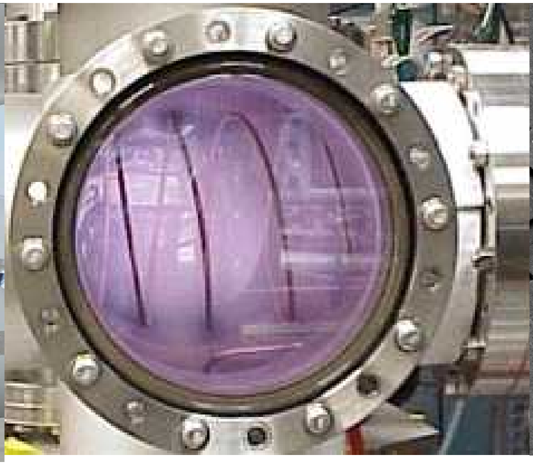
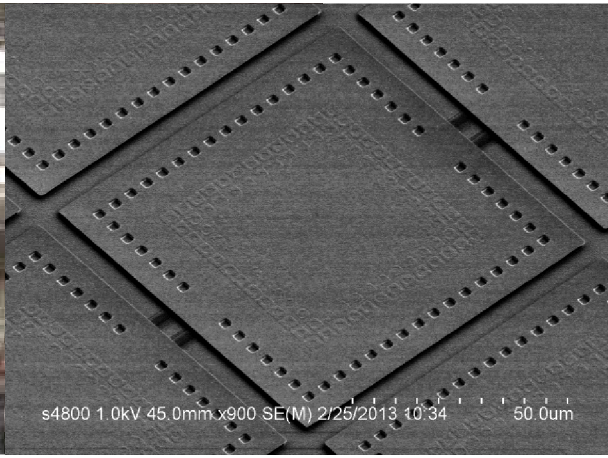
UUR

SAND2015-2051C

Exceptional service in the national interest

Sandia National Laboratories





Sandia Laser Applications: Some of these are not like the others

Bill Seng, SNL Dept. 1118

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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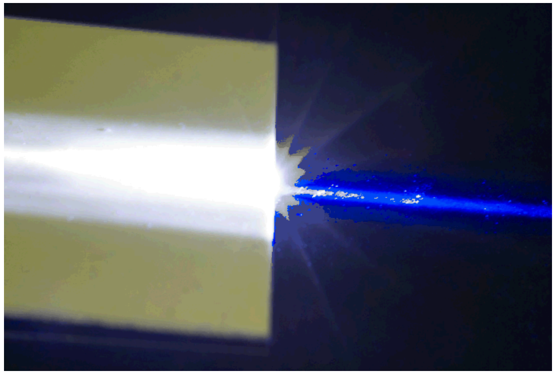
Outline

- What is Sandia? What do we do?
  - Yesterday, Today
  - Laser Stats at Sandia
  - How we (now) approach safety through Engineered Safety
- Now for the fun part – laser applications
  - Materials analysis – wafer scale
  - (Outdoor) chemical analysis – broad area
  - High Energy Density probing – the big “Z” machine
  - Laser ablation – small area
  - Inertial sensing - Atomic scale force
  - Illumination for the future
  - And more …if time

