberg, A.E. (2015) "Dynamics of energy transfer in a conjugated dendrimer driven by ultrafast localization of excitons" Journal of the American Chemical Society: 137, 11637-11644 C2013B0039

Ganguly, M., Bradsher, C., Goodwin, P., Petty, J.T. (2015) "DNA-directed fluorescence switching of silver clusters" The Journal of Physical Chemistry C: 119, 49 C2013B0066

Ghimire, N.J., Luo, Y., Williams, D.J., Bauer, E.D., Ronning, F. (2015) "Magnetotransport of single crystalline NbAs" Journal of Physics: Condensed Matter: 27, 152201 U2015A0081

Ghimire, N.J., Ronning, F., Williams, D.J., Scott, B.L., Luo, Y., Thompson, J.D., Bauer, E.D. (2015) "Investigation of the physical properties of the tetragonal CeMAI4Si2 (M=Rh, Ir, Pt) compounds" Journal of Physics: Condensed Matter: 27, 025601 U2015A0081

Haroz, E.H., Duque, J.G., Simpson, J., Barros, E., Telg, H., Hight Walker, A.R., Tu, X., Zheng, M., Kono, J., Doorn, S.K. (2015) "Asymmetric excitation profiles in the resonance raman response of armchair carbon nanotubes" Physical Review B: 91, 205446 C2013A0029

Harper, J.C., Carson, B.D., Bachand, G.D., Arndt, W.D., Finley, M.R., Brinker, C.J., Edwards, T.L. (2015) "Laser machined plastic laminates: Towards portable diagnostic devices for use in low resource environments" Electroanalysis: 27, 11 C2013B0007

Henderson, I.M., Quintana, H.A., Martinez, J.A., Paxton, W.F. (2015) "Capable crosslinks: Polymersomes reinforced with catalytically active metal-ligand bonds" Chemical Materials: 27, 408 U2015A0062

Hollingsworth, J.A., Htoon, H., Piryatinski, A., Gotzinger, S., Sandoghdar, V. (2015) "When excitons and plasmons meet: Emerging function through synthesis and assembly" MRS Bulletin: 40, 768 C2014A0001

Hong, M., Ren, F., Wang, Y.Q., Zhang, H., Xiao, X., Fu, D., Yang, B., Jiang, C. (2015) "Size-dependent radiation tolerance and corrosion resistance in ion irradiated CrN/AlTiN nanofilms" Nuclear Instruments and Methods in Physics Research B: 342, 137 C2013B0011

Hong, Y.J., Lee, C.H., Yoo, J., Kim, Y.J., Jeong, J., Kim, M., Yi, G.C. (2015) "Emission color-tuned light-emitting diode microarrays of nonpolar InxGa1-xN/GaN multishell nanotube heterostructures" Scientific Reports: 5, 18020 U2014B0041

Janish, M.T., Carter, C.B. (2015) "In-situ TEM observations of the lithiation of molybdenum disulfide" Scripta Materialia: 107, 22-25 U2013A0103

Janish, M.T., Mackay, D.T., Liu, Y., Jungjohann, K.L., Carter, C.B., Norton, M.G. (2015) "TEM in situ lithiation of tin nanoneedles for battery applications" Journal of Material Sciences: 10.1007 U2013A0103

Janish, M.T., Kotula, P.G., Boyce, B.L., Carter, C.B. (2015) "Observations of fcc and hcp tantalum" Journal of Materials Science: 50, 10 U2013A0103

Janish, M.T., Mook, W.M., Carter, C.B. (2015) "Nucleation of face-centered cubic Ta when heating thin films" Scripta Materialia: 96, 21-24 U2013A0103

Johnson, P.E., Muttil, P., Mackenzie, D., Carnes, E.C., Pelowitz, J., Mara, N.A., Mook, W.M., Jett, S.D., Dunphy, D.R., Timmins, G.S., Brinker, C.J. (2015) "Spray-dried multiscale nano-biocomposites containing living cells" ACS Nano: 9, 7 C2013B0007

Kalathi, J.T., Kumar, S.K., Rubinstein, M., Grest, G.S. (2015) "Rouse mode analysis of chain relaxation in polymer nanocomposites" Soft Matter: 11, 4123 U2014A0051

Karan, N. S., Keller, A. M., Sampat, S., Roslyak, O., Arefin, A., Hanson, C. J., Casson, J. L., Desireddy, A., Ghosh, Y., Piryatinski, A., Iyer, R. , Htoon, H., Malko, A. V. & Hollingsworth, J. A. (2015) "Plasmonic Giant Quantum Dots: Hybrid Semiconductor-Metal Nanostructures for Truly Simultaneous Optical Imaging, Photothermal Effect and Thermometry" Chem. Sci: *6*, 2224-2236. U2013B0037, RA2012B0008, and U2013A0134

Keyan-Bennaceur, J., Schmidt, B.A., Gaucher, S., Laroche, D., Lilly, M.P., Reno, J.L., West, K.W., Pfeiffer, L.N., Gervais, G. (2015) "Mechanical flip-chip for ultra-high electron mobility devices" Scientific Reports: 5, 13494 U2014A0003

Khromova, I., Navarro-Cia, M., Brener, I., Reno, J.L., Ponomarev, A., Mitrofanov, O. (2015) "Dipolar resonances in conductive carbon micro-fibers probed by near-field terahertz spectroscopy" Applied Physics Letters: 107, 021102 C2012B0064

Kilina, S., Kilin, D., Tretiak, S. (2015) "Light-driven and phonon-assisted dynamics in organic and semiconductor nano-structures" Chemistry Review: 115, 5929-5978 C214B0092

Kim, H., Lee, J.T., Magasinski, A., Zhao, K., Liu, Y., Yushin, G. (2015) "In-situ TEM observation of electrochemical lithiation of sulfur confined within inner cylindrical pores of carbon nanotubes" Advanced Energy Materials: 10, 1002 C2013A0021

Koechner, M.C., Pande, J.H., Merkley, S., Henderson, S., Fullwood, D.T., Bowden, A. (2015) "Remote in situ strain sensing of carbon fiber structures using embedded conductive materials" Composites Part B: 69, 534 C2013A0091

Kraehnert, R., Ortel, E., Paul, B., Eckhardt, B., Kanis, M., Liu, R., Antoniou, A. (2015) "Electrochemically dealloyed platinum with hierarchical pore structure as highly active catalytic coating" Catalysis Science and Technology: 5, 206 U2014A0082

Lamoreux, L., Adams, P., Banisadr, A., Stromberg, Z., Graves, S., Montano, G., Moxley, R., Mukundan, H. (2015) "An optical biosensor for detection of pathogen biomarkers from Shiga toxin-producing Escherichia coli in ground beef samples" Proceeding of SPIE: 9310, 931004

Laroche, D., Huang, S.H., Nielsen, E., Chuang, Y., Li, J.Y., Liu, C.W., Lu, T.M. (2015) "Scattering mechanisms in shallow undoped Si/SiGe quantum wells" AIP Advances: 5, 107106 C2012B0019

Laroche, D., Huang, S.H., Nielsen, E., Liu, C.W., Li, J.Y., Lu, T.M. (2015) "Magneto-transport of an electron bilayer system in an undoped Si/SiGe double-quantum-well heterstructure" Applied Physics Letters: 106, 143503 C2012B0019

Lee, S., Zhang, W., Khatkhatay, F., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L. (2015) "Ionic conductivity increased by two orders of magnitude in micrometer-thick vertical yttria-stabilized ZrO2 nanocomposite films" Nano Letters: 15, 7362 C2013A0005

Lee, S., Zhang, W., Jia, Q.X., Wang, H., MacManus-Driscoll, J.L. (2015) "Strain tuning and strong enhancement of ionic conductivity in SrZrO3-RE2O3 (RE=Sm, Eu, Gd, Dy, and Er) nanocomposite films" Advanced Functional Materials: 25, 4238 C2013A0005

Leonard, F., Song, E., Li, Q., Swartzentruber, B., Pan, W., Martinez, J., Wang, G. (2015) "Simultaneous thermoelectric and optoelectronic characterization of individual nanowires" Nano Letters: 15, 8129 C2013B0112

Li, B., Pan, L., Tai, Y., Graf, M., Zhu, J.X., Bassler, K., Ting, C.S. (2015) "Unified description of superconducting pairing symmetry in electron-doped Fe-based-122 compounds" Physical Review B: 91, 220509 U2015A0094

Li, C., Liu, S., Hurtado, A., Wright, J.B., Xu, H., Luk, T.S., Figiel, J.J., Brener, I., Brueck, S.R.J., Wang, G.T. (2015) "Annular-shaped emission from gallium nitride nanotube lasers" ACS Photonics: 10.1021 RA2014A0014

Li, J., Yu, K. Y., Chen, Y., Song, M., Wang, H., Kirk, M. A., Li, M., Zhang, X., (2015) "In Situ Study of Defect Migration Kinetics and Self-Healing of Twin Boundaries in Heavy Ion Irradiated Nanotwinned Metals. Nano Letters: 15 (5), 2922-2927. C2015A0021.

Li, N., Demkowicz, M., Mara, N., Wang, Y.Q., Misra, A. (2015) "Hardening due to interfacial He bubbles in nanolayered composites" Materials Research Letters: DOI: 10.1080/21663831.2015.1110730. U2013B0018

Li, N., Misra, A., Shao, S., Wang, J. (2015) "Experimental Quantification of Resolved Shear Stresses for Dislocation Motion in TiN" Nano Letters: 15, 4434 U2014A0085.

Li, N., Yadav, S., Liu, X.Y., Wang, J., Hoagland, R., Mara, N.A., Misra, A. (2015) "Growth and stress-induced transformation of zinc blended AIN layers in Al-AlN-TiN multilayers" Scientific Reports: 5, 18554 U2014B0058

Li, N., Yadav, S., Liu, X.Y., Wang, J., Hoagland, R., Mara, N.A., Misra, A. (2015) "Quantification of dislocation nucleation stress in TiN through high-resolution in situ indentation experiments and first principles calculations" Scientific Reports: 5, 15813 U2014B0058

Li, Z., Tan, X., Kalisvaart, P., Janish, M.T., Mook, W.M., Jungjohann, K.L., Carter, C.B., Mitlin, D. (2015) "Coupling in-situ TEM and ex-situ analysis to understand heterogeneous sodiation of antimony" Nano Letters: 15, 10 U2013B0051

Liu, J., Kilina, S., Tretiak, S., Prezhdo, O.V. (2015) "Ligands slow down pure-dephasing in semiconductor quantum dots" ACS Nano: 9, 9106-9116 C2014B0092

Liu, S., Li, C., Figiel, J.J., Brueck, S.R.J., Brener, I., Wang, G.T. (2015) "Continous and dynamic spectral tuning of single nanowire lasers with subnanometer resolution using hydrostatic pressure" Nanoscale: 7, 21 RA2014A0014

Liu, Y., Vishniakou, S., Yoo, J., Dayeh, S.A. (2015) "Engineering heteromaterials to control lithium ion transport pathways" Scientific Reports: 5, 18482 U2013B0062

Liu, Y., Wang, H., Zhang, X., (2015) "In Situ TEM Nanoindentation Studies on Stress-Induced Phase Transformations in Metallic Materials." JOM: the journal of the Minerals, Metals & Materials Society: 68 (1), 226-234. C2013B0013.

Luk, T.S., de Ceglia, D., Liu, S., Keeler, G.A., Prasankumar, R.P., Vincenti, M.A., Scalora, M., Sinclair, M.B., Campione, S. (2015) "Enhanced third harmonic generation from the epsilon-near-zero modes of ultrathin films" Applied Physics Letters: 106, 151103 RA2014B0009

Luo, Y., Li, H., Dai, Y.M., Miao, H., Shi, Y.G., Ding, H., Taylor, A.J., Yarotski, D.A., Prasankumar, R.P., Thompson, J.D. (2015) "Hall effect in the extremely large magnetoresistance material WTe2" Applied Physics Letters: 107, 182411 U2013B0125

Ma, X., Hartmann, N.F., Baldwin, J.K.S., Doorn, S. K., Htoon, H. (2015) "Room-temperature single-photon generation from solitary dopants of carbon nanotubes" Nature Nanotechnology 10, 671-675

MacManus-Driscoll, J.L., Suwardi, A., Kursumovic, A., Bi, Z., Tsai, C.F., Wang, H., Jia, Q.X., Lee, Q.J. (2015) "New strain states and radical property tuning of metal oxides using a nanocomposite thin film approach" APL Material: 3, 062507 U2012B0069

Maksud, M., Yoo, J., Harris, C.T., Palapati, N.K.R., Subramanian, A. (2015) "Young's modulus of [111] germanium nanowires" APL Materials: 3, 116101 U2014A0084

Mance, J.G., Felver, J.J., Dexheimer, S.L. (2015) "Observation of structural relaxation during exciton self-trapping via excited-state resonant impulsive stimulated Raman spectroscopy" Journal of Chemical Physics: 142, 084309 C2014A0088

Martin, E.J.J., Berube, N., Provencher, M.C., Silva, C., Doorn, S.K., Grey, J.K. (2015) "Resonance raman

spectroscopy and imaging of push-pull conjugated polymer/fullerene solar cells" Journal of Material Chemistry C: 3, 6058 RA2011B0019

Mayer, C., Li, N., Mara, N.A., Chawla, N. (2015) "Micromechanical and in situ shear testing of Al-SiC nanolaminate composites in a transmission electron microscope (TEM)" Materials Science and Engineering A: 621, 229-235 C2014A0011

McFarland, H.L., Ahmed, T., Zhu, J.X., Balatsky, A.V., Haraldsen, J.T. (2015) "First-principles investigation of nanopore sequencing using variable voltage bias on graphene-based nanoribbons" Journal of Physical Chemistry Letters: 6, 2616 U2013B0009

Middleton, R.S., Carey, J.W., Currier, R.P., Hyman, J.D., Kang, Q., Karra, S., Jimenez-Martinez, J., Porter, M.L., Viswanathan, H.S. (2015) "Shale gas and non-aqueous fracturing fluids: Opportunities and challenges for supercritical CO2" Applied Energy: 147, 500 C2014A0054

Mitrofanov, O., Luk, T.S., Brener, I., Reno, J.L. (2015) "Plasmonic enhancement of sensitivity in terahertz (Thz) photo-conductive detectors" Terahertz Emitters, Receivers, and Applications: 9585 U2014A0072

Mitrofanov, O., Luk, T.S., Brener, I., Reno, J.L. (2015) "Photoconductive terahertz near-field detector with a hybrid nanoantenna array cavity" ACS Photonics: 2, 12 U2014A0072

Modine, N. A. and Hatcher, R. M. (2015) "Representing the Thermal State in Time-Dependent Density Functional Theory" Journal of Chemical Physics: 142, 204111 U2011A1097

Moon, J.S., Liang, Y., Stevens, T.E., Monson, T.C., Huber, D.L., Mahala, B.D., Winiarz, J.G. (2015) "Off-resonance photosensitization of a photorefractive polymer composite using PbS nanocrystals" Journal of Physical Chemistry C: 119, 24 C2008A151

Mukherjee, S., Bowman, D.N., Jakubikova, E. (2015) "Cyclometalated Fe(II) complexes as sensitizers in dye-sensitized solar cells" Inorganic Chemistry: 54, 2 C2012B0052

Myers, S. M., Wampler, W. R., and Modine, N. A. (2015) "Recombination by Band-to-Defect Tunneling near Heterojunctions in Irradiated Bipolar Devices: a Theoretical Model" Sandia Report: 2015-7650 U2015B0021

Nguyen, B.M., Swartzentruber, B.S., Ro, Y.G., Dayeh, S.A. (2015) "Facet-selective nucleation and conformal epitaxy of Ge shell on Si Nanowires" Nano Letters: 15, 11 U2013B0062

Orfield, N. J., McBride, J. R., Wang, F., Buck, M. R., Keene, J. D., Reid, K. R., Htoon, H., Hollingsworth, J. A. & Rosenthal, S. J. Quantum Yield Heterogeneity in Nonblinking Quantum Dots Revealed by Atomic Structure-Quantum Optics Correlation. ACS Nano, Under Revision, (2015). U2014B0001

Ovezmyradov, M., Magedov, I.V., Frolova, L.V., Chandler, G., Garcia, J., Bethke, D., Shaner, E.A., Kalugin, N.G. (2015) "Chemical vapor deposition of phosphorous- and boron-doped graphene using phenyl-containing molecules" Nanoscience and Nanotechnology: 15, 7 C2013A0099

Palapati, N.K.R., Pomerantseva, E., Subramanian, A. (2015) "Single nanowire manipulation within dielectrophoretic force fields in the sub-crossover frequency regime" Nanoscale: 7, 3109 C2014A0027

Parashar, V., Durand, C.P., Hap, B., Amorim, R.G., Pandey, R., Tiwari, B., Zhang, D., Liu, Y., Li, A.P., Yap, Y.K. (2015) "Switching behaviors of graphene-boron nitride nanotube heterojunctions" Scientific Reports: 5, 12238 U2014B0070

Pathak, S., Li, N., Mook, W.M., Hoagland, R.G., Baldwin, J.K., Misra, A., Wang, J., Mara, N.A. (2015) "On the origins of hardness in Cu-TiN nanolayered composites" Scripta Materialia: 109, 48-51 U2014B0058

Park, Y., Zhugayevych, A., Postpuna, O., Kyu, S.W., Park, Y.S., Park, B., Martinez, J.S., Park, J., Tretiak, S., Wang, H.L. (2015) "A new pH sensitive fluorescent and white light emissive material through controlled intermolecular charge transfer" Chemical Science: 6, 789-797 U2015A0016

Perez del Pino, A., Gyorgy, E., Logofatu, C., Puigmarti-Luis, J., Gao, W. (2015) "Laser-induced chemical transformation of graphene oxide-iron oxide nanoparticles composites deposited on polymer substrates" Carbon: 10.1016 RA2012A0009

Porter, M.L., Jimenez-Martinez, J., Martinez, R., McCulloch, Q., Carey, J.W., Viswanathan, H.S. (2015) "Geo-material microfluidics at reservoir conditions for subsurface energy resource applications" Lab on a Chip: 10.1039 C2014A0054

Prasai, D., Klots, A.R., Newaz, A.K.M., Niezgoda, J.S., Orfield, N.J., Escobar, C.A., Wynn, A., Efimov, A., Jennings, G.K., Rosenthal, S.J., Bolotin, K.I. (2015) "Electrical control of near-field energy transfer between quantum dots and two-dimensional semiconductors" Nano Letters: 15, 4374 U2013A0080

Ramasamy, K., Gupta, R.K., Palchoudhury, et al. (2015) "Layer-Structured Copper Antimony Chalcogenides (CuSbSexS2-x): Stable Electrode Materials for Supercapacitors" Chemical Materials: 27, 379-386 (2015). U2014A0029

Ramasamy, K., Gupta, R.K., Sims, H., et al. (2015) "Layered Ternary Sulfide CuSbS2 Nanoplates for Flexible Solid-State Supercapacitors" Journal of Material Chemistry A: 3, 13263-13274 U2014A0029

Rishinaramangalam, A.K., Mishkat Ul Masabih, S., Fairchild, M.N., Wright, J.B., Shima, D.M., Balakrishnan, G., Brener, I., Brueck, S.R.J., Feezell, D.F. (2015) "Controlled growth of ordered III-nitride core-shell nanostructure arrays for visible optoelectronic devices" Journal of Electronic Materials: 44, 1255 C2014B0063

Sampat, S., Karan, N. S., Guo, T., Htoon, H., Hollingsworth, J. A. & Malko, A. V. Multistate blinking and scaling of the recombination rates in individual silica coated CdSe/CdS nanocrystals. ACS Photonics **2**, 1505-1512, (2015). U2013A0134

Sampat, S., Mohite, A.D., Crone, B., Tretiak, S., Malko, A., Taylor, A.J., (2015) "Tunable charge transfer dynamics at Tetracene/LiF/C60 Interfaces" Journal of Physical Chemistry C: 119, 1286-1290 U2014B0093

Sautter, J., Staude, I., Decker, M., Rusak, E., Neshev, D.N., Brener, I., Kivshar, Y.S. (2015) "Active tuning of all-dielectric metasurfaces" ACS Nano: 9, 4308

Shcherbakov, M.R., Neshev, D.N., Hopkins, B., Shorokhov, A.S., Staude, I., Melik-Gaykazyan, E.V., Decker, M., Ezhov, A.A., Miroschnichenko, A.E., Brener, I., Fedyanin, A.A., Kivshar, Y.S. (2015) "Nonlinear properties of 'magneticlight'" Asia Pacific Physics Newsletter: 4, 57-58 U2014A0030

Shcherbakov, M.R., Neshev, D.N., Hopkins, B., Shorokhov, A.S., Staude, I., Melik-Gaykazyan, E.V., Decker, M., Ezhov, A.A., Miroschnichenko, A.E., Brener, I., Fedyanin, A.A., Kivshar, Y.S. (2015) "Enhanced third-harmonic generation in silicon nanoparticles driven by magnetic response" Nano Letters: 10.1021 U2014A0030

Shcherbakov, M.R., Shorokhov, A.S., Neshev, D.N., Hopkins, B., Staude, I., Melik-Gaykazyan, E.V., Ezhov, A.A., Miroshnichenko, A.E., Brener, I., Fedyanin, A.A., Kivshar, Y.S. (2015) "Nonlinear interference and tailorable third-harmonic generation from dielectric oligomers" ACS Photonics: 2, 578 U2014A0030

Schoeppner, R.L., Wheeler, J.M., Zechner, J., Michler, J., Zbib, H.M., Bahr, D.F. (2015) "Coherent interfaces increase strain-hardening behavior in tri-component nano-scale metallic multilayer thin films" Materials Research Letters: 3, 2 C2014B0081

Song, E., Li, Q., Swartzentruber, B.S., Pan, W., Wang, G.T., Martinez, J.A. (2015) "Enhanced thermoelectric transport in modulation-doped GaN/AlGaN Core/Shell nanowires" Nanotechnology: 27, 015204 C2013B0112

Staude, I., Khardikov, V., Fofang, N., Liu, S., Decker, M., Neshev, D., Luk, T.S., Brener, I., Kivshar, Y. (2015) "Shaping photoluminescence spectra with magnetoelectric resonances in all-dielectric nanoparticles" ACS Photonics: 2, 172 U2014A0030

Sukrittanon, S., Liu, R., Ro, Y.G., Pan, J.L., Jungjohann, K.L., Tu, C.W., Dayeh, S.A. (2015) "Enhanced conversion efficiency in wide-bandgap GaNP solar cells" Applied Physics Letters: 107, 153901 U2013B0062

Sun, C., Zheng, S., Wei, C. C., Wu, Y., Shao, L., Yang, Y., Hartwig, K. T., Maloy, S. A., Zinkle, S. J., Allen, T. R., Wang, H., Zhang, X., (2015) "Superior radiation-resistant nanoengineered austenitic 304L stainless steel for applications in extreme radiation environments." Scientific Reports: *5*, 7801. C2015A0021.

Sun, L., Li, A., Luk, T.S., Yang, X., Gao, J. (2015) "Nonlocal effective medium analysis in symmetric metal-dielectric multilayer metamaterials" Physical Review B: 91, 195147 U2013A0035

Tai, Y.Y., Wang, C.C., Graf, M., Zhu, J.X., Ting, C.S. (2015) "Emergent topological mirror insulator in t2g-orbital systems" Physical Review B: 91, 041111 U2015A0094

Tanaka, A., Chen, R., Jungjohann, K., Dayeh, S. (2015) "Strong geometrical effects in submillimeter selective area growth and light extraction of GaN light emitting diodes on sapphire" Scientific Reports: 5, 17314 U2013B0062

Tian, M., Wang, W., Liu, Y., Jungjohann, K.L., Harris, C.T., Lee, Y.C., Yang, R. (2015) "A Three-dimensional carbon nano-network for high performance lithium ion batteries" Nano Energy: 11, 500-509 C2013B0134

Upadhya, P.C., Martinez, J.A., Li, Q., Wang, G.T., Swartzentruber, B.S., Taylor, A.J., Prasankumar, R.P. (2015) "Space and time resolved spectroscopy of sing GaN nanowires" Applied Physics Letters: 106, 263103 C2013B0093

Veith, G.M., Doucet, M., Baldwin, J. K., Sacci, R.L., Fears, T. M., et al. (2015) "Direct Determination of Solid-Electrolyte Interphase Thickness and Composition as a Function of State of Charge on a Silicon Anode" Journal of Physical Chemistry C 119, 20339-20349

Viswanathan, H.S., Hyman, J.D., Karra, S., Carey, J.W., Porter, M.L., Rougier, E., Currier, R.P., Kang, Q., Zhou, L., Jimenez-Martinez, J., Makedonska, N., Chen, L., Middleton, R.S. (2015) "Using discovery science to increase efficiency of hydraulic fracturing while reducing water usage" Hydraulic Fracturing: Environmental Issues: Chapter 3 C2014A0054

Vreeland, E.C., Watt, J., Schober, G.B., Hance, B.G., Austin, M.J., Price, A.D., Fellows, B.D., Monson, T.C., Hudak, N.S., Maldonado-Camargo, L., Bohorquez, A.C., Rinaldi, C., Huber, D.L. (2015) "Enhanced nanoparticle size control by extending LaMer's mechanism" Chemistry of Materials: 27, 17 C2014B0127

Wang, X., Fan, F., Wang, J.W., Wang, H., Tao, S., Yang, A., Liu, Y., Chew, H.B., Mao, S.X., Zhu, T., Xia, S. (2015) "High damage tolerance of electrochemically lithiated silicon" Nature Communications: 6, 8417 C2012A0045

Wang, X., Pan, Z., Fan, F., Wang, J.W., Liu, Y., Mao, S.X., Zhu, T., Xia, S. (2015) "Nanoscale deformation measurement with high-resolution transmission electron microscopy and digital image correlation" Journal of Applied Mechanics, Transactions ASME: 82, 121001 C2012A0045

Wang, Z., Luk, T.S., Tan, Y., Ji, D., Zhou, M., Gan, Q., Yu, Z. (2015) "Tunneling-enabled spectrally selective thermal emitter based on flat metallic films" Applied Physics Letters: 106, 101104 U2013B0151

Xu, E.Z., Li, Z., Martinez, J.A., Sinitsyn, N., Htoon, H., Li, N., Swartzentruber, B., Hollingsworth, J.A., Wang, J., Zhang, S.X. (2015) "Diameter dependent thermoelectric properties of individual SnTe nanowires" Nanoscale: 7, 2869 C2013A0093

Xu, Y., Aguiar, J.A., Yadav, S.K., Anderoglu, O., Baldwin, J.K., Wang, Y.Q., Valdez, J.A., Misra, A., Luo, H.M., Uberuaga, B.P., Li, N. (2015) "Solute redistribution and phase stability at FeCr/TiO2-x interfaces under ion irradiation" Acta Materialia: 89, 364-373 U2014B0058

Xu, Y., Yadav, S.K., Aguiar, J.A., Anderoglu, O., Baldwin, J.K., Wang, Y.Q., Misra, A., Luo, H., Uberuaga, B.P., Li, N. (2015) "Irradiation-induced formation of a spinel phase at the FeCr/MgO interface" Acta Materialia: 93, 87 U2013B0018.

Xue, S., Fan, Z., Chen, Y., Li, J., Wang, H., Zhang, X., (2015) "The formation mechanisms of growth twins in polycrystalline Al with high stacking fault energy" Acta Materialia: 101, 62-70. C2015A0021

Yang, S.M., Lee, S., Jian, J., Zhang, W., Jia, Q.X., Wang, H., Noh, T.W., Kalinin, S.V., MacManus-Driscoll, J.L. (2015) "Strongly enhanced oxygen ion transport through Sm-doped CeO2 nanopillars in nanocomposite films" Nature Communications: 6, 8588

Yan, H., Chuang, C., Zhugayevych, A., Tretiak, S., Dahlquisti, F.W., Bazan, G.C. (2015) "Modeling inter-aromatic distances in Geobacter sulfurreducens pili relevant to biofilm charge transport" Advanced Materials: 27, 1908-1911 U2015A0016

Yoo, J., Nguyen, B.M., Campbell, I.H., Dayeh, S.A., Schuele, P., Evans, D., Picraux, S.T. (2015) "Si radial p-i-n junction arrays for photovoltaics with built-in light concentrators" ACS Nano: 9, 5 U2013B0062

Yu, K. Y., Fan, Z., Chen, Y., Song, M., Liu, Y., Wang, H., Kirk, M. A., Li, M., Zhang, X., (2015) "In situ Observation of Defect Annihilation in Kr Ion-Irradiated Bulk Fe/Amorphous-Fe2Zr Nanocomposite Alloy." Materials Research Letters: 3 (1), 35-42. C2013B0013.

Zeng, J., Gao, J., Luk, T.S., Litchinitser, N.M., Yang, X. (2015) "Structuring light by concentric-ring patterned magnetic metamaterial cavities" Nano Letters: 10.1021 C2014B0011

Zhang, G.P., Si, M.S., Bai, Y.H., George, T.F. (2015) "Magnetic spin moment reduction in photoexcited ferromagnets through exchange interaction quenching: beyond the rigid band approximation" Journal of Physics: Condensed Matter: 27, 206003 U2014A0015

Zhang, G.P., Zhu, H.P., Bai, Y.H., Bonacum, J., Wu, X.S., George, T.F. (2015) "Imaging superatomic molecular orbitals in a C60 molecule through four 800-nm photons" World Scientific: 29, 1550115 U2014A0015

Zhang, W., Fan, M., Li, L., Chen, A., Su, Q., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2015) "Heterointerface design and strain tuning in epitaxial BiFeO3:CoFe2O4 nanocomposite films" Applied Physics Letters: 107, 21290 U2012B0069

Zhang, W., Li, L., Lu, P., Fan, M., Su, Q., Khatkhatay, F., Chen, A., Jia, Q.X., Zhang, X., MacManus-Driscoll, J.L., Wang, H. (2015) "Perpendicular exchange biased magnetotransport at the vertical La0.7Sr0.3MnO3-NiO heterointerface" Nanoscale: 7, 13808 U2012B0069

Zheng, S., Shao, S., Zhang, J., Wang, Y., Demkowicz, M., Beyerlein, I., Mara, N.A. (2015) "Adhesion of voids to interfaces with non-uniform energies" Scientific Reports: 5, 15428 U2008A119

Zheng, X., Shen, S., Ren, F., Cai, G., Xing, Z., Liu, Y., Liu, D., Zhang, G., Xiao, X., Wu, W., Jiang, C. (2015) "Irradiation-induced TiO2 nanorods for photoelectrochemical hydrogen production" International Journal of Hydrogen Energy: 10.1016 C2013B0011

Zhou, M., Yi, S., Luk, T.S., Gan, Q., Fan, S., Yu, Z. (2015) "Analog of superradiant emission in thermal emitters" Physical Review B: 92 U2013B0151

Zhou, X.W., Ward, D.K., Doty, F.P., Zimmerman, J.A., Wong, B.M., Cruz-Campa, J.L., Nielson, G.N., Chavez, J.J., Zubia, D., McClure, J.C. (2015) "A prediction of dislocation-free CdTe/CdS photovoltaic multilayers via nano-patterning and composition grading" Progress in Photovoltaics: 10.1002 C2104A0050

Zhu, F., Men, L., Guo, Y., Zhu, Q., Bhattacharjee, U., Goodwin, P.M., Petrich, J.W., Smith, E.A., Vela, J. (2015) "Shape evolution and single particle luminescence of organometal halide perovskite nanocrystals" ACS Nano: 9, 3 U2012B0008

Zhugayevych, A., Tretiak, S. (2015) "Theoretical description of structural and electronic properties of organic photovoltaic materials" Annual Review of Physical Chemistry: 66, 305-330 U2015A0016

4.c. BES Questionnaire

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**
Fiscal Year: **FY13-FY15**

USER SATISFACTION Mini-Survey

Question Number		
	1,425	Number of Users (sum Q. 1 plus Q. 2)
37	821	Number of Users who filled out a Mini-Survey

Please circle only one number for Questions 1-4 or mark NA if the question does not apply.

1 How satisfied were you with the fraction of the year that the facility operates?

100% =	595	123	20	2	0	53
	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable

2 How satisfied were you with the schedule or service (i.e., was the time or service delivered on schedule and was downtime kept to a minimum)?

100% =	557	147	25	6	2	57
	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable

3 How satisfied were you with the performance (i.e., was beam or service maintained close to specifications)?

100% =	556	149	22	10	0	80
	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable

4a. How satisfied were you with the support for users provided by the facility staff?

100% =	618	87	22	2	0	57
	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable

4b. How satisfied were you with the support for users provided by the staff scientists or beam line staff?

100% =	648	85	18	6	0	30
	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable

6. What was the subject of your use of this facility this year?

		#
a.	Basic research	586
b.	Applied research	349
c.	Developed a new or improved product, process or technology	52

7. How do you intend on communicating the knowledge gained at this facility?

a.	Publish in peer-reviewed open literature	733
b.	Present findings at professional society meeting	575
c.	Acquired a patent	86
d.	Other	22

8. What additional benefits did you gained at this facility?

a.	Furthered the goals of the Department of Energy	373
b.	Obtained access to unique capabilities not available elsewhere (e.g., forefront experiments; one-of-a-kind instruments; distinctive materials or services)	602
c.	Facilitated collaborative interactions (e.g., stimulated new ideas for future experiments, increased multidisciplinary work; enabled a new approach within your discipline)	584
d.	Trained students (undergraduate, graduate or postdoctoral associate)	325
*e.	Other benefit(s); please specify:	11

4.d. User Executive Committee Report

The CINT Users Executive Committee (UEC) is a body of representatives elected from and by the users that provides input to the CINT Program Management Team, regarding facilities, operations, science, and quality of the on-site user environment. All UEC members are active CINT users, having either a current or very recently completed CINT user project. The current UEC members are:

Professor Don Lucca, *Chair*, Oklahoma State University
Dr. Tito Busani, University of New Mexico
Professor Judith Driscoll, University of Cambridge
Professor John Grey, University of New Mexico
Professor Diane Lidke, University of New Mexico
Dr. Eric Shaner, *Internal Laboratory Representative*, Sandia National Laboratories
Dr. Meenakshi Singh, *Postdoc Representative*, Sandia National Laboratories
Dr. Erika Vreeland, *Industrial Advisor*, Senior Scientific LLC
Professor Karen Winey, University of Pennsylvania

The extensive research expertise of UEC members span the interests of the CINT scientific community reflected in the scientific thrust structure and other relevant groups such as students, post-docs, or specialty focus groups. During the 2013-2015 period, the UEC has been active in building the CINT community as described below:

CINT User Facility Performance:

- The UEC offers a means for users to provide feedback on facility performance via e-mail which complements the standard user satisfaction surveys. We are please to report that the UEC has not received any negative comments from the community regarding the operation of the facility.

- Based on the written comments on the user satisfaction surveys, the user community is very well satisfied with the operational performance of CINT. The CINT management welcomes suggestions for improvement. We note that some common suggestions are not within the ability of CINT to provide, such as on-site housing or user travel support. In such circumstances, CINT management respectfully explains the constraints or priorities that prevent the implementation of the user's suggestion.

CINT User Meetings:

- CINT User meetings have been held every year since 2001 with increasing participation by users as well as the UEC. Initially, these meetings focused on information dissemination about the CINT facilities under development and construction with the addition of external invited speakers. Now they have evolved into a dynamic technical meeting that highlights state of the art research – carried out by CINT users and staff scientists – and external speakers in the fields of interest to the CINT community. The UEC participates in the planning and program content of the user meeting including selection of the symposia topics and speakers. The meeting format enables extensive technical discussion via open microphone periods following all lectures.

- During the annual User Meeting, the UEC meets privately and also hosts an informal open forum for current and prospective users to share information about, and provide feedback on, CINT operations and management. This has resulted in lively, constructive dialogue targeted not only towards operational improvements but also to a better understanding of DOE, BES and CINT policies.

Other UEC Engagement:

- The UEC partnered with CINT to provide guidance for the NSRC portal content that contains information

on the NSRC program and is a clearinghouse of information on the capabilities at all NSRC sites.

- The UEC consulted with CINT to develop and iterate on the CINT 2020 strategic plan to ensure identification of and implementation plans for new capabilities and science strategy that represent areas of high user interest.

Future Plans:

- The UEC will continue to hold periodic conference calls and participate in annual meetings with the CINT management team. These provide a convenient mechanism for the management to update the UEC on current CINT activities, a forum for the UEC and management to formulate new initiatives, and a cooperative atmosphere in which to discuss and resolve user concerns.

- In 2016, the UEC will co-organize the annual CINT User Meeting, September 19-20, in Santa Fe. Additionally, UEC members will work with CINT staff on continued strategies for effectively collecting and addressing user feedback through the user surveys and other communication mediums.

- Throughout 2016-2019, the UEC will work with the CINT Communications & Outreach Manager to use the CINT website as a forum to highlight CINT user technical accomplishments, publicize noteworthy user accomplishments, and solicit input for future CINT capabilities. BES user facilities are often critical enablers for early career research scientists and hence can provide important visibility for the high-impact achievements of the next generation of National scientific leaders.