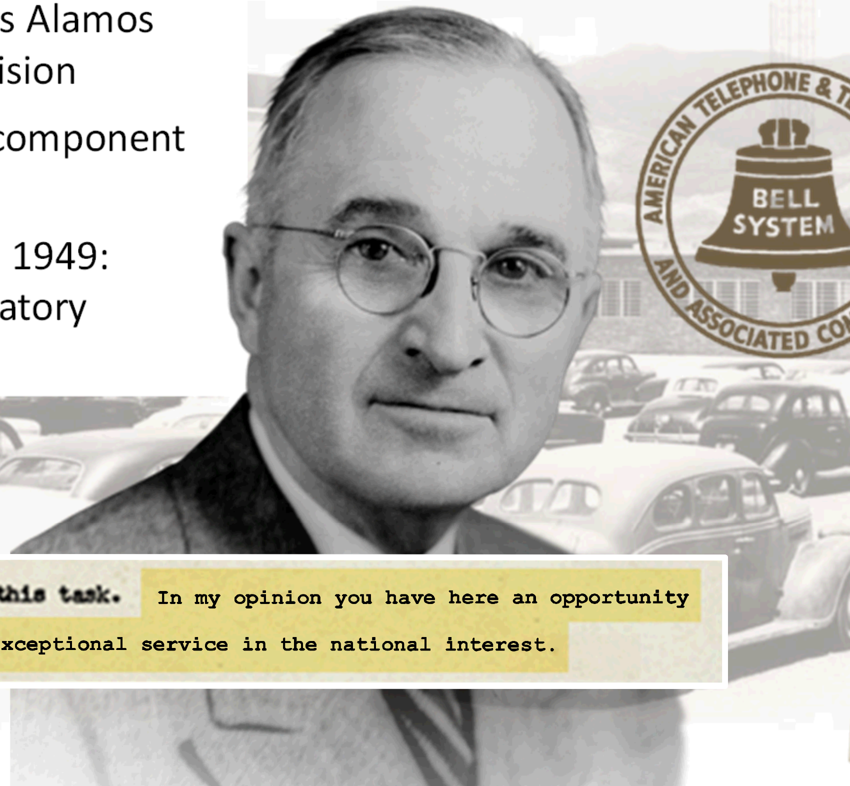


Sandia's History

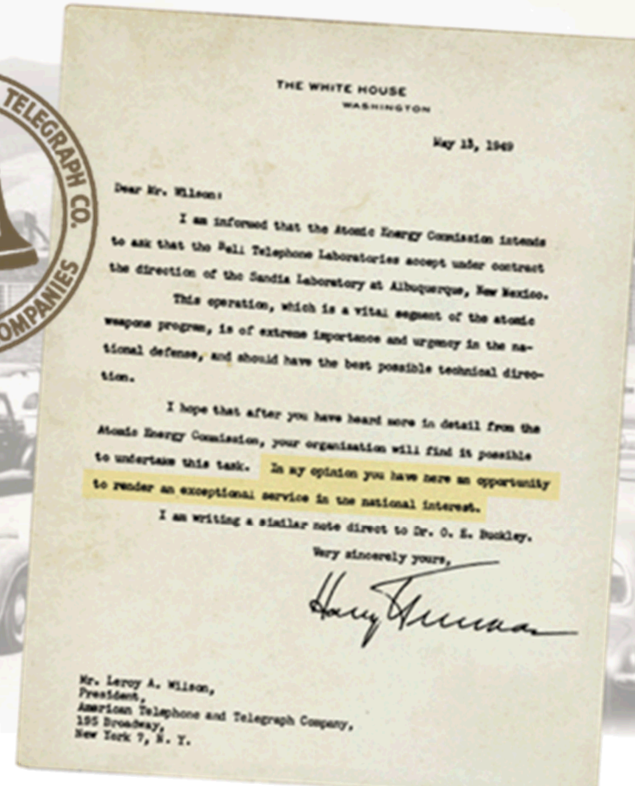
Sandia National Laboratories

Exceptional service in the national interest

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory established



to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

Sandia Sites

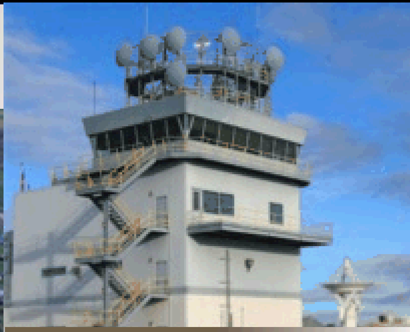