4.e. Degrees Granted and Post-doc Career Advancement

In addition to the knowledge gained through nanoscience research, CINT is proud to contribute to the scientific community by providing opportunities for education and technical training that promote individual career advancement and help prepare our users and early career employees to be future scientific leaders. The following graduate students have completed advanced degrees based on research performed, at least in part, at CINT:

Alexander Neumann	The University of New Mexico
Amy Boncella	Colorado State University
Francisco Buitrago	University of Pennsylvania
Grant Bleier	The University of New Mexico
Hope Quintana	New Mexico State University
Jayson Briscoe	New Mexico State University
Jeremy Wright	The University of New Mexico
Joseph S. Smalley	University of California, San Diego
Lucas Lamb	New Jersey Institute of Technology
Nate Brady	University of Alabama-Birmingham
Stoyana Alexandrova	Cambridge University
Zachary Stevens	Colorado School of Mines

These undergraduate students have been engaged in research at CINT during the course of earning their degree:

Amanda Flores	The University of New Mexico
Cassandra Miller	The University of New Mexico
Grant Bleier	The University of New Mexico
Gretchen Schober	The University of New Mexico
Haneen Martinez	The University of New Mexico
Jessica Vanderburg	The University of New Mexico
John Corsi	The University of New Mexico
Jolie Lucero	The University of New Mexico
Jonathan Tollerud	Swinburne University of Technology
Luke McClintock	University of Alabama-Birmingham
Kayla Capener	The University of New Mexico
Kimberly Childress	The University of New Mexico
Mackenzie May	The University of New Mexico
Mariah Austin	The University of New Mexico
Oksana Tretiak	The University of New Mexico
Peter Sinclair	Washington State University
Rachel Anderson	The University of New Mexico
Samuel Maldonado	The University of New Mexico

The interdisciplinary nature of nanoscience, exposure to two National Laboratories, and intellectually stimulating interactions with enthusiastic CINT users together make CINT an attractive environment for post-doctoral research. The CINT science community has grown in the past three years and will continue to add post-doctoral researchers as resources permit. Our current CINT post-docs are listed in section 1c. The

individuals below are former CINT post-docs who have completed their CINT appointments and now have other professional positions:

Aaron Keller, Assistant Professor, William Jewell College
Adamska Ludmila, Postdoc, Boston University
Andrew Leenheer, Sandia National Laboratories staff member
Andriy Zhugayevych, Faculty, SkolkovoTech, Russia
Bill Mook, Sandia National Laboratories staff member
Collin Decker, Sandia National Laboratories staff member
Dan Bolintineanu, Sandia National Laboratories staff member
Devin Close, Scientist, ARUP Laboratory
Douglas Shepherd, Assistant Professor, University of Colorado Denver
Erik Haroz, Los Alamos National Laboratory staff member
Eva Balaog, Assistant Professor, University of New England
Hao Li, postdoc, University of Houston
Ian Henderson, Postdoctural fellow, Sandia National Laboratories
Iltai Kim, Assistant Professor, Texas A&M University - Corpus Christi
Jingbo Qi, Assistant professor, PEAC Institute of Multiscale Sciences
John Bowlan, Los Alamos National Laboratory staff member
John Carpenter, Los Alamos National Laboratory staff member
Kaiyuan Yu, Assistant Professor China Petroleum University, Beijing, China
Koushik Ghosh, Scientist, Eastman Chemical Company
Leyma DeHaro, Scientist, Senior Scientific, LLC Matt DeVore, Technical Staff Member at Los Alamos Laboratory 2015, currently Associate Professor, Evangel University
Matthew Tomes, OSA Design Engineer, Finisar Corporation
Minah Seo, currently a staff scientist at Korea Institute of Science and Technology
Nathaniel Grady, Sandia National Laboratories staff member
Navaneetha Subbaiyan, Corning Incorporated
Oleksiy Roslyak, Faculty, Fordham University
Pengfei Zhang, faculty position, Zhejiang University of Technology
Prakash Sista, Scientist, SABIC
Rajib Pramanek, postdoc, Syracuse University
Ranjan Singh, Assistant Professor, Nanyang Technological University
Rolando Valdes Aguilar, Assistant professor, Ohio State University
Salvatore Campione, Sandia National Laboratories staff member
Sheng Liu, Sandia National Laboratories staff member
Stephane Boubanga Tombet, Associate professor, Tohoku University
Yu-Miin Sheu, Assistant professor at Chiao Tung University (winner of 2015 Postdoctoral Publication Prize in Experimental Sciences)
Saumen Chakrabortty, Assistant Professor, university of Mississippi
Shraddha Vachhani, Hysitron, Inc.
Shijian Zheng, Professor at Institute for Metal Research, Shenyang, China. 2011-2014
Siddhartha Pathak, Assistant Professor at University of Nevada, Reno
Steven Hayden, Scientist, Aramco Services Company
Weizhong Han, Assistant Professor, Xi'an Jiaotong University
Yang Liu, Faculty, North Carolina State University

4.f. Invited Lectures for all CINT staff and users

CINT STAFF

Bachand, G.D., Paxton, W.F., Bouxsein, N.F., and Henderson, I.M.,"Motor-driven assembly of dynamic, self-Healing lipid and polymer nanotube networks," 2015 Materials Research Society Spring Meeting, Symposium L : Bioinspired Micro- and Nano-Machines ─ Challenges and Perspectives, San Francisco, CA, April 6-10, 2015.

Brener, I., "Strong Coupling in the Subwavelength Limit Using Metamaterial Resonators," CUDOS Workshop, Shoal Bay, Australia, Feb. 4-8, 2013.

Brener, I., "3D (passive) and 2D (active) Metamaterials at Infrared Optical Frequencies," University of Sydney, Sydney, Australia, Feb. 11, 2013.

Brener, I., "New Directions in Active and Tunable Metamaterials," CLEO, San Jose, CA, Jun. 10-14, 2013.

Brener, I., "Active Metamaterials based on Strong Coupling to Semiconductor Excitations," SPIE Optics+Photonics, San Diego, CA, Aug. 25-29, 2013.

Brener, I., "Active and Tunable Metamaterials based on Strong and Ultra-strong Coupling to Semiconductor Excitations," The 7th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics- Metamaterials'2013, Bordeaux, France, Sept. 16-21, 2013.

Brener, I., "Voltage-Tunable Metamaterials in the Mid-Infrared," CUDOS Workshop, Phillip Island, Victoria, Australia, Feb. 10, 2014.

Brener, I., "3D (passive) and 2D (active) Metamaterials at Infrared Optical Frequencies," University of New Mexico, Albuquerque, NM, Jan. 31, 2014.

Brener, I., "Optical Magnetism from Dielectric Resonator Metamaterials," META'14, the 5th International Conference on Metamaterials, Photonic Crystals and Plasmonics, Singapore, May 20, 2014.

Brener, I., "Voltage Tunable Strong Coupling with Planar Metamaterials: From Fundamentals to Optoelectronic Devices," Metamaterials 2014,Coppenhagen, Denmark, Aug. 25, 2014.

Brener, I., "Metasurfaces and Epsilon-Near-Zero Modes in Semiconductors," IWEM VI, Santa Fe, NM, Spet. 22, 2014.

Brener, I., "Waves, Light and Artificial Lighting," National Science Bowl, Washington, D.C., April 24, 2014.

Brener, I., "Metasurfaces and Epsilon-Near-Zero Modes in Semiconductors," Nanometa 2015, Seefeld, Austria, Jan. 5, 2015.

Brener, I., "Active Dielectric and Metallic Metasurfaces: Strong Coupling, Tuning and Nonlinerities, University of New Mexico, Albuquerque, NM, Mar. 11, 2015.

Brener, I., "Dielectric Resonator Metasurfaces: Optical Magnetism, Emission and Optical Devices," MRS, San Francisco, CA, April 9, 2015.

Brener, I., “Active Metasurfaces: Metamaterials meet Optoelectronics,” Industrial Affiliates Rice, Houston, TX, April 8, 2015.

Brener, I., “Active Dielectric and Metallic Metasurfaces: Strong Coupling, Tuning and Nonlinearities,” AMOLF, Amsterdam, Netherlands, Jun. 8, 2015.

Brener, I., “Optical Magnetism and Active Devices from All Dielectric Metasurfaces,” PIERS, Prague, Czech Republic, Jul. 6, 2015.

Brener, I., “Active Dielectric and Metallic Metasurfaces: Strong Coupling, Tuning and Nonlinearities,” University of New Mexico, Albuquerque, NM, Jul. 17, 2015.

Brener, I., “Tunable and Nonlinear Metasurfaces: Metamaterials meet Optoelectronics,” Metamaterials Science and Technology Workshop, San Diego, CA, Jul. 21, 2015.

Brener, I., “Active Dielectric and Metallic Metasurfaces: Strong Coupling, Tuning and Nonlinearities,” META’15, New York, NY, Aug. 3, 2015.

Brener, I., “Nonlinear Optics with Metasurfaces,” SPIE Photonics, Sydney, Australia, Dec. 7, 2015.

Brener, I., “Recent Progress in Linear and Nonlinear Optical Metasurfaces,” Australian National University, Canberra, Australia, Dec. 4, 2015.

Brener, I., “Active Infrared Metasurfaces: Strong Coupling, Spectral Tuning and Optical Nonlinearities,” Northrop Gurnman, Redondo Beach, CA, Dec. 11, 2015.

Chen, H.-T., “Metasurfaces for Optical Antireflection and Polarization Manipulation,” MRS Fall Meeting, Boston, MA, Nov. 29 – Dec. 4, 2015.

Chen, H.-T., “Terahertz Metasurfaces for Antireflection Coatings,” The 40th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), Hong Kong, Aug. 23 – 28, 2015.

Chen, H.-T., “Ultra-Broadband THz modulation by active hybrid metamaterials,” The Fifth Shenzhen International Conference on Science and Technology (SICAST 5), Shenzhen, China, Aug. 19 – 22, 2015.

Chen, H.-T., “Electrically Driven Terahertz Metamaterial Diffraction Modulators,” “Terahertz Metasurface Antireflection Coatings,” “Few-Layer Metasurfaces for High Efficiency Linear Polarization Conversion and toward Planar Flat Optics,” The 36th Progress In Electromagnetics Research Symposium (PIERS), Prague, Czech Republic, Jul. 6 – 9, 2015.

Chen, H.-T., “New opportunities arising from THz metamaterials: Propagation control and signal modulation,” Keck Center for Terahertz Communications and Imaging Kick-off Review, Rice University, Houston, TX, Nov. 14, 2014.

Chen, H.-T., “Few-layer ultrathin terahertz metamaterials,” The 6th International Workshop on Electromagnetic Metamaterials (IWEM-VI), Santa Fe, NM, Sept. 22 – 23, 2014.

Chen, H.-T., “Ultra-broadband terahertz modulation by active hybrid metamaterials,” The 39th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), Tucson, AZ, Sept. 14 – 19, 2014.

Chen, H.-T., "Few-layer planar terahertz metamaterials for antireflection, perfect absorption, polarization control, and wavefront shaping," The 8th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Metamaterials'2014), Copenhagen, Denmark, Aug. 25 – 28, 2014.

Chen, H.-T., "From metamaterials to metasurfaces," The 8th Joint Meeting of Chinese Physicists Worldwide (OCPA8), Singapore, Jun. 23 – 27, 2014.

Chen, H.-T., "Electrically driven terahertz metamaterial diffraction modulators," The 5th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 2014), Singapore, May 20 – 23, 2014.

Chen, H.-T., "Tunable and nonlinear superconducting terahertz metamaterials," The 5th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 2014), Singapore, May 20 – 23, 2014.

Chen, H.-T., "Ultrathin terahertz meso-photonic materials: Emergent functionalities and potential applications," Mesoscale Science Frontiers, Santa Fe, NM, May 13 – 16, 2014.

Chen, H.-T., "Broadband and high-efficiency terahertz metamaterial linear polarization converters," The 38th International Conference on Infrared, Millimeter and TerahertzWaves (IRMMW-THz-2013), Mainz, Germany, Sept. 1 – 6, 2013.

Chen, H.-T., "Metamaterials for broadband linear polarization conversion and near-perfect anomalous reflection and transmission," The 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META13), Sharjah, United Arab Emirates, Mar. 18 – 22, 2013.

Chen, H.-T., "Active terahertz metamaterials," Photonics West Conference, San Francisco, CA, Feb. 2 – 7, 2013.

Chen, H.-T., "Applying Metamaterials to Solve Terahertz Challenges ," Seminar at Notre Dame University, Mar. 20, 2015.

Chen, H.-T., "Emergent Electromagnetic Functionalities in Few-Layer Metamaterials," Seminar at Southeast University, China, Dec. 22, 2014.

Chen, H.-T., "Emergent Electromagnetic Functionalities in Few-Layer Metamaterials," Seminar at Tianjin University, China, Dec. 16, 2014.

Chen, H.-T., "Emergent Electromagnetic Functionalities in Few-Layer Metamaterials," Seminar at Nankai University, China, Dec. 15 & 17, 2014.

Chen, H.-T., "Emergent Electromagnetic Functionalities in Metamaterials for Terahertz Applications," Seminar at Georgia Institute of Technology, Sept. 8, 2014.

Chen, H.-T., "Emergent Electromagnetic Functionalities in Few-Layer Metamaterials," Colloquium at South Florida University, Sept. 5, 2014.

Chen, H.-T., "Metamaterials and metasurfaces: principle, structure, functionality, and application," Colloquium at Penn State University, Mar. 20, 2014.

Chen, H.-T., "Terahertz metamaterials – structure design, material integration, and emergent functionality," Seminar at Molecular Foundry, Lawrence Berkeley National Laboratory, Feb. 11, 2014.

Karl, N., Reichel, K., Chen, H.-T., Taylor, A. J., Brener, I., Benz, A., Reno, J., Mendis, R., and Mittleman, D. M., "An Electrically Driven Terahertz Modulator With Over 20 DB Of Dynamic Range," The 38th International Conference on Infrared, Millimeter and TerahertzWaves (IRMMW-THz-2013), Mainz, Germany, Sept. 1 – 6, 2013.

Doorn, S.K., "Photon Statistics and Materials Development Towards Single Photon Emitters Based on Doped Single-Wall Carbon Nanotubes," PacifiChem 2015, Honolulu, HI, Dec. 2015.

Doorn, S.K., "Dopant-Induced Exciton Trapping in Semiconducting Carbon Nanotubes: Spectroscopy and Dynamics," TSRC Workshop on Nanomaterials: Computation, Theory, and Experiment, Telluride, CO, Jul. 2015.

Doorn, S.K., "Dopant-Induced Exciton Trapping in Semiconducting Carbon Nanotubes: Spectroscopy and Dynamics," Dept. of Physics Seminar Series, University of Antwerp, Antwerp, Belgium, Jun. 2015.

Doorn, S.K., "Photoluminescence Carrier Dynamics and Photon Statistics of Covalent Dopant-Induced Trap States in Single Wall Carbon Nanotubes," 6th International Workshop on Nanotube Optics and Nanospectroscopy (WONTON 2015), Kloster Banz, Germany, Jun. 2015.

Doorn, S.K., "Photoluminescence Carrier Dynamics and Photon Statistics of Covalent Dopant-Induced Trap States in Single Wall Carbon Nanotubes," 227th Electrochemical Society Meeting, Chicago, IL, May 2015.

Doorn, S.K., "Harnessing Dark Excitons: Interplay of Chemistry and Optics in the 1-D World of Carbon Nanotubes," Dept. of Chemistry Seminar Series, UW-Madison, April 2015.

Doorn, S.K., "Interplay of Chemistry and Optics in the 1-D World of Carbon Nanotubes," Department of Chemical Engineering Seminar Series, MIT, Boston, MA, Dec. 2014.

Doorn, S.K., "Single Tube Imaging and Spectroscopic Studies of Novel Emitting States in Covalently Doped Semiconducting Carbon Nanotubes," Symposium on Carbon Nanotubes—Synthesis, Properties, Functionalization and Applications, MRS National Meeting, Boston, MA, Dec. 2014.

Doorn, S.K., "Interplay of Chemistry and Optics in the 1-D World of Carbon Nanotubes," LANL Center for Nonlinear Studies, Q-Mat Seminar Series, Los Alamos, NM, Nov. 2014.

Doorn, S.K., "Probing, Controlling, and Exploiting the 1-D Surface Chemistry of Carbon Nanotubes," University of New Mexico, School of Engineering Colloquium, Albuquerque, NM, Oct. 2014.

Doorn, S.K., "Photoluminescence Studies of the 1-Dimensional World of the Carbon Nanotube Surface," University of North Texas, Chemistry Dept. Colloquium, Denton, TX, Oct. 2014.

Doorn, S.K., "Photoluminescence Imaging and Spectroscopic Studies of Low-Level Covalent Doping in Carbon Nanotubes," ESP 2014, 7th Conference on Excited State Processes in Electronic and Bio Nanomaterials, Santa Fe, NM, Jun. 2014.

Doorn, S.K., "Excitonic Fine Structure in Oxygen Doped Carbon Nanotubes," 225th Electrochemical Society Meeting, Orlando, FL, May 2014.

Doorn, S.K., “Photoluminescence Probes of the 1-D Surface Environment of Carbon Nanotubes,” BEST Seminar Series, School of Engineering, UC-Merced, May 2014.

Doorn, S.K., “Photoluminescence Probes of the 1-D Surface Environment of Carbon Nanotubes,” NREL, Golden, CO, Mar. 2014.

Frischknecht, A.L., “Ionic Aggregation and Dynamics in Ionomer Melts: Insights from Molecular Simulations,” Frontiers in Physics, Pattern Formation, and Complex Materials Far From Equilibrium, Washington, D.C., Oct. 26, 2015.

Frischknecht, A.L., “Simulations of Ionic Aggregate Morphology and Dynamics in Ionomer Melts,” Physics Department Colloquium, Emory University, Atlanta, GA, Sept. 1, 2015.

Frischknecht, A.L., “Ionic Aggregation and Dynamics in Ionomer Melts: Insights from Molecular Simulations,” Telluride Science Research Conference on Polymer Physics, Telluride, CO, Jun. 24, 2015.

Frischknecht, A.L., “Polymer Brush-Mediated Interactions in Nanorod-Polymer Composites,” High Polymer Research Group 55th Meeting, Pott Shrigley, United Kingdom, April 28, 2015.

Frischknecht, A.L., “Simulations of Ion Aggregation and Transport in Ion-Containing Polymers,” Gordon Research Conference on Macromolecular Materials, Ventura, CA, Jan. 11, 2015.

Frischknecht, A.L., “Simulations of Ionic Aggregation in Ionomer Melts,” AIChE Annual Meeting, Atlanta, GA, Nov. 20, 2014.

Frischknecht, A.L., “Simulations of Ionic Aggregation in Ionomer Melts,” ACS National Meeting, San Francisco, CA, Aug. 12, 2014.

Frischknecht, A.L., “Atomistic Simulations of Aggregation in Ionomer Melts,” APS March Meeting, Denver, CO, Mar. 5, 2014.

Frischknecht, A.L., “Ionic Aggregation and Dynamics in Ionomers: Insights from Molecular Simulations,” Gordon Research Conference on Colloidal, Macromolecular & Polyelectrolyte Solutions, Ventura, CA, Feb. 16-21, 2014.

Frischknecht, A.L., “Polymer Field Theories and Classical DFT: Applications to Polymer Brushes and Nanocomposites,” Polymer Modeling Mini-Symposium, ExxonMobil Research and Engineering Co, Annandale, NJ, Jul. 24, 2013.

Frischknecht, A.L., “Simulation of Ionic Aggregation and Ion Dynamics in Ionomers,” seminar, National Institute of Standards and Technology, Gaithersburg, MD, May 31, 2013.

Frischknecht, A.L., “Coarse-grained Simulations of Ion-Containing Polymers,” Physics Department Colloquium, Pomona College, Claremont, CA, April 16, 2013.

Frischknecht, A.L., “Simulation of Ionic Aggregation and Ion Dynamics in Ionomers,” Department of Chemistry Seminar, Clemson University, Clemson, SC, Jan. 24, 2013.

Goodwin, P.M., “Cellobiohydrolase Binding on Cellulose Observed by Time-Resolved Super-Resolution Single-Molecule Imaging,” CINT User Meeting, Santa Fe NM, Sept. 21-22, 2015.

Grest, G.S., "Modeling of Nanoparticles in Solution and at Interfaces," Joint NSRC Workshop on Nanoparticle Science, Argonne National Laboratory, Nov. 5-6, 2012.

Grest, G.S., "Nanoparticles in Complex Fluids, at Interfaces, in Polymers: Topology Matters," American Physical Society, Baltimore, MD, Mar. 18–22, 2013.

Grest, G.S., "Dynamics of Entangled Polymer Melts: Linear, Rings, and Beyond," North American Thermal Analysis Society, Plenary Lecture, Santa Fe, NM, Sept. 15-17, 2014

Grest, G.S., K. Michael Salerno, Dan S. Bolintineanu, and J. Matthew D. Lane, "Nanoparticle Self-Assembly," American Chemical Society, San Francisco, CA, Aug. 10-13, 2014.

Grest, G.S., "Nanoparticle Dynamics in Polymer Matrices," Mainz Simulation Days, Mainz, Germany, Jun. 10-12, 2015.

Grest, G.S., "Nanoparticle Dynamics in Polymer Matrices," LAMMPS Users Workshop, Albuquerque, NM, April 5-7, 2015.

Jia, Q.X., "Role of interfaces on competing interactions of ferroic films," MRS Fall Meeting, Boston, MA, Nov. 29 - Dec. 4, 2015.

Jia, Q.X., "Nanomaterials integration for multifunctionalities: A pathway to materials design and innovation," Materials Research Day at Univ. of Texas, San Antonio, TX, Aug. 24, 2015.

Jia, Q.X., "Control and manipulation of competing interactions of ferroic films," International Mater. Res. Congress, Cancun, Mexico, Aug. 16 - 20, 2015.

Jia, Q.X., "The role of interfaces on the functionalities of complex metal-oxide films," Quantum Matter Workshop, Santa Fe, NM, May 18 - 21, 2015.

Jia, Q.X., "Understanding, exploiting, and controlling competing interactions of complex metal-oxide films," University at Buffalo, Buffalo, NY, Mar. 16, 2015.

Jia, Q.X., "Effect of interfaces on competing interactions of functional complex metal-oxides," University of Connecticut, Storrs, CT, Oct. 17, 2014.

Jia, Q.X., "Microstructural evolution in ion irradiated heteroepitaxial dielectric films," the Mater. Sci. & Technol. 2014 Conf. & Exhibition, Pittsburgh, PA, Oct. 12 - 16, 2014.

Jia, Q.X., "Effect of interfaces on ferroic properties of composite films," Int'l Symp. on Emerging Multifunctional & Bio-Directed Mater., San Antonio, TX, Oct. 10 - 11, 2014.

Jia, Q.X., "Pushing the limits of polymer-assisted deposition for a wide range of electronic materials," University at Buffalo, Buffalo, NY, Oct. 1, 2014. (Distinguished lecture)

Jia, Q.X., "Polymer-assisted deposition: one simple process, a large number of electronic materials," Summer Lecture Series, Laboratory's National Security Education Center, Los Alamos National Laboratory, Los Alamos, NM, Jul. 18, 2014.

Jia, Q.X., "Electronic materials synthesized by a polymer-assisted deposition," University of Illinois at Urbana Champaign, Urbana, IL, May 2, 2014.

Jia, Q.X., "Self-assembled epitaxial nanocomposite films: their strain control and functionalities," New Mexico Tech, Socorro, NM, Mar. 7, 2014.

Jia, Q.X., "Polymer-assisted deposition for a wide range of epitaxial ferroic metal-oxide films," Electronic Materials and Applications, Orlando, FL, Jan. 22 - 24, 2014.

Jia, Q.X., "Nucleation and growth of epitaxial films using polymer-assisted deposition," University of Texas at San Antonio, San Antonio, TX, Nov. 7, 2013.

Jia, Q.X., "Toward tunable functionalities using epitaxial nanoscaffolding films," the Mater. Sci. & Technol. Conf. & Exhibition, Montreal, Quebec, Canada, Oct. 27 - 31, 2013.

Jungjohann, K. L., Harrison, K. L., Leenheer, A. J., Hahn, N. T., Harris, T. C., Sullivan, J. P., Zavadil, K. R., "Electrode-Electrolyte Interfaces: Quantitative Electrochemistry during In-Situ S/TEM Imaging," New Mexico American Vacuum Society Meeting, Albuquerque, NM, May 19, 2015.

Jungjohann, K. L., Leenheer, A. J., Harrison, K. L., Hahn, N. T., Harris, T. C., Sullivan, J. P., Zavadil, K. R., "Quantitative Electrochemistry of Anode Materials for Li-ion Batteries using in-situ S/TEM," Advanced Structural and Chemical Imaging Meeting, Pullman, WA, May 20-22, 2015.

Jungjohann, K., Woehl, T., Parent, L., Abellan, P., Arslan, I., "Advanced Electron Microscopy Techniques for In-Situ Liquid Imaging of Metal Nanoparticles towards Water-Phase Catalysis," Pacifichem 2015, Honolulu, HI, Dec. 15 – 20, 2015.

Lilly, M.P., "Manipulating single electrons in semiconductor devices for quantum computing," Condensed Matter Seminar at Purdue University, W. Lafayette, IN, Oct. 4, 2013.

Lilly, M.P., "Manipulating single electrons in semiconductor devices for quantum computing," CNAM Seminar Series, University of Maryland, 2014.

Lilly, M.P., "Manipulating single electrons in semiconductor devices for quantum computing," Q-Mat Seminar Series, Los Alamos, NM, 2015.

Lilly, M.P., "Transport in interacting 1D double quantum wires," Condensed Matter Seminar, University of Utah, Feb. 2015.

Luk, T.S., "Perfect absorption in ultrathin low loss near-zero-permittivity (NZP) material," University Faculty Senator Distinguished Lecture at the University of Alabama, Huntsville, April 11, 2014.

Mara, N.A., "Interface Facilitated Deformation in Bimetallic Nanolayered Composites," 2015 MRS Fall Meeting, Boston, MA, Dec. 1, 2015.

Mara, N.A., "Interfacial Structure Effects on the Mechanical Behavior of Layered Nanocomposites," invited seminar at Drexel University, Philadelphia, PA, May 13, 2015.

Mara, N.A., Bronkhorst, C.A., Beyerlein, I.J., "Damage Tolerant Bulk Nanocomposites," LANL Global Security Program Briefing, LANL SCIF, Feb. 23, 2015.

Mara, N.A., Bronkhorst, C.A., Beyerlein, I.J., "Damage Tolerant Bulk Nanocomposites," LANL Unmanned Aerial Systems (UAS) Workshop, Feb. 4, 2015.

Mara, N.A., "Multifunctional Materials at LANL," Nano-Global Security Deep Dive, Los Alamos Research Park, Nov. 13, 2014.

Mara, N.A., Zheng, S., Nizolek, T., Carpenter, J., Mook, W.M., Pollock, T., Wang, J., Beyerlein, I.J., "Effect of Interface Structure on the Mechanical Behavior of Nanolamellar Composites," MS&T 2014, Pittsburgh, PA, Oct. 12-16, 2014.

Mara, N.A., Zheng, S., Nizolek, T., Carpenter, J., Mook, W.M., Pollock, T., Wang, J., Beyerlein, I.J., "Mechanical Behavior of Bulk Layered Nanocomposites Produced via Severe Plastic Deformation," 2014 Pan American Materials Conference, Sao Paolo, Brazil, Jul. 21-25, 2014.

Mara, N.A., Zheng, S., Nizolek, T., Carpenter, J., Mook, W.M., Pollock, T., Wang, J., Beyerlein, I.J., "The Mechanical Behavior of Nanolaminate Materials," Gordon Conference on Thin Films and Small Scale Mechanical Behavior, Bentley College, Waltham, MA, Jul. 13-18, 2014.

Mara, N.A., Zheng, S., Nizolek, T., Carpenter, J., Mook, W.M., Pollock, T., Wang, J., Beyerlein, I.J., "Mechanical Response of Bulk Nanocomposites Produced via Severe Plastic Deformation," 17th U.S. National Congress on Theoretical and Applied Mechanics, Michigan State University, Jun. 15-20, 2014.

Mara, N.A., "Large scale production of Cu/Nb multilayers with Extreme Radiation Tolerance," LANL briefings for Department of Energy, Nuclear Engineering, DOE Germantown April 22, 2014.

Mara, N.A., "Building the Iron Man Suit: Developing the science behind lightweight, damage-tolerant nanocomposites," Bradbury Science Museum Lecture, Los Alamos, NM, April 9, 2014.

Mara, N.A., Liu, C., Lovato, M.L., Mook, W.M., Clarke, K.D., Alexander, D.J., Blumenthal, W.R., Dombrowski, D.E., "Measurement of Fracture Behavior in LEU Fuel Plates containing Al/Zr/U-10Mo Interfaces," LANL Materials for the Future Capability Review, May 4-7, 2014.

Mara, N.A, Zheng, S., Nizolek, T., Carpenter, J., Mook, W.M., Pollock, T., Wang, J., Beyerlein, I.J., "Influence of biphase interfacial character on the mechanical response of nanolamellar composites," TMS 2014 Annual Meeting and Exhibition, San Diego, CA, Feb. 2014.

Mara, N.A., Beyerlein, I.J., "Twinning from bimetal interfaces," International workshop on twinning (international workshop via videoconference), hosted by Prof. L. S. Toth, University of Metz, France, Nov. 13, 2013.

Mara, N.A., "Severe Plastic Deformation of Bulk Nanocomposites: Stability of Microstructure and Interfaces at Extreme Strains and Temperatures," Keynote Lecture Plasticity 2014, Freeport, Bahamas, Jan. 2014.

Mara, N.A., Zheng, S., Carpenter, J., Wynn, T., Kang, K., Han, W.Z., Nizolek, T., Pollock, T., Wang, J., Beyerlein, I.J., "Bi-phase Boundary Evolution in Bulk Laminar Nanocomposites Produced by Accumulative Roll Bonding," MS&T 2013, Montreal, Canada, Oct. 27-31, 2013.

Mara, N.A., Carpenter, J., Zheng, S., Han, W.Z., Nizolek, T., Wang, J., Beyerlein, I.J., "Mechanical behavior of preferred interfaces in bulk multilayer nanocomposites produced via Accumulative Roll Bonding," Nanoscale Multilayers 2013, Madrid, Spain, Oct. 1-4, 2013.

Mara, N.A., Zheng, S., Carpenter, J., Nizolek, T., Pollock, T., Wang, J., Kang, K., Han, W.Z., Beyerlein, I.J., "High strength and thermally stable bulk nanolayered composites," Nanoscale Multilayers 2013, Madrid, Spain, Oct. 1-4, 2013.

Mara, N.A., Zheng, S., Nizolek, T., Carpenter, J., Mook, W.M., Pollock, T., Wang, J., Beyerlein, I.J., "High-strength and thermally stable bulk nanolayered composites," Pacific Rim International Conference on Advanced Materials and Processing, Waikoloa, HI, Aug.2013.

Mara, N.A., Li, N., Han, W.Z., Carpenter, J., Zheng, S., Nizolek, T., Eftink, B.P., Beyerlein, I.J., Wang, J., Kang, K., Misra, A., "Large strain deformation of bulk laminar nanocomposites produced via Accumulative Roll Bonding," 4th International Workshop on Remote Electron Microscopy and In-Situ Studies, Lisbon, Portugal, May 22-24, 2013.

Mara, N.A., Carpenter, J., Mook, W.M., Han, W.Z., Zheng, S., Nizolek, T., Wynn, T.A., Wang, J., Beyerlein, I.J., "Large strain deformation of bulk laminar nanocomposites produced via Accumulative Roll Bonding," MRS Spring Meeting, San Francisco, CA, April 1-4, 2013.

Mara, N.A., Han, W.Z., Carpenter, J., Zheng, S., Beyerlein, I.J., Wang, J., Kang, K., Misra, A., "Bi-metal interface facilitated deformation twinning," Keynote Talk, Plasticity 2013, Nassau, Bahamas, Jan. 3-9, 2013.

Martinez, J.S., "Genetically encoded materials," SACNAS a Key Note Talk, Fall 2015.

Martinez, J.S., "Genetically encoded nanocluster assemblies: photophysics and catalytic function," Pacifichem, Fall 2015.

Martinez, J.S., "Genetically encoded optical and biological materials," DTRA Techwatch seminar, Winter 2015.

Martinez, J.S., "Genetically encoded functional materials: regenerative medicine, optoelectronics and biosensing," Univeristy of New Mexico STMC, Spring 2015.

Martinez, J.S., University of New Mexico-LANL Cancer Retreat, 2015.

Martinez, J.S., "Genetically engineered materials: mixing biology, chemistry, and materials science," CNLS Q-Mat Seminar, Los Alamos, NM, 2014.

Martinez, J.S., "Genetically encoded optical materials," Excited State Processes Conference, Santa Fe, NM, 2014.

Martinez, J.S., "Genetically encoded optical materials," University of Utah, Department of Chemistry Colloquium, 2014.

Martinez, J.S., "Genetically Encoded Materials," Curie Lecturship, University of Utah, 2014.

Martinez, J.S. "Fluorescent molecular-like metal nanoclusters," 2014 ACS, Dallas TX, 2014.

Martinez, J.S., "Fluorescent noble metal nanoclusters," A key note talk, Symposium on size selected Clusters, Davos, Switzerland.

Martinez, J.S., "Clusters, Nanocrystals and Nanostructures," Gordon Conference, 2013.

Martinez, J.S., MRS Spring 2013 Conference, Symposium N, San Francisco CA, 2013.

Montano, G. A., "Membrane Composite Nanomaterials- Tuning the Environment, not the Molecule," New Mexico Institute of Mining and Technology, Feb. 2012.

Montano, G. B., "Membrane Composite Nanomaterials- Tuning the Environment, not the Molecule," Metro State College, Nov. 2011.

Montano, G. B., "Membrane Composite Nanomaterials- Tuning the Environment, not the Molecule," University of New Mexico, Albuquerque, NM, Sept. 2011.

Montano, G.A., "Pushing the lipid envelope: using bio-inspired nanocomposites to understand and exploit lipid membrane limitations," APS March Meeting, Mar. 2016.

Montano, G.A., "Pushing the lipid envelope: using bio-inspired nanocomposites to understand and exploit lipid membrane limitations," NM Tech University, Feb. 2016.

Montano, G.A., "Pushing the lipid envelope: using bio-inspired nanocomposites to understand and exploit lipid membrane limitations," UT San Antonio, Sept. 2015.

Montano, G.A., "Investigating soft materials surfaces and dynamics," NM AVS, Sept. 2015.

Montano, G.A., "The Strength of One, the Power of Many," UNM IMSD Program, April 2015.

Montano, G.A., "The Strength of One, the Power of Many," Texas Tech, SACNAS, April 2015.

Montano, G.A., "Understanding bioenergy machines: Natural/artificial and somewhere in between," Invited Talk-ASU Science Society, Oct. 2014.

Montano, G.A., "Biochemical-assisted lithography: patterning and modification of supported lipid bilayers using a biological amphiphile," Invited Talk- Metro State College, Denver, CO, April 2014.

Montano, G.A., "Nanocomposites for Enhanced Biological Stability," Invited Talk- SACNAS National Conference, San Antonio, TX, Oct. 2013.

Ohta, T., "Electronic dispersion in two overlapping graphene sheets: Impacts of long-range atomic ordering and periodic potentials," 9th International Symposium on Atomic Level Characterizations for New Materials and Devices, Kona, HI, Dec. 2-6, 2013.

Ohta, T., "Electronic dispersion from long-range atomic ordering and periodic potentials in two overlapping graphene sheets," 60th Annual AVS International Symposium and Exhibition, Long Beach, CA, Oct. 27 –Nov. 1, 2013.

Ohta, T., "Electronic dispersion from long-range atomic ordering and periodic potentials in two overlapping graphene sheets," The 19th American Conference on Crystal Growth and Epitaxy and the 16th U.S. Biennial Workshop on Organometallic Vapor Phase Epitaxy, Keystone, CO, Jul. 25, 2013.

Ohta, T., "Electronic dispersion from long-range atomic ordering and periodic potentials in two overlapping graphene sheets," Materials Research Society Spring Meeting & Exhibit, San Francisco, CA, April 1, 2013.

Paxton, W.F., “Artificial Micro/Nanomachines in Low Reynolds Number Environments,” Materials Research Society, San Francisco, CA, April 5-9, 2015.

Paxton, W.F., “Polymersome Permeability and Fusion,” 2014 CINT User Meeting, Santa Fe, NM, Sept. 22-23, 2014.

Prasankumar, R.P., “Using ultrafast optical microscopy to unravel carrier dynamics in semiconductor nanowires,” PacChem, 2015.

Prasankumar, R.P., “Using ultrafast optical and terahertz spectroscopy to unravel carrier dynamics in quantum and Dirac materials,” , Q-Mat seminar, LANL, Los Alamos, NM, Oct. 20, 2015.