Albuquerque, New Mexico

Livermore, California

Kauai, Hawaii

Waste Isolation Pilot Plant, Carlsbad, New Mexico

Pantex Plant, Amarillo, Texas



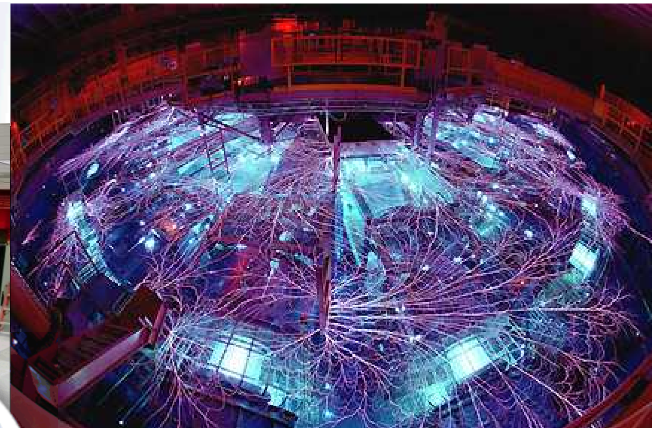
Tonopah, Nevada

Sandia National Laboratories

Our Research Framework

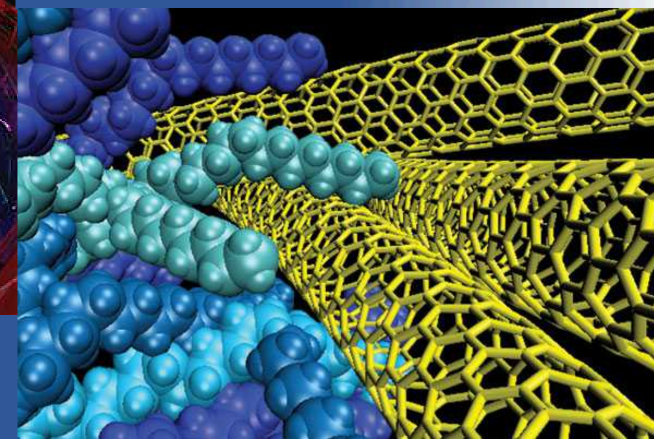
Strong research foundations play a differentiating role in our mission delivery