Prasankumar, R.P., “Ultrafast Science: Quicker than the Blink of an Eye,” TEDxLANL, Los Alamos, NM, Jul. 29, 2015.

Prasankumar, R.P., “Shedding new light on magnetoelectric coupling in multiferroic oxide heterostructures,” ICMAT, 2015.

Prasankumar, R.P., “Unraveling the Interplay Between Electric and Magnetic Order in Multiferroic Oxide Heterostructures,” Quantum and Dirac Materials for Energy Applications Conference, Mar. 10, 2015.

Prasankumar, R.P., “Using ultrafast optical spectroscopy to unravel fundamental properties of one-and-two-dimensional nanostructures,” UNM Chemistry Department, Albuquerquem NM, Jan. 30, 2015.

Prasankumar, R.P., “Unraveling the Interplay Between Electric and Magnetic Order in Multiferroic Oxide Heterostructures,” Physics Seminar, MIT, Dec. 2, 2014.

Prasankumar, R.P., “Unraveling the Interplay Between Electric and Magnetic Order in Multiferroic Oxide Heterostructures,” Condensed Matter Physics Seminar, University of Connecticut, Oct. 28, 2014.

Prasankumar, R.P., “Unraveling the Interplay Between Electric and Magnetic Order in Multiferroic Oxide Heterostructures,” Physics Seminar, Boston College, Oct. 8, 2014.

Prasankumar, R.P., “Unraveling the Interplay Between Electric and Magnetic Order in Multiferroic Oxide Heterostructures,” Physics Seminar, University of Alabama-Birmingham, Oct. 3, 2014.

Prasankumar, R.P., “Taming the nanoscale to go beyond the limits of nature,” TEDxABQ Salon-Technology, Albuquerque, NM, Aug. 12, 2014.

Prasankumar, R.P., “Using ultrafast optical spectroscopy to explore magnetoelectric coupling in multiferroic oxide heterostructures,” OIST workshop, Jul. 2014.

Prasankumar, R.P., “Using Ultrafast Optical Microscopy to Track Carriers Through Space and Time,” NIST seminar, Jun. 25th, 2014.

Prasankumar, R.P., “Using Ultrafast Optical Spectroscopy to Explore Magnetoelectric Coupling in Multiferroic Oxide Heterostructures,” ECE graduate seminar, University of New Mexico, Albuquerque, NM, May 2, 2014.

Prasankumar, R.P., “Ultrafast Dynamics in Semiconductor Nanowire Heterostructures,” scheduled for presentation at the Nanowire Workshop, NAMBE (October 2013, couldn’t attend due to govt shutdown).

Prasankumar, R.P., "Using Ultrafast Optical Spectroscopy to Explore Magnetoelectric Coupling in Multiferroic Oxide Heterostructures," CINT user workshop, Sept. 2013.

Prasankumar, R.P., "Using Ultrafast Optical Spectroscopy to Unravel the Fundamental Properties of One-and-Two-Dimensional Nanostructures," University of New Mexico, Albuquerque, NM, Jul. 15, 2013.

Prasankumar, R.P., "Nanophotonics at the DOE Nanoscale Science Research Centers," CLEO, 2013.

Stevens, M.J., "A New Picture of Ionomer Structure and Dynamics," US-Poland Workshop on the "Thermodynamics of Complex Fluids and Interfaces," Warsaw, Poland, Jun. 2014.

Stevens, M.J., "Recent Advances in Molecular Dynamics Simulations of Polymers," AICHE, Salt Lake City, UT, Nov. 2015.

Stevens, M.J., "Ionomer Melt Structure and Dynamics: connecting modeling and experiment," American Chemical Society, Boston, MA, Aug. 2015.

Stevens, M.J., "A New Picture of Ionomer Structure and Dynamics," Physics Seminar at University of Colorado at Boulder, Feb. 2015.

Stevens, M.J., "Simulations of single molecule pulling experiments on ssDNA," Telluride Workshop on Biophysical Dynamics, Jul. 2013.

Tretiak, S., "Theoretical insights into multiscale electronic processes in organic photovoltaics," 251st ACS National Meeting, San Diego, CA, Mar. 2016.

Tretiak, S., "A few roadblocks on the way toward efficient perovskite photovoltaics," 251st ACS National Meeting, San Diego, CA, Mar. 2016.

Tretiak, S., "Our journey to the land of excited state dynamics in large molecules," 251st ACS National Meeting, San Diego, CA, Mar. 2016.

Tretiak, S., "Our journey to the land of excited state dynamics in large molecules," 251st ACS National Meeting, San Diego, CA, Mar. 2016.

Tretiak, S., "A few lessons from non-adiabatic excited state dynamics simulations of large molecules," Pittcon 2016: ABB- Bomem-Michelson Award symposium, Atlanta, GA, Mar. 2016.

Tretiak, S., "A journey to the land of excited state dynamics in organic semiconductors," 2016 Mesilla Chemistry Workshop on Electrochemical Processes: Photovoltaics and Charge Transfer in Nanomaterials, Mesilla, NM, Jan. 2016.

Tretiak, S., "A few roadblocks on the way toward efficient perovskite photovoltaics," PacificChem 2015, Honolulu, HI, Dec. 2015.

Tretiak, S., "A few lessons from non-adiabatic excited state dynamics simulations of large molecules," PacificChem 2015, Honolulu, HI, Dec. 2015.

Tretiak, S., "A journey to the land of excited state dynamics in organic semiconductors," Skolkovo Institute of Science and Technology (SkolTech), Moscow, Russia, Nov. 2015.

Tretiak, S., "First principle calculations of electronic transport in organic and bio-systems using atomistic structures," Biological Electron Transfer Meeting, Research Triangle Park, NC, Sept. 2015.

Tretiak, S., "A few roadblocks toward efficient perovskite photovoltaics," Penn Conference in Theoretical Chemistry, University of Pennsylvania, Philadelphia, PA, Jul.2015.

Tretiak, S., "Chemical functionalization and optical properties of carbon nanotube materials," Telluride Workshop on Non-equilibrium Phenomena, Nonadiabatic Dynamics and Spectroscopy, Telluride, CO, Jul. 2015.

Tretiak, S., "A few roadblocks toward efficient perovskite photovoltaics," Telluride Workshop on Spontaneous Coherence and Collective Dynamics, Telluride, CO, Jul. 2015.

Tretiak, S., "Quantum chemistry, DFT and excited state molecular dynamics: modeling of functional electronic materials," 9th Q-bio Summer School, University of New Mexico, Albuquerque, NM, Jul. 2015.

Tretiak, S., "Toward efficient perovskite photovoltaics," 11th International Conference on Optical Probes, Hong Kong, HK, Jun. 2015.

Tretiak, S., "Non-adiabatic excited state dynamics simulations of extended molecular systems," Kyoto University, Kyoto, Japan, Jun. 2015.

Tretiak, S., "From engineering interfaces in soft electronic materials to efficient perovskite photovoltaics," Kyoto University, Kyoto, Japan, Jun. 2015.

Tretiak, S., "From engineering interfaces in soft electronic materials to efficient perovskite photovoltaics," University California, Santa Barbara, CA, May 2015.

Tretiak, S., "From engineering interfaces in soft electronic materials to efficient perovskite photovoltaics", "Multiscale DFT modeling of functional electronic materials", "Non-adiabatic excited state dynamics simulations of extended molecular systems" (3 invited lectures), University of Southern California, Los Angeles, CA, May 2015.

Tretiak, S., "From engineering interfaces in soft electronic materials to efficient perovskite photovoltaics," North Dakota State University, Fargo, ND, May 2015.

Tretiak, S., "From engineering interfaces in soft electronic materials to efficient perovskite photovoltaics," University of Rochester, Rochester, NY, Mar. 2015.

Tretiak, S., "Evolution of photoexcited states in extended molecular chromophores," 249th ACS National Meeting, Denver, CO, Mar. 2015.

Tretiak, S., "Evolution of photoexcited states in extended molecular chromophores," 55th Sanibel Symposium, St. Simons Island, GA, Feb. 2015.

Tretiak, S., "Evolution of photoexcited states in extended molecular chromophores," Department of Physics and Astronomy, the University of Utah, Salt Lake City, UT, Feb. 2015.

Tretiak, S.,"Theoretical insights into multiscale electronic processes in organic photovoltaics," Materials Research Society (MRS) Fall Meeting, Boston, MA, Dec. 2014.

Tretiak, S., “Photoexcited conjugated chromophores: conformational dynamics, relaxation path- ways and energy transfer,” Materials Science and Engineering Conference, San Antonio, TX, Oct. 2014.

Tretiak, S., “Photoexcited conjugated chromophores: conformational dynamics, relaxation path- ways and energy transfer,” Department of Chemistry and Biochemistry, Texas Tech University, Lubbock, TX, Oct. 2014.

Tretiak, S., “Photoexcited conjugated chromophores: conformational dynamics, relaxation path- ways and energy transfer,” Department of Chemistry, University of South Dakota, Vermillion, SD, Sept. 2014.

Tretiak, S., “Efficient Non-Adiabatic Excited State Dynamics Simulations in Extended Molecular Systems,” Telluride workshop: Excited States and Time-dependent Electronic Structure Theory, Telluride, CO, Jul.2014.

Tretiak, S., “Efficient Non-Adiabatic Excited State Dynamics Simulations in Extended Molecular Systems,” CUNY workshop: Theoretical and Practical Challenges in Nonadiabatic Quantum Dynamics, New York, NY, May 2014.

Tretiak, S., “Efficient Non-Adiabatic Excited State Dynamics Simulations in Extended Molecular Systems,” Department of Materials Science and Engineering, Boston University, Boston, MA, May 2014.

Tretiak, S., “Photoexcited Conjugated Chromophores: Conformational Dynamics, Relaxation Pathways, and Energy Transfer,” Department of Chemistry, Michigan State University, East Lansing, MI, April 2014.

Tretiak, S., “Exciton Scattering approach for conjugated macromolecules: from electronic spectra to electron-phonon coupling,” Annual March Meeting of the APS, Denver, CO, Mar. 2014.

Tretiak, S., “Life of photoexcited conjugated chromophores: the movie,” Materials Research Society (MRS) Fall Meeting, Boston, MA, Dec. 2013.

Tretiak, S., “Life of photoexcited conjugated chromophores: the movie,” CECAM workshop: Quantum Dynamics in Molecular and Nano-Materials, Tel-Aviv, Israel, Nov. 2013.

Tretiak, S., “Dynamics of excitons and phonons at the nanoscale,” Nanyang Technological University, Singapore, Oct. 2013.

Tretiak, S., “Dynamics of excitons and phonons at the nanoscale,” Skolkovo Institute of Science and Technology (SkolTech), Moscow, Russia, Oct. 2013.

Tretiak, S., “Life of photoexcited conjugated chromophores: the movie,” IPAM Workshop on Solar Cells, UCLA, Los Angeles, CA, Sept. 2013.

Tretiak, S., “Localization of electronic excitations in organic semiconductors: theoretical views from different angles,” 246th ACS National Meeting, Indianapolis, IN, Sept.2013.

Tretiak, S., “Localization of electronic excitations in organic semiconductors: theoretical views from different angles,” Telluride Workshop on Non-equilibrium Phenomena, Nonadiabatic Dynamics and Spectroscopy, Telluride, CO, Jul. 2013.

Tretiak, S., “Life of photoexcited conjugated chromophores: the movie,” 10th International Conference on Optical Probes, Durham, UK, Jul. 2013.

Tretiak, S., "Localization of electronic excitations in organic semiconductors: theoretical views from different angles," Cambridge University, Cambridge, UK, Jul. 2013.

Werner J.H., "Three dimensional time-gated tracking of non-blinking quantum dots in live cells," SPIE Photonics West, San Francisco, CA, Feb. 4-10, 2015.

Werner J.H., "Methods of Measuring Diffusion on Live Cell Membranes," Q-Bio Summer School, University of New Mexico, Albuquerque, NM, Aug. 4, 2014.

Werner J.H., "Three Dimensional Single Molecule Tracking and Quantitative Microscopy," Quantitative BioImaging Workshop, Albuquerque, NM, Jan. 2014.

Werner J.H., "Single Molecule and Single Cell Measurements," Q-Bio Summer School, Santa Fe, NM, Jul. 26, 2013.

CINT USERS

Bufford, D.C., "Connecting bulk material behavior to nanoscale mechanisms by in situ transmission electron microscopy (TEM)," New Mexico Tech Department of Mechanical Engineering Seminar, Socorro, NM, Dec. 2015.

Carroll, M.S., Ten Eyck, G.A., Lilly, M., Rochette, S., Pioro-Ladriere, M., "Towards long coherence time spin control for quantum information: Characterization of silicon quantum dots and micro-magnets integration," International Symposium on Transport and Nanotechnology, Atsugi Kanagawa, Japan, Nov. 26-29, 2014.

Carter, C.B., Matthew Janish, Paul G. Kotula, Justin M. Roller, David Mackay, Fei Huang, Yang Liu, Katherine L. Jungjohann, Chris Cornelius, Radenka Maric, and M. Grant Norton; *TEM Studies of Nanomaterials and Nanodevices*; The 4th International Symposium on Advanced Microscopy and Theoretical Calculations; May 8-10, 2014 in Nagoya, Japan.

Chan, C.K. "Spatially Resolved Chemical and Electronic Structure of Thin-Film Photovoltaics," Electronic Materials and Applications 2014 (American Ceramics Society), Orlando, FL, Jan. 2014.

Chan, C.K., Kellogg, G.L., Noufi, R., Korgel, B., Dwyer, D. "Spectroscopic Low-Energy & Photoemission Electron Microscopy Characterization of CIGS," 2nd Department of Energy SunShot Thin-Film Photovoltaics Workshop, Golden, CO, Oct. 2013.

Chan, C.K., Ohta, T., Kellogg, G.L., Pernik, D., Korgel, B., Mansfield, L., Noufi, R., Ramanathan, K. "Photoemission and Low-Energy Electron Microscopy (PEEM and LEEM) Studies of Cu(In,Ga)Se2," Photovoltaic Materials 2014 Surface Analysis Meeting, Albuquerque, NM, June 2014.

Chan, C.K. "Thin Film Photovoltaics: From Low Efficiency Materials to High Performance Devices to Module Bankability Discussion Club," U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Solar Energy Technologies Office, Washington, DC, July 2014.

Chang, J.P. "Synthesis and Integration of Multifunctional and Complex Oxide Materials," University of California, Davis, Chemical Engineering Department, Davis, CA, May 2013.

Chang, J.P "Synthesis and Integration of Multifunctional and Complex Oxide Materials," 4th International Conference on Plasma Nanoscience (iPlasmaNano-IV), Monterey, CA, Aug. 2013.

Chang, J.P. "Synthesis and Integration of Multifunctional and Complex Oxide Materials," Electronic Materials Applications, Orlando, FL, Jan. 2014.

Civale, L. 16th US-Japan Workshop on Advanced Superconductors, Dayton, OH, July 2013.

Civale, L. Electronic Materials and Applications (EMA), Orlando, FL, Jan. 2014.

Civale, L. Superconductivity for Energy. Paestum, Italy, May 2014.

Civale, L. "Vortex Matter in Nanostructured Superconductors (VORTEX VIII)," Eighth International Conference, Rhodes, Greece, Sept. 2013.

Dayeh, S.A. et al., "Nanoscale Heterogeneous Reactions and Interfaces in Ge/Si and for III-V on Si Integrated Devices," *224th ECS Meeting*, San Francisco, CA, Oct. 28, 2013.

Dayeh, S.A. et al., "Nanoscale Heterogeneous Reactions and Interfaces in Ge/Si and for III-V on Si Integrated Devices," *IBM Watson Research Center*, Dec. 16, 2013.

Dayeh, S.A. et al., "Material Heterointegration at Multiple Scales for Energy Applications," *Engineers for a Sustainable World Annual Meeting*, San Diego, CA, April 9, 2014.

Dayeh, S.A. et al., "Bio- and CMOS-compatible 3D Platforms for Neural Interfaces," *CMOS Emerging Technologies Research*, Grenoble, France, Jul. 8, 2014.

Dayeh, S.A. et al., "Compound and Alloyed Contacts to Ge/Si and InGaAs Nanowires and FinFETs," *SPIE Meeting*, San Diego, CA, Aug. 17-21, 2014.

Dayeh, S.A. et al., "Nickel Compound and Alloy Contacts to Nanoscale Si, Ge, and InGaAs Channels," *Solid State Devices and Materials (SSDM2014)*, Tsukuba, Japan, Sept. 8-11, 2014.

Dayeh, S.A. et al., "Heterointegration Technologies for Advanced 3D Neural Interfaces," *226th Electrochemical Society Meeting*, Cancun, Mexico, Oct. 5-10, 2014.

Dayeh, S.A. et al., "3D Penetrating Neuronal Probes on Insulating and Flexible Substrates for Brain Mapping," *Functional Nanomaterials Workshop*, King Abdullah University of Science and Technology, Jeddah, Saudi Arabia, Mar. 14-17, 2015.

Dayeh, S.A. et al., "Scalable Nanowire Technologies for Physiological Interfaces," *Seminar at the Solid State Physics Department*, Lund University, Sweden, Jun. 3, 2015.

Dayeh, S.A. et al., "Nanoscale Solid State Devices for Physiological Interfaces," *Seminar at SABIC*, Pittsfield, MA, Jun. 20, 2015.

Dayeh, S.A. et al., "Nanoscale Electronic Materials for Neurophysiological Interfaces," *IEEE Nanotechnology Materials and Devices Conference*, Anchorage, AK, Sept. 15, 2015.

Dayeh, S.A. et al., “Probing Greater Details in Brain Activity with Smaller Nanowire Probes,” *Neurotechnology Research in San Diego*, Sanford Burnham Consortium, San Diego, CA, Sept. 19, 2015.

Dayeh, S.A. et al., “Scalable Nanowire Technologies for Physiological Interfaces,” *Applied Physics Colloquium at Harvard John A. Paulson School of Engineering*, Harvard University, MA, Nov. 13, 2015.

Dexheimer, S.L. “Ultrafast Dynamics of Polaron Formation,” Condensed Matter Physics Seminar, University of Colorado, Boulder, CO, Apr. 2014.

Dexheimer, S.L. "Ultrafast Dynamics of Polaron Formation," Physics Colloquium, Oregon State University, Corvallis, OR, May 2014.

Dyer, G.C., Aizin, G.R., Allen, S.J., Grine, A.D., Bethke, D., Reno, J.L., Shaner, E.A. “Coherent phenomena in terahertz 2D plasmonic structures: strong coupling, plasmonic crystals, and induced transparency by coupling of localized modes,” SPIE DSS, May 2014.

Dyer, G.C., Aizin, G.R., Allen, S.J., Grine, A.D., Bethke, D., Reno, J.L., Shaner, E.A “Strong coupling of delocalized and localized resonances in voltage tunable terahertz 2D plasmonic crystals,” SPIE-Active photonic materials VI, Aug. 2014.

Frischknecht, A. L. “Ionic Aggregation and Dynamics in Ionomers: Insights from Molecular Simulations,” Gordon Research Conference on Colloidal, Macromolecular & Polyelectrolyte Solutions, Ventura, CA, Feb. 2014.

Kamaraju, N., Pan, W., Ekenberg, U., Gvozdic, D.M., Boubanga-Tombet, S., Upadhya, P.C., Reno, J., Taylor, A.J., Prasankumar, R.P., “Terahertz magneto-optical spectroscopy of two-dimensional hole systems,” EDISON’19, Jun. 2015.

Laroche, D., Gervais, G., Lilly, M.P., Reno, J.L., “Coulomb Drag in Vertically-Integrated Quantum Wires,” 20th International Conference on 2D Electron Physics, Wroclaw, Poland.

Laroche, D., Gervais, G., Reno, J.L., Lilly,M.P., “1D-1D Coulomb Drag Signature of a Luttinger Liquid,” International Conference on the Physics of Semiconductors, Austin, TX, Jul. 2014.

Liu, S., “Optical magnetic mirrors using all dielectric metasurfaces&III-V semiconductors based dielectric metamaterials”. International Conference on Materials for Advanced Technologies (ICMAT) 2015, Singapore, Singapore, June 30, 2015

Lund, M., “Stress Oddities: A Look at Nanoscale Mechanics,” Honors Lecture Series at Bemidji State University, Nov. 16, 2015.

Maiorov, B. Coated Conductors and Applications (CCA) Jeju, South Korea, Dec. 2014.

Maiorov, B. International Symposium on Superconductivity (ISS), Tokyo, Japan Nov. 2014.

Maiorov, B. Spring Meeting MRS, San Francisco, CA, Apr. 2014.

Maiorov, B. USAEUCAS, Genova, Italy, Sept. 2013.

Mitlin, D., et al., "Anodes for Sodium Ion Batteries based on Tin-Germanium-Antimony Alloys," MRS Fall, 2015.

Runt, J. "Dynamics of Precise Ethylene – Acrylic Acid Copolymers and Ionomers Using Dielectric Spectroscopy," 7th International Discussion Meeting on Relaxations in Complex Systems, Barcelona, Spain, July 2013.

Runt, J. "Dynamics of Precise Ethylene – Acid Copolymers and Ionomers Using Dielectric Spectroscopy," 8th International Conference on Broadband Dielectric Spectroscopy, Wisła, Poland, Sept. 2014.

Sarobol, P., Hall, A.C., Urrea, D.A., Chandross, M.E., Carroll, J.D., Boyce, B., Mook, W.M, Kotula, P.G., McKenzie, B.B., Bufford, D.C. "Deformation behaviors of sub-micron and micron sized alumina particles in compression," Materials Engineering Seminar, Purdue University, West Lafayette, IN, Sept. 2013.

Seo, M.A., Yoo, J., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P., "Tracking charge carriers through space and time in single silicon core-shell nanowires," MRS Fall Meeting, 2014.

Seo, M.A., Yoo, J., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P., "Tracking charge carriers through space and time in single silicon core-shell nanowires," 247th ACS National Meeting, 2014.

Seo, M.A., Yoo, J., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P., "Ultrafast Optical Microscopy on Single Semiconductor Nanowires," SPIE Photonics West, 2014.

Seo, M.A., Yoo, J., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P., "Mapping carrier diffusion in single silicon core-shell nanowires with ultrafast optical microscopy," ICMAT-2013, Singapore, 2013.

Sheu, Y.-M., et al, "Using Ultrafast Optical Spectroscopy to Explore Magnetoelectric Coupling in Multiferroic Oxide Heterostructures", PIPT5, Jun. 2014.

Sheu, Y.-M., Trugman, S.A., Yan, L., Chuu, C.-P., Bi, Z., Qi, J., Jia, Q.X., Taylor, A.J., Prasankumar, R.P., "Using Ultrafast Optical Spectroscopy to Explore Magnetoelectric Coupling in Multiferroic Oxide Heterostructures," MS&T 2013, Oct. 2013.

Singh, M., Bielejec, E.S., Pacheco, J.L., Perry, D.L., Ten Eyck, G.A., Bishop, N., Wendt, J.R., Luhman, D., Lilly, M., Carroll, M.S., "Silicon nanostructures with counted antimony donors," Silicon Nanoelectronics Workshop, Albuquerque, NM, Aug. 18-19, 2014.

Staude, I., Decker, M., Chong, K.E., Neshev, D.N., Brener I., Kivshar Y.S., "Functional photonic nanostructures based on resonant dielectric nanoparticles",*invited talk*, SPIE Micro+Nano Materials, Devices, and Systems, Sydney, Australia, December 2015.

Staude I., Sautter, J., Decker, M., Rusak, E., Neshev, D.N., Brener, I. and Kivshar, Y.S., "Active Tuning of Silicon Nanodisk Metasurfaces", *invited talk*, Progress in Electromagnetics Research Symposium (PIERS) 2015, Prague, Czech Republic, July 2015.

Staude, I. and Kivshar Y.S., "All-dielectric Nanophotonics: Magnetic Response, Fano Resonances, Functional Metasurfaces, and Nonlinear Effects", *invited talk*, CLEO/Europe-EQEC 2015, Munich, Germany, June 2015.

Staude, I., Neshev, D. N., Shcherbakov, M.R., Miroshnichenko A. E, Decker, M., Fedyanin, A.A., Brener, I., and Kivshar, Y.S., "Linear and nonlinear properties of all-dielectric metamaterials", *invited talk*, SPIE Optics+Photonics 2014, San Diego, USA, August 2014.

Staude, I., Miroshnichenko A.E., Decker, M., Fofang N.T., Liu, S., Gonzales, E., Dominguez, J., Luk, T.S., Neshev D.N., Brener, I., and Kivshar, Y.S., "Silicon-Nanodisks for Resonant Directional Scattering and Light Extraction", *invited talk*, Meta 2014 Conference, Singapore, May 2014.

Staude, I., Miroshnichenko A. E., Decker, M., Fofang, N.T., Liu, S., Gonzales, E., Dominguez, J., Luk, T.S., Neshev D.N., Brener, I., and Kivshar, Y.S., "Silicon Nanodisks for Magnetic-Light Nanophotonics", *invited talk*, Australia and New Zealand Conference on Optics and Photonics (ANZCOP), Fremantle, Australia, December 2013.

Taylor,A.J., Prasankumar, R.P., Rodriguez, G., Yarotski, D., Jia, Q.X., Trugman, S., "Ultrafast dynamics in correlated electron materials," ICMAT-2013, Singapore, 2013.

Wang, G., *III-Nitride Nanowires for Solid-State Lighting*, Workshop on Emerging Lighting Solutions, 1/11/13, Montreal, Canada .

Wang, G. T., *Nanowires: A New Architecture for Solid-State Lighting*, Seminar at University of Southern California, 3/6/13, Los Anglees, CA .

Wang, G. T., *Nanowires for Future Optoelectronics*, 2013 Materials Science Research Foundation External Review Panel, 3/12/13, Albuquerque, NM .

Wang, G. T., *Nanowires as an Architecture for Solid-State Lighting*, 7th Taiwan Solid State Lighting Symposium (2013 tSSL), 3/26-27/13, Taipei, Taiwan .

Wang, G. T., *Nanowires for Solid-State Lighting*, EFRC PI Meeting, 7/18/13, Washington, DC .

Wang, G., *Nanowires: A Future Architecture for Solid-State Lighting*, Fall 2013 National Meeting of the American Chemical Society, 9/8-12/13, Indianapolis, IN .

Wang, G. T., *III-Nitride Nanowire Heterostructures by Top-Down and Combined Top-Down Bottom-Up Approaches*, North American Molecular Beam Epitaxy Conference (NAMBE 2013), 10/5-11/13, Banff, Canada

Wang, G. T., *III-Nitride Nanowires: Novel Materials for Light Emission*, AVS 60th International Symposium and Exhibition, 10/27-11/1/13, Long Beach, CA .

Wang, G. T., *III-Nitride Nanowires: New Materials for Light Emission*, Nanowires 2013, 11/11-15/13, Rehovot, Israel

Wang, G. T., *III-Nitride Nanowires for Visible Optoelectronics*, 8th Workshop on Frontiers in Electronics (WOFE 2013), 12/17-20/13, San Juan, Puerto Rico .

Wang, G. T., *III-Nitride Nanowires for Future Optoelectronics*, Seminar at Arizona State University, 3/27/14, Tempe, AZ .

Wang, G. T., Q. Li, J. B. Wright, H. Xu, S. Liu, J. J. Wierer, D. D. Koleske, A. Hurtado, T. S. Luk, J. J. Figiel, C. Li, S. R. Brueck, G. Subramania, G. Balakrishnan, I. Brener, *Top-Down III-Nitride Nanowires: from LEDs to Lasers,* SPIE Optics+Photonics Meeting, 8/18-21/14, San Diego, CA .

Wang, G. T., J. B. Wright, H. Xu, A. Hurtado, C. Li, S. R. J. Brueck, Q. Li, T.-S. Luk, J. J. Figiel, I. Brener, *Mode and Polarization Control in Gallium Nitride Nanowire Lasers,* 2014 Progress in Electromagnetics Research Symposium (PIERS 2014), 8/25-28/2014, Guangzhou, China .

Wang, G. T., *III-Nitride Nanowires for Future Optoelectronics,* International Symposium on Materials for Enabling Nanodevices (ISMEN2014), 9/3-5/14, Tainan, Taiwan .

Wang, G. T., *III-Nitride Nanowires: Novel Materials for Future Optoelectronics,* ISSLED 2014 Meeting, 12/14-19/14, Kaohsiung, Taiwan .

Wang, G. T., *III-Nitride Nanowires for UV-Visible Optoelectronics,* 2015 IEEE Photonics Society Summer Topicals Meeting, 7/13-15/15, Nassau, Bahamas .

Wang, H., Opportunities in oxide nanocomposites with new functionalities, NAE Focused Workshop, January 2016.

Wang, H., The Frontier of Nanocomposite Designs, Purdue University, 2015.

Wang, H., Novel functionalities by materials design, University of Southern California, 2014.

Wang, H., Opportunities in oxide nanocomposites with new functionalities, ICC5 meeting, 2014.

Wang, H., Novel Interface designs in oxide systems, MS&T, 2014.

Wang, H., Interfacial strain in ceramic nanocomposites with integrated functionalities, invited speaker at ISIF (International Symposium of Integrated Functionalities), August 2013.

Wang, H., Effects of grain boundaries and phase boundaries in vertical aligned nanocomposites, invited speaker at Electronic Materials and Applications, Orlando, January 2013.

Wang, H., invited speaker at MS&T conference, Montreal, Canada, October 2013.

Yoo, J., “Photovoltaic performances of three-dimensional architecture Si radial p-i-n junction nanowire arrays”, Renewable Energy and the Environment Congress, Tucson, AZ, November 3–6, 2013.

Yoo, J., “Silicon nanoepitaxy for photovoltaic applications”, SPIE Nano+Engineering, San Diego, CA, August 17–21, 2014.

Yoo, J., “Radial epitaxy at nano/mesoscale dimensions for device applications”, Seminar at the Department of Electrical and Computer Engineering of The University of California San Diego, La Jolla, CA, September 25, 2014.

Yoo, J., "Silicon Nanowires for Photovoltaic Applications”, EMN Photovoltaics Meeting, Orlando, Florida, January 12–15, 2015.

Yoo, J., “Silicon-Germanium epitaxy for radial nanowire heterostructures”, SPIE Nano+Engineering, San Diego, CA, August 11–15, 2015.

Yoo, J., “Radial epitaxy for group-IV semiconductors for basic energy sciences and applications”, The 9th International Conference on Advanced Materials and Devices, Jeju, Republic of Korea, December 7–9, 2015.

Zavadil, K. R., Y. Liu, K. L. Jungjohann, P. G. Kotula, and N. T. Hahn; *Quantitative Operando Electrochemical TEM to Study Alloying for Advanced Battery Anodes*; The Minerals, Metals and Materials Society 2014, 143rd Annual Meeting; February 16-20, 2014 in San Diego, CA.

Presentations/Contributed

Caro, A., Fu, E.G., Mook, W.M., Martinez, E., Wang, Y.Q., Baldwin, K., Sheehan, C., Caro, M. “Radiation Response of Gold Nanofoams,” TMS 2014, San Diego, CA, Feb. 2014.

Caro, M., Fu, E.G., Mook, W.M., Wang, Y.Q., Baldwin, K., Sheehan, C., Caro, A. "Radiation effects on nanofoams mechanical properties," MRS Fall Meeting, Boston, MA, Dec. 2013.

Caro, M., Fu, E.G., Wang, Y.Q., Baldwin, K., Sheehan, C., Caro, A., Zepeda-Ruiz, L., Bringa, E., Nastasi, M., “Radiation Effects in Nanoporous Gold,” TMS Meeting on Functional Nanomaterials, San Antonio, TX, Mar. 2013.

Caro, M., Fu, E.G., Zepeda-Ruiz, L., Mook, W.M., Wang, Y.Q., Baldwin, K., Sheehan, C., Bringa, E., Nastasi, M., Caro, A., “Radiation Response of Nano-scale Gold Foams,” 8th Pacific Rim In.t Congress for Advanced Materials and Processing (PRICM-8), Waikoloa, HI, Aug. 2013.

Caro, M., Mook, W.M., Fu, E.G., Wang, Y.Q., Baldwin, J.K., Sheehan, C., Zepeda-Ruiz, L., Bringa, E., Nastasi, M., Caro, A., "Radiation Effects on Mechanical Properties of Nanoscale Gold Foams," CINT Workshop, Santa Fe, NM, Sept. 2013.

Chan, C.K. “Developing Spectroscopic Photoemission Electron Microscopy (PEEM) for Imaging Nanoscale Variations in the Chemical and Electronic Structure of Thin Film Photovoltaics,” DOE-EERE SunShot Grand Challenge Summit and Peer Review, Anaheim, CA, May 2014.

Chan, C.K., Ohta, T., Kellogg, G.L., Mansfield, L., Noufi, R. “Evidence of p- to n-type inversion at CIGS grain boundaries: A depth-dependent surface electron microscopy study,” American Physical Society March Meeting, Denver, CO, Mar. 2014.

Chan, C.K., Ohta, T., Kellogg, G.L., Pernik, D., Korgel, B., Mansfield, L., Noufi, R., Ramanathan, K. “Direct Observation of Grain Boundary PN Junction Potentials in CIGS Using Photoemission and Low Energy Electron Microscopy (PELEEM),” 40th IEEE Photovoltaics Specialists Conference. June 2014.

Chan, C.K., Ramanathan, K., Noufi, R., Ohta, T., Kellogg, G.L., Korgel, B., Modine, N.A., Dwyer, D. “Spectroscopic Photoemission Electron Microscopy (Spec-PEEM) for Imaging Nanoscale Variations in the Chemical and Electronics States of Thin-Film Photovoltaics,” CY13 Q3 Update DOE-EERE SunShot BRIDGE Quarterly Update, Nov. 2013.

Chan, C.K., Ramanathan, K., Noufi, R., Ohta, T., Kellogg, G.L., Korgel, B., Modine, N.A., Dwyer, D. “Spectroscopic Photoemission Electron Microscopy (Spec- PEEM) for Imaging Nanoscale Variations in the Chemical and Electronics States of Thin-Film Photovoltaics,” CY13 Q4 Update DOE-EERE SunShot BRIDGE Quarterly Update, Feb. 2014.

Chan, C.K., Ramanathan, K., Noufi, R., Ohta, T., Kellogg, G.L., Korgel, B., Modine, N.A., Dwyer, D. "Spectroscopic Photoemission Electron Microscopy (Spec-PEEM) for Imaging Nanoscale Variations in the Chemical and Electronics States of Thin-Film Photovoltaics," CY14 Q1 Update DOE-EERE SunShot BRIDGE Quarterly Update, May 2014.

Cho, J., Perng, Y.C., Membreno, D., Cirigliano, N., Dunn, B., Chang, J.P. "Engineering Lithium-Containing Ionic Conductive Thin Films by Atomic Layer Deposition for Lithium-ion Battery Applications," AVS 60th International Symposium and Exhibition, Long Beach, CA, Oct. 2013.

Cho, J., Seegmiller, T., Lau, J., Smith, L., Hur, J., Dunn, B., Chang, J.P. "Engineering Lithium-Containing Ionic Conductive Thin Films by Atomic Layer Deposition for Lithium-ion Battery Applications," AVS International Symposium, Baltimore, MD, Nov. 2014.

Cho, J., Seegmiller, T., Lau, J., Smith, L., Hur, J., Dunn, B., Chang, J.P. "Engineering Lithium-Containing Ionic Conductive Thin Films by Atomic Layer Deposition for Lithium-ion Battery Applications,"AIChE Annual Meeting, Atlanta, FL, Nov. 2014.

Choi, U.H., Masser, E., Runt, J., Buitrago, F., Middleton, R., Winey K., Cordaro, J., Frischknecht A., Wagener, K. "Dynamics of Precise Ethylene – Acid Copolymers and Ionomers Using Dielectric Spectroscopy," APS March Meeting, Denver, CO, Mar. 2014.

Mahajan, K.D, Vieira, G., Ruan, G., Bouxsein, N., Dorcéna, C.J., Lustberg, M., Bachand, G., Chalmers, J., Sooryakumar, R., Winter, J.O. "Towards a Biologically Inspired Nano-Factory for Molecular Assembly, Capture, Transport, and Characterization," AIChE Annual Meeting, San Francisco, CA, Nov. 2013.

Mahajan, K.D, Vieira, G., Ruan, G., Bouxsein, C.J., Lustberg, M., Bachand, G., Chalmers, J., Sooryakumar, R., Winter, J.O. "Nanoengineered Platform for Molecular Capture, Detection, and Manipulation," 4th International Conference on Bioengineering, Fort Lauderdale, FL, Jan. 2013.

Mahajan, K.D, Vieira, G., Ruan, G., Bouxsein, N., Duong, A., Lustberg, M., Bachand, G., Wyslouzil, B.E., Chalmers, J.J., Sooryakumar, R., Winter, J.O. "Magnetic quantum dots for simultaneous Detection, Manipulation, and tracking at nanoscale," ACS National Meeting, New Orleans, LA, Apr. 2013.

Mance, J.G., Felver, J.J., Dexheimer, S.L. "Exciton Localization Probed via Excited-State Resonant Impulsive Stimulated Raman Spectroscopy," Conference of Lasers and Electro-Optics 2013, San Jose, CA, June 2013.

Mance, J.G., Morrissey, F. X., Felver, J.J., Dexheimer, S.L. "Coupled electronic and vibrational dynamics of exciton self-trapping in structurally tunable quasi-one-dimensional materials," Gordon Research Conference on Ultrafast Phenomena in Cooperative Systems, Ventura, CA, Feb. 2014.

Schaffer, Z. "Ordered Bulk Heterojunction from a Single Block Copolymer," UNM, July 2014.

Small, L.J., Spoerke, E.D., Wheeler, D.R., Wolf, S., Vandelinder, V., Bachand, G., Courchaine, E. "Electrochromism vs. The Bugs: Developing WO3 Thin Film Windows to Control Photoactive Biological Systems," Electronic Materials and Applications 2014, Orlando, FL, Jan. 2014.

Ting, C.L., Stevens, M.J., Frischknecht, A.L. "Coarse-grained ionomer melts under an external electric field," APS March Meeting, Denver, CO, Mar. 2014.

Vetterick, G., Barr, C., Baldwin, J. K., Kirk, M., Baldo, P., Misra, A., Taheri, M.L. "Point Defect Cluster Interactions with Grain Boundaries in Nanocrystalline Iron," TMS 2013. San Antonio, TX, Mar. 2013.

Vetterick, G., Barr, C., Baldwin, J. K., Kirk, M., Baldo, P., Misra, A., Taheri, M.L. "Point Defect Cluster Interactions with Grain Boundaries in Nanocrystalline Fe and Fe-Cr." TMS 2013. San Antonio, TX, Mar. 2013.

Vreeland, E.C., Price, A. D., Fellows, B. D., Schober, G. B., Monson, T. C., Hance, B. G., Huber, D. L. "Kinetically Controlled, Size Tunable Iron Oxide Nanocrystal Synthesis," Frontiers in Biomagnetic Particles, Telluride, CO, 2013.

Winter, J.O. “Magnetic Quantum Dots for Quantitative Cell and Molecular Separations,” Colloidal Semiconductor Nanoparticles Gordon Research Conference, Providence, RI, July 2014.

Winter, J.O. "Magnetic quantum dot enabled technologies for nanoscale manipulation," ACS National Meeting, New Orleans, LA, Apr. 2013.

Winter, J.O. “Nanomaterials in Bioengineering: Tissue Engineering, Drug Delivery, and Imaging,” College of Engineering, Nanjing University, Nanjing, China, Sept. 2014.

Winter, J.O. “Toward Nanomachines: Bio-Inspired Assembly, Transport and Manipulation at the Nanoscale,” Northwestern University, Evanston, IL, June 2014.

Winter, J.O. “Magnetic Quantum Dots for Imaging, Diagnostics, and Biomechanical Manipulation,” University of Texas, Austin, Austin, TX, Apr. 2014.

Winter, J.O. “Integrating Biological and Engineering Transport at the Nanoscale,” Northwestern University, Evanston, IL, Nov. 2013.

Winter, J.O. “Engineering a Bio-inspired Nanofactory for Assembly, Capture, and Transport,” Auburn University, Auburn, AL, Oct. 2013.

Wolf, S., Small, L.J., Vandelinder, V.S., Courchaine, E., Bachand, G.D., Spoerke, E.D. “Controlling Photo-Stimulated Biological Proton Pumping with an Electrochromic Window,” Rio Grande Symposium on Advanced Materials, Albuquerque, NM, Oct. 2013.

4.g. Honors and Awards

Staff Awards

2013

- A. Frischknecht, Employee Recognition Award for Individual Technical Excellence from Sandia National Laboratories
- G. Bachand, CINT Scientist, Sandia National Laboratories Employee Recognition Award , W87 MC3730 Detonator Significant Finding Investigation Team
- I. Brener, IEEE Fellow Award
- J. Hollingsworth, LANL Fellows' Prize for Research
- N.A. Mara, National Institutes of Justice Body Armor Challenge Finalist
- P. Goodwin, Defense Programs Team Award of Excellence, "Shock Wave Compression of Argon Gas"

2014

- A. Frischknecht, elected 2016 Vice Chair and 2018 Chair of the Polymer Physics Gordon Research Conference.
- A. Sanders, CINT Communications and Outreach Manager, was selected as one of the "Women that Inspire" at Los Alamos National Laboratory
- G. Bachand, CINT wins R&D Award based on collaborative user projection in Anthrax detection (George Bachand)
- G. Montano, elected President of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) Board of Directors. SACNAS is the largest multicultural and multidisciplinary scientific society in the Nation.
- I. Brener, IEEE Fellow. He was recognized for contributions to terahertz science and technology.
- J. Nogan, presented inaugural "Exceptional Service Award" from Sandia Vice President Robert Leland and Sandia's Science & Technology Division.
- Q. Jia, Fellow of Materials Research Society
- S. Doorn, Fellow of the American Physical Society
- S. Tretiak, Fellow of the American Physical Society.

2015

- C. Hanson, LANL Distinguished Student Award.
- D. Huber, has been featured by Sandia's "Partnership Annual Report". Specifically, it highlighted that the Senior Scientific–Sandia (CINT) collaboration has resulted in joint intellectual property, advancement of Senior Scientific products, and progress towards new cancer detection technology.
- G. Bachand, BadX awarded 2015 TechConnect Innovation Awardee at the TechConnect National Innovation Summit.
- G. Bachand, BaDx selected as the Best Tech of the Year by Popular Science (December, 2015). This technology has been dubbed as the "smallest, safest Anthrax detector." It won the Grand Winner Award under category of Security.

- G. Bachand, Federal Laboratory Consortium (FLC) for Technology Transfer award for BaDx (Bacillus anthracis Diagnostics). The technology has been licensed to Aquila, a small, woman-owned New Mexico company.
- G. Bachand, Sandia National Laboratories Employee Recognition Award, for creating a portable diagnostic device to detect anthrax in low resource environments, and concurrently reducing the risk of theft and misuse of Bacillus anthracis (BaDx)
- H. Chen, LANL Fellows' Prize. The ceremony was held on February 9, 2016.
- H.T. Chen, APS Fellow with citation of "For contributions to the development of active metamaterials and devices, and the development and understanding of few-layer metamaterials and metasurfaces, especially in the terahertz frequency range."
- I. Brener, article entitled "High-efficiency dielectric Huygens' surfaces" has been listed as the top 5 (March 2015) most downloaded papers from Advanced Optical Materials (Wiley-VCH).
- N. Mara, et al, 2015 Buehler best paper award, "Processing and Deformation Behavior of Bulk Cu-Nb Nanolaminates".
- P. Goodwin, NNSA Letter of Appreciation, "In-situ Shock Temperature Measurements"
- S. Tretiak, 2014 LANL Postdoctoral Distinguished Mentor Award to recognize his distinguished performance as a mentor.
- X. Ma, Postdoc Distinguished Performance Award from LANL.
- Y.M. She, LANL Postdoctoral Publication Prize (2015) in Experimental Sciences. She was selected as the winner for her paper entitled "Using ultrashort optical pulses to couple ferroelectric and ferromagnetic order in an oxide heterostructure", published in Nature Communications

User Awards

2013

- A. Usheva, William F. Milton award from Harvard University for innovation research on DNA Functionality
- B. Alexandrov, International Senior Marie Curie Fellowship for THz-DNA Research, COFUND by Durham University, UK
- C.B. Carter, 2013 Distinguished Scientist Award from the Microscopy Society of America
- G. Fredrickson, University of California, Santa Barbara, Fellow of the American Association for the Advancement of Science
- G. Voth, 2013 American Chemical Society Division of Physical Chemistry Award in Theoretical Chemistry
- G. Voth, International Academy of Quantum Molecular Science
- H. Wang, TEES Fellow, Texas A&M University
- J. Brinker, 2013 Federal Laboratory Consortium, Outstanding Regional Partnership
- J. Brinker, UNM Health Sciences Center/Sandia National Laboratories Partnership
- K. Winey, University of Pennsylvania, elected a Fellow of the Materials Research Society and became a TowerBrook Foundation Faculty Fellow
- N. Chawla, Brimacombe Medalist – The Minerals, Metals, and Materials Society (TMS). Recognizes an individual (at the mid-career level) with sustained excellence and achievement in business, technology, education, public policy, or science related to materials science and engineering.
- W. Goddard, Award for Distinguished Scientific Achievement in Catalysis 7th World Congress Oxidation Catalysis

- X. Zhang, TEES (Texas Engineering Experiment Station) Fellow Award

2014

- A. Malko, received NSF Career award
- A. Malko, received tenure promotion (letter of support provided by CINT)
- G. Voth, 2014 Stanislaw M. Ulam Distinguished Scholar, Los Alamos National Laboratory
- H. Wang, ASM International Fellow, Class of 2014
- H. Wang, TEES Senior Fellow, Texas A&M University
- J. Brinker, Board of Directors, Materials Research Society
- J. Brinker, 2014 Federal Laboratory Consortium, Notable Technology Development Award, Nano-Stabilized Enzymatic Membrane for CO2 Capture
- W. Goddard, Named 2014 ISI Highly Cited Chemist
- X. Zhang, College of Engineering Holleran-Bowman Faculty Fellow Award
- X. Zhang, Gulf Oil/Thomas A. Dietz Career Development Professor

2015

- A. Subramanian, a CINT user at Virginia Commonwealth University, has received a five-year, $505,000 National Science Foundation early career award to make lithium-ion batteries — which power electric vehicles and portable electronic devices.
- B. Alexandrov, LANL THEORHETICAL Science Highlights (09-02-15) for *Rare noncoding point mutations associated with schizophrenia and bipolar disorder*
- C. A.Yablinsk. (Winner) Characterization of Irradiation Effects in Nanoscale Stable Precipitation-Strengthened Steels. - LANL Postdoc Research Day. June, 2015. (user)
- C.E. Strauss, Distinguished Performance Award (2016,LANL Remote Sensing)
- E. Trigg, a graduate student in Materials Science and Engineering at the University of Pennsylvania, has won a DOE Office of Science Graduate Student Research (SCGSR) award to conduct research at CINT in 2015. His research project, "Understanding and Controlling the Local Structure of Self-Assembled Ionically Conductive Sheets in Precise Copolymers," will be performed under the mentorship of Professor Karen Winey and in collaboration with Dr. Mark Stevens at the CINT Core Facility, Sandia National Laboratories, Albuquerque, NM.
- H. Wang, a long time CINT user from University of Texas A&M, has been elected as the fellow American Ceramic Society.
- H. Wang, Distinguished Research Achievement Award, Association of Former Students, Texas A&M University (1 out of 5 per year)
- H. Wang, The O'Donnell Award in Engineering Category, TAMEST (The Academy of Medicine, Engineering, and Science of Texas, one per year)
- J. Driscoll, University of Cambridge, Fellow of Materials Research Society.
- J. Brinker, 2015 Conference Organizing Committee, Session Chair, Featured Speaker Fourth International Conference on Multifunctional Hybrid and Nanomaterials, Sitges/Barcelona, Spain, March 9-13, 2015
- J. Driscoll, University of Cambridge, 2015 Joule Medal and Prize from Institute of Physics (IOP).
- P. Atanassov, elected Vice President of the International Society of Electrochemistry (ISE)
- S. Anderson, promoted to Associate Director for Surface Analysis and Nano-imaging

- S. Anderson, Robert W. Parry Teaching Award
- T. Nizolek, a CINT user and student from UCSD, received the Jacquet-Lucas Award in Metallography at the M&M conference. He worked on high strengths Cu and Nb layered composite at CINT.
- Two CINT users, Ms. Vaidya and Mr. Abeyta, high school students, received an all-expenses-paid trip to the 2015 Intel International Science & Engineering Fair, where they placed third in the microbiology category. Prior to that award, they won the Senior Division Life Sciences Grand Award at the New Mexico State Science & Engineering Fair. They performed this under the supervision of Dr. Omberg at Los Alamos National Laboratory.

5. Future Directions

In the last three years, CINT has maintained a very high level of scientific productivity and impact through its vibrant user community and forefront efforts of its thrust-based program. Our vision remains clear — the establishment of a single scientific community focused on nanoscience integration. To derive the ultimate benefit from nanoscience, our distinct drivers will require the assembly of diverse nanoscale materials across multiple length scales to design and achieve new properties and functionality; in other words, nanomaterials integration. Progress in both the science and technology of integration are critical components of the DOE's vision for NSRC s to be major contributors in the national advancement of nanoscience through enabling rapid progress of nanotechnology and serving critical needs in energy, national security, and economic development. CINT's focus on nanoscale integration is one mechanism to define its unique role among the NSRCs.

Addressing integration science challenges will require commitment from the entire nanoscience community. Through its thrusts, CINT focuses on key aspects of these challenges: (1) understanding and controlling fundamental photonic, electronic, and magnetic interactions in nanostructured optical materials; (2) understanding and controlling electrical and mechanical properties arising from confinement of the nanoscale interactions within nanostructures; (3) understanding solution-based, "bottom-up" approaches for the development of integrated soft, biological, and composite materials; and (4) developing analytical and computational approaches that enable the simulation and predication of competing interactions, resultant material structure, and properties that occur in integrated nanomaterials systems. Thus, CINT's success in advancing the science of nanoscale integration depends on building a strong scientific staff, a suite of world-class capabilities, and an outstanding community of users based on these focus areas.

During the next three years, CINT will continue to build on these solid foundations and extend our knowledge of the science and technology in nanomaterials integration to address challenges at the frontiers of matter and energy outlined in the BESAC report ("Transformative Opportunities for Discovery," November 2015). Through collaborations with CINT users to develop new nanotechnology applications, the Center will continue having major impact as an NSRC. Our goal remains sustained recognition as the leader in nanoscience integration by the broad scientific community.

Achieving our goals will require persistent focus on multiple fronts. Foremost are (1) continuously growing our user program to reach the broadest possible community while making optimal use of our existing infrastructure; (2) enabling opportunities for the coalescence and involvement of our user community around high-impact integration, which will accelerate progress; (3) advancing our thrust-based science to retain a leadership position in nanoscale research and integration that engages new users and lays the foundation for new nanotechnology implementation; and (4) recapitalizing our capabilities to maintain world leadership in the synthesis, fabrication, characterization, and theory of nanostructured materials and integration. Some specific higher-level examples of new and continuing scientific directions within our thrusts during the next three years are summarized in Table 5.1; they are also described in greater detail in the individual Thrust FWPs. Strategic new directions in our science program are outlined in Section 5.e.

Table 5.1 Scientific Directions for the CINT Thrusts in the New Review Period

NEM Thrust:
• Advancing discovery platform capabilities, fabrication methodology, and characterization tools
• Single spin devices and spin control methodologies for quantum information
• Nanoscale plasticity and fracture
• Controlled functionality in nanocomposite films
• Nanowires for new energy concepts

NPON Thrust: • Chemical and physical synthesis and processing of optical low-dimensional nanophotonic structures • Optical properties of low-dimensional nanostructures • Nanoplasmonics, hybrid metamaterials, and metasurfaces for advanced functionality and optical nonlinearities • New instrument development for synthesis and characterization
SBCN Thrust: • Development and application of imaging of soft materials • Synthesis of soft nanostructured materials, hybrids, and composite that can be used for energy storage, transduction, and sensing
TSNP Thrust: • Modeling of hierarchical structure and dynamics in soft matter • Theory of excitation and transport in nanostructured systems • Emergent phenomena at surfaces and interfaces

At the heart of our strategy is deepening the coherence and coupling between CINT and its user community through the Center's unique set of world-class capabilities for addressing integration science. We look optimistically toward new scientific frontiers, many of which are being described in BESAC reports ("Directing Matter and Energy: Five Challenges for Science and the Imagination," November 2017; "Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery," November 2015). Enormous opportunities exist for CINT to help shape and contribute to the success of these science frontiers. Many exciting new challenges that CINT is particularly well-suited to address include mesoscale science ("*From Quanta to the Continuum: Opportunities for Mesoscale Science*," Basic Energy Science Advisory Committee Report, September 2012); and energy transformation, hierarchical assemblies, interfaces, advanced imaging, and harnessing coherence in light and matter. The priority research directions identified in these reports can all be meaningfully mapped to CINT expertise and capabilities. Furthermore, the Center's internal strategic planning process has identified hiring scientists with expertise in nanoscale integration as the highest priority in each of our three experimental thrusts. Such strategic hires will ensure that science at CINT is optimally aligned with BESAC objectives.

5.a Description and prioritization of plans for future instruments and facilities upgrades, including recapitalization issues

5.a.1 Background and Overview

Modern facilities housing state-of-the-art equipment are essential components of any nanoscience user facility. Since its inception, CINT has involved the user community in defining the equipment and facilities essential to carry out its nanoscience integration science. The total lab space offered by the two CINT locations is 38,000 square feet, making CINT the largest NSRC. As described in Section 2.c., CINT also has several leveraged facilities associated with our host institutions that support user program operations and provide enhanced nanoscience research capabilities such as synthetic and characterization laboratories. Through ongoing space utilization audits, CINT has retained some flexibility for the addition of new capabilities that enable the Center to grow and meet evolving user community needs.

Although the current fiscal climate limits CINT's ability to acquire major capital purchases, an FY2012 decision to raise the threshold for capital equipment within DOE to $500K has enabled some latitude in using operating funds for major equipment procurement that would previously have been deemed capital level (>$50K). In a continuous evaluation of equipment needs, CINT maintains a prioritized list of targeted capabilities. Strategic equipment acquired recently through such operating funds (typically at levels in the few $100K range) is described

in section 5.a.2. Novel instrumentation, synthesis capability, and newly introduced discovery platforms developed within CINT, described in section 5.a.3, are often made possible through significant leveraging of funds uniquely available via our host institutions. For future investment, CINT has also identified a set of new instruments in the same cost range that will further enhance our nanoscience integration user program and its impact. These are described in section 5.a.4 (future envisioned capability). Finally, recent host institution investment in CINT is enabling the Center to move ahead with the acquisition of two major (~$500–$700K level) unique capability purchases that will define new directions for integration of multiple nanoscale materials into 2D and 3D architectures and permit optical characterization at nm resolution limits (also described in section 5.a.4). These capabilities will enhance our ability to integrate nanomaterials into systems using state-of-the-art cleanroom tools and address the important scientific issues related to in-situ studies of nanomaterials during synthesis and under external stimuli. This plan necessarily requires coordination with our staffing needs; a coordinated plan is detailed in section 5.d.2.

5.a.2 Approved Commercial Instruments recently acquired or under acquisition

Superconducting Nanowire Single Photon Detector:

CINT has acquired an Eos 410 Superconducting Nanowire Single-Photon Detector from Single Quantum BV (Figure 5.1). This new detector is capable of detecting single photons in the 0.2 to 2.2 μm spectral range with high detection efficiency in the near-IR (>25% at 1300 nm), low timing jitter (<50 ps), low dark counts (<100 Hz), and high count rate (<10 ns dead time). Performance of this detector in the 1.0–1.5 μm spectral range is unparalleled by any existing detectors. This detector is particularly well-suited for time tagged, time-correlated, single-photon counting experiments for characterizing carrier dynamics and other emission properties such as the fluorescence intermittency of individual, near-IR-emitting, semiconductor nanostructures. Furthermore, because our detector has four active channels that can be coupled to optical fibers, it can also be coupled with: (1) Hunbry Brown-Twiss, photon correlation/cross-correlation experiments; and (2) Hou-Ou-Mandel, single-photon interference experiments for characterizing quantum optical properties of nanostructures (e.g., photon statistics, photon indistinguishability, entanglement, etc.). Example data for oxygen doped nanotubes demonstrated for the first time to show single-photon emission, demonstrable only through application of this unique new capability, are displayed in Figure 5.1. This detector will play a critical role in evaluating the opto-electronic and quantum technological functionalities of a wide range of NIR-emitting nanostructures and nanostructure-plasmonic/photonic couples.

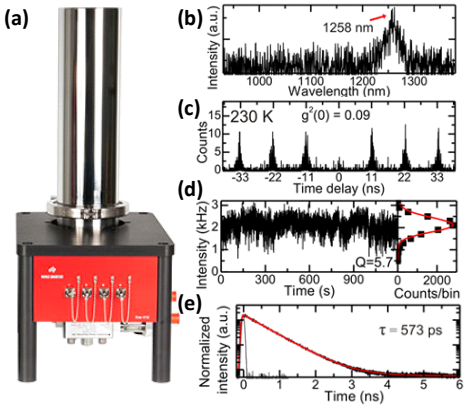


Figure 5.1. (a) Eos 410 super conducting nanowire detector. (b) PL spectrum of a solitary oxygen dopant emitting at 1.26 μm. (c-e) 2nd order photon correlation spectrum, PL time trace and PL decay curves of the dopant state acquired in a single experiment using Eos 410. The gray line of (e) is the instrument response.

9 Tesla Superconducting Magnet and Microscopy Cryostat for Single Nanostructure Magneto-PL/Raman Capability:

CINT is acquiring a Janis 9-Tesla superconducting magnet and an ST500 continuous-flow microscopy cryostat (shown in Figure 5.2) to construct a single nanostructure magneto-photoluminescence (PL)/Raman facility. The magnet/cryostat assembly will accommodate samples to up 13 mm, provide temperature control between 3–420 K, and the 9-liter liquid-He dewar of the magnet will permit 24-hour continuous operation at peak field strength. This system will serve as the core of a single nanostructure imaging and spectroscopy capability

Figure 5.2. 9 T Superconducting magnet and ST 500 microscopy cryostat.

with a suite of wavelength tunable lasers and ultra-sensitive low-light detectors (CCDs and InGaAs diode arrays), which are available to perform high-resolution PL, PLE, and resonant Raman spectroscopies under magnetic field. This system can also be coupled with the superconducting nanowire single-photon detector (noted above) to perform time-resolved PL and photon correlation spectroscopies under high magnetic fields. This capability will open new avenues for investigation to a broad anticipated user base in the areas of 2-D materials (graphene, transition metal dichalcogenides), semiconducting nanostructures (nanowires, quantum dots, carbon nanotubes), and multifunctional complex metal oxide films. Examples of science areas that will benefit from this capability include spintronics, relevant materials studies, investigation of exciton fine structure, origins of new optical states in doped materials, interplay of bright and dark exciton states, and triplet-singlet interactions.

Fourier Transform Infrared Spectroscopy:
CINT has implemented four new FTIR spectrometers with a variety of attachments and measurement modalities that allow transmission and reflection measurements at different temperatures and from the near-to-far infrared range. These systems are currently being used to study optical properties of metasurfaces and their coupling to solid state excitations, as well as their thermal emission properties. One FTIR (Bruker) can be used with a Helium flow cryostat to carry out measurements from ~6 K to room temperature. For absolute thermal emissivity emission measurements, a vacuum chamber with heated sample holder is integrated to an FTIR spectrometer. The sample holder accepts a sample size of 1 cm x 1 cm that can be rotated about a single axis to allow angular dependent (~5 degree resolution) measurements. The maximum sample temperature is about 1000 K. For transmission and reflection spectral measurements of very small sample sizes (<100 _m2), an infrared microscope equipped with broadband reflective optics is integrated with an FTIR spectrometer.

Electron Beam Induced Current (EBIC) Measurement Capability:
Our newly acquired electron beam-induced current (EBIC) measurement system provides researchers with the capability for performing spatially resolved electrical characterization of materials and devices at nano/mesoscales with concurrent acquisition of morphological information (see Figure 5.3). Our EBIC system has 0.76 fA sensitivity with wide dynamic range of 108 dB. Electrical bias can be applied to nanomaterials/ devices under observation. The EBIC system adds to CINT's nano-characterization capability for device studies at the single-nanostructure level and provides synergy with the CINT nanofabrication suite.

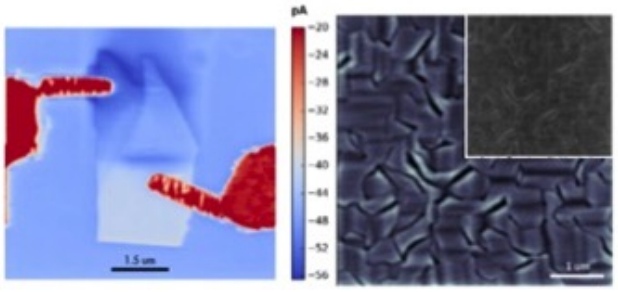


Figure 5.3. EBIC map of monolayer MoS device (left). EBIC map (right) of GaAs thin film reveals antiphase boundary which is not clearly observed in secondary scanning electron microscopy image (inset).

Temperature-dependent Microprobe Station:
Recently CINT installed a temperature-dependent microprobe station in which sample temperature can be continuously controlled in the range of 80–580 K via a Joule-Thomson refrigerator and resistive heater. The microprobe station has four probe configurations applicable to field effect transistor and resistivity measurements. The station can be connected to CINT's electrical characterization suite, including semiconductor parameter analyzer and capacitance-voltage measurement system. The flexibility of measurement configuration and temperature-dependent measurement provides researchers with opportunities for monitoring performances of nano/microdevices at various temperatures corresponding to the operation conditions of real devices. A quartz window on top of the probe station provides optical access for simultaneous photoexcitation of samples as well.

Multipurpose Small Angle X-Ray Scattering (SAXS):
Small-angle x-ray scattering (SAXS) has emerged as a fundamental method for the structural analysis of materials. SAXS offers medium-resolution structure determination of nano- and meso-ordered materials,

thereby yielding size and shape information on both crystalline and non-crystalline particles and macromolecules without the need for destructive sample preparation. SAXS commonly delivers information on the 5–150 nm range on bulk (solution or solid) samples. SAXS experiments conducted in a grazing incidence configuration (GI-SAXS) provide information on layered/surface adsorbed materials. A modular instrument featuring an adjustable camera-to-sample distance can be used for performing wide-angle scattering (WAXS) studies and structure determination on shorter length scales (1–5 nm). CINT has recently installed a modular x-ray scattering system that permits wide-angle (WAXS), small-angle (SAXS), and grazing incidence x-ray scattering (GI-SAXS) experiments on a range of samples, including thin films, solution, and solids under environmental control. This instrument will have application in materials science, structural biology, polymer and colloidal chemistry.

Hysitron Triboindenter 950:
This new nanomechanical test platform is a significant upgrade over the Keysight/Agilent nanoXP that it replaced. The Tribo 950 is capable of probing mechanical behaviors over a wide range of strain rates (~10^{-5} to 10^{1} s^{-1}), temperatures (RT to 800 °C), and sample geometries (indentation, micropillar compression, and cantilever bending). This equipment was the first Hysitron unit installed worldwide that combines high-temperature testing with high load continuous stiffness measurements up to 8 Newtons maximum load. The previous instrument user base, which was focused on room temperature, quasistatic, and dynamic indentation/ compression measurements, is currently transitioning to the new Tribo 950. These new capabilities are available to CINT users, and the Center has formally partnered with Hysitron to spur development of new test strategies for in-situ and operando mechanical testing based on this new nanomechanical test platform.

Laser Amplifier with Twin Optical Parametric Amplifiers for Near to Far-Infrared Pump-Probe Spectroscopy:
A new system consisting of a laser amplifier and dual optical parametric amplifiers (OPA) from Coherent Inc. will arrive by August 2016. The system will be used to study the dynamics of a variety of metasurfaces, including those based on epsilon-near-zero layers and electron-correlated materials. It will provide high-energy femtosecond pulses from the near-to-far infrared. The system consists of a one-box Astrella-USP-1K fs Ti:sapphire amplifier with integrated Vitara-T oscillator, delivering pulse energies of >7.0 mJ at a 1 kHz repetition rate with 35 fs pulse widths. The oscillator is paired with dual OPA: TOPAS-Twins (1160-2600 nm) with difference frequency module TOPAS-NDFG1/2 (2600–15000 nm). These two independently tunable OPAs are integrated into a single monolithic housing. Both OPAs share the same white-light source to provide excellent and bound-up stability of both outputs. Shared white light enables the user to passively generate carrier envelope phase (CEP) locked mid-IR pulses in the 4–20 μm range. Representative tuning curves for the integrated system are shown in Figure 5.4.

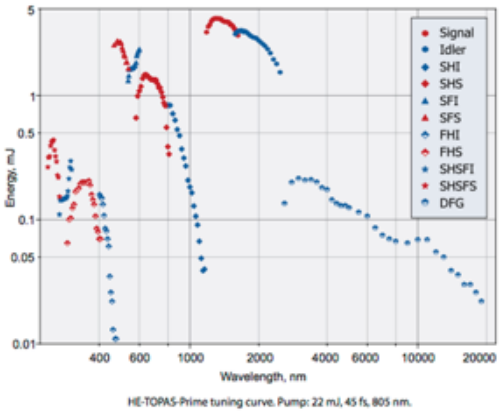


Figure 5.4. HE-TOPAS tuning curve.

5.a.3 Discovery Platforms and CINT-Developed Synthesis Tools and Instrumentation

Discovery Platforms are microfabricated structures or devices expressly designed and produced to create or characterize nanoscale materials. This might be a complex device with many "experiments" on chip or a relatively simple microfabricated structure that is used in conjunction with other laboratory instruments. To facilitate their use by the broadest range of researchers, Discovery Platforms are designed for maximum flexibility while remaining optimized for their intended purpose. New developments include

Electrochemistry TEM Discovery Platform
While commercially available in situ TEM capability is offered by other NSRCs, CINT offers a significant-

ly more powerful in situ Electrochemistry TEM Discovery Platform capability that outperforms commercial systems through a number of unique features. The electrochemical TEM discovery platform is microfabricated at the MESA facility at Sandia National Laboratories. The liquid-cell (Figure 5.5) is composed of two independent chips where the lid and base parts are epoxied together to form a ~120 nm liquid gap between the independent windows. The lid has two fluid fill ports. In comparison to commercial electrochemical TEM cells, CINT's capability provides the following advantages: experimental customization of the electrode materials and layouts; evenly thin liquid layers; 10 individually controlled electrodes for multiple experiments within the same environmental conditions; and low-current control and sensitivity (necessary for measurements on individual nanostructures) for quantitative analysis ranging from electrochemical data to structural/chemical information of nanoscale electrode areas. In addition to these advantages, CINT facilities provide custom patterning of electrode materials and tailoring the platform to optimal experimental design on an individual proposal basis. This custom patterning has enabled CINT's development of quantitative temperature control of liquid within the cell, where the temperature is measured in real-time during the experiment.

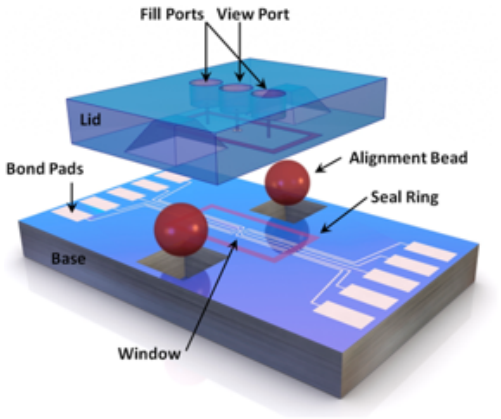


Figure 5.5 Electrochemical TEM Discovery Platform.

Quantitative elevated temperature control has been developed for general studies on nanomaterial growth and assembly in a liquid, and for temperature control during electrochemical cycling. Quantitative temperature control in a TEM has always been a concern due to inability to sense the temperature during heating near the specimen while imaging in the TEM. CINT has overcome this barrier by integrating two sense-leads within the patterned heating platform (Figure 5.6). These sensors have been verified for accuracy by independently measuring the temperature of a liquid metal (sealed within the cell) using electron-energy loss spectroscopy to correlate plasmon shifts that relate to temperature changes in the liquid metal. Direct correlation between these two measurements removes the ambiguity of accurate temperature measurement, while using our platform for a temperature-controlled liquid-phase experiment within the TEM. Commercial companies are offering temperature control in a liquid-cell, though they cannot provide on-column measurement during the experiment.

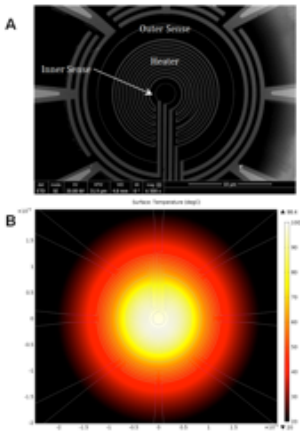


Figure 5.6 A) SEM image of patterned heater and sense leads in CINT's electrochemical TEM discovery platform. B) COMSOL model of T profile.

CINT has also demonstrated success in the area of electrochemical research in nanomaterial growth, assembly, and battery research using the Electrochemistry TEM Discovery Platform. Work at CINT during the past three years has optimized approaches for integrating nanomaterials on the electrodes within the window region of the electrochemical TEM platform. Integration with the dual-micromanipulator system within the SEM has enabled a pick-and-place technique for individual nanowires/nanofibers/nanoparticles. Additionally, pairing with the focused ion beam (FIB) enables placement of sectioned nanoscale thick films. Good electrical contact with these materials has been obtained using localized metal contact deposition patterned with electron-beam lithography and FIB deposition of conductive carbon or platinum for air-sensitive materials.

New Developments for Microfluidics Discovery Platform

CINT has developed a Microfluidic Discovery Platform to enable the controllable and reproducible synthesis of a variety of nanomaterials. Researchers at the Center have established a standard form factor and fluidic connection for microchips of a variety of designs (Figure 5.7). This, coupled with our temperature controls, allows users to perform a host of different reactions on chips while varying the number of reagents, the order

and timing of additional reaction times, and the reaction temperatures in systems with or without droplets or slugs. Much of this can now be systematically varied to understand the effect of these reaction parameters on the properties of the nanomaterials. Some of the nanomaterial properties can be measured in real time using in situ UV-visible and NIR spectroscopy. This system has been applied to the controlled synthesis of a range of metal and oxide nanoparticles with useful optical and magnetic properties in collaboration with several users.

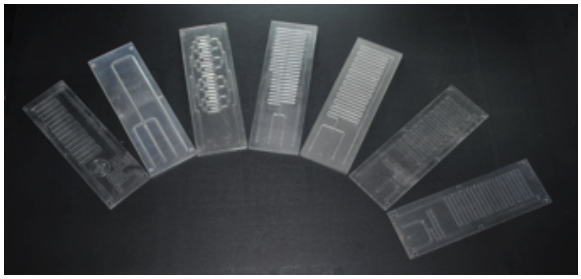


Figure 5.7 A range of microfluidic chip designs available for the Microfluidic Discovery Platform that feature a standard form factor and use a standard fluidic connector.

Flow-SLS Nanowire Synthesis Reactor

The Center has created the solution-phase equivalent to vapor-liquid-solid (VLS) growth in a chemical vapor deposition (CVD) chamber by adapting flask-based solution-liquid-solid (SLS) growth to synthesis in a microfluidic reactor (depicted in Figure 5.8). Specifically, using a custom microfluidics chip designed and fabricated for this purpose, metal-nanoparticle growth catalysts are held in a flow of solution-phase reactants and growth-controlling ligands. The resulting nanowires, like their VLS counterparts, grow from a solid substrate. The dynamic nature of this synthesis (in contrast to conventional flask-based synthesis) affords: greater control over growth; new opportunities to study growth mechanisms; and, most significantly, the ability to fabricate complex axial heterostructures. CINT researchers look forward to working with users to further exploit this new technique because it allows for the controlled synthesizing of high-quality, single-crystalline semiconductor nanowires with built-in nanoscale/mesoscale interfaces.

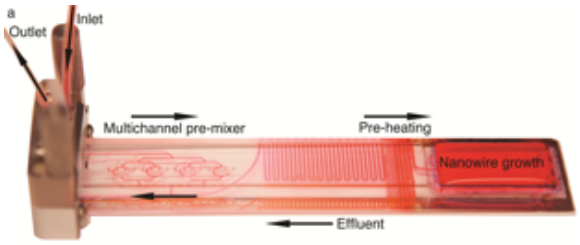


Figure 5.8 Image of a Flow-SLS microfludic reactor chip.

Automated Reactor System with in situ Diagnostics for Combinatorial Approaches to Hetero-Nanomaterials Synthesis

This custom, computer-controlled reactor system (Figure 5.9) comprises eight parallel reactors that can be individually addressed with a combined capability for (1) fully automated, software controlled “round-the-clock” chemical-precursor additions, (2) automated sampling, and (3) programmed in-situ optical characterization (absorption, fluorescence, turbidity). Reactor maximum volume and temperature are 250 mL and 300 °C, respectively. This unique system will prove a versatile and powerful tool for the controlled, quasi-combinatorial solution-phase synthesis of simple and complex nanostructures, especially heterostructured nanoparticles like thick-shell (“giant”) core/shell quantum dots and multicomponent/multifunctional nanoparticles. It will enable more rapid discovery of new nanomaterials, as well as optimization and scale-up of known optical nanomaterials.