Computing & Information Sciences

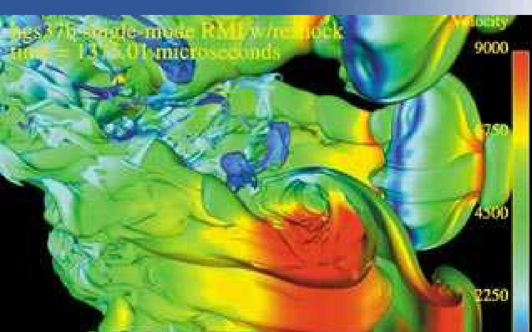


Radiation Effects & High Energy Density Science

Materials Sciences

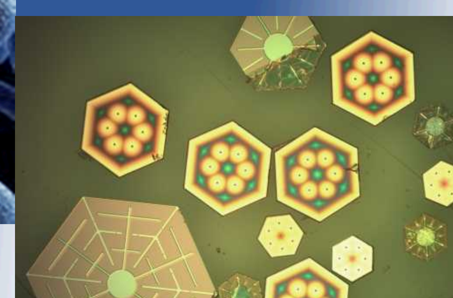


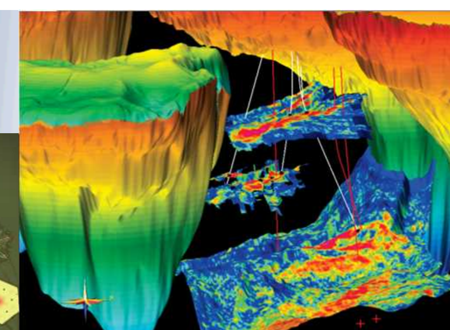
Engineering Sciences



Bioscience

Nanodevices & Microsystems





Geoscience

Sandia Addresses National Security Challenges

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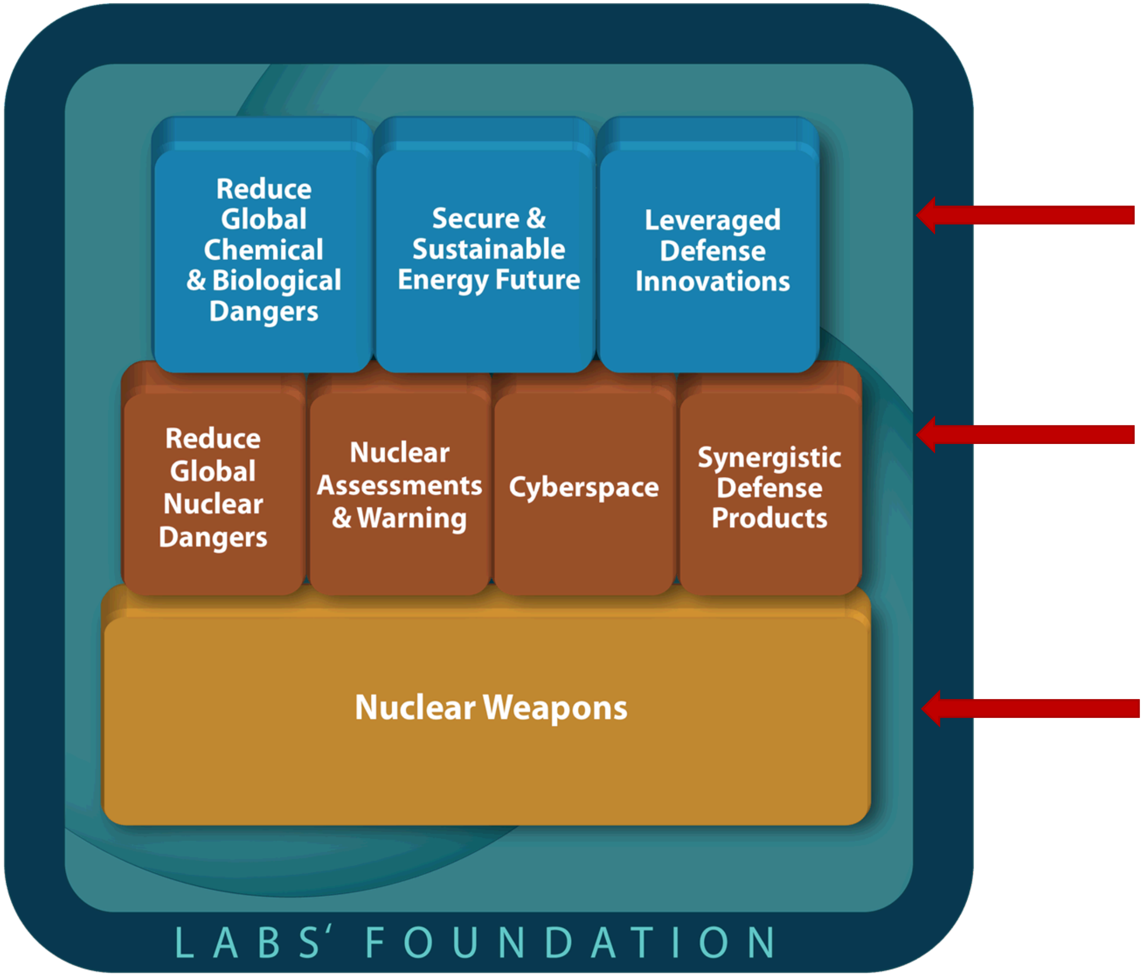
1950s	1960s	1970s	1980s	1990s	2000s	2010s
Nuclear weapons	Development engineering	Multiprogram laboratory	Missile defense work	Post–Cold War transition	START Post 9/11	LEPs Cyber, biosecurity proliferation
Production and manufacturing engineering	Vietnam conflict	Energy crisis	Cold War	Stockpile stewardship	National security	Evolving national security challenges