Figure 5.9 Image of automated reactor system for synthesis of hetero-nanomaterials.

Integrated Microfluidics for Characterizing Biomolecular Self-Assembly

Over the past three years, CINT has developed capabilities in soft lithography, specifically photolithography and replica molding, which were applied to create multilayered,polydimethylsiloxane (PDMS) microfluidic devices for use in high-resolution optical characterization. Presently, issues with oxidative damage to biomolecular components and probe bleaching resulting from fluorophore excitation have presented significant limitations

with respect to high-resolution optical characterization methods. To address these issues, a multilayered PDMS device was designed that contained microfluidic channels to control delivery of the materials for characterization, as well as a channel system for nitrogen gas. Using the intrinsic permeability of PDMS, nitrogen gas enabled the complete deoxygenation of the fluid during introduction and visualization. Furthermore, this unique microfluidic system can significantly enhance the lifetime of a range of fluorescent probes and enable the use of high excitation power. More importantly, the device significantly reduces inactivation of the biomolecular components by reducing the production of oxidative radicals resulting from fluorophore excitation. These devices have already been used to characterize and understand a unique dynamic self-assembly process, and will also have direct applications in CINT's differentiating capability in high-resolution optical characterization (e.g., single-particle 3D tracking).

Targeted Functionality through Genetically Encoded Polymers

The Center has created a new capability to generate genetically encoded polymers and evolve those polymers for newly defined functions in a matter of days. Genetically encoded polymers (GEPs), (e.g., elastin, silk, resilin) are programmed at the DNA level and synthesized biologically. Like synthetic polymers, GEPs consist of short repeating units of sequences that define their materials and mechanical properties, such as reversible temperature/pH-based phase transitions, tensile strength, and resilience. Additionally, GEPs enable the design of specific, tunable material properties at the DNA level with control over function and structure that is unparalleled by synthetic polymers. Moreover, the DNA not only informs the organism which GEP to synthesize, it also serves as an ID-tag for identification of the functional material within large pools of polymers. For example, large (10^8), diverse libraries of genetically encoded polymers and rapidly identified functional materials were created from a one pot reaction—by using a genetic technique akin to evolution (requiring hours not years to define functionality). For example, using these techniques, CINT scientists have shown that polymers that induce naïve stem cells can be selected to quickly differentiate toward cartilage (Figure 5.10). And, these results have been extended to produce optical polymers with new mechanical, temperature or pH responsive optical effects. This new capability in genetically encoded polymers and their combinatorial selection of functional materials allows for polymeric materials to be quickly tuned for new functions (e.g., new phase transitions, polymer-cell interfaces, polymer-nanomaterials interfaces, and new optical materials for light emitting devices).

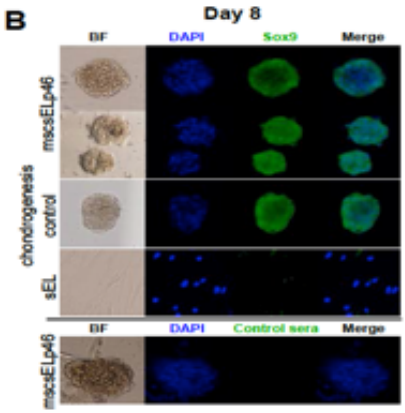


Figure 5.10 Genetically encoded polymers, important for regenerative medicine, can be selected quickly from large libraries for specific functions.

Spatially-Correlated Spectroscopic/Structural/Compositional Imaging

CINT, in collaboration with Vanderbilt University, has recently developed a novel experimental approach capable of performing advanced single nanostructure optical spectroscopies and high-resolution transmission electron microscopy on the same set of individual giant nanocrystal quantum dots (gQDs). For correlated TEM-optical spectroscopy studies, fluorescent fiducial markers were used to mark an area on an 8-nm-thick ultra-flat silicon dioxide support film on a TEM grid. To avoid electron beam-induced damage and charging to the gQD, an optical spectroscopy experiment (e.g., wide field imaging, TRPL, PL lifetime, g(2), etc.) was performed first. Then, an imaging substrate with the deposited sample is transferred to the high-resolution

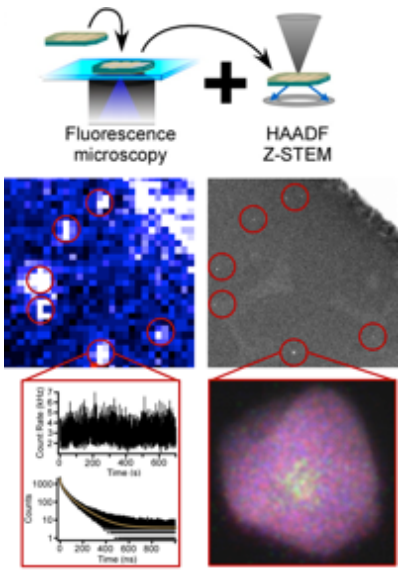


Figure 5.11 Depiction of range of information available from correlated micro-PL/HAAD/STEM-EDS on a single quantum dot.

scanning TEM; and, the specific QDs that were investigated optically are located with reference to the fiducial marker. Through this process, the optical properties can be correlated with both detailed atomic structure and with composition, which is revealed through scanning TEM energy dispersive x-ray spectroscopy (STEM-EDS, Figure 5.11).

Simultaneous Two-Color Correlated Photoluminescence Imaging

From doped carbon nanotube stonewcore-shellcom positions for giant quantum dots, CINT is developing new classes of optical emitters for multiple wavelengths. Full characterization of emission behaviors, and how emission at different wavelengths is correlated in space and time, in these new materials will provide important feedback for the synthesis strategies and understanding of underlying photophysics. Toward this end, a simultaneous correlated two-color imaging instrument was developed that provides direct wide-area photoluminescence imaging of multi-wavelength emitters (Figure 5.12). The system provides wide-area excitation of a sample, followed by collection of the PL onto the image plane of two imaging detectors: a 2D CCD for imaging in the visible to near-IR, and a 2D InGaAs array for imaging at longer near-IR wavelengths. Sensitivity allows frame-to-frame imaging at ms timescales. The system is paired with a confocal imaging capability that allows raster scanning to build up spectroscopic images and fluorescence lifetime images, all of which may be directly correlated with each other for hyperspectral dynamic information.

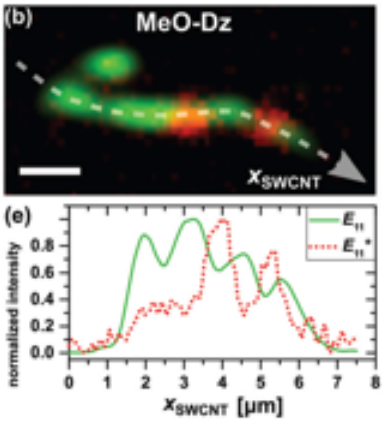


Figure 5.12 2-color correlated image data showing carbon nanotube exciton (green) and dopant-state (red) emission.

Bessel Beam Selective Plane Illumination Microscopy

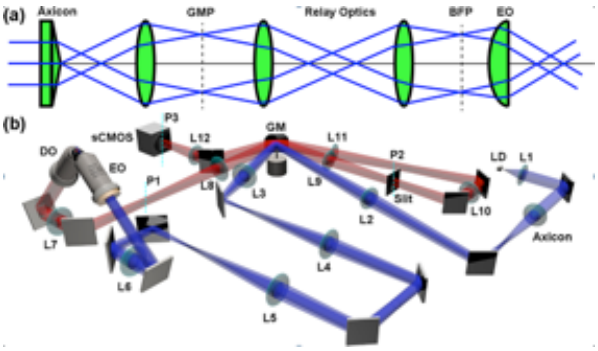


Figure 5.13 Confocal Bessel beam scanning microscope. (a) Beam path for the creation of a Bessel beam. GMP, galvo mirror plane; BFP, back focal plane; and EO, excitation objective. (b) Schematic diagram of the experimental setup. LD, laser diode; GM, galvo mirror; L, lens; DO, detection objective. The scanning frequency is 500 Hz.. From Zhang et al **Opt. Lett**. 2014

A light-sheet illumination microscope was recently developed at CINT that can perform fast 3D imaging of select samples (biological cells or soft materials) using a raster scanned Bessel beam for fluorescence excitation (Figure 5.13). A unique folded optical pathway enables a single galvo mirror to be used for scanning the Bessel beam, de-scanning the fluorescence through a stationary spatial filter, and then re-scanning the fluorescence across an imaging sensor (CCD or CMOS camera). Compared to two-photon Bessel beam excitation or other confocal line scanning approaches, our method is lower cost, simpler, and doesn't require calibration and synchronization of multiple galvo mirrors. Furthermore, CINT scientists recently demonstrated the capability of fast 3D imaging and background rejection capabilities of this microscope with fluorescent beads embedded in PDMS and imaging fluorescently labeled actin filaments in fixed 3T3 cells.

3D Tracking Single Molecule Fluorescence Resonance Energy Transfer (smFRET)

smFRET has emerged as a powerful tool to study biomolecular conformation and conformational dynamics. However, most smFRET studies to date examine molecules immobilized on a surface (for increased observation time) or examine molecules as they rapidly diffuse through a small, nearly diffraction limited probe volume in solution, thereby, only providing a brief snapshot of molecular conformation. To overcome these problems of traditional single molecule FRET, CINT's 3D single molecule tracking microscope was recently expanded to simultaneously monitor two colors (a fluorescence donor and acceptor) such that one can follow a single FRET-labeled biomolecule in 3D while simultaneously monitoring its conformation and conformational dynamics. In

addition to studying protein or biomolecular folding interactions, this microscope could be used to explore biomolecular association reactions or to visualize the assembly and dynamics of select soft materials (such as DNA origami, certain diblock copolymer morphologies, or peptide assemblies).

Combined Spinning Disk 3D-Tracking Imaging

Our tracking microscope is a custom confocal microscope that uses a unique spatial filter geometry and active feedback (200 times per second) to follow fast, 3D motion of single quantum dots, organic dyes, or fluorescent proteins. Previously, when following single quantum dot labeled proteins in live cells with the 3D tracking microscope, only a white-light image of the cell was obtained while tracking the molecule of interest. To better visualize the cellular structures around (and perhaps interacting with) the molecule, CINT scientists are tracking in 3D. Additionally, they have recently upgraded this custom molecular tracking system to exploit two-photon excitation (for tracking) and acousto-optically modulated (AOM) laser spinning disk imaging (for 3D visualization of the cell during the trajectory, see Figure 5.14).

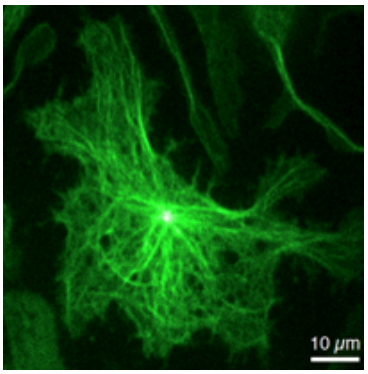


Figure 5.14 Fluorescence image of the actin cytoskeleton (labeled with the fluorescent dye Alexa 488) obtained in the tracking microscope with 40 msec integration.

Note: the image in Figure 5.14 was obtained in 40 milliseconds, a time short enough to make motion-blur (due to piezo stage movement while tracking); this is a negligible effect.

Terahertz Magneto-Optical Spectroscopy

In recent years, THz time-domain spectroscopy (THz-TDS) has been used as a non-contact probe of conductivity in a wide range of materials. In addition, the ability to do THz-TDS measurements in a high magnetic field has allowed researchers to probe exotic phenomena in condensed matter physics, such as the quantum Hall effect. Recently, CINT developed a THz magneto-optical spectroscopy system (Figure 5.15), allowing researchers to perform THz-TDS measurements on a variety of samples in magnetic fields up to 8 T and temperatures as low as 1.5 K. Initial experiments focused on THz time-domain spectroscopic (THz-TDS) measurements on GaAs-based 2DEGs and 2DHGs, revealing a nonlinear dependence of the cyclotron frequency on magnetic field for B>4 T that was due to the non-parabolic valence band structure of the 2DHG. More recently, the system has been modified to optically photoexcite samples and measure the photoinduced changes in the transmitted THz pulse (optical-pump, THz-probe (OPTP) spectroscopy) at low temperatures and high magnetic fields. To the best of our knowledge, this CINT system is one of only five tabletop systems worldwide with these capabilities. The next improvement to CINT's system will enable scientists to photoexcite samples with intense THz electric fields, which would make the system even more unique and powerful (Only two other systems with this capability are known to exist.) These changes will allow scientists to examine the physics of a wide variety of materials (e.g., semiconductor nanostructures, Dirac materials, and superconductors) in previously unexplored regimes that will likely reveal a wide range of novel physical phenomena.

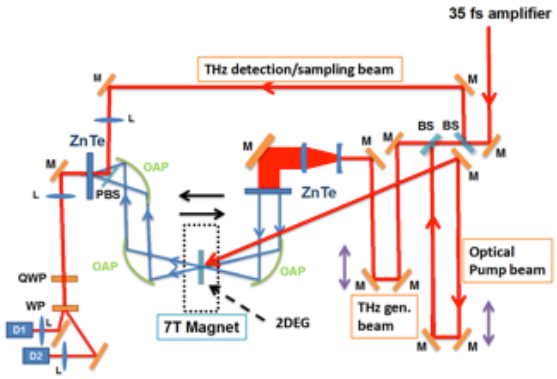


Figure 5.15 Schematic of THz-magneto-optical spectroscopy system.

Capability for Fabrication and Testing of Integrated Photonics Devices for Classical and Quantum Information Processing

During the last three years, CINT has established capabilities for fabricating and testing integrated photonics devices for classical and quantum information processing. Our current materials include both silicon and silicon

nitride waveguides. The Center is in the process of adding lithium niobate and aluminum nitride as well. High-quality waveguides of three varieties can be fabricated at CINT: conventionally etched (3–5 dB/cm), partially etched (1 dB/cm), and etchless (<1 dB/cm). Also, metal heaters (NiCr or Ti), grating couplers, distributed Bragg gratings, ring resonators, polymer spot size converters, and photonics crystals can be fabricated. CINT researchers developed several additional features, including the ability to dice and polish chip edges and multi-port fiber-chip couplers with <1 dB of loss per facet. Finally, the capability has been developed at CINT to fabricate in-situ single ion detectors that can be used to accurately determine the activation yield of artificial color centers fabricated by ion implantation. In the Center's test lab, there are currently four custom optical probe stations and a suite of lasers, single-photon sources, detectors, and counters and other high-speed electronics useful for a variety of quantum and classical photonics experiments. Fiber tapers with sub-micron diameters can also be fabricated at CINT. Finally, the MESA facility has been leveraged to connect users to additional capabilities offered at Sandia National Labs in the area of integrated photonics and quantum information processing.

Users are currently accessing these capabilities to demonstrate single-photon switching in SiV-color centers in diamond. They use micro-resonators to: perform low-light level nonlinear optics in alkali and noble gases; demonstrate CINT's first generation lithium niobate devices for producing extremely low-threshold nonlinear up-conversion and down-conversion, and acting as single-photon sources. The best-in-class low-loss fiber-to-chip coupling technology at CINT has also attracted a number of new users interested in photonic quantum information processing.

Environmental Scanning Force Microscopy:

Scanning Force Microscopy has the ability to measure forces between a cantilever probe and a surface that provides information regarding the properties of adhesion and binding. CINT researchers have developed a capability in scanning force microscopy based upon an Asylum MFP-3DSA Atomic Force Microscopy platform. This instrument has been equipped with humidity control, temperature control, and an extended piezo with a Z range of 40 μm. Furthermore, the instrument is unique amongst NSRCs since it has all the capabilities of any other in situ AFM, but with the addition of 0% – 100% humidity control and an extended piezo system. This extended piezo system allows for the ability to image or measure forces on non-ideal materials that may have significant roughness, which typically makes them unmeasurable via standard AFM. In addition, in-house colloid probe manufacturing has been developed at CINT, enabling the generation of colloid-cantilever probes of high reproducibility using the lab's cleanroom capabilities. Moreover, these probes have exhibited a substantial increase in force measurement reproducibility over commercial products. Both colloid-probe manufacturing and scanning force microscopy have been applied to a current project directed at measuring adhesion of small particles to real-life substrates (e.g., concrete, wood, vegetation, etc.). Via CINT's AFM design, scientists can replicate environmental variations such as humidity and temperature, and measure non-ideal surfaces (e.g., concrete). Via probe design, it is also possible to generate colloid probes of desired size and functionality, and to have the ability to extend the technology to create probes with attachments of choice (e.g., biological spores). Applications of this technology at CINT over the next three years will focus on the study of membrane interactions and three-dimensional, high-resolution imaging of soft, dynamic materials.

Tunable Deep UV (DUV) Light Source for Low Energy Electron Microscope - Photoemission Electron Microscope (LEEM-PEEM):

CINT has developed a wavelength tunable deep ultraviolet (DUV) light source for photoemission electron microscopy. The tunable DUV light source is based on a pressurized xenon lamp, which produces high-intensity white light in the ultraviolet and DUV spectral ranges. The wavelength tuning is achieved by coupling a compact monochromator to this xenon lamp. One area of application is to spatially resolve and quantify the band alignment across lateral interfaces. Band alignment is an important parameter to evaluate for understanding the interfacial electron transport between dissimilar materials, where offsets of electronic states are commonly found. To accomplish this goal, two measurement modalities were developed based on the valence band photoemission and the threshold photoemission to evaluate the alignments of the valence band as well as the work function. This new setup has been employed in a user project focusing on few-layer transition metal dichalco-

genides to determine the evolution of the electronic states as a function of the layer thickness. It is expected that surface defects might also be detected and imaged in some material systems, in which photoemission yield is high. Thus, this new capability provides unique experimental opportunities to the CINT user community with an emphasis on nanocrystalline semiconductors and semiconductor surfaces.

SECARS Microscope

A Surface-Enhanced Coherent Antistokes Raman Spectroscopy (SECARS) microscope was developed at CINT for vibrational imaging of nanoscale samples deposited on gold nanopyramid substrates by taking advantage of plasmonic field enhancement on a surface. This system functions both as a broadband CARS microspectrometer and an imaging microscope. Excitation pump and Stokes optical beams are derived from a femtosecond laser/amplifier/OPA system and are in the visible range. With this microscope, Anti-Stokes detection is done in epi configuration. The distinctive feature of this system, born out of SERS substrate geometry, is the elevation of local field hot spots above the surface—rather than burying them into the surface as is the case for standard substrates. This feature allows for the study of continuous samples, such as biomolecules, deposited on the substrate to experience strong plasmonic fields.

5.a.4 Future Envisioned Capabilities

Liquid-Mechanical Discovery Platform

In the ongoing effort to expand CINT's suite of available discovery platforms and advance the Center's liquid TEM capabilities, scientists are integrating mechanical control over a nanoscale wire/thin-film specimen into the lab's electrochemical TEM discovery platform. The aim is to develop a first-of-its-kind platform for quantitative mechanical loading within a hermetically sealed liquid environment for high-resolution TEM analysis. This advance will provide enhanced environmental control over a specimen to include quantitative stress control in addition to electrochemical and elevated temperature control. For example, this capability will enable investigation of: nanoscale mechanisms of stress-induced failure of electrodes in battery materials; mechanical characterization of nanoscale bio-composites; and, stress-corrosion-cracking.

CINT is in the final stages of designing the MEMS platform; fabrication in the MESA facility is targeted for mid-2016. The base platform design will be reconfigured from the existing state-of-the-art electrochemical TEM platform, Figure 5.5, with the integration of a TEM compatible uniaxial tensile device that is currently being assimilated for use at CINT. This load controlled tensile testing unit will operate un-obstructed within the imaging gap of ~500 nm for optimal imaging through the liquid enclosure (load and displacement control may be possible in this geometry). Two design and fabrication sequences will be performed, with the first round concentrating on various MEMS actuators (thermal, electrostatic, and piezoelectric) on the base chip, followed by optimization in the second sequence. In addition to platform design, enhanced stage control is under development to manipulate the sample within the TEM discovery platforms. Additionally, holder designs may be produced in replicate to provide the opportunity to lend the stages and platforms to users for conducting experimental research with these unique CINT capabilities at their home institutions. Dissemination of such resources will broaden the impact of CINT's TEM discovery platforms for use anywhere in the world on compatible JEOL and FEI TEMs.

Microfluidics Discovery Platform:

CINT is continuously expanding the capabilities of the microfluidic discovery platform both in the range of chips available as well as in the level of automation and real time interrogation. Significant future plans enhancing current chip materials with items such as glass and several polymers including metal and other multiple material chips for new applications. Computer automation of fluid flows for systemic variation of stoichiometry and reaction time is also under way. In addition, scientists are adding to the real time detection capabilities with plans to attempt to integrate light scattering, magnetic property measurements, and small-angle x-ray scattering (SAXS). These additional capabilities will significantly expand our user base by making experiments more efficient, less-labor intensive, and able to yield important information about a wider range of properties to support the user community.

New Capabilities for Understanding Electron and Phonon Carrier Transport:
Possessing a fundamental understanding of energy carrier transport in nanostructured materials is vital for developing next-generation solid-state electronics, energy conversion, and energy storage devices. Keen knowledge of electron and phonon transport in low-dimensional systems allows CINT researchers to tailor and engineer materials to perform most effectively. Depending on the relative dimension (L_C) of the nanoscale material with respect to the carrier wavelength (l), transport occurs in a boundary-scattering regime ($L_C \sim l$) or in a quantum-limited regime ($L_C << l$). These limits are further determined by temperature and its impacts on phonon coupling, thereby, providing a route to elucidate transport mechanism. To address this issue, CINT will develop a wide-temperature range (10 mK - 330 K) dilution refrigerator. Typical cryogenic systems only permit a narrow range of operation, for example 10 mK - 1 K or 1 K - 300 K. However, our wide-range instrument will fill a technical void and enable the acquisition of transport data from a purely classical regime to a purely quantum-limited regime. Thus, this new instrument will provide a thorough and fundamental understanding of electron and phonon transport. The instrument would also be the first-ever of its wide-temperature range design and exist only at CINT. To benefit users, this tool would be equipped with a magnet, to enable magneto transport studies, and optical access, a feature rarely found in dilution refrigerators. Compared to conventional electrical transport measurements that probe ground and low-energy states, optical probes allow one to directly study high-energy excited states. Optical access in such an instrument would attract potential users interested in high-energy excitations of composite fermions, spin texture of quantum Hall states, dispersion of magneto-plasmons, and excitations of Wigner crystals. Combined with novel CINT techniques for performing high-frequency (microwave) electrical measurements, the dilution refrigerator would also further extend our user base to persons interested in spin qubit research, for quantum computing applications.

Deep Ultraviolet (DUV) Ultrafast Laser Excitation for Photoemission Electron Microscopy:
By extending CINT's recently developed tunable DUV light sources (section 5.a.3), scientists will expand the Center's PEEM capability to utilize an ultrafast DUV laser as a new light source. This system will overcome the significant limitation of PEEM instrumentation that is reliant on near-IR and visible pulsed excitation, for which studies of typically larger bandgap materials require two-photon excitation processes. To overcome this limitation, scientists intend to develop a PEEM coupled to a DUV ultrafast laser with its energy higher than the work function of most semiconductor and metallic materials. By coupling a DUV laser to PEEM, two major imaging schemes will be developed using: polarization control of light to interrogate orbital symmetry and magnetism (via linear and circular dichroic imaging); and, a pump-probe beam line to study ultrafast electron dynamics. The pulsed nature of the DUV laser also will enable pump-probe studies, for example, of spatially inhomogeneous polycrystalline materials to investigate charge carrier lifetimes within crystalline grains and at grain boundaries. Worldwide, PEEM instruments coupled to ultrafast DUV laser are only in the development stage, and there is none provided in any NSRC user facility. Once developed, the DUV-laser PEEM will be a differentiating capability of CINT, and will it complement our other optical and microscopy capabilities.

New Directions in Fluorescence Correlation Spectroscopy:
Scanning and two-focus fluorescence correlation spectroscopy (FCS) capabilities will be added to CINT's suite of FCS tools. In conventional FCS calibration of the lateral dimension and shape (aspect ratio) of the probe volume is obtained by measurement of the autocorrelation function (ACF) of a reference fluorophore with a known diffusion coefficient. However, drawbacks to this approach that limit the precision of conventional FCS for the measurement of diffusion coefficients include sensitivity of the ACF to optical saturation and spherical aberrations. Both scanning and two-focus FCS incorporate an additional length standard into the structure of the FCS probe volume (scan circle diameter, inter-focus distance) that is insensitive to optical saturation and spherical aberration effects. Thereby, it permits precise FCS determination of molecular diffusion coefficients.

We routinely use FCS to make measurements of diffusion coefficients for the determination of hydrodynamic radii of fluorescent moieties (e.g., proteins, metal nanoclusters) of interest to CINT external users. All of these measurements will benefit from increased precision afforded by two-focus and scanning FCS.

Biomolecular Motor Engineering with Unnatural Amino Acids

Prior work by the Bachand group at CINT has established a foundational capability in the design and synthesis of a wide range of biomolecular motors for use in hybrid nanomaterials and systems. In the next funding period, the Center will expand this differentiating capability to include site-specifically introduced unnatural amino acids (UAAs; e.g., p-(propargyloxy)-phenylanlanine) into various motor protein systems (for example, see Figure 5.16). Transformative advances in synthetic biology allow researchers to expand Nature's genetic code through UAAs that display novel, non-biological functional groups into structural and functional proteins. The wide range of biorthogonal chemistries offered by UAAs may be used to alter, modulate, and characterize function. For example, the catalytic activity and efficiency of enzymes may be enhanced by selectively incorporating UAAs into the protein's active site. With respect to characterization, the introduction of UAAs permits the selective placement of functional groups with the unprecedented precision needed for CINT researchers to study structure-function relationships at the single molecule level. Finally, unique chemical moieties may also be used to precisely locate and orient active proteins on synthetic substrates. This new capability will not only further CINT's differentiating capability in biomolecular synthesis but also advance our visualization (single molecule tracking/imaging) efforts.

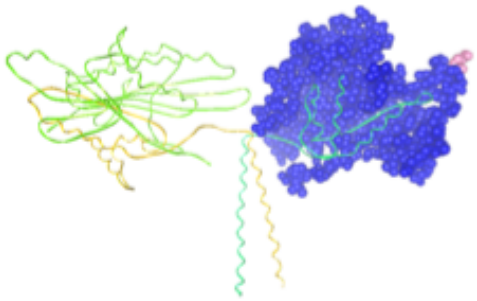


Figure 5.16 Crystal structure of a kinesin motor showing the introduction of an unnatural amino acid (pink) for use in single molecule assays.

Back Focal Plane Imaging

Fourier microscopy (or back focal plane imaging) is emerging as a powerful tool for analysis of quantum emitters, optical nanostructures, and their interactions. Possibilities exist (as examples) for characterizing molecular orientations, emission radiation patterns and directivity of optical antennas. CINT is in the process of expanding our simultaneous color PL imaging capability to also encompass back focal plane imaging and to directly pair this new tool to a spectroscopic capability as well. Initial targets for study will be probing: (1) the strong coupling behaviors between emitters and plasmonic structures; and, (2) the emission pattern control for emitters interacting with new meta- and dielectric structures.

Extension of Resonance Raman Excitation Sources for Spectroscopy and Imaging

CINT dye laser Raman excitation sources will be upgraded to a Matisse 2 system from Spectra-Physics that provides narrow linewidth (4 MHz), actively stabilized, and auto-tuned operation with highest available output powers and reliability. The system will be fully integrated with the Center's wavelength doubling capability to extend our excitation range well into the UV, pushing wavelengths to as short as 270 nm (currently limited to 345 nm) and simultaneously filling wavelength gaps in the visible. The extended UV excitations will enable scientists to probe currently inaccessible electronic transitions and energy ranges, plus expand the set of materials studied. CINT envisions fully coupling these wavelengths to the micro-spectroscopy system as well.

Host-Institution Investments:

Recent LANL host institution investments are enabling the purchase of large-dollar item purchases for strategic reinvestment in CINT spectroscopic and soft-fabrication capabilities. Strategic facilities development is also targeting a new vision for a dedicated soft-fabrication capability for the center. Following are descriptions of these significant new investments:

Scattering-Type Scanning Near-Field Optical Microscopy (neaSNOM)

The NeaSPEC neaSNOM is the only commercially available scattering-type Scanning Near-field Optical Microscope (s-SNOM) on the world-market that is specifically designed and engineered for Atomic Force Microscopy (AFM) based tip-enhanced near-field optical measurements, illustrated in Figure 5.17. The modules

in neaSNOM enable near-field measurements with a 10–20 nm spatial resolution throughout the spectral range from UV/Vis to sub-THz frequencies without introducing additional dispersion—a key feature for time-resolved near-field measurements. There have been a large number of applications identified and addressed with neaSNOM, ranging from nanoscale chemical identification of materials to optical analysis of functional nanostructures and characterization of photonic nanodevices or waveguide structures. It is a capability that was recommended by the CINT Science Advisory Committee. With investment from LANL, CINT will acquire the neaSNOM and establish this unique capability to serve the user community.

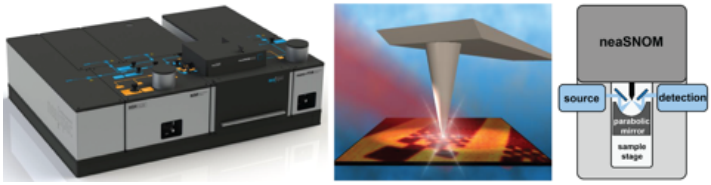


Figure 5.17 Image of the nearSNOM system (left), its AFM tip based optical scattering operation principle (middle), and the optical system within the microscope head.

The neaSNOM microscope is designed to provide unprecedented optical access to the AFM probing tip in order to illuminate the tip by external light sources and detect the tip-scattered light. Different light sources and detection modules can be implemented depending on the research project. The microscope's modular design can be easily reconfigured according to specific needs. This flexibility is particularly important for serving CINT's vibrant user community with a variety of measurement wavelengths and requirements. This capability will be further enhanced by the expertise provided by personnel in the NPON thrust and Laboratory of Ultrafast Materials and Optical Sciences. Thus, this new capability will allow scientists to investigate complex physical behaviors in systems including, but not limited to, strongly correlated materials, plasmonic response and wave propagation in 2D materials (e.g., graphene and quantum wells), nanowires and carbon nanotubes, resonances in metamaterials, and other nanostructured functional photonic devices. Moreover, it will attract and serve serving CINT users in these research fields.

3D Printing Capability

Through LANL institutional investment, CINT is also expanding its capability for soft materials fabrication and integration. The Center is purchasing the Nanoscribe which is acritical piece of equipment and state-of-the-art platform for 2D and 3D printing. The Nanoscribe offers the highest resolution 3D printing on the market. Furthermore, the tool offers two writing modes: 1) ultra-precise 3D structures and 2) a high-speed galvo-mode for rapid layer-by-layer structuring. Through this instrument researchers intend to adapt CINT's large library of nanoparticle colloids and polymers as functional, nanostructured inks that will be patterning into 3D or 2D architectures. The Nanoscribe will serve as a core capability envisioned for a new Soft Fab Lab under development.

Vision for a Soft Fab Lab

CINT is creating a vision for a new Soft Fab Lab whose capabilities will be highly complementary with those for fabrication of hard materials that already existing at the Core Facility. The Soft Fabrication Laboratory at CINT will be a user facility dedicated to the creation of hierarchically structured (multi-length scale) materials that are multi-functional and spatially reconfigurable (dynamic). These capabilities will permit combining bottom-up self-assembly with top-down pattering for the construction of multi-length scale integrated systems. The laboratory will broadly be composed of a clean room, wet chemical hoods, laminar flow hoods, soft lithography capabilities, soft materials processing equipment (post self-assembly processing), and metrology. Presently, a dedicated capability in soft materials fabrication does not exist within the DOE NSRC complex, yet it has been identified in CINT's strategic plan as a future capability that will enable users to fabricate and integrate soft/hard, and nano/microstructures.

The soft materials fabrication laboratory at CINT will leverage noted existing expertise and capabilities in the synthesis and preparation of self-assembled nanostructured soft materials (polymer, hydrogels, lipid constructs). Additionally, it will extend structural ordering beyond nano to the micro- and macro-regimes. Furthermore,

top-down patterning and soft lithography will serve to introduce greater complexity and functionality in CINT's self-assembled nanostructured materials. (Details are provided in the SBCN FWP).

Currently the SBCN thrust has several emerging efforts incorporating soft lithography and patterning that will lay the ground work for CINT's planned efforts. For example, the use of biomacromolecule-mediated patterning of supported lipid bilayers patterned has been demonstrated using microcontact printing (Adams, P.; Swingle, K.; Paxton, W. Nogan, J.; Lamoureux, L.; Firestone, M. A.; Mukundan, H.; Montano, G. "Exploiting lipopolysaccharide-induced deformation of lipid bilayers to modify membrane composition and generate two-dimensional geometric membrane array pattern," *Scientific Reports* (2015), 5, 1–9). This aforementioned effort provides a critical seed for bridging bottom-up self-assembly with top-down patterning to create multi-length scale soft materials that will function as dynamic structured scaffolds for the spatial organization of functional nanocomponents. Capabilities development will focus on two specific areas:

1. Extension of length scale and structural complexity through the integration of self-assembled soft materials within patterned soft materials.
2. Adapting soft "inks" (e.g., colloidal solutions of nanoparticles and polymers) for patterning with a research grade 3D printer, the Nanoscribe.

These efforts will serve to establish a differentiating capability within CINT that will support a growing user community in soft lithography and patterning. As part of our strategic planning efforts, researchers have identified a suite of tools necessary to stand-up a soft materials fabrication and processing capability, including a proposed acquisition process through FY20 (see Table 5.2). CINT has already benefited from a LANL institutional investment in the soft materials fabrication and processing laboratory through commitment of funds to purchase a critical piece of equipment, the Nanoscribe, mentioned above.

Table 5.2. Acquisition strategy for Soft Fab Lab concept through FY20.

Equipment	**Presently In-house**	**FY17**	**FY18**	**FY19**	**FY20**
Fabrication Tools					
DPN6000 (Nanoink) Dip Pen Lithography					
Mask aligner(s)					
Oxygen plasma					
2D Microarray printer (Arrayit-Nanop2)					
MkerWise S60 mini 3D printer					
UV-Nanoimprint Lithography & Mask Aligner					
Metrology Tools					
Probe Station					
Profilometer					
Ellipsometer					
Optical Microscopes					
Contact Angle (First 10 Angstroms)					
Nanotomography (Xradia nanoCT)					
Processing Tools					
Spin Coater(s)					
Silane Vapor Deposition					

PDMS Casting Station					
Spray Coaters					
LB Trough					
Dip-coaters					
Electrophoretic Deposition					
Staffing*					
Technical Staff Member					
Technologist					

*Staffing refers to permanent additions that are presently beyond the scope of our operating budgets. Thus, we are proposing two new hires that would require additional operating funds beginning in FY18.

In summary, these new capabilities (both commercial and CINT developed) have tremendously evolved in the last three years. They will enable an unprecedented level of CINT user research targeted toward revealing the fundamental science of nanomaterials integration. The Center's envisioned capabilities will move these studies toward the strategic directions defined for CINT's future and represent ongoing efforts for continuous revitalization of capabilities.

5.b Challenges and potential problems

The triennial review process provides an important opportunity to reflect on the many accomplishments in developing and expanding CINT's user program, and in advancing its vision for nanoscience integration. It also provides a chance to take stock of the challenges and potential concerns anticipated in the future. Many of the challenges that CINT encounters are endemic to all the NSRCs (e.g., anticipating ES&H impacts, particularly in the uncharted realm of nanomaterial safety). The Center is fortunate indeed to have developed a broad and very active user community. This provides a sound foundation on which to continue building and diversifying. Below four high-priority challenges are identified (where appropriate, mitigation strategies have been or are being implemented):

- Staff Recruitment and Retention: Nanoscience is undeniably one of the most explosive growth areas in all of science. Opportunities that are available for both early career and more senior investigators are vast. These opportunities range from program development in response to new funding solicitations to career advancement options across the spectrum from post-doctoral appointees to senior staff scientists. While this is a very healthy state of affairs for the field of nanoscience, it has some very tangible and in some cases potentially undesirable consequences for CINT and associated organizations. As described below (section 5.d), CINT has had several staff and leadership departures due to career advancement and technical leadership opportunities. On the positive side, when faced with needing to fill staff vacancies, this Center has the advantage of: a broad portfolio of mission-oriented research that attracts highly talented scientists who can collaborate with CINT staff; two host Laboratories which both have international reputations; and, the flexibility to offer employment options at either of the host Laboratories.
- Recruiting Industrial Users: Like the other NSRCs, CINT continues to aggressively recruit users from the industrial sector. To enhance our efforts, CINT created an Industrial Advisor position on the User Executive Committee and appointed Dr. Erika Vreeland of Senior Scientific to this role. Through her leadership and CINT user feedback, it's been recognized that two barriers to greater industrial participation are: (1) speed of access; and, (2) legal terms and conditions required in the NSRC User Agreement. To mitigate the first barrier, the CINT rapid access proposal mechanism offers industry the opportunity to access CINT with a lead-time of only two to three weeks necessary to conduct time-critical research. Indeed, this has been the primary access mechanism for many of our new industrial users. As another strategy for increasing our industrial user numbers, CINT has recently launched a new Industrial Seminar Series. Our first seminar resulted in two proposals, one rapid access and one full proposal. The next speaker will be hosted in June

2016. These strategies are bringing significant success. CINT has had an increase every year in its number of Industrial users. Indeed, from FY10–FY12 to FY13–15 the number increased from 64 to 116, respectively. And, industrial users from FY13–FY15 are 8% of the Center's total user base.

- Facility Recapitalization: The CINT Core and Gateway Facilities were constructed and instrumented in 2005–06. Much of their existing high-value capital equipment (cost >$500K) is reaching its nominal lifetime. Thus, recapitalization is becoming an increasingly urgent issue to ensure the Center is positioned to provide leading world-class capabilities and quality support to our user community. This is most evident in our Integration Laboratory, where many of industry's comparable cleanrooms tools are at least one generation ahead of CINT processing tools. To remain competitive and at the forefront, it must be ensured that CINT has access to the best resources available.
- ES&H for Nanomaterials: Engineered nanomaterials continue to attract an appropriate degree of scrutiny from the standpoint of health and safety. As with all new classes of materials, there is a heightened level of concern from the public about unknown and potentially unforeseen consequences of exposure to nanomaterials. This is so particularly because of nanomaterials' intrinsic size and therefore potential mobility within living organisms. CINT is quite proud of the proactive stance taken by the Center's staff, management and host Laboratories to enact safe work practices and policies regarding nanomaterials. As the worldwide nanoscience community continues to grow and the knowledge base for nanoscale material safety expands, CINT anticipates that areas of uncertainty will diminish and research protocols can be based on broadly accepted data for such materials. Furthermore, this will benefit the standardization of nanomaterials research methods across user institutions and CINT.

5.c Estimate of expected trends in user demand by class of user and by discipline

During the past three years, CINT has seen significant growth in its user program both in the number of proposals submitted and users served. Through expanded outreach efforts to industry and to underserved user communities, as well as through the development of new capabilities and expertise that will attract a new user population segment, the Center hopes to achieve even more growth in the coming three-year period.

While CINT continues to grow as a user facility, it is believed that the user program's mechanics have achieved a level of maturity which serves the facility's user community very well. Specifically, by offering semi-annual Calls for User Proposals (Spring/Fall) in combination with an off-cycle rapid access submission mode, CINT is reliably meeting user needs. The Center's performance metrics for the most recent review period relative to the previous triennial period (2010–2012) support this assertion. Specifically, there has been growth in the number of proposals submitted and substantial growth in the number of users. For example, between 2013 and 2015, 693 user proposals were submitted (a 6% increase over the previous triennial period) of which 571 were accepted. During this same period, CINT sponsored 1425 total users (a 34% increase). This gratifying trend is expected to continue in the next triennial period, fueled by a continuing focus on compelling integration nanoscience. As noted by CINT leadership and associated NSRCs, the strong demand for CINT facilities and services resulting from its highly collaborative business nature may be tempered by capacity limitations that force the rejection of a higher percentage of good quality user proposals. It can be realistically anticipated that the number of proposal submissions will reach a steady state of approximately 250 to300 per year. Yet, the complexity and extent of research proposed in each submission will vary in response to policy guidelines implemented by CINT and driven by BES metrics. For example, instead of a single potential proposal that requested access to multiple CINT capabilities, the submission might be broken into multiple "smaller" proposals if the applicants perceived a higher success rate by doing so. In fact, CINT is already encouraging a more defined scope of work in each proposal so that: (1) it can be accurately assessed; and, (2) the labs' capability loads can be appropriately scheduled. Similarly, the size of a proposed user team could be influenced by the capability availability or success rate of accessing CINT. Therefore, it is important to be mindful that NSRC user proposals can, and do, differ significantly from user proposals that are submitted to obtain a fixed quantity of instrument time at a traditional BES user facility.

Projected user population growth is anticipated to result from sustaining the interest of CINT's current constituency, predominantly academic and internal (SNL or LANL) users, while attracting new users through a variety of mechanisms. First, CINT researchers frequently pursue studies in a highly collaborative mode within and across all thrusts. This research philosophy serves in part to combine an existing nuclei of nanoscience integration researchers with synergistic interests at the facility. These will be increasingly visible areas of signature science for which CINT's strategic planning has identified potential users (see section 5.d). One mechanism for user recruitment and for communicating these strategic collective capabilities is through user workshops and symposia focused on these themes at CINT's annual user conference. A second source of new users is anticipated from currently under-served sectors, such as industry and small business. Like other NSRCs, CINT has not yet fully attracted such participants; although as previously noted, there has been an increase in the Center's industrial user community in the recent three year period. To enhance services to this community, joint NSRC outreach activities targeting this sector host an industrial seminar series and workshops specifically oriented to private-sector technology companies to learn how CINT can be of value to their business objectives, and enable our host Labs' technology transfer divisions to connect with identified market segments. Although previous private sector feedback indicates that some external factors, such as intellectual property agreements and full cost recovery requirements, may be a significant deterrence to collaborating with CINT, alternative avenues for engagement with this sector are being pursued. In addition, CINT will make direct efforts to recruit DOE-sponsored PIs working in nanoscience. While the Office of Science core programs remain the Center's best opportunity in this regard, supporting research efforts in EFRCs, the EERE, and APAR-E programs is an additional way to directly couple CINT user facilities with PI proposed work. Finally, innovative directions for research in CINT's internal science program (in some cases enabled by new hires) will naturally attract new users.

Other anticipated user trends reflect what CINT users' value most about the facility. The Center's four scientific thrusts continue to attract user proposals with comparable levels of demand. Each proposal identifies a lead CINT scientist as well as additional preferred CINT scientists who would work with the user if their proposal was accepted. Such staff selections help in assessing the demand for expertise and capabilities within and across the four science thrusts. Additionally, special attention is given to opportunities in which CINT's experimental and theory/simulation expertise may be incorporated to strengthen a user project; and, this potential will be suggested to prospective users if not already recognized. An important persistent trend is that approximately half of all proposals request to work with more than one CINT lead scientist and/or multiple CINT capabilities. This repeated request demonstrates that the ability to form research teams is strongly valued by the NSRC user community. It is also a distinguishing characteristic of NSRC user facilities, in contrast to conventional user facilities at which proposals are directed to a specific instrument. A natural extension of this teaming would be user proposals that span several NSRCs. The ongoing differentiation among the five NSRCs presents an excellent opportunity for enhanced cooperation as a system of complementary user facilities accessible via a coordinated application process.

The final significant trend is user demand for collaborative and continuing, multi-year relationships with CINT scientists. CINT scientists also recognize the need to accommodate, and often cultivate, research projects that simply cannot be launched, conducted, completed and documented within the typical 18-month duration of an approved user project. Many user projects are highly collaborative with CINT scientists, and therefore involve much more time and effort than merely obtaining data during an on-site visit. In response to this need, CINT continues to entertain Continuation User Proposals in which the current user can request ongoing access to CINT based upon previous accomplishments. Continuation proposals are externally reviewed and scored in competition with new proposals to ensure that no bias is given to current users. Furthermore, the Center is instituting more stringent project reporting that specifically requires documentation of productivity for use in evaluating associated continuation proposals.

Ultimately, the availability of the CINT scientist remains the limiting factor in building strong scientific relationships with facility users. Thus, future staffing plans include additional technologist positions to support efficient

operations, multiplex staff members' time, and prevent the staff burnout — which is a systemic problem at heavily scheduled BES User Facilities.

5.d Strategic vision of scientific growth directions and key staffing decisions that support this vision

5.d.1 Strategic vision of scientific growth directions

Research at CINT is rooted in its focus on integration science, defined as assembling diverse nanoscale materials across multiple length scales to discover, understand, design and achieve new properties and functionality. CINT's vision for scientific growth is inextricably linked to this focus on integration. The scientific challenges of integration demand a spectrum of synthesis, characterization and systems fabrication capabilities that span the sub-nanometer to micron length scales. Nanoscale integration thus extends from the synthesis and fabrication of individual nanoscale building blocks (which may combine different materials into specific heterostructures), to the assembly of these building blocks (for example as nanocomposites or patterned arrays), and finally to the incorporation of these components into complex functional structures and systems.

Connecting with and expanding CINT's user community is central to the implementation of this strategy. The Center will build on its strong, thrust-based foundation that has been established over the years. These thrust activities are the basis of our scientific and user programs. In addition, several larger, high-impact integration challenges, inspired by the nanoscience community and that require cross-thrust collaboration, have been identified. Pursuit of these three representative integration challenges provides a five-year strategic outlook for CINT. It also enables the Center to identify capabilities that the nanoscience research community will need for realization of the smart integration of nanomaterials into innovative and competitive technologies. To meet these challenges, CINT will bring together expertise and capabilities from across all four science thrusts. An underlying theme of all three challenges is a fully integrated feedback loop of synthesis, fabrication, characterization, and modeling. This information will allow the nanoscience community to realize, develop the ability to predict, and a priori design unprecedented materials functionalities and innovative systems. Further details of how specific thrust activities map into the integration opportunities are contained in the thrust FWPs and summarized in Section 5.e.

Science Vision: Challenges in Nanomaterials Integration

5.d.1.a Innovative Nanofabrication, Integration, and "Up-Scaling" Methods to Incorporate Quantum-Size Nanostructures into Arbitrary 2D and 3D Architectures.

Semiconductor nanowires and nanotubes are important building blocks for next-generation energy-harvesting and energy-storage systems, optoelectronics (from single-photon sources to low-threshold lasers), photodetectors, and even sensors for chemical or biological agents. Significant progress has been made in recent years in the precision bottom-up synthesis of single-crystalline, controllably doped, and heterostructured (both radially and axially) nanowires, as well as in the selective preparation of nanotubes with specified structure and chirality. In addition, substantial improvements have been made in top-down techniques in 2D heterostructured thin films to fabricate, grow, and understand nanomaterials with desired electronic and optoelectronic properties. These properties could lead to future innovation for energy-efficient light capture (e.g., solar energy, light/radiation detection) and light emission (e.g., solid state lighting, quantum communication). CINT is already at the frontier of these research areas, and is perfectly poised to address the challenges in:

- Innovation in nanofabrication and integration of the growth of arbitrary, 3D, multifunctional, quantum-size structures.
- Integration and "up-scaling" methodologies for transforming 1D nanowires and nanotubes into 2D and 3D architectures, and ensemble systems designed for advanced functionality.

CINT has state-of-the-art capabilities in molecular beam epitaxy (MBE) growth of high-mobility III-V planar heterostructures. CINT's MBE is in demand by users worldwide to grow high-purity, ultra-high mobility As-based III-V compound semiconductor structures with atomic monolayer precision for fundamental studies of 1D and

2D nanomaterials. CINT has a 9,000 ft2 clean room facility with processing tools that can reach a resolution of tens of nanometers. CINT specializes in the synthesis of semiconductor nanowires by solution-phase and chemical vapor deposition (CVD) approaches to produce single crystal nanowires, radially and axially hetero-structured nanowires, and complex architectures consisting of Si/Ge, III-V and other compound semiconductor materials. Hybrid 3D nanostructures are being fabricated by growing Si and Ge nanowires and their heterostructures on 2D graphene and transition metal dichalcogenides. The capability to modulate the catalyst composition in-situ in the Si-Ge CVD system enables precise control of nanomaterial characteristics. The CINT nanomanipulator is a custom two-probe device located inside a scanning electron microscope. It is used for in-situ quantitative nanostructure electrical characterization as well as the fabrication of single nanowire devices for ex-situ electrical, thermal, and optical property measurements. CINT's Discovery Platform for in-situ TEM measurements of electrochemical processes in single nanowires has enabled many discoveries in this area. For example, silicon nanowire structures are attractive for use in next-generation energy-storage systems for their high-energy density as negative electrodes for Li-ion batteries. The high surface area of the nanowire structures allows for the accommodation of the 300% volume expansion during charging. In scaling up these materials, CINT researchers are investigating the degradation mechanisms of silicon nanowire arrays in comparison to degradation within individual amorphous and single crystalline structures. In addition, researchers are developing design strategies to mitigate the capacity loss that occurs when active materials are disconnected from the current collector. CINT has demonstrated the application of ultrafast wide field optical microscopy for multi-scale characterization, and has routinely used ultrafast pump-probe optical spectroscopies to study the carrier behavior in single nanowires. CINT is leading the theory of rigorous quantum mechanical modeling of electron-phonon coupling in quantum wire systems in nonequilibrium conditions. CINT also has unique theoretical expertise in electrical and thermal transport through metal/superconductor heterostructures that enables a straightforward generalization to semiconductor heterostructures. In addition, CINT developed a nonequilibrium Green's function technique to calculate the dynamics of quantum spins and quantum dots under nonequilibrium conditions. Furthermore, these capabilities are complemented by state-of-the-art density-functional theory (DFT) calculations of semiconductor heterostructures. The DFT has been expanded to calculate the binding of van der Waals materials and the excitonic states in organometallic perovskites for solar cells, as well as the electronic properties of quantum impurities in metallic media..

Toward the future: Traditionally, nanomaterial system fabrication has been carried out in planar structures (Figure 5.18). More recently, however, 3D architectures have started to emerge in micro- and nano-electronics that will ultimately expand their utility to many technologies including consumer electronics, energy, and biomedicine. However, this expansion will require substantial innovation in the nanofabrication, growth, and integration of quantum-size structures.

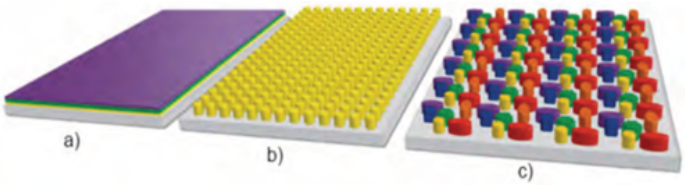


Figure 5.18 (a) Thin films, (b) a homogeneous nanowire array, and (c) an hypothetical device based on heterogeneous nanoscale integration of dissimilar structures.

Combinations of bottom-up and top-down growth and nanofabrication techniques have been used successfully to create "vertical" nanowires (Figure 5.19) in a few material systems such as group IV and certain III-V semiconductors. More complex 3D structures that contain a variety of semiconductors with sections of varying dimensional confinement (1D, 2D, and 3D) are required for new applications such as: low threshold lasers, quantum information and computation, new transistor architectures that go beyond the semiconductor roadmap, and novel optomechanical systems. To realize this vision, hybrid multi-sequential combinations of bottom-up and top-down synthesis techniques must be developed in a variety of combined semiconductor families,

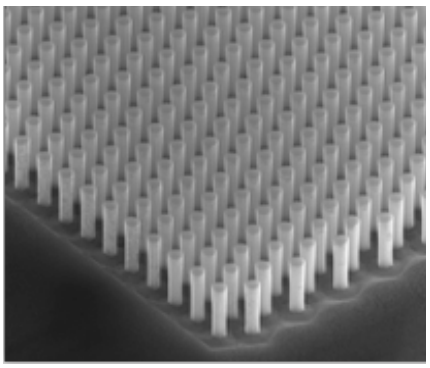


Figure 5.19 Nanowire array.

possibly oxides or diamond. One hypothetical example of an application where heterogeneous integration of dissimilar structures and materials could be used is single-photon sources for quantum information processing. An ideal single-photon-on-demand source could be made from an electrically injected quantum dot. One option for accomplishing this is to fabricate a nanodevice made from different direct bandgap III-V semiconductors emitting at different wavelengths. For further multiplexing and routing, the semiconductors must be placed in specific locations in a 3D arrangement for subsequent coupling to passive waveguides made from group IV semiconductors. Developing architectures such as this will require the integration of different dimensional structures into a larger functional microstructure.

CINT is looking to expand its growth capabilities into other semiconductor families such as large band gap semiconductors (i.e., III-Nitrides, diamond) and low band gap materials (e.g., InGaAs/InP, antimonides), plus expand the MBE effort into high-mobility group IV materials. The integration of different semiconductor materials laterally and vertically will necessitate the development of new hybrid growth techniques with in situ sample handling and characterization in vacuum, all combined with new nanofabrication techniques. In addition to the expansion and combination of epitaxial capabilities, new nanofabrication techniques must be developed to create arbitrary top down nanostructures that go beyond "vertical etching." CINT researchers envision the capability to create quantum wires that lie horizontally in several planes, and with arbitrary control of their diameters and connectivity to other top-down or bottom-up defined sections.

CINT has exceptional capabilities in synthesis and characterization of individual nanowires. Probes have been developed that make it possible to determine electrical, optical, and thermal properties at the level of a single nanowire or nanotube, and even to physically manipulate single wires. However, one of the biggest challenges in nanowire science is how to integrate, up-scale, and organize structures and architectures into ensemble systems that are functionally relevant.

CINT is well positioned to answer this challenge by leveraging its established capabilities including: nanowire and nanotube synthesis and chemical modification; nano-manipulation for direct measurement of nanostructure properties; and, fabrication of single nanowire devices in order to address the fundamental issues of integration. These issues include

- manage the interface effects between individual nanostructures in interconnected networks and composite mesoscale structures;
- bridge the gap between emergent nanoscale functionality and macroscale performance;
- develop geometries that harness the exceptional axial diffusion behaviors of 1D systems; and,
- determine the ion and electron transport behaviors at the junctions of nanostructures.

CINT will expand the Discovery Platforms for thermoelectric and electrical characterization and in-situ TEM measurements of transport and electrochemical processes in single nanowires. Through understanding the core degradation mechanisms that plague nanowire arrays, CINT researchers are developing design rules to implement these structures into bulk electrodes for integration into Li-ion energy-storage systems. The electrochemical TEM Discovery Platform will be redeveloped for enhanced environmental control for novel operando testing to expand the "lab-in-a-gap" capabilities. Additionally, CINT will develop unprecedented capabilities in multi-scale characterization, including integrating wide field observation with nano- and mesoscale resolution in up-scaled three-dimensional architectures.

Meeting the modeling challenge: CINT's ultimate goal in this area is to develop a fundamental understanding of the interfacial interactions between nanoscale components with 2D and 3D confinement (i.e., nanowires and quantum dots) and their host materials, and how these interfacial interactions affect the overall functionality of the hybrid structures, thus leading to optimization and control by design. Toward this end, CINT will pursue the following directives:

- Develop a predictive capability for the relationship between interfacial structure (microstructure and vacancies/defects) and carrier transport across interfaces. This goal will be accomplished through first-principles calculations of structural instability at interfaces and the functionality, including local electronic structure and transport, across the interfaces.
- Develop a new theoretical framework to address transport properties across entire hybrid structures at the ensemble scale. This framework will be based on the first-principles calculations for both individual nanowires/QDs and the interfaces; and, it will help establish the relation between the structure functionality and electronic, optical, and transport properties at the mesoscale.

CINT's current capabilities and expertise in the growth of high-mobility As-based III-V planar heterostructures, the liquid- and solid-phase growth of heterostructured nanowires, the fabrication and characterization of single-nanowire devices, and the theoretical underpinning of nonequilibrium quantum-scale transport enable us to address issues at the foundation of integration—such as bridging the gap between nanoscale functionality and macroscale performance, and determining nanoscale ion, electron, and thermal transport at the junctions of nanostructures. However, to implement such a drive toward full integration will require CINT to add personnel with expertise in the architecture and design of nanostructures into up-scaled devices. Furthermore, to realize a broader set of functional and semiconductor systems, CINT will have to incorporate new growth reactors for high-quality III-V and group IV thin-film materials. Finally, to provide more precise control of heterostructured nanowires, future enhancements to the CVD system would include adding a plasma ignition system to expand the growth rate and changing the heater system for precise control of the growth rate.

5.d.1.b Hybrid Material Interactions for Generation and Manipulation of Light

SStructured hybrid materials can be engineered to have novel photonic properties that emerge only as a result of multi-material interactions. These materials can also include pre-designed properties for novel photon generation and manipulation. CINT is advancing the understanding and application of these revolutionary hybrid systems by addressing the most significant open questions surrounding the control, integration, and enhancement of the response of two classes of materials and their associated assemblies:

- Materials and structures that control and modify electromagnetic energy (plasmonics, metamaterials); and,
- Materials and assemblies that actively generate and harvest electromagnetic energy.

CINT's foundations for leading in this area rest on the Center's multidisciplinary capabilities for generating unique photonic materials and characterizing them with powerful spectroscopic tools, paired with an ability to control compositions and assembly routes to define interaction geometries across multiple length scales and degrees of complexity. CINT is an international leader in developing exceptional photonic materials with switchable and highly tunable photon emission properties. Examples include proprietary non-blinking quantum dots and novel microfluidic control of synthesis for axially heterostructured nanowires. Our doped carbon nanotubes provide new multifunctionality and boosted quantum yields, and highlight CINT's ability to isolate specific tube structures and control their surface chemistries. Together, the facility's emitters provide multi-photon to single-photon behaviors across classical to quantum regimes (Figure 5.20). Pioneering efforts in nanomaterials assembly include soft templating approaches for creation of hybrid functional systems with hierarchical structures that are reconfigurable and

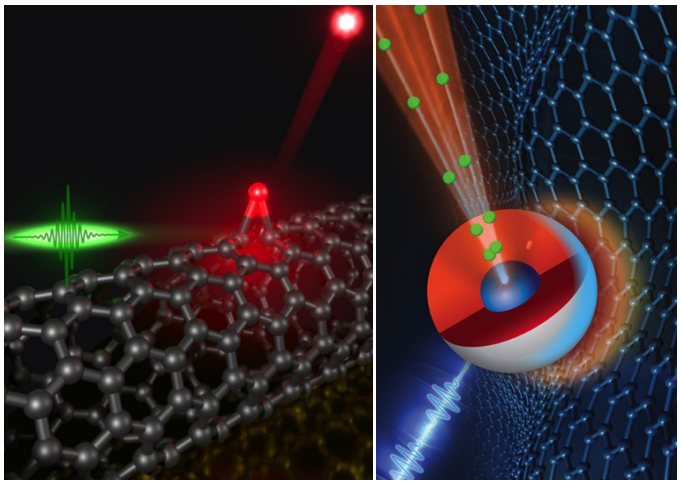


Figure 5.20 Example non-classical photon emitters arising from engineered materials interactions.

responsive. In addition, innovative dip pen nanolithography at the Center is providing unprecedented control over the placement of emitters on photonic, plasmonic, and metamaterials structures which, thereby, allows significant opportunity for the manipulation of light. CINT has been a world leader in the area of metamaterials (THz to near infrared) for nearly a decade; and, it now leads the world in all-dielectric metamaterials as well. CINT's position in this field is enabled by its direct access to nanofabrication and expitaxial growth facilities. Advances in these materials are driven by world-class spectroscopic characterization, including ultrafast tools that provide fs resolution across THz to soft x-ray energies that are unavailable elsewhere. Paired with the broadest continuous excitation range available for Raman spectroscopy (near-IR to UV) and state-of-the art tools for microscopic imaging, spectroscopy, and dynamics measurements of single nanoelements, CINT capabilities for optical characterization of nanomaterials are unmatched. Furthermore, the facility's first-principles DFT simulation capability encompasses nearly all flavors of electronic structure codes for understanding electronic, optical and vibrational properties of complex materials. In particular, LANL-owned nonadiabatic excited-state molecular dynamics capability excels at modeling the largest systems accessible for nonlinear and time-dependent spectroscopy. Theory efforts are further founded in DFT and classical electromagnetic theory simulation for metamaterials modeling and design.

Moving forward, CINT will draw upon these strengths to approach the following opportunities in hybrid photonic materials research:

Generating and actively manipulating novel emitting states and photon correlation statistics: Accessing new emission regimes of expanded wavelengths, enhanced quantum yields, and tunable or selectable photon statistics and dynamics, which requires defining interactions in terms of the relative placement and orientation of materials within the hybrid structure, while also controlling the hybrid composition over multiple dimensionalities. Additionally, CINT will expand the hybrid materials community's ability to generate and actively manipulate novel emitting states and photon correlation statistics by addressing the following challenges:

- Identifying and realizing candidate materials that are likely to generate targeted optical behaviors from hybrid interactions, such as tailoring of plasmonic interactions aimed at enhancing biexciton emission.
- Synthesizing and/or integrating multi-component systems with the appropriate interaction geometries to create a desired functionality, such as harnessing metamaterial interactions with dopant states of emitters for directional emission or enhanced coupling to photonic waveguides.
- Generating desired optical responses in emergent electronic structures by manipulating interactions across multiple length-scales within interfacial environments. Examples include use of soft responsive systems to modulate coupling between embedded optical emitters for on-demand behaviors.

CINT will employ a variety of materials processing techniques, including direct synthesis, self-assembly, nanofabrication, and directed placement to further understanding of these issues. CINT will also move beyond traditional synthetic and processing approaches by tapping soft-materials assembly methods with the potential to harness the responsive and highly tunable nature of bio-inspired systems.

Active, multifunctional plasmonic and metamaterial interactions: Hybrid materials interactions have significant potential for establishing new functionality and enhanced manipulation of the medium in which light is generated, harvested, or propagated. Hybrids enable a move from passive to active plasmonic and metamaterials. Hybrids also form a basis for new concepts including: metamolecules (in which the collective interactions of individual metamaterial elements or atoms create new function); "plasmonics on demand" (where localized materials interactions automatically generate desired resonances in optimized locations); and, tailored and enhanced optical nonlinearities in metamaterials coupled to different materials. Unprecedented multifunctionality will then result, giving simultaneous control of polarization states, beam steering, and focusing; integrating perfect absorption of light directly into optoelectronic architectures; or ultimately integrating hybrid metatmaterials directly with emerging concepts in emitting materials. To realize this extraordinary multifunctionality, CINT will use its integrated efforts in synthesis, characterization, and modeling to address the following challenges:

- Devising nontraditional plasmonic systems (e.g., graphene hybrids or emerging epitaxial oxides) that cannot be accessed with more traditional noble metal approaches.
- Designing multifunctional metamaterial behaviors through metamolecule concepts (shown in Figure 5.21).
- Generating hybrid interactions coupled to metamaterials architectures to provide active/dynamic control and tuning of enhanced metamaterial response and their optical nonlinearities.

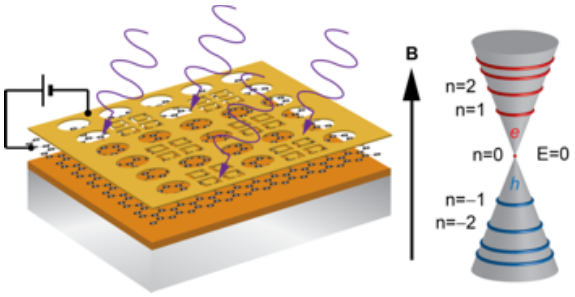


Figure 5.21. Integrated metamolecule-based metamaterials.

Meeting the modeling challenge: CINT's ultimate goal in this area is to create hybrid materials by design. This will entail significant advances in predictive modeling. In particular, the state-of-the-art must be dramatically advanced in areas such as electronic structure, dynamics, environment, and interfacial interactions at length-scales between the molecular and macroscopic. To meet this modeling challenge, CINT will pursue the following opportunities:

- Develop a predictive capability for designing new optical functionality arising from materials interactions such as between plasmons in metallic systems (e.g., metal nanoparticles, Dirac metals) and excitons in semiconductor nanoemitters.
- Understand materials coupling mechanisms and identify the most interesting and promising materials interactions, both in terms of composition and interaction geometries, to pursue as routes to novel optical behaviors.
- Develop new theoretical concepts capable of optimizing electronically active networked structures by accessing the middle-length scales of significance for understanding integrated hybrid behaviors and obtaining targeted optical responses.

CINT's current expertise and capabilities in hybrid materials provide a strong foundation for pursuing the above prospects. Yet, the full range of effort in this area will require CINT to expand its materials generation capability to include new techniques capable of placement of optical nanoparticles with nm precision. Additionally, its strengths in single-nanoparticle spectroscopic characterization could be significantly enhanced by adding capability for single nano-element Raman and magneto-optical spectroscopy while also expanding ultrafast capabilities to include single-photon counting techniques at wavelengths longer than the near-IR. Furthermore, CINT will bring the full strength of our integrated efforts in synthesis, characterization, and modeling to bear on these issues. Model development will work hand-in-hand with experimentation in this rapidly expanding field, to enable the establishment of the most relevant test systems for validation of predictive models. Finally, there is significant new opportunity for developing robust approaches to model exciton-plasmon coupling and pioneering the area of "phononics" (manipulation of phonons and phonon coupling phenomena).

5.d.1.c. Hierarchical Structure & Dynamics in Soft Matter

Scientific opportunity: A grand challenge in nanoscience integration is the ability to propagate the intrinsically unique behaviors of nanoscale materials into functional materials and systems at the macroscale. Nature provides a vast array of blueprints by which this challenge can be achieved in soft materials. For example, cephalopods (e.g., squids) are able to rapidly change their color at the organismal level based on changes in structure (and associated function) across multiple length scales, beginning with the active reorganization of pigment granules at the sub-cellular level. CINT's goal is to develop strategies (principles and soft materials) that will enable the hierarchical assembly of individual nanoconstituents so as to harness their collective or emergent behaviors. It is anticipated that the multiscale and multidimensional assembly of nanoscale building blocks will lead to the next-generation photonic (e.g., solid-state lighting, lasing, color tuning), electronic (i.e., beyond silicon electronics), and energy storage technologies.

Positional science and capabilities: Current CINT capabilities include the synthesis of a wide range of both natural and engineered functional nanoconstituents, structured soft materials that can serve as platforms for the spatial/orientational organization of the individual nanocomponents, and multiscale modeling and visualization tools, all of which serve to position CINT for realizing this scientific opportunity. Specifically, CINT has established expertise in the large-scale production of naturally derived, functional biomolecules including transport nanomotors, (kinesin and dynein motor proteins), light-driven proton pumps (bacteriorhodopsin), light-gated ion transporters (channel rhodopsin), and rotary actuators (F1-ATP synthase). This effort is complimented by unique capabilities in the synthesis of engineered nanoparticles, including fluorescent metal nanoclusters, non-blinking quantum dots, high-explosive detonation nanocarbons, plasmonic nanoparticles, magnetic nanoparticles, and chemically tailored carbon nanotubes and graphene.

In the area of hierarchically structured soft materials for the assembly of nanoconstituents into functional complexes/composites, CINT's capabilities include the development of bio-derived (lipid) matrices, artificial biomembranes, genetically engineered responsive peptides/polymers, wholly synthetic block copolymer constructs (vesicles), structured dual conducting poly(ionic liquids), and stimuli-responsive blends of lipids and polymers.

To understand the interplay between materials properties and assembled structure, high-performance codes and computers with overlap in length and time scales (i.e., atomistic simulations to multi-million atom, fully atomistic simulations) are well-suited for identifying molecular-scale processes in nanoparticle assemblies. Development of coarse-grained models from the underlying atomistic models is expanding the spatial and temporal ranges significantly, while maintaining key chemistry.

Advanced characterization techniques are crucial for understanding the structure and functional dynamics of assemblies/complexes across a broad range of time and length scales. CINT has world-leading capabilities for the visualization of both the spatial distribution of nanoconstituents within complex environments and their dynamics. A three-dimensional single molecule/particle tracking microscope, developed at CINT, images the fine details of complex dynamic systems. For example, the precise step sizes of motor proteins propagating within a biomembrane have been imaged (Figure 5.22). Super resolution fluorescence microscopy provides images of fluorescently labeled samples to a resolution of 10–20 nm (a factor of 10 below the diffraction limit of 250 nm), approaching the resolution of electron microscopy. In concert with these imaging techniques, correlated AFM and fluorescence imaging affords unique capabilities combining single-molecule sensitivity with time-correlated singe-photon counting. These world-class visualization capabilities are augmented with: an environmental scanning force microscope that yields information on the adhesion and binding characteristics of nanocomponents; and, an in-house x-ray scattering (SAXS/WAXS) instrument which provides greater structural details (from 100s of nm to Å).

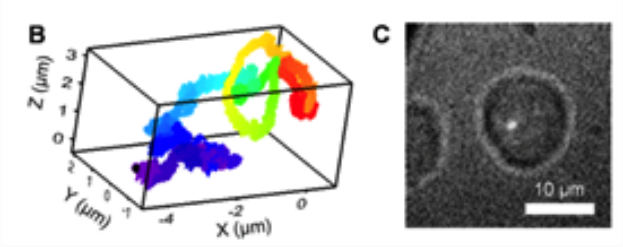


Figure 5.22 (Left panel) 3D trajectory of a single allergy antibody (IgE) labeled with a single gQD on a plasma membrane. (Right panel) White light image of the cell during the trajectory map.

Synthesis and fabrication of soft materials: Drawing on the above-mentioned strengths, CINT will push the state of the nanoscience beyond the synthesis and fabrication of simple homogeneous building blocks (nanoconstituents) and composites and seek to create integrated systems that combine multiple functional components and exhibit emergent properties (Figure 5.23). In addition, the responsive soft matrices will promote dynamic and/or programmable interfaces that drive structural reorganization and associated changes in macroscopically observed composite function. The optimization of CINT's "toolbox" of stimuli-responsive, structured soft materials will then allow for the multi-scale assembly of disparate nano-objects. This will serve

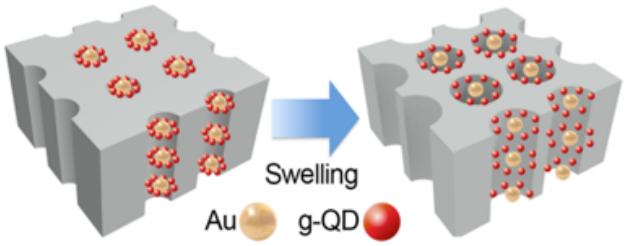


Figure 5.23 Water-induced swelling and contraction of a tetragonally perforated lamellar structured polymer serves to regulate macroscopic optical response of spatially organized plasmonic NPs (Au) and emitters (gQDs).

to fulfill, for example, our vision of hybrid materials for the controlled manipulation of light (reference to 5.d.1.b Hybrid Material Interactions for Generation and Manipulation of Light). Critical to achieving these goals will be the nano- to mesoscale assembly of nanoparticles. Controlling the spatial arrangement of the individual nanocomponents within a responsive matrix will allow for dynamic tuning of their spatial proximity and therefore active regulation of the macroscopic properties of the material. For example, the spatial organization of nanoscale emitters (gQDs/nanocarbons) and plasmonic (metal) nanoparticles doped or in-situ synthesized within a hierarchically structured soft matrix will offer a means for achieving super-radiance, plasmon-assisted lasing, and the dynamic control over photon emission or light interaction ("color tuning")—all component materials that could ultimately be integrated to form next-generation nanophotonic devices. CINT's current collection of structured soft materials, however, will require synthetic modification to possess the following materials attributes:

- Distinct regions for spatial organization of the functional nanoconstituents
- Environmental-responsivity for active reconfiguration of the nanoparticle arrangement and hence composite properties
- Processability for extension of the structure into macroscopic dimensions
- Compliant interfacial chemistry for coupling to traditional device materials (e.g., metals and ceramics)/architectures
- Requisite balance to afford mechanical durability without sacrificing dynamics

Another area requiring significant investment will be infrastructure (instrumentation, tools, clean room space, and expertise) to expand our efforts in top-down patterning/lithography and processing of self-assembled (bottom-up) soft materials. That is, full realization of nanocomposites with complex functionality will require the ability to generate 2-D and 3-D patterned materials that will allow for the integration of nanoconstituents over a full range of length scales (spanning nano to macro), this aspect of CINT's work will require the addition of a Soft Fabrication Laboratory. The facility will contain a suite of 2-D and 3-D patterning tools, including capabilities for micro/nano-contact printing, moulding, inkjet printing, optical lithography, and scanning-probe-based direct-write techniques.

Multimodal characterization: Concurrent with advancing the fabrication of soft materials, substantial improvements in modeling tools applicable for understanding multi-length scale and temporal phenomena will also be pursued, thereby aiding in the a priori design of the materials and analysis of multimodal characterization data. For example, LAMPS codes development at Sandia will be used to improve our image analysis capabilities.

In recent years, considerable progress in optical microscopy has enabled characterization of soft and biological materials with spatial resolution well below optical diffraction limits, and with high temporal resolution. CINT has led the effort in developing imaging and visualization tools for single bio-macromolecule/particle tracking. While these techniques are well suited for evaluating the dynamics of individual nanoscale components, they often lack the ability to capture details of the molecular structure of complex assemblies. A full understanding of complex composite materials requires imaging structure and structural dynamics over a full range of length and time scale. Future efforts within CINT will focus on achieving this goal by improving optical tracking capabilities to achieve single molecule resolution and by combining other characterization tools, such as force microscopy, x-ray scattering and electron microscopy into a single platform. A specific opportunity for advancing

multimodal characterization will be the coupling of x-ray scattering/diffraction which provides atomic resolution with the images and trajectory information provided by 3-D optical tracking. It is anticipated that integration of these techniques onto a single platform will yield structure and structural dynamics over the Angstrom to micron length scale.