National Security Mission Areas

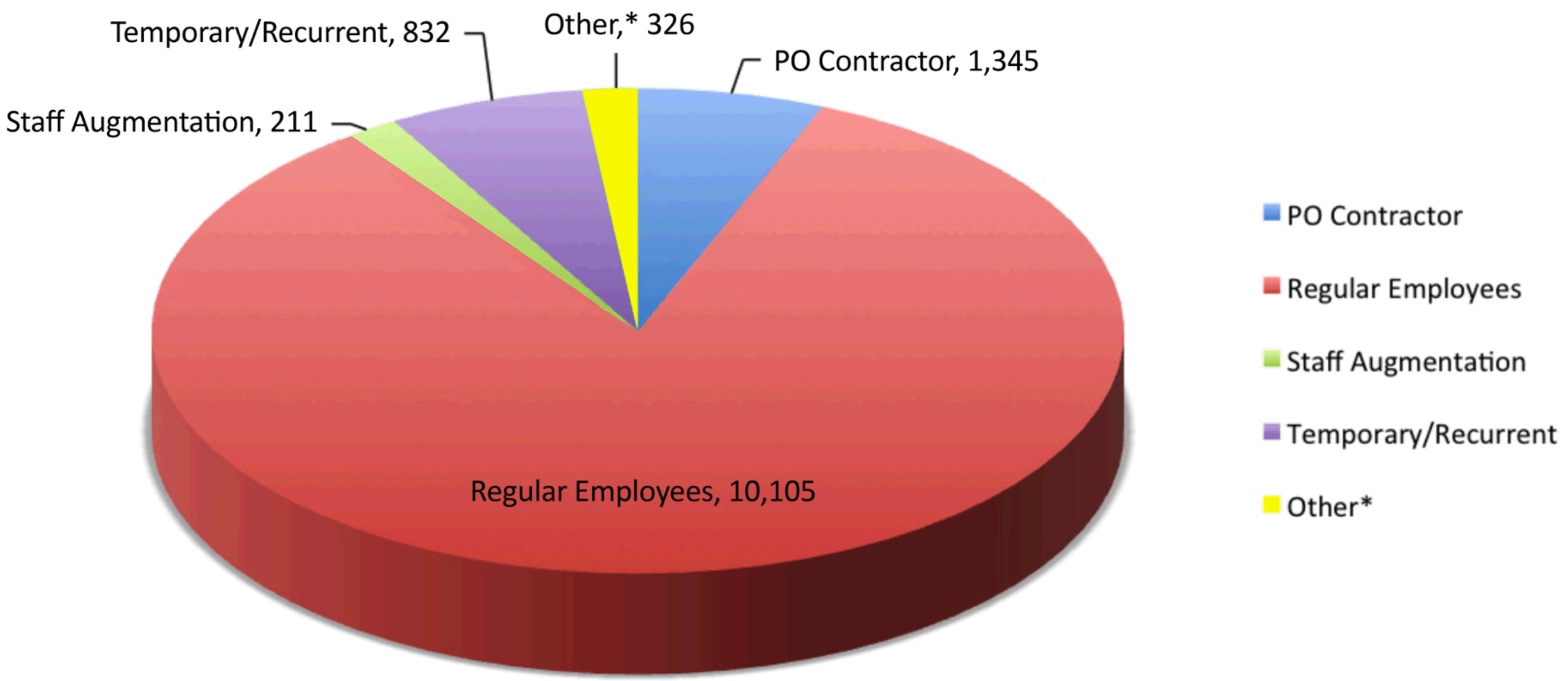


- Top row: Critical to our national security, these three mission areas leverage, enhance, and advance our capabilities.
- Middle row: Strongly interdependent with NW, these four mission areas are essential to sustaining Sandia's ability to fulfill its NW core mission.
- Bottom row: Our core mission, nuclear weapons (NW), is enabled by a strong scientific and engineering foundation.