5.d.2 Key staffing decisions that support the vision

Staffing needs and hiring are driven to grow CINT's consortium of world-class personnel and support its user program. These actions are, of course, rooted in the need to support existing essential capabilities for integration nanoscience and to develop new capabilities in response to user demand and evolution in nanoscience. In addition, CINT's hiring is necessarily strongly coupled to our instrumentation plans (Section 5a). Support for the Center's post-doctoral program is also an essential ingredient in staffing plans to help achieve the vitality needed to remain competitive. Thus, CINT's strategy falls into three categories; (1) staffing decisions to maintain existing user and science programs; (2) staffing needs to expand user and science programs; and, (3) postdoctoral staffing to promote vitality and serve as a recruiting pool for permanent staffing.

5.d.2.a Staffing decisions to maintain existing user & CINT science programs

CINT has matured to the stage in which the facility is experiencing a steady-state evolution of staffing changes. Over the review period, several CINT staff members have transitioned to new responsibilities and/or left the Center to pursue new career options. Although these transitions naturally lead to loss of expertise, they provide opportunities to bring in new staff that are strategically recruited and selected to achieve scientific and programmatic goals.

CINT Director

In June 2014, CINT Director David Morris accepted advancement within Los Alamos National Laboratory to a position of Division Director for LANL's Chemistry Division. At that point, Neal Shinn moved to the position of CINT Director and an international search was performed for a new CINT co-director. In the interim period, Quanxi Jia (the thrust leader of NEM) took on responsibilities for CINT programs in the acting co-director role, while Kristin Omberg filled in as acting MPA-CINT group leader at LANL for administrative functions. Upon completion of the search, Quanxi Jia was chosen as the new co-director in April 2015. CINT's most recent leadership transition began in January 2016 when Director Neal Shinn announced his retirement from Sandia, effective March 2016. Quanxi Jia was officially appointed as the CINT director February 2016. A new international search is being undertaken to identify a successor, and a search committee is in place. In the interim, Sean Hearne is serving as acting CINT co-director.

CINT Thrust Leaders

The CINT thrust leadership has remained stable over the past review period. The only change was in October 2015 when Igal Brener and Stephen Doorn switched roles within the NPON thrust, with Stephen now being the thrust leader and Igal being the partner science leader.

CINT Scientists

The retirement of Gary Kellog at the CINT Core presented an opportunity for new NEMs staffing. Taisuke Ohta was hired through a competitive international search. He brings research interests and capability in atomic arrangement, electronic structure, and mesoscopic-scale diffusion processes on surfaces. His current activities center on applications of low-energy and photoemission electron microscope (LEEM-PEEM) for problems in materials ranging from semiconductors to 2D crystals.

Due to staffing changes at the CINT Gateway, there is also the opportunity to add new direction to the NEMs team. An internationally competitive search is currently underway, with a broad expertise scope being considered in the areas of thin film synthesis of metallic, semiconducting and ceramic materials, electronic and structural characterization, and measurement of functional and mechanical behaviors.

5.d.2.b Staffing needs to expand user and CINT science programs:
Despite uncertainties introduced by the current fiscal climate, as a part of its strategic planning exercises, CINT includes consideration of new staffing directions for each of the four thrusts that will support overall growth in the Center's user program. As noted previously, the ability to support additional user projects is presently limited to a significant extent by available staff time. The staffing requests identified below arose from CINT's most recent strategic planning efforts and is projected to support user program growth by approximately 30%. These needs are broken out by thrust area below.

Nanophotonics and Optical Nanomaterials:

- CINT scientist (0.5 FTE) specializing in integration of optical nanomaterials and structures
- Technical support (0.5 FTE) for the dip-pen nanolithography system to enable more rapid development of this capability, currently unique to CINT amongst the nanoscience centers
- Technical support (0.5 FTE) for the time-resolved PL system. This system has numerous detection modalities requiring extensive training; therefore, every new user requires several days of training to become proficient in its use.
- Additional thrust allocation for postdoctoral support to broaden research across the thrust

Nanoscale Electronics and Mechanics:

- CINT scientist (0.5 FTE) focusing on thin film synthesis and property measurement
- Technical support (2 FTE) to optimize the instrumentation within the Integration Lab for user studies
- Additional thrust allocation for postdoctoral support to broaden research across the thrust

Soft, Biological and Composite Nanomaterials:

- CINT Scientist (0.5 FTE) with an expertise that can help thrust collectively achieve further integration from the microscale to the macroscale
- Technical support (1 FTE) for recent acquisition of new instrumentation with primary responsibility for maintaining instrumentation and training/helping users on the facility's wide variety of instrumentation
- Additional thrust allocation for postdoctoral support to broaden research across the thrust

Theory and Simulation of Nanomaterials:

- Additional thrust allocation for postdoctoral support to broaden research across the thrust

5.d.2.c Summary of Staffing Strategy:
Through efforts to streamline management structure and fill vacancies within staff ranks in a timely manner, CINT has endeavored to optimize existing resources to maintain its forefront integration nanoscience program. Within the coming year, it is anticipated that all existing vacancies in CINT leadership and scientist ranks will be filled. Should sufficient funding levels become available, the Center's longer-term hiring strategy delineated previously includes the addition of 3 FTE for CINT scientist new hires, 5 FTE for additional technical support, and could support CINT's ability to increase the user program to potentially 650 users per year.

In conclusion, it is vital to recognize the indispensable contributions that CINT-funded postdoctoral researchers make toward the Center's science efforts, capability development, and user interactions. CINT postdoctoral support is an essential part of establishing significant new science directions that keep research efforts relevant and at the forefront of a broad range of nanoscience pursuits. Being on the vanguard of nanoscience forms the foundation for CINT's new and continuing users' interest in working with the facility. Pursuit of these new science directions frequently entails development of novel experimental capability and theory methodology that also becomes an attractive draw to the user base. Interactions with users are quite frequently in a highly

collaborative mode, which opens valuable opportunities for postdocs to interact with researchers beyond CINT staff. Thus, every contribution by a postdoctoral associate is highly intertwined with pursuing the Center's thrust objectives. Moreover, the postdoctoral support plays a critical enabling role in the success of the CINT 50% model for leveraging institutional and other support, which is fundamental to the ability of CINT scientists to effectively develop new research directions. Thus, CINT-funded postdocs provide irreplaceable contributions to CINT science, capability development, and user interactions. In turn, the postdocs receive significant benefit from a productive and enriching scientific experience, yielding high-impact publications and providing ties to many colleagues both within and outside CINT. With these considerations in mind, continued support of the postdoctoral program is needed. The current level of BES-funding allocated to postdoctoral research associates and the program's impacts will be objectively evaluated. Additionally, the number of postdocs funded by CINT will be balanced with the number of internal postdoctoral fellowships from host institutions.

5.e Strategic plan of the facility for the next five years

While the promise of nanoscience as captured in the 2000 National Nanotechnology Initiative, which gave rise to the NSRC program in DOE, continues unabated, new frontiers in science that derive in part from this investment continue to emerge. Challenges at the frontiers of matter and energy and mesoscale science, as defined in the recent BESAC reports ("Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery," November 2015, and "From Quanta to the Continuum: Opportunities for Mesoscale Science," September 2012), represent the most exciting new opportunities. CINT's fundamental scientific expertise and user facility resources can contribute tremendously to these new areas. As clearly indicated by the BESAC reports, the Center's research community needs to fully exploit a suite of user facilities to maintain its world leadership in nanoscience. In short, it is anticipated that nanoscience integration could spark revolutionary changes in technologies, and CINT is particularly well-positioned to make immediate and impactful contributions to the fields outlined in BESAC reports. Furthermore, internal strategic planning has identified integration scientists as the highest priority hires for each of the facility's three experimental thrusts. Such strategic hires by CINT will ensure that its science is optimally aligned to objectives of BES.

By creating a collaborative community of diverse users matched with CINT's expert scientists and advanced capabilities, the Center fosters high-impact nanoscience discoveries, leads next-generation technique development, and advances the frontiers of knowledge beyond that achievable by individual researchers or any single institution. As the next review period begins, CINT is taking to heart guidance from DOE and the BESAC that will further enable world-leading science and capabilities. CINT will also emphasize outreach efforts to the industrial user community to: accelerate nanotechnology research, market its efforts as captured in the recent BESAC report "Science for Energy Technology: Strengthening the Link between Basic Research and Industry," and promote core research programs sponsored by the DOE Office of Science. These industrial outreacha efforts as described in Section 1.d.3 include focused sessions at CINT's annual user conferences, special seminars from industries, as well as more targeted interactions with the host laboratories' technology transfer divisions and local technology incubators. Such efforts have resulted in an increase in the number of industrial users for this review period. For example, there has been an increase every year in the number of industrial users hosted by CINT— almost double the amount of industrial users from FY10–FY12 (64) to FY13–15 (116). And, industrial users for FY13–FY15 were 8% of the total user base. Yet, there is still room for growth in this user category. It should be noted that CINT support for Office of Science core program research is perhaps best reflected in its engagement with Energy Frontier Research Centers (EFRCs), Single-Investigator and Small-Group Research (SISGR) Initiatives, and the Early Career Research Program. Furthermore, CINT plays an important role in supporting other DOE programs from Office of Energy Efficiency & Renewable Energy (EERE) and Advanced Research Projects Agency-Energy (APAR-E). The Center will continue to target Office of Science core program research through direct interactions with PIs, including outreach to new awardees across multidisciplinary fields.

Building on current strengths, CINT's vision also includes further growth as a nanoscience user facility. In particular, enormous opportunities are available to fully develop the concept of CINT as a center of innovation

that brings together communities of researchers and broadly promotes industry/academia/federal research facility collaborations and collaborative networks. Within the context of centers of innovation, it is critically important that CINT plays an expanded role in integrating the Center's user communities with its co-located user facility and the leveraged capabilities available at both host institutions. In particular, CINT's co-located user facility (the NSF-funded Pulsed Field Facility of the National High Magnetic Field Lab) and leveraged capabilities (including the Microsystems Engineering and Science Applications [MESA] Complex at SNL, Ion Beam Materials Laboratory at LANL, In-situ Ion Irradiation Transmission Electron Microscopy [I3TEM] Facility at SNL, and Laboratory of Ultrafast Materials and Optical Science at LANL) present enormous opportunities to advance more collaborative user interactions. Lastly, there are significant opportunities for CINT to contribute to the success of SC-sponsored research across the entire spectrum of its projects; note the Center is already providing support to SC and other DOE-related programs as discussed above.

The real engine of strategic growth within the Center over the next five years will, of course, continue to be thrust-based science and an ongoing focus on and exploration of its differentiating strengths deriving from the overall focus on integration nanoscience. All four thrusts are proactively immersed in an assessment of their specific strengths and the directions of their scientific areas at the international level. These assessments have led to a set of targeted research areas for each thrust for the future that will ensure that CINT maintains its leadership role in integration nanoscience and provides its user community with the capabilities and expertise necessary to compete in nanoscience and beyond. These research directions are also optimally aligned with our representative center-wide strategic directions such as: (1) innovative nanofabrication, integration, and "up-scaling" methods to incorporate quantum-size nanostructures into arbitrary 2D and 3D architectures; (2) hybrid material interactions for generation and manipulation of light; and (3) hierarchical structure and dynamics in soft matter (see details from http://cint.lanl.gov/_docs/CINT2020-2016.pdf). A brief list of CINT's targeted research areas by thrust is outlined here. Detailed description of the frontiers can be found from FWPs for the individual thrust.

Soft Biological & Composite Nanomaterials (SBCN)

- Multi-length scale fluidics for optimized synthesis of nanoparticles
- Soft nanostructures as functional nanoconstituent integration platforms
  - Network polymers- hetero-nanoconstituent composites
  - Protein-based polymersomes/block-copolymers composites
  - Genetically encoded optical polymers
- Active, motor-driven assembly of multidimensional materials
- Visualization of soft materials
  - Spatio-temporal imaging on the nanoscale
  - A nanoscale view of complex biological processes

Nanophotonics and Optical Nanomaterials (NPON)

- Synthesis, processing, and manipulation of low-dimensional nanostructures
  - Alloyed nanoparticles and 2-D layered materials for energy conversion and storage
  - Synthesis-structure-function correlations: rapid evolution of new complex functional optical nanomaterials
  - Surface chemistry, functionalization, and synthesis of carbon nanomaterials
- Optical Spectroscopy of low-dimensional nanostructures
  - Development of novel spectroscopic capabilities
  - Fundamental photophysics of low-D optical materials

  - Defect states in 1-D and 2-D systems as building blocks for quantum information technologies
- Integrated quantum photonic and optomechanical circuits
- Emergent functionality of mesoscopic assemblies
- Hybrid metamaterials and metasurfaces for advanced functionality and optical nonlinearities
- Ultrafast spectroscopic studies

Nanoscale Electronics and Mechanics (NEM)

- Advanced capabilities
  - Liquid-mechanical discovery platform and TEM
  - Molecular beam epitaxy of high-mobility III-V structures
  - LEEM/PEEM development
  - New capabilities for understanding electron and phonon carrier transport
- Single spin devices
  - Nanoelectronics for quantum information
  - Limits of fabrication
  - Integrated cryo-devices for measurements
- In-situ mechanical characterization of nanostructured materials
- Controlled functionalities in nanocomposite films
- Nanowires for new energy concepts

Theory and Simulation of Nanoscale Phenomena (TSNP)

- Hierarchical structure and dynamics in soft matter
  - Nanoparticle structure and assembly
  - Structure of the nanoscale
- Excitation and transport in nanostructured systems
  - Energy harvesting, non-adiabatic excitation and quasiparticle dynamics
  - Understanding tunneling and transport experiments
- Emergent Phenomena at Surfaces and Interfaces
  - Emergent properties in strongly correlated heterostructures
  - Semiconducting compound surface and interface structure
- Model and methods development

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: The Center for Integrated Nanotechnologies (CINT)

Fiscal Year: 2013 Date submitted: 18-Oct-13

SUMMARY DATA

Facility USERS this Fiscal Year (*Researchers who submitted a successful proposal—see definitions*)

Question Number — Add an asterisk (*) in this column next to any question that has additional information appended.

				Remote Access		Off-Site
1		356	Number of Badged Users			
2		91	Number of Other Users; Itemize:	0	plus	91

- **First-Time Users** (subset of Q. 1-2) — NSRCs only

				Remote Access		Off-Site
3		189	Number of Badged Users			
4		26	Number of Other Users; Itemize:	0	plus	26

- **Researchers Associated with Experiments** (i.e., Facility Users, Q. 1-2, plus their co-proposers)

5		535	Number of Badged Users and Co-Proposers
6		185	Number of Other Users and Co-Proposers

Obtain Specialty Services or Materials; Itemize (no research proposal; e.g., purchases)

7		0	Enter appropriate categories for your facility here
		Sum of Entries →	*For example…*
			Institutions that Utilize the Transplutonium Program
			Institutions that Obtain Medical Isotopes

Facility Configuration

8		N/A	Number of Beam Lines (*or analogue*) Available to Users
9		N/A	Number of Additional Beam Lines Possible.
10	*		Provide Facility Schematic Diagram(s) to Explain Above Configurations

Facility Hours of Operation for Users (365 days = 8,760 hours)

11		N/A	Maximum Number of Hours for Users (under optimal budget) (excludes machine research, operator training, accelerator physics, etc.)
12		N/A	Scheduled Hours of Operation for Users
13		N/A	Scheduled Hours Delivered to Users (may not exceed Q 12)
14		N/A	Unscheduled Hours Delivered to Users
15	*	N/A	*Next Fiscal Year* - Planned Hours for Users (attach schedule)

Beam Line Hours of Operation for Users (from Q. 35)

16		N/A	Beam Line Hours Scheduled
17		N/A	Beam Line Hours Delivered
18		N/A	Beam Line Hours Used

Number of Scientific Publications

19		220	*Estimate* of Facility Publications for this Fiscal Year
20		217	*Final* Facility Publications for *Previous Calendar Year*

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**
Fiscal Year: **2013**

User Demographics

	447	Number of Users (sum Q. 1 plus Q. 2)

Question Number

Gender

21		Female
		Male
0	447	Information Not Available

Race/Ethnicity

22		American Indians or Alaskan Natives
		Asians/Pacific Islanders
		Black, non-Hispanics
		Hispanics
		White, non-Hispanics
0	447	Information Not Available

Age

23		Under 20 years
		20-29 years
		30-39 years
		40-49 years
		50-59 years
		60-69 years
		Over 69 years
0	447	Information Not Available

Citizenship

24	282	U.S. Citizen
	76	Foreign National, non-Sensitive Countries
	89	Foreign National, Sensitive Countries
0	0	Terrorist-Sponsoring Nations (U.S. State Department's list)

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2013**

User Affiliations

447 Number of Users (sum Q. 1 and 2 or itemize them separately)

Question Number

Employer (User's Research Institution)

Question Number					
25	210	U.S.	Academic		
	0		Host DOE laboratory -- associated with host user facility		
	154		Host DOE laboratory -- not associated with facility		
	3		Other DOE laboratories		
	6		Non-DOE federally funded institution		
	40		Industry		
	0		Other	413	Subtotal U.S.
	30	Foreign	Academic		
	1		National laboratory		
	3		Industry		
0			Other	34	Subtotal Foreign

Employment Level

26	2	Undergraduate student
	80	Graduate student
	92	Postdoctoral research associate
	270	Faculty member / professional staff / research scientist
	3	Retired or self employed
0	0	Other

Type of User

27	447	General User only
	0	Partner User only
0	0	Both a General User and a Partner User

Proprietary Research

28	447	Users conducting only nonproprietary research
	0	Users conducting nonproprietary and proprietary research
0	0	Users conducting only proprietary research

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2013**

Geographic Distribution of U.S. User Institutions

413 Subtotal U.S. (from subtotal within Question 25)

Question Number

U.S. State of User's Research Institution (Must sum to "Subtotal U.S." for Question 25)

29

1	Alabama	2	Nevada
0	Alaska	0	New Hampshire
3	Arizona	0	New Jersey
0	Arkansas	264	New Mexico
22	California	6	New York
13	Colorado	2	North Carolina
4	Connecticut	1	North Dakota
0	Delaware	3	Ohio
2	Florida	2	Oklahoma
3	Georgia	0	Oregon
0	Hawaii	18	Pennsylvania
0	Idaho	2	Rhode Island
4	Illinois	2	South Carolina
3	Indiana	1	South Dakota
2	Iowa	4	Tennessee
0	Kansas	17	Texas
0	Kentucky	1	Utah
0	Louisiana	0	Vermont
0	Maine	3	Virginia
7	Maryland	2	Washington
4	Massachusetts	1	West Virginia
5	Michigan	0	Wisconsin
5	Minnesota	0	Wyoming
0	Mississippi		
2	Missouri	0	District of Columbia
0	Montana	0	Puerto Rico
2	Nebraska	0	Other (itemize below)

0

Itemize other U.S. territories here.

If any → *For example…*

Guam

U.S. Virgin Islands

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**
Fiscal Year: **2013**

Information Derived from Experiment Demographics

	447	Number of Users from Q. 1-8

Question Number

Source of Support (number of users)

30	68	DOE, Office of Basic Energy Sciences
	0	DOE, Office of Biological and Environmental Research
	1	NNSA
	115	DOE, other (includes LDRD)
	1	Homeland Security
	14	DOD
	88	NSF
	29	NIH
	3	NASA
	0	USDA
	23	Other U.S. Government
	22	Industry
	23	Foreign
0	60	Other

Subject of Experiment or Service (number of users)

31	261	Materials sciences
	19	Physics (excludes condensed matter physics)
	15	Chemistry (excludes materials chemistry)
	10	Polymers
	22	Medical applications
	23	Biological and life sciences (excludes medical applications)
	1	Earth sciences
	0	Environmental sciences
	40	Optics
	29	Engineering
	10	User facility instrumentation or technique development
	0	Purchase of specialty services or materials
0	17	Other

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2013**

Budget Data

Question Number

Annual Budget ($ in thousands)

32	950	Utilities
	1,250	Maintenance / operations of sources
	410	ES&H
	120	Security
	1,440	Operators/Technicians
	7,200	R&D
	7,400	User support
	1,780	Facility administration
	0	Other (itemize)
	20,550	Total Annual Operating Budget (sum of above)
	0	Capital Equipment
	0	AIP
	0	GPP/GPE
	20,550	**Total Annual Budget** (sum of Operating, CE, AIP and GPP/GPE)

Sources of Funding for Annual Budget ($ in thousands)

33	20,550	DOE, BES - Division of Scientific User Facilities		
		Division of Materials Sciences and Engineering		
		Division of Chemical Sciences, Geosciences, and Biosciences		
	0	DOE (other)		Itemize other DOE sources here
	Sum of Entries →			
	0	Other		Itemize other non-DOE sources here
	Sum of Entries →			
0	20,550	**Total Annual Budget** (same value as for Question 31)		

Facility Replacement Cost ($ in thousands)

			YEAR
34	75,000	Original cost of facility (then-year dollars) →	2,005
	149,000	Replacement cost of original facility (this-year dollars)	

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2013**

USER SATISFACTION Mini-Survey

Question Number		
37	447	Number of Users (sum Q. 1 plus Q. 2)
	207	Number of Users who filled out a Mini-Survey

Please circle only one number for Questions 1-4 or mark NA if the question does not apply.

1 **How satisfied were you with the fraction of the year that the facility operates?**

100% =	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable	
	158	26	4	1	0	18	207

2 **How satisfied were you with the schedule or service (i.e., was the time or service delivered on schedule and was downtime kept to a minimum)?**

100% =	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable	
	135	37	8	3	2	22	207

3 **How satisfied were you with the performance (i.e., was beam or service maintained close to specifications)?**

100% =	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable	
	134	37	5	2	0	29	207

4a. **How satisfied were you with the support for users provided by the facility staff?**

100% =	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable	
	168	17	6	1	0	15	207

4b. **How satisfied were you with the support for users provided by the beam line staff?**

100% =	5 *Very Satisfied*	4 *Satisfied*	3 *Neither Satisfied Nor Dissatisfied*	2 *Dissatisfied*	1 *Very Dissatisfied*	NA Not Applicable	
	168	16	8	2	0	13	207

5 **Please provide comments for any score rating of 1 or 2 on Questions 1-4 above.**

***** Summarize responses succinctly on another sheet.

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: The Center for Integrated Nanotechnologies (CINT)

Fiscal Year: 2013

USER SATISFACTION Mini-Survey (continued)

Question Number

37 (*continued*)

			#
6	**What was the subject of your use of this facility this year? (circle the subject that best applies)**		
	a.	Basic research	147
	b.	Applied research	33
	c.	Developed a new or improved product, process or technology	16
7	**How do you intend on communicating the knowledge gained at this facility? (circle all answers that apply)**		
	a.	Publish in peer-reviewed open literature	178
	b.	Present findings at professional society meeting	142
	c.	Acquired a patent	19
	d.	Other	10
8	**What additional benefits did you gained at this facility? (circle all answers that apply)**		
	a.	Furthered the goals of the Department of Energy	90
	b.	Obtained access to unique capabilities not available elsewhere (e.g., forefront experiments; one-of-a-kind instruments; distinctive materials or services)	153
	c.	experiments, increased multidisciplinary work; enabled a new approach within your discipline)	146
	d.	Trained students (undergraduate, graduate or postdoctoral associate)	57
*	**e.**	Other benefit(s); please specify:	7

9 **Are the training and safety procedures appropriate? If not, how would you change them?**

* Summarize responses succinctly on another sheet.

10 **What would you like this facility to do differently?**

* Summarize responses succinctly on another sheet.

11 **Other comments.**

* Summarize responses succinctly on another sheet.

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: The Center for Integrated Nanotechnologies (CINT)
Fiscal Year: 2014 Date submitted: 17-Oct-14

SUMMARY DATA

Facility USERS this Fiscal Year (*Researchers who submitted a successful proposal—see definitions*)

Question Number — Add an asterisk (*) in this column next to any question that has additional information appended.

			Remote Access	Off-Site	Mail-in
1		373 Number of On-site Users			
2		92 Number of Remote Users	Breakouts: 3	89	0

NSRCs only — Light/Neutron only

- **First-Time Users** (subset of Q. 1-2)

			Remote Access	Off-Site	Mail-in
3		160 Number of On-site Users			
4		29 Number of Remote Users	Breakouts: 0	29	0

- **Researchers Associated with Experiments** (i.e., Facility Users, Q. 1-2, plus their co-proposers)

5		491 Number of On-site Users and Co-Proposers
6		190 Number of Remote Users and Co-Proposers

Obtain Specialty Services or Materials; Itemize (no research proposal; e.g., purchases)

7		0	Enter appropriate categories for your facility here
		Sum of Entries →	*For example…*
			Institutions that Utilize the Transplutonium Program
			Institutions that Obtain Medical Isotopes

Facility Configuration

8		N/A	Number of Beam Lines (*or analogue*) Available to Users
9		N/A	Number of Additional Beam Lines Possible.
10	*		Provide Facility Schematic Diagram(s) to Explain Above Configurations

Facility Hours of Operation for Users (365 days = 8,760 hours)

11		N/A	Maximum Number of Hours for Users (under optimal budget) (excludes machine research, operator training, accelerator physics, etc.)
12		N/A	Scheduled Hours of Operation for Users
13		N/A	Scheduled Hours Delivered to Users (may not exceed Q 12)
14		N/A	Unscheduled Hours Delivered to Users
15	*	N/A	*Next Fiscal Year* - Planned Hours for Users (attach schedule)

Beam Line Hours of Operation for Users (from Q. 35)

16	N/A	Beam Line Hours Scheduled
17	N/A	Beam Line Hours Delivered
18	N/A	Beam Line Hours Used

Number of Scientific Publications

19	215	*Estimate* of Facility Publications for this Fiscal Year
20	206	*Final* Facility Publications for *Previous Calendar Year*
20 (a)	71	*Final* High Impact Publications for *Previous Calendar Year*

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

User Demographics

	465	Number of Users (sum Q. 1 plus Q. 2)

Question Number

Gender

21		Female
		Male
0	465	Information Not Available

Race/Ethnicity

22		American Indians or Alaskan Natives
		Asians/Pacific Islanders
		Black, non-Hispanics
		Hispanics
		White, non-Hispanics
0	465	Information Not Available

Age

23		Under 20 years
		20-29 years
		30-39 years
		40-49 years
		50-59 years
		60-69 years
		Over 69 years
0	465	Information Not Available

Citizenship

24	309	U.S. Citizen
	71	Foreign National, non-Sensitive Countries
	85	Foreign National, Sensitive Countries
0	0	Terrorist-Sponsoring Nations (U.S. State Department's list)

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

User Affiliations

465 Number of Users (sum Q. 1 and 2 or itemize them separately)

Question Number

Employer (User's Research Institution)

Question Number					
25	176	U.S.	Academic		
	0		Host DOE laboratory -- associated with host user facility		
	202		Host DOE laboratory -- not associated with facility		
	3		Other DOE laboratories		
	7		Non-DOE federally funded institution		
	37		Industry		
	0		Other	425	Subtotal U.S.
	39	Foreign	Academic		
	0		National laboratory		
	0		Industry		
0	1		Other	40	Subtotal Foreign

Employment Level

26	0	Undergraduate student
	82	Graduate student
	69	Postdoctoral research associate
	309	Faculty member / professional staff / research scientist
	5	Retired or self employed
0	0	Other

Type of User

27	465	General User only
	0	Partner User only
0	0	Both a General User and a Partner User

Proprietary Research

28	465	Users conducting only nonproprietary research
	0	Users conducting nonproprietary and proprietary research
0	0	Users conducting only proprietary research

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

Geographic Distribution of U.S. User Institutions

425 Subtotal U.S. (from subtotal within Question 25)

Question Number

U.S. State of User's Research Institution (Must sum to "Subtotal U.S." for Question 25)

29

1	Alabama	2	Nevada
0	Alaska	0	New Hampshire
2	Arizona	3	New Jersey
0	Arkansas	299	New Mexico
15	California	7	New York
7	Colorado	3	North Carolina
5	Connecticut	2	North Dakota
0	Delaware	2	Ohio
4	Florida	1	Oklahoma
4	Georgia	0	Oregon
0	Hawaii	9	Pennsylvania
0	Idaho	1	Rhode Island
4	Illinois	5	South Carolina
3	Indiana	0	South Dakota
0	Iowa	2	Tennessee
0	Kansas	19	Texas
2	Kentucky	2	Utah
0	Louisiana	0	Vermont
0	Maine	2	Virginia
3	Maryland	2	Washington
4	Massachusetts	0	West Virginia
5	Michigan	1	Wisconsin
2	Minnesota	0	Wyoming
0	Mississippi		
2	Missouri	0	District of Columbia
0	Montana	0	Puerto Rico
0	Nebraska	0	Other (itemize below)

0

Itemize other U.S. territories here.

If any → *For example…*

Guam

U.S. Virgin Islands

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

Information Derived from Experiment Demographics

	465	Number of Users from Q. 1-8

Question Number

Source of Support (number of users)

30	72	DOE, Office of Basic Energy Sciences
	0	DOE, Office of Biological and Environmental Research
	2	NNSA
	142	DOE, other (includes LDRD)
	0	Homeland Security
	25	DOD
	61	NSF
	31	NIH
	5	NASA
	0	USDA
	29	Other U.S. Government
	16	Industry
	29	Foreign
0	53	Other

Subject of Experiment or Service (number of users)

31	310	Materials sciences
	26	Physics (excludes condensed matter physics)
	9	Chemistry (excludes materials chemistry)
	9	Polymers
	0	Medical applications
	24	Biological and life sciences (excludes medical applications)
	2	Earth sciences
	0	Environmental sciences
	47	Optics
	24	Engineering
	7	User facility instrumentation or technique development
	0	Purchase of specialty services or materials
0	7	Other

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

Budget Data

Question Number

Annual Budget ($ in thousands)

32	900	Utilities
	1,200	Maintenance / operations of sources
	450	ES&H
	150	Security
	1,400	Operators/Technicians
	7,030	R&D
	7,800	User support
	1,750	Facility administration
		Other (itemize)
	20,680	Total Annual Operating Budget (sum of above)
		Capital Equipment
		AIP
		GPP/GPE
	20,680	**Total Annual Budget** (sum of Operating, CE, AIP and GPP/GPE)

Sources of Funding for Annual Budget ($ in thousands)

33	20,680	DOE, BES - Division of Scientific User Facilities		
		Division of Materials Sciences and Engineering		
		Division of Chemical Sciences, Geosciences, and Biosciences		
	0	DOE (other)		Itemize other DOE sources here
	Sum of Entries →			
	0	Other		Itemize other non-DOE sources here
	Sum of Entries →			
0	20,680	**Total Annual Budget** (same value as for Question 32)		

Facility Replacement Cost ($ in thousands)

			YEAR
34	75,000	Original cost of facility (then-year dollars) →	2005
	155,000	Replacement cost of original facility (this-year dollars)	

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

USER SATISFACTION Mini-Survey

Question Number		
37	465	Number of Users (sum Q. 1 plus Q. 2)
	243	Number of Users who filled out a Mini-Survey

Please circle only one number for Questions 1-4 or mark NA if the question does not apply.

1 **How satisfied were you with the fraction of the year that the facility operates?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	186	37	8	0	0	11	242

2 **How satisfied were you with the schedule or service (i.e., was the time or service delivered on schedule and was downtime kept to a minimum)?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	171	50	9	2	0	11	243

3 **How satisfied were you with the performance (i.e., was beam or service maintained close to specifications)?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	160	50	7	4	0	18	239

4a. **How satisfied were you with the support for users provided by the facility staff?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	190	27	7	0	0	14	238

4b. **How satisfied were you with the support for users provided by the beam line staff?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	201	26	5	2	0	7	241

5 **Please provide comments for any score rating of 1 or 2 on Questions 1-4 above.**

* Summarize responses succinctly on another sheet.

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **2014**

USER SATISFACTION Mini-Survey (continued)

Question Number

37 (*continued*)

			#
6	**What was the subject of your use of this facility this year? (circle the subject that best applies)**		
	a.	Basic research	176
	b.	Applied research	59
	c.	Developed a new or improved product, process or technolog	18
7	**How do you intend on communicating the knowledge gained at this facility? (circle all answers that apply)**		231
	a.	Publish in peer-reviewed open literature	231
	b.	Present findings at professional society meeting	185
	c.	Acquired a patent	33
	d.	Other	11
8	**What additional benefits did you gained at this facility? (circle all answers that apply)**		
	a.	Furthered the goals of the Department of Energy	114
	b.	Obtained access to unique capabilities not available elsewhere (e.g., forefront experiments; one-of-a-kind instruments; distinctive materials or services)	194
	c.	experiments, increased multidisciplinary work; enabled a new approach within you discipline)	183
	d.	Trained students (undergraduate, graduate or postdoctoral associate)	116
*	**e.**	Other benefit(s); please specify:	2

9 **Are the training and safety procedures appropriate? If not, how would you change them?**

* Summarize responses succinctly on another sheet.

10 **What would you like this facility to do differently?**

* Summarize responses succinctly on another sheet.

11 **Other comments.**

* Summarize responses succinctly on another sheet.

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: The Center for Integrated Nanotechnologies (CINT)

Fiscal Year: FY15 Date submitted: 16-Oct-15

SUMMARY DATA

Facility USERS this Fiscal Year (*Researchers who submitted a successful proposal—see definitions*)

Add an asterisk (*) in this column next to any question that has additional information appended.

Question Number				Remote Access	Off-Site	Mail-in
1		430	Number of On-site Users			
2		83	Number of Remote Users	Breakouts: 4	79	0
• **First-Time Users** (subset of Q. 1-2)					NSRCs only	Light/Neutron only
3		182	Number of On-site Users			
4		25	Number of Remote Users	Breakouts: 1	24	0

• **Researchers Associated with Experiments** (i.e., Facility Users, Q. 1-2, plus their co-proposers)

5		532	Number of On-site Users and Co-Proposers
6		175	Number of Remote Users and Co-Proposers

Obtain Specialty Services or Materials; Itemize (no research proposal; e.g., purchases)

7		0	Enter appropriate categories for your facility here
		Sum of Entries →	*For example…*
			Institutions that Utilize the Transplutonium Program
			Institutions that Obtain Medical Isotopes

Facility Configuration

8		N/A	Number of Beam Lines (*or analogue*) Available to Users
9		N/A	Number of Additional Beam Lines Possible.
10	*		Provide Facility Schematic Diagram(s) to Explain Above Configurations

Facility Hours of Operation for Users (365 days = 8,760 hours)

11		N/A	Maximum Number of Hours for Users (under optimal budget) (excludes machine research, operator training, accelerator physics, etc.)
12		N/A	Scheduled Hours of Operation for Users
13		N/A	Scheduled Hours Delivered to Users (may not exceed Q 12)
14		N/A	Unscheduled Hours Delivered to Users
15	*	N/A	*Next Fiscal Year* - Planned Hours for Users (attach schedule)

Beam Line Hours of Operation for Users (from Q. 35)

16		N/A	Beam Line Hours Scheduled
17		N/A	Beam Line Hours Delivered
18		N/A	Beam Line Hours Used

Number of Scientific Publications

19		235	*Estimate* of Facility Publications for this Fiscal Year
20		228	*Final* Facility Publications for *Previous Calendar Year*
20 (a)		66	*Final* High Impact Publications for *Previous Calendar Year*

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

User Demographics

	513	Number of Users (sum Q. 1 plus Q. 2)

Question Number

Gender

21		Female
		Male
0	513	Information Not Available

Race/Ethnicity

22		American Indians or Alaskan Natives
		Asians/Pacific Islanders
		Black, non-Hispanics
		Hispanics
		White, non-Hispanics
0	513	Information Not Available

Age

23		Under 20 years
		20-29 years
		30-39 years
		40-49 years
		50-59 years
		60-69 years
		Over 69 years
0	513	Information Not Available

Citizenship

24	346	U.S. Citizen
	75	Foreign National, non-Sensitive Countries
	92	Foreign National, Sensitive Countries
0	0	Terrorist-Sponsoring Nations (U.S. State Department's list)

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

User Affiliations

513 Number of Users (sum Q. 1 and 2 or itemize them separately)

Question Number

Employer (User's Research Institution)

Question Number					
25	168	U.S.	Academic		
	21		Host DOE laboratory -- associated with host user facility		
	240		Host DOE laboratory -- not associated with facility		
	2		Other DOE laboratories		
	10		Non-DOE federally funded institution		
	35		Industry		
	0		Other	476	Subtotal U.S.
	35	Foreign	Academic		
	1		National laboratory		
	1		Industry		
0	0		Other	37	Subtotal Foreign

Employment Level

26	10	Undergraduate student
	97	Graduate student
	86	Postdoctoral research associate
	319	Faculty member / professional staff / research scientist
	1	Retired or self employed
0	0	Other

Type of User

27	513	General User only
	0	Partner User only
0	0	Both a General User and a Partner User

Proprietary Research

28	513	Users conducting only nonproprietary research
	0	Users conducting nonproprietary and proprietary research
0	0	Users conducting only proprietary research

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

Geographic Distribution of U.S. User Institutions

476 Subtotal U.S. (from subtotal within Question 25)

Question Number

U.S. State of User's Research Institution (Must sum to "Subtotal U.S." for Question 25)

29

1	Alabama	2	Nevada
0	Alaska	0	New Hampshire
0	Arizona	0	New Jersey
1	Arkansas	354	New Mexico
12	California	7	New York
3	Colorado	2	North Carolina
6	Connecticut	1	North Dakota
0	Delaware	4	Ohio
4	Florida	1	Oklahoma
4	Georgia	0	Oregon
0	Hawaii	14	Pennsylvania
0	Idaho	1	Rhode Island
4	Illinois	3	South Carolina
4	Indiana	1	South Dakota
1	Iowa	2	Tennessee
0	Kansas	18	Texas
0	Kentucky	3	Utah
0	Louisiana	0	Vermont
0	Maine	2	Virginia
1	Maryland	2	Washington
6	Massachusetts	0	West Virginia
7	Michigan	1	Wisconsin
0	Minnesota	0	Wyoming
0	Mississippi		
1	Missouri	2	District of Columbia
0	Montana	0	Puerto Rico
1	Nebraska	0	Other (itemize below)

0

Itemize other U.S. territories here.