Our Workforce

- Total Sandia workforce: 12,819
- Regular employees: 10,105
- Advanced degrees: 6,054 (59%)

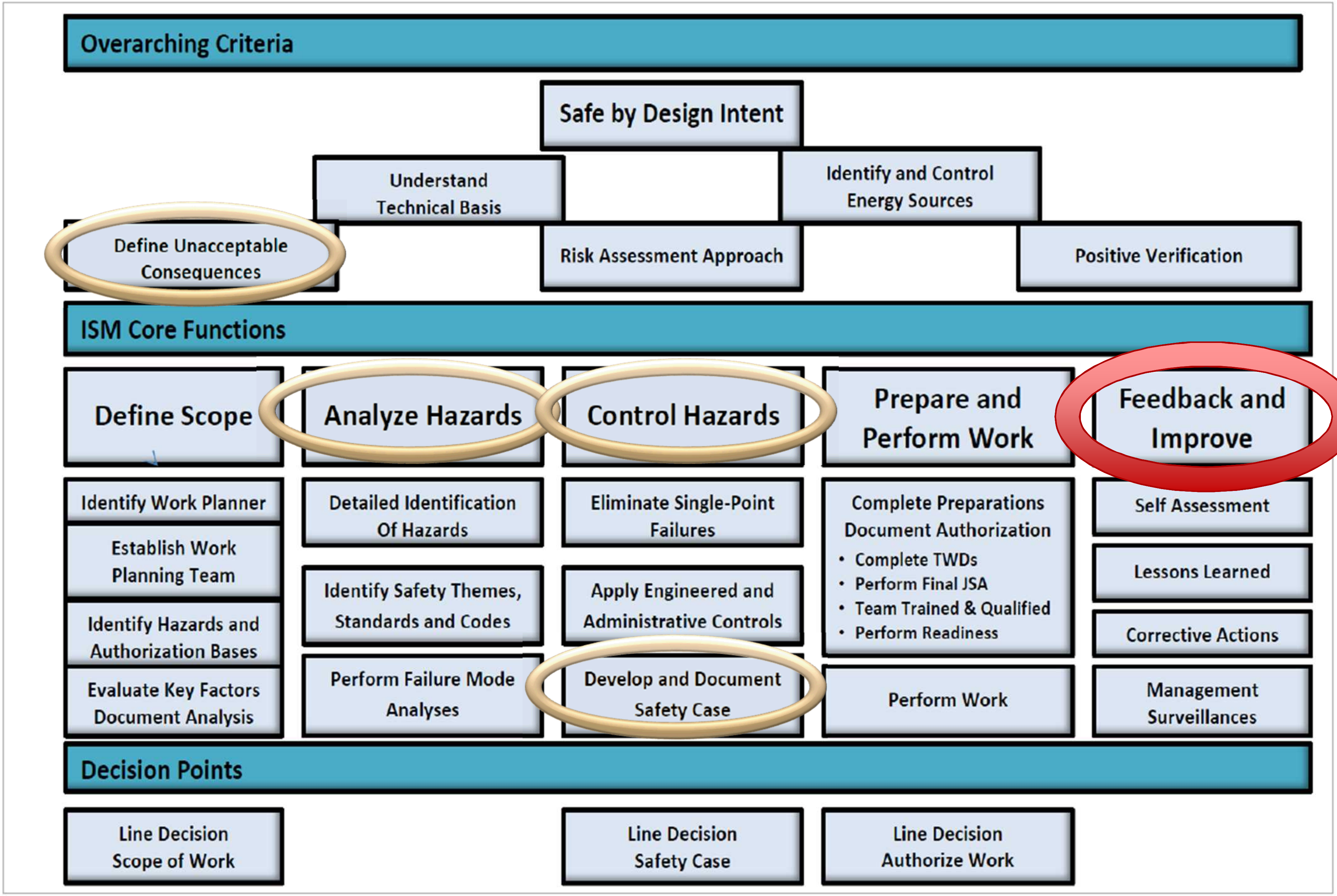
Data as of January 16, 2015



** Other badged personnel*

Sandia Laser Stats (CY 2014)

- Inventory
  - NM – 1075
  - CA – 331
- Types
  - Enclosed indoor systems all the way to outdoor
  - UV, Visible, IR, White Light
- Laser Control Areas (Class 3B or 4 operations)
  - NM -170
  - CA – 27
- Safety Officers
  - 1 Corporate LSO
  - 26 Deputy LSOs
- Regulatory Driver from DOE is 10 CFR 851
  - “Worker Safety and Health Program”


Overarching Criteria
Safe by Design Intent
Understand Technical Basis
Identify and Control Energy Sources
Define Unacceptable Consequences
Risk Assessment Approach
Positive Verification
ISM Core Functions
Define Scope
Analyze Hazards
Control Hazards
Prepare and Perform Work
Feedback and Improve
Identify Work Planner
Establish Work Planning Team
Identify Hazards and Authorization Bases
Evaluate Key Factors Document Analysis
Detailed Identification Of Hazards
Identify Safety Themes, Standards and Codes
Perform Failure Mode Analyses
Eliminate Single-Point Failures
Apply Engineered and Administrative Controls
Develop and Document Safety Case
Complete Preparations Document Authorization
• Complete TWDs
• Perform Final JSA
• Team Trained & Qualified
• Perform Readiness
Perform Work
Self Assessment
Lessons Learned
Corrective Actions
Management Surveillances
Decision Points
Line Decision Scope of Work
Line Decision Safety Case
Line Decision Authorize Work

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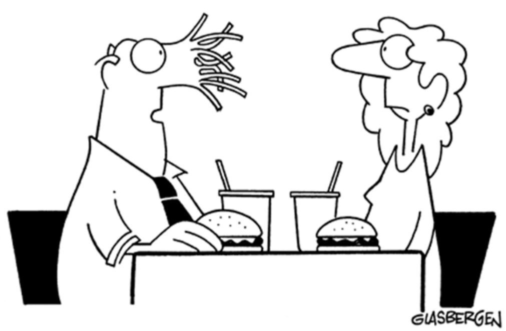
Sandia Engineered Safety – 5 Q's

- Who is the decision maker?
- What are the unacceptable consequences?
- How can the safety system fail?
- What are the safety system controls?
  - Administrative
  - Engineering
- How do we know the safety system works?

Purpose of Engineered Safety

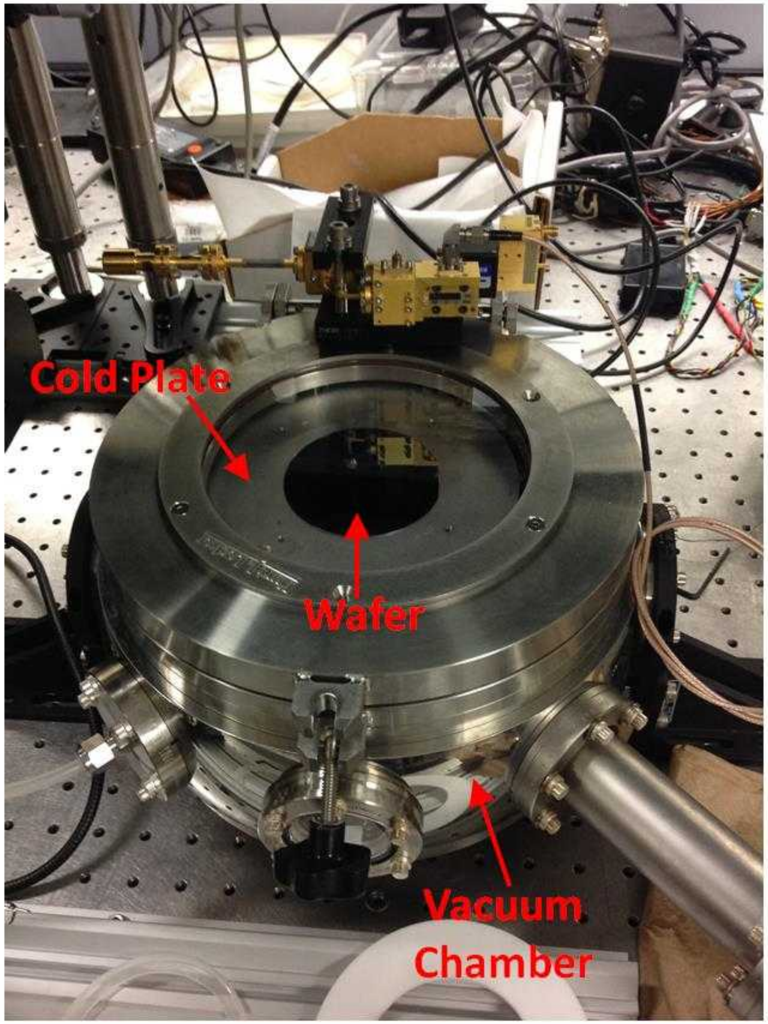
- Evidence critical thinking
- 5 Questions lead to…
  - FMEA
  - Mitigation
    - Engineered Ctrls
      Administrative Ctrls