If any →

	For example…
	Guam
	U.S. Virgin Islands

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

Information Derived from Experiment Demographics

	513	Number of Users from Q. 1-8

Question Number

Source of Support (number of users)

30	89	DOE, Office of Basic Energy Sciences
	0	DOE, Office of Biological and Environmental Research
	0	NNSA
	151	DOE, other (includes LDRD)
	0	Homeland Security
	29	DOD
	72	NSF
	37	NIH
	6	NASA
	0	USDA
	26	Other U.S. Government
	15	Industry
	37	Foreign
0	51	Other

Subject of Experiment or Service (number of users)

31	291	Materials sciences
	49	Physics (excludes condensed matter physics)
	9	Chemistry (excludes materials chemistry)
	18	Polymers
	11	Medical applications
	36	Biological and life sciences (excludes medical applications)
	3	Earth sciences
		Environmental sciences
	55	Optics
	24	Engineering
	7	User facility instrumentation or technique development
		Purchase of specialty services or materials
0	10	Other

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

Budget Data

Question Number

Annual Budget ($ in thousands)

Question Number		
32	950	Utilities
	1,400	Maintenance / operations of sources
	450	ES&H
	160	Security
	1,400	Operators/Technicians
	7,000	R&D
	7,900	User support
	1,750	Facility administration
		Other (itemize)
	21,010	Total Annual Operating Budget (sum of above)
		Capital Equipment
		AIP
		GPP/GPE
	21,010	**Total Annual Budget** (sum of Operating, CE, AIP and GPP/GPE)

Sources of Funding for Annual Budget ($ in thousands)

33	21,010	DOE, BES - Division of Scientific User Facilities	
		Division of Materials Sciences and Engineering	
		Division of Chemical Sciences, Geosciences, and Biosciences	
	0	DOE (other)	Itemize other DOE sources here
	Sum of Entries →		
	0	Other	Itemize other non-DOE sources here
	Sum of Entries →		
0	21,010	**Total Annual Budget** (same value as for Question 32)	

Facility Replacement Cost ($ in thousands)

			YEAR
34	75,000	Original cost of facility (then-year dollars) →	2005
	155,000	Replacement cost of original facility (this-year dollars)	

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

USER SATISFACTION Mini-Survey

Question Number		
37	513	Number of Users (sum Q. 1 plus Q. 2)
	370	Number of Users who filled out a Mini-Survey

Please circle only one number for Questions 1-4 or mark NA if the question does not apply.

1 **How satisfied were you with the fraction of the year that the facility operates?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	250	60	8	1	0	24	343

2 **How satisfied were you with the schedule or service (i.e., was the time or service delivered on schedule and was downtime kept to a minimum)?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	233	70	10	3	0	24	340

3 **How satisfied were you with the performance (i.e., was beam or service maintained close to specifications)?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	261	62	10	4	0	33	370

4a. **How satisfied were you with the support for users provided by the facility staff?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	259	43	9	1	0	28	340

4b. **How satisfied were you with the support for users provided by the beam line staff?**

	5 Very Satisfied	4 Satisfied	3 Neither Satisfied Nor Dissatisfied	2 Dissatisfied	1 Very Dissatisfied	NA Not Applicable	
100% =	278	43	5	2	0	10	338

5 **Please provide comments for any score rating of 1 or 2 on Questions 1-4 above.**

* Summarize responses succinctly on another sheet.

DO NOT REFORMAT THIS EXCEL FORM

Basic Energy Sciences (BES) Annual Facilities Questionnaire

Facility: **The Center for Integrated Nanotechnologies (CINT)**

Fiscal Year: **FY15**

USER SATISFACTION Mini-Survey (continued)

Question Number

37 (*continued*)

			#
6	**What was the subject of your use of this facility this year? (circle the subject that best applies)**		
	a.	Basic research	263
	b.	Applied research	257
	c.	Developed a new or improved product, process or technology	17
7	**How do you intend on communicating the knowledge gained at this facility? (circle all answers that apply)**		
	a.	Publish in peer-reviewed open literature	323
	b.	Present findings at professional society meeting	247
	c.	Acquired a patent	33
	d.	Other	0
8	**What additional benefits did you gained at this facility? (circle all answers that apply)**		
	a.	Furthered the goals of the Department of Energy	168
	b.	Obtained access to unique capabilities not available elsewhere (e.g., forefront experiments; one-of-a-kind instruments; distinctive materials or services)	254
	c.	experiments, increased multidisciplinary work; enabled a new approach within your discipline)	254
	d.	Trained students (undergraduate, graduate or postdoctoral associate)	151
*	**e.**	Other benefit(s); please specify: *Obtain preliminary data for NIH grant application*	1
9	**Are the training and safety procedures appropriate? If not, how would you change them?**		
	*	Summarize responses succinctly on another sheet.	
10	**What would you like this facility to do differently?**		
	*	Summarize responses succinctly on another sheet.	
11	**Other comments.**		
	*	Summarize responses succinctly on another sheet.	

5 Please provide comments for any score rating of 1 or 2 on Questions 1-4 above.

***** *Summarize responses succinctly on another sheet.*

1 **How satisfied were you with the fraction of the year that the facility operates?**

The MBE machine was down at different times for a spread period of time. This has hindered the growth of high quality GaAs 2DEG systems

2 **How satisfied were you with the schedule or service (i.e., was the time or service delivered on schedule and was downtime kept to a minimum)?**

This was particularly about the Schedule - it took us a VERY long time to find out our project had been approved, so we had moved onto other things. We were able to connect with people down at the labs and get the work done, but we couldn't send an individual down to the labs to do the work ourselves, which was dissapointing.

Raw data was lost making data unpublishable, we re acquired the data at another facility

3 **How satisfied were you with the performance (i.e., was beam or service maintained close to specifications)?**

The SQUID seems to be down a lot and in high demand. Our measurements were delayed several times.

We were unable to make the films we requested.

4a. **How satisfied were you with the support for users provided by the facility staff?**

Lack of calibration compromised data, data took longer to obtain that expected

4b. **How satisfied were you with the support for users provided by the beam line staff?**

We tried to work with the CINT staff member responsible for the e-beam writer to develop a waveguide process. He was not at all experienced in patterning for waveguide type applications, and did not have much process development experience, or e-beam writer experience at a researcher (rather than engineer at a company) level. I think it would serve CINT and its user community better if CINT tried to recruit PhD level staff for the e-beam writer -- someone who is an expert in nanofabrication, and thus has a tool set to address problems they haven't previously seen -- as will typically be the case in CINT supported research. In addition, the JEOL 6300FS e-beam writer is a very expensive machine, that seems just a couple of small investments short of being able to use its potential to enable high fidelity and high resolution lithography. One missing part is Beamer exposure control software, and another is the 5th lens on the column.

Process the initial paperwork faster. It takes CINT staff up to 6 months to process my students (US citizens and part-time or full time LANL employees) paperwork. this is 1/3 of the project length.

9	**Are the training and safety procedures appropriate? If not, how would you change them?**
	**Summarize responses succinctly on another sheet.*
	Yes (150+ responses)
	Different training for short-term visits.
	It's nice the safety training is "online", but I would prefer not to have to fax the tests. Also, some kind of feedback or test results would be nice.
	New or infrequent Integration Lab users need to be trained and authorized more rigorously to ensure familiarity with the tools in IL and to avoid improper tool operations.
	People were very helpful, however, some of the instructions are quite long and if the instruction goes too fast, you miss a lot. It might be nice to have U-Tube type videos for many of the instruments.
	Some of the training documents were just copies of forms filled out by some laboratory manager. These forms conveyed the necessary information. However it was like getting your necessary calories from eating grass: it's possible but absolutely unsatisfying.
	Staff are very concerned with safety of all users. This is good.
	The amount of theoretical training (paperwork/exams) was too high, most things are better learned hands-on, from the scientists familiar with the instruments.
	The instrument training is great, but the safety procedures (training) are onerous and seem to assume that scientists have no common sense.
	The laser safety training required for a student to work on a LANL system was prohibitively long. Thus, despite signficant experience with high-power lasers here in my lab, the student on site at LANL could only watch and advise. This hampered our ability to help out with the measurements and increased the burden on CINT scientists
	They are very appropriate and allows users to understand more about equipment operation, logistics, chemical handling, protection of intellectual property and more.
	Training is appropriate, but administration has to tell me if my training is up to date. It would be nice if I could keep track of it myself.
	Training procedure is good. However , a short video of the training for each equipment will help new user learn the equipment faster , once trained
	Trainings are OK. They are very efficient, especially for clean-room trainings.
	Very appropriate. When possible the staff would not require training and perform the tasks needing that training in a very timely manner.
	Very good, better than expected.
	Very well executed
	Very well thought out procedures and related training.
	Yes, everything was laid out in documents. We then had to pass several quizzes before being granted access to CINT. Perhaps a structured orientation at CINT would have been more helpful in the beginning.
	Yes, however, with the user facility in mind, shorter training periods would benefit the possibility of shorter research stays and thus also faster collaborative interactions.
	Yes, I especially appreciated the in person meeting with John in which several CINT specific safety and efficiency issues were discussed.
	Yes, the training and safety procedures are well designed and appropriate to keep a safe working environment and also to carry on and adopt at home institutions.
	Yes, they are appropriate, though it is unfortunate that they take ~1 month (IL training) preventing short term visits.
	Yes, they are appropriate. I really liked the training portion, in addition to the written material, in which one of CINT scientist sat down with a small group of us being trained and discussed different aspects about the integration facility and offered advice on use of the lab.

10	**What would you like this facility to do differently?**
	**Summarize responses succinctly on another sheet.*
	Wouldn't change anything (100+ responses)
	24 hours access for non-national (4)
	A more friendly access to computers for collaborators abroad
	Add the atomic layer deposition tool available at the Sandia Core facility, to the Los Alamos Gateway facility.
	Additional instruments, particularly SEM and FIB systems, to facilitate quicker turn-around (shorter wait time to use the equipment) and longer session times required for more in-depth experiments.
	At the present time, trained users can operate the SEM modified e-beam writers at CINT. Maybe in the future allow the trained users to operate the full-scale e-beam lithography machine?
	Basic instruments such as HRTEM and STEM may be over subscribed. If possible, additional HRTEM /STEM and supporting staff would help users to achieve their goals faster.
	Be closer so I could utilize it more.
	Be stricter on scheduling high usage equipment such as the SEM. With the new SEM being installed this problem will probably be tamed.
	Better interactions/communication between CINT staff and campus PIs
	CINT is a great facility. It would be beneficial to the entire research community if more staff and equipment were added to CINT to facilitate granting more user proposals.
	CINT is still not well known in the nanoscience community. It needs more advertisement in both US and worldwide.
	CINT needs a mechanism for very quick proof of concept experiments. Rapid access still takes too long.
	Cleaner labs. More hands-on interactions from staff if desired by the users. Email lists or similar for everyone who occasionally works in a lab - I'd come back after a month and find equipment missing, lab supplies moved, etc. I never was notified and sometimes my own samples were moved.
	Collaborations were excellent, nothing to add beyond that
	Continue fostering the CINT-LANL CINT-Sandia communication
	Faster turn around time on the user proposals. (3)
	Have a road that allows users to exit on Southern instead of Eubank
	Having another high-end TEM (5)
	Hire more postdocs to aid in collaborative research
	I think expanding the existing facility
	I hope that you give your scientists the opportunity to do what is equivalent to sabbaticals outside CINT. I also like to see more hiring for technicians and facility staff to reduce the load of work on scientists and postdocs to give them more opportunity to do research, seek funding and collaborations they don't need necessarily to do all the work for, and grow professionally.
	I would like to see a procedure put in place that would allow coordination between CINT proposals and applications for funding from other agencies.
	I would like to see more detailed capabilities listed on the website, e.g. what tools the integration lab has available.
	If possible, please speed up the badge approving process.
	It would be helpful to have the cleanroom budget for materials and supplies increased.
	It would be nice if CINT could provide support for short term stays for students and faculty, or even long term sabbatical stays for faculty.
	It would be useful to have external video conferencing. However, that may not be allowed due to camera and video policies.
	It would have been wonderful if CINT could have performed true transient absorption spectra on polymer films.
	Learning from this experience I would probably have set clearer milestones for CINT...they could have been renegotiate with system downtime and the sequester
	Maybe align duration of access grants with duration of typical university grants (3-5 years) (5)

More accessibility for transmission electron microscopy, high resolution-scanning electron microscopy, etc. I found the availability of such devices are very limited (at least that is what I heard when I was putting a proposal together for CINT scientists). More funding (collaborative research and scholarship) for local students and scientist at New Mexico universities (UNM, NMSU, NMT, etc.) will also help the state to further develop.
More collaborations between research areas (e.g. nanophotonics and biomaterials).
More machine time and staffs. Some popular machines (HRTEM, etc) required a bit of waiting.
More research capability on site (such as Aberration corrected TEM) and extended access per proposal.
More supporting staffs on HR(S)TEM.
Perhaps a little more rapid notification of proposal acceptance. We had a bit of a panic planning a last minute trip when we hadn't yet heard that our new proposal was approved.
Promote better relationships between Cint staff and collaborators
Proposals should run for a longer time, with all the training and scheduling, it's hard to finish a project in the give time, especially since it took several months after the official start date to get access to the facilities.
Provide my CINT collaborator John Reno more resources for his job.
Provide some support for visiting users (students, for example).
Replace the Trion Chlorine ICP with a PlasmaTherm Chlorine ICP
Support studies in structural materials and provide equipment upgrades in this area.
The administrative details could be more clear. Sometimes it is unclear where the training session is located or what prerequisites are necessary for the training.
The CINT user proposals work great the way they are organized currently.
The collaborations with CINT scientists are truly rewarding and helpful. CINT should strive to accept even more user proposals. Also, the duration of the user proposals should ideally be extended to a period of three years that coincides with typical time that DOD and NSF projects are funded for.
The duration of the CINT user proposals could perhaps be made longer. A 3 year cycle is the most appropriate, which is in line with typical time-line for proposals submitted to most scientific agencies. 18 months is sometimes short to fully execute the proposed ideas.
There is an obvious bottleneck of ebeam time to be fixed which I believe will be solved within a few weeks from now. I feel that the CINT management might want to weigh in the benefit of attracting top grad students and post doc scholars.These can be from the United States. This workforce will greatly assist the splendid scientific and technical staff that is already in place at CINT.
This is a well organized facility with great scientists and staff. Particularly notable is how open they are to collaborate and work with outsiders. There is no other place like it in the country.
Upgrade the QCM (quartz crystal microbalance) to the newest model
We have a rapid access proposal but it will expire 2 months before the next regular proposal kicks in. Maybe in the future a rapid access proposal should be granted a time period long enough so that there is no gap in between.
We like our collaboration with CINT staff, we like CINT facility and techniucal capability. Also, communication and approach of CINT is very nice.

11	**Other comments.**
	**Summarize responses succinctly on another sheet.*
	As the PI on this project, I can say that our CINT user proposal was noted by reviewers as a clearly positive aspect of my NIH grant proposal (1R01AI116894). This proposal has received a priority score that should be fundable in NIAID May council, although a final funding decision has not yet been announced. I think that our collaborations at CINT with Dr. Bachand (who wrote a letter of support for the grant) and Mr. Nogan were instrumental to the reviewers' comments that our proposal was very innovative, and the collaborative team including these individuals was noted as a particular strength of the project.
	Because we are able to work out prototype processes at CINT, we have gained the attention of potential larger partners such as SONY and Amgen.
	Chad Rhoades, a student who works with me, was given a summer internship at Los Alamos which will aid in our colaboration at this laboratory.
	CINT continues to improve!
	CINT is a unique and valuable resource to scientists working in a broad spectrum of fields.
	CINT is developing into one of the jewels of US research infrastructure. Carry on!
	CINT personnel and facilities have been and will be key for the success of our project in. We feel honored to have the contributions from CINT scientists and we think the collaboration between institutions is going great.
	CINT provides a research quality clean room maintained by professionals with excellent tools available to users. Such tools are often costly and time consuming to maintain. Finding so many of them in one clean room maintained by a friendly, competent staff is a great blessing to the research community.
	CINT staff, postdocs, and CINT users get together in the CINT user conference to celebrate accomplishments in the previous years. Much less attention is given to CINT staff and the admin and technical levels. When I look at the CINT website, I don't see that you acknowledge and value your admin and staff support. As a user of the IL a few years ago, I have witnessed the tremendous efforts that John Nogan puts to keep the facility running; no difference whether it is late night or weekend, the priority is to keep the equipment running to facilitate CINT scientist, postdoc and user operation. I would be very delighted as I am sure the many tens of users that used the IL to see you acknowledge and reward John's efforts, even with a symbolic services award.
	Collaborative work with CINT scientist is the reason I was invited to submit a paper. I gained a lot of traction on a new spray technology that I'm trying to bring up at SNL. This technology has applications that can be used to support DOE missions. It is critical that CINT stays and enables us to understand the science behind newly developed processes.
	Everything worked better than I anticipated.
	Excellent staff support, both administratively and technically.
	Excellent user facility and outstanding staff members.
	Excited to keep being a user here!
	I am relatively new to CINT and as such cannot speak to specifics at this point but so far my experience has been good. Thanks to everyone at CINT especially Dr. William Mook
	I am very grateful for the opportunity of being a user of the CINT facility.
	I deeply appreciate and acknowledge the great activities of CINT.
	I greatly appreciate the opportunity to work with the scientists at CINT.
	I had a really wonderful experience during my visit last time. The CINT staff were really helpful in carrying out the experiments.
	I had a very positive interaction, the CINT collaboration led to the completion of the dissertation of a Ph.D. student, and should lead to 2 journal publications which are being written presently.
	I have been able to publish in the top scientific journals thanks to the collaboration with John Reno
	I like it very much!
	I receive materials from my CINT colleague John Reno but do not use CINT facilities directly
	I thank all the economical supporters to allow us having so near this magnificent facilities for the development of scientific knowledge and technological advances for the benefit of human kind. Thanks!!
	I would like to personally commend John Nogan for offering outstanding support during my time at Sandia CINT.
	It is wonderful to work together with the scientist in CINT.
	It was a disappointment to us and our collaborators that we were not able to obtain ultrafast transient absorption data after multiple attempts. We were able to obtain this data with established collaborators at National Lab and academic facilities.
	I've had excellent interactions with CINT staff. The facilities are exceptional, the level of interaction and attention to detail is unparalleled. This is truly a facility that performs top research and employs wonderful and collaborative staff at the top of their game.

Most of the time, someone was always available to me when I had questions about the AFM.
My research and biotech (virtual) startup company are most grateful for CINT's working with us---especially when we have research delays that were unanticipated. CINT graciously waited until we were activated again and picked up where we left off
My use was only a collaboration with people who made material samples, which I measured in my experiment. This year's round of samples did not lead to any results, but conversations with the CINT scientists involved brought to my attention other materials that might be promising for future measurements.
On one of the specialized optoelectronic instruments I proposed to use in the proposal, I did not use it at all after 6 months (for a period of 1 year) because I was only able to access the instrument for total of 15 days out of 6 months I intended to use. The time limitation was so severe that I had to give up the planned experiments. I feel that this problem needs to be solved. Due to the nature of my experiments, I had to occupy the instruments for 3-4 days continuously once I start the experiments, and it seemed that the owner group did not like that their experiments will be delayed during that period of the time. I do not know how much of the instrument time should be dedicated to the CINT users but I feel that some arrangements should have been possible between pursing my experiments under CINT user proposal & owner group experiments.
So far very happy with support from John Nogan, Tony James, and Doug Pete in the CINT clean room. Also, no problem with badging, even for my foreign student, so happy about that too.
Superb MBE Growth
Thank the CINT staff for their strong support.
Thank you for the assistance you have provided us over the years.
Thank you very much for supporting our user proposal. We look forward to fruitful collaboration on the next project!
Thanks for your services; you could also think and let us know how we can help you from our home institutions.
The CINT scientists and staff I have worked with are especially flexible and anxious to accommodate new materials and processes. CINT clearly embraces innovation and provides excellent value to the scientific community.
The collaboration with CINT has made a major contribution toward helping our group establish a Terahertz Photonics research program at Lehigh University. We have obtained some very important research results that advance the field of terahertz quantum cascade lasers, which we will be publishing soon (late 2014 and late 2015). The CINT collaboration also led to a National Science Foundation CAREER award for the primary investigator (Sushil Kumar).
The expertise provided by CINT gateway staff is superior and excellent.
The staff at both Los Alamos and Sandia have been very helpful and contributed a great deal to my research. I have found the quality of the facilities and staff to be among the best I have had opportunity to work with.
This collaborative facility provides the a stimulating environment for scientific growth.
This is a great facility, very open and can help provide access to unique tools. Staff is excellent, very knowledgeable and professional.
This is a valuable national resource.
This is my first experience with CINT and I will likely apply in the future when more funding to support the effort is available on our end
We enjoyed our interaction at cint and hope full and continued support for cint to support the research community.
We really anticipated using the facility but unfortunately we couldn't get our subject materials released during the period of the project. CINT had no part in this. We hope one day to use the facility.
expanded.

12	**Please list or describe any <u>unique</u> CINT expertise/capabilities important to you as a CINT user**
	Theoretical expertise of Dr. Jian-Xin Zhu
	Electrochemical impedance spectroscopy.
	FIB, SEM, Polishing
	TEM Capabilities
	John Nogan's in depth semiconductor/cleanroom knowledge
	High purity GaAs/AlGaAs MBE and EBL with JEOL writer
	Liquid-cell discovery platform.
	1) optical characterization of materials including fluorescence microscopy, super resolution microscopy, and single molecule detection 2) other imaging methods such as atomic force microscopy and electron microscopy.
	1, Technical user support. 2, Theoretical support.
	3D nanoparticle tracking/super-resolution microscopy
	A unique capability lies in the CINT scientists who have long experience on the topic. The facilities are self-contained, providing adequate services from fabrication to measurement.
	Ability to fabricate and characterize specialized magnetic nanoparticles
	ability to perform complex property measurements on nanomaterials
	Accelerator beams.
	Access to a cleanroom, good microscopy facilities
	Access to imaging equipment and the biophysicists.
	Access to the dual beam FIB has been paramount to my research.
	Access to the SEM and sputter machine
	Accessibility to computational and experimental tools all in one location.
	Collaborative research, theory expertise, surface probing technical experties
	Advanced facilities and excellent staff
	Advanced methods for single particle / single molecule characterization of optically active materials such as those in the Goodwin lab.
	Advanced microscopy for soft/biological materials.
	advanced protein engineering
	Although it's not really "unique" in a broad sense, the F30 TEM provides capabilities that I do not otherwise have easy access to as a Sandian.
	Atomic layer deposition system in close proximity to a SEM with focused ion beam milling capability.
	Availability of instrumentation and expertise. This is particularly useful for acquisition of preliminary data, furthering formation of collaborations, and application to multi-disciplinary grants.
	UNM does not have a Quantum Design Magnetic Properties Measurement System (MPMS) it would be great if CINT had one available as a user facility. Ditto for a Physical Properties Measurement System (PPMS).
	Both e-beam writing and the cleanroom access are very important to our project
	Certainly the thin film deposition expertise and capabilities. I am learning more about CINT capabilities and continue to look for opportunities to increase CINT collaborations.
	CINT expertise in surface fabrication and lithography as well as the interface of these technologies with biological systems is critical to our project.
	CINT has cleanroom and measurement facility at one place.
	CINT has one of the premier in situ mechanical characterization facilities in the country. The in situ nanoindenter with the Helios provides a unique imaging and mechanical testing of nanomaterials that does not exist anywhere else in the country. The vapor deposition capabilities in my experience do not exist anywhere else since they bring a body of knowledge on thin film deposition along with their unique deposition and thin film characterization capabilities (eg RBS) Further access provided to irradiation work is truly unique and exceptional and allows one to pursue fundamental science with a combination of tools that does not exist anywhere else in the country.

CINT provides equipment which not available in our school
CINT's broad nanofabrication capabilities and unique materials characterization resources are important to me as a user.
CINT's expertise on tool training and safety procedures has been very important to me as a CINT user.
Classical Density Functional Theory of fluids and polymers.
clean room is complete and well maintained, the procedures are very accurate
Cleanroom facility (10)
Cleanroom processing including : SEM/EBeam lithography, photo-lithography, metal deposition, acid etching Low temperature measurements (cryogenics),
Closed loop of expertise in electronic materials research as a great resource to leverage CINT user projects. Our group have benefited from the use of the Electron Beam Lithography and Transmission Electron Microscopy tools to report several firsts in electronic materials and devices. IL staff support is phenomenal.
IL staff support is phenomenal.
Collaborative interactions with the CINT scientists
Comprehensive clean room facility and associated staff support high resolution electron microscopies
Computational facilities.
Computational materials science.
Computational methods for polymer and soft matter, in particular the combination of molecular dynamics (MD) and Fluid Densify Functional Theory (F-DFT).
Computing facilities. Atomistic and coarse-grain molecular dynamics.
Computing hardware and software (including in house developed) for materials modeling
Deposition of thin films. in situ SEM with indenter.
Detailed molecular simulations and modeling
Dr. John Reno provides state-of-the-art semiconductor material
Dr. John Reno's Molecular Beam Epitaxy facility at CINT is one of the best in the world for growth of nanostructures semiconductor superlattices for quantum cascade lasers. With our collaboration with CINT and access to Dr. Reno's expertise, we are able to make some significant contributions to the field of terahertz quantum cascade lasers.
Dr. Willie Luk's ellipsometry measurement capability is unique and important to my research.
E beam lithography jeol jbx 6300
Easy cleanroom access, low temperature expertise and facilities.
E-beam lithography and knowledge of staff members
E-beam lithography, Atomic layer epitaxy
EBL, ALD, and others
EBL, Fab capability
Electron-beam lithography, reactive ion etching, quantum dots, dielectric materials nanostructuring
Excellent CINT scientists are capable of stimulating collaborative discussion and improving experimental plan. This must be a strong advantage of CINT, distinguished from other laboratory.
Excellent fabrication skills. World class facility enables us to do cutting edge research.
Excellent staff to use cutting edge instruments with us.
Expertise and instrumentation to synthesize and characterize nano-materials.
Film fabrication (skilled technical support), nanomechanical testing, etc.
FTIR ellipsometry. It would be nice to have a cryostat with low-temperature capabilities.
Growth of excellent III-V semiconductor materials by John Reno
Growth of semiconductor materials.
Heterostructure material provided by John Reno is among the best in the world
High performance computing
High resolution TEM, STEM, and some clean room equipment including e beam lithography
High-quality MBE growth carried out by John Reno and his technical assistant.
HR(S)TEM and STM-TEM.
I could accomplish something that I never imaged to do.
I use the QCM for two programs and I would like to see this old model upgraded. The company no longer supports this model and it will expire soon. Also, it is not capable of being used with organic solvents, whereas the newest model is fully capable of being used with organic solvents.
In situ TEM (10)
In situ TEM micro-compression In situ TEM with heating stage
In situ tem, probe sem, thermoelectric platform, conductive afm, colloidal tip afm, optical tweezer platform.
In-situ TEM and design of wet electrochemistry cell
In-situ TEM for battery materials
In-situ TEM, scanning probe microscopy, clean room
Instrument scientist is very knowledgeable and helpful, and I've been able to accomplish my work with little downtime because of them.
Integration lab tools Access & input to Staff scientists.
Integration lab, TEM, CVD growth
Integration Lab: Align 3 (backside IR alignment lithography)
Ion beam analysis
Ion beam technology
Ion implanter and Ion beam analysis techniques
it is a complete platform to enable all processes of my device fabrication. Great.
Materials characterization, materials growth, fab
Interaction with other laboratories and academia. CINT is unique because CINT is designed the right way, and CINT do work, remarkably well, as a relatively young ""center"". And it is a true center."
John L. Reno has unique and valuable expertise in the fabrication of semiconductor nanostructures. He was able to guide the design of samples for specific our optically pumped NMR studies.
John Nogan has shared his processing expertise with me which has led to a faster path to working devices.
Kevin Baldwin's help with making evaporated films has been very valuable. I also use the FEI Quanta SEM with EDX regularly.
Large scale EBL facilities and expertise.
Large-area electron-beam lithography, unique materials like custom synthesized quantum dots, advanced optical spectroscopy facilities
Leem expertise
Lisa Phipps
Lithography and optical characterization.
Low energy electron microscopy (Kellogg, Ohta), nanomanipulator and scanning probes (Swartzentruber), optical characterization (Luk), nanoparticle chemistry (Ivanov), theory and simulation (Modine).

Low energy electron microscopy--both the tool itself and the expertise to use it. These are very uncommon and very valuable.
Material synthesis and device fabrication.
Materials characterization Soft materials development Nano materials
MBE growth facilities.
MBE machine for wafer growth.IR VASE for wafer characterization.
Most important to my research is semiconductor nanostructure/thin film synthesis and characterization. In this regard, the cleanroom facilities (processing tools, lithography, especially SEM tools) have been invaluable.
A few user facility capabilities I haven't had access to (and would like to) are: -high resolution XRD, cathodoluminescence"
My lab uses materials prepared by scientists at CINT, so I am directly using their expertise, and indirectly using CINT's characterization of the materials
My main interaction is with Jim Werner. His unique instrumentation has made it possible to perform experiments that could not be done anywhere else.
My research is heavily focused on small scale mechanical characterization of materials and access to the state-of-the-art nanoindentation equipment has been critical to my work. Also, discussions with N. Mara (CINT, LANL) are extremely valuable in the interpretations of our findings.
nano to micro level property measurements of materials.
Nanofabrication services
Nanoindentation and Magellan Electron Microscopy. Nate Mara is a unique talent and was very useful in the design of experiments.
Nanomechanical Testing Equipment
No place in New Mexico, or even the region offers the depth of facilities available at CINT.
Optical fluorescence imaging and analysis techniques.
Optical pump - THz probe spectroscopy system
Our collaboration with Dr. Peter Goodwin for his expertise in super resolution imaging is of high importance to our research.
Protein engineering (2)
Purification of molecular motors (proteins) by CINT was invaluable to my research. Dr. Bachand and his staff could not have been more helpful.
QD development
Raman experiments using tunable lasers, infrared fluorescence-excitation experiments, preparation of particular samples, ...
Raman spectroscopy at multiple wavelength
Scanning tunneling microscope with ultrafast laser in the same laboratory--essential for my measurements
SEM/FIB system
SEM-EDS, sputtering and e-beam evaporation for preparation of thin films
Semiconductor growth and IR characterization
Small angle X-ray scattering analysis
smart, enthusiastic and knowledgeable people as well as great state of the art equipment that WORKS!
Specimen preparation (deposition), Magellan (SEM) Triboindenter (nanoindentation)
Sputter deposition, dry plasma etch, SEM, profilometry
Steve Doorn's expertise for nanotube separation
Supercomputer access
TEM, optical characterization, e-beam lithography of 'exotic' materials
The ability to talk to CINT scientists, faculty, and other users about process that I am conducting and ways to improve my approach on my process.
The availability of unique characterization equipment.
The collaborations and instrumentation available to me at CINT have been an invaluable resource for the company I work for. With the help of the facilities at CINT we are able to do more meaningful research in order to push our field forward more.
The combination of a scanning tunneling microscope and ultrafast laser was available with a single investigator in one room. It is difficult to get these two types of equipment in a single laboratory.
The combination of computational and visualization capabilities along with the interaction of skilled staff scientists in theoretical and experimental areas is quite unique.
The equipment itself is outstanding. I'm not sure it is unique but the sum total of the types and quality of instrumentation for all manner of experiments is more impressive than any other lab facility I've used. Some of the staff scientists are extremely knowledgeable and helpful too.
The excellence of the CINT staff knowledge.
The femto-second laser, positioning equipment and read out systems are all important
The high level of scientific knowledge of CINT members, nd computational facilities
The in-situ transmission electron microscopy technique and the CINT unique expertise are very important to our research.
The Integration Lab clean room has critically important process tools with available scanning electron microscopes in close proximity and the support of a highly competent staff.
The integration lab facilities; expertise in photonics research; expertise in device fabrication techniques
The integration lab with back-end processing/characterization, in-situ mechanical nanoprobe and the TEM are the most important capabilities for my current research. Also, the expertise in material growth for elemental and compound semiconductors, nano fabrication, and all aspects of TEM experimental are prime and nationally unique to this facility.
The ion Beam Materials Lab is a unique CINT expertise/capabilities important to me. There are no other user facilities in the US that offer this.
The liquid-cell TEM and the clean-room
The MBE growth of high quality two-dimensional systems is among the best and important for material development and basic research.
The protein preparation and genetic engineering expertise of CINT.
The Radiation group in the nanoscience center is very important
The regular availability of the TEM along with the wide verity of the TEM holders.
The training I received by CINT scientists and post docs on the Atomic Force Microscope was great.
There is no ""one thing"" that CINT has (expertise or capability) which I cannot find in one area or another of LANL or the DOE complex. However, what I really appreciate about CINT is the collaborative opportunities and research ideas brought forth by simply having talented people in close contact with each other and with world-class equipment. I can design entire experimental programs, multi-year, which could fit proposal calls from LDRD, DOE, DOD, NASA etc without ever leaving the building.
so, I believe) to chat informally about ideas and experiments. It is easy to learn things at CINT, and I never get the feeling that the scientists are territorial or selfish.
thin film deposition and characterization
Thin film deposition, ion irradiation, high resolution transmission electron microscopy, nanoindentation
Thin film fabrication and Ion Beam Analysis techniques.
Thin film metal deposition, Electron beam lithography
Thin film, ion beam, MFM and PFM
This is an excellent research clean room where the tools are accessible to the experimenter but maintained by professionals. The staff considers requests for changes/adjustments to tools and has been happy to accommodate me.
Transient absorption and fluorescence capability

Ultra-fast spectroscopy
Ultrafast transient absorption. Ultrafast TA in applied magnetic fields.
Ultra-resolution SEM
Unique electronic device characterization system such as a 4-probe STM system.
Unique silicon and germanium nanowire CVD growth capability at LANL
Vapor liquid solid epitaxy is the primary tool used for growth of nanowires, which is very specialized. The growth expertise of the group (led by Tom Picraux) was essential for obtaining good quality samples, beyond just the system itself.
Very knowledgeable staff and expert principle scientist in optics, plasmonic, spectroscopy and nano-science. The willingness to collaborate and work together as a team. This makes collaboration fruitful and exciting.
Very specific expertise in sample preparation of nanotubes.
We are working collaboratively on a technology development that could lead to commercialization, aiding the (improving) the health care costs of Americans
We collaborate with Dr. John Reno for growth of semiconductor superlattice based Quantum Cascade Lasers (QCLs) in his Molecular Beam Epitaxy machine. His machine produces some of the best quality growths of such devices in the United States. Over the years, out collaboration has resulted in various records for performance of THz QCLs, and in my view, the reseach field of THz QCLs has greatly benefitted in the United States primarily due to the MBE growth expertise and facilities at CINT.
We received unexpectedly good samples. Iron coated wafers 3000-Å thick with roughness less than 10 Å. Samples included alloys. The ability to both make and characterize the samples using XRF was a major benefit. Could not have done my experiment without these capabilities. Preliminary discussions with the manager and other staff members was very helpful.
We used the nanoindentation facilities. We received a great amount of help from all the staff and very much appreciate the opportunity to work collaboratively with them.
We were able to fabricate a solar cell using high vacuum (low pressure) equipment, sample preparation and characterization. The service and support from John Nogan, Corey Parsons, Jeffrey Nelson and all the scientist at CINT were absolutely high and with all their good will in order to help us doing the experiments and understanding the nature of problem to solve using their equipment and facilities.
Well maintained facilities, and very experienced CINT scientists