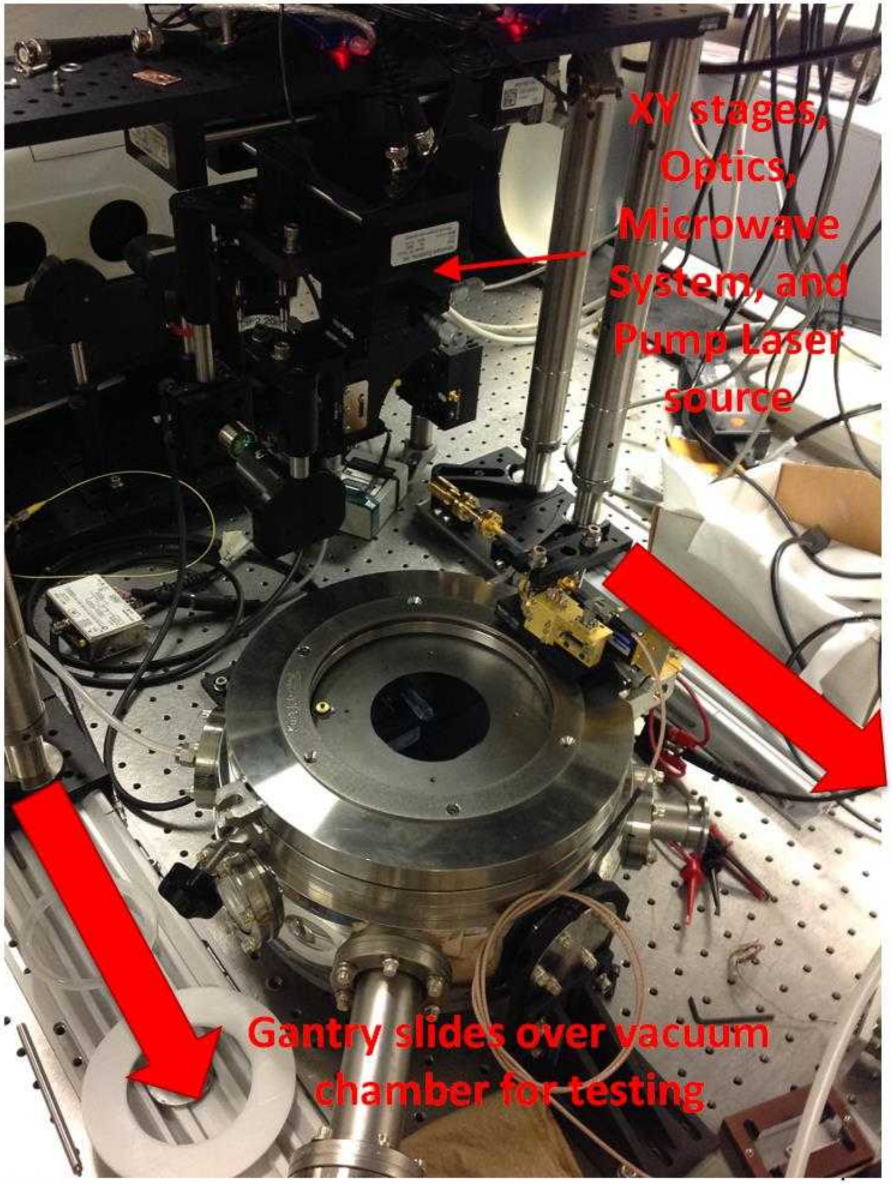


"Oh, it was just like any other day at work. Except for the part where I sneezed by the paper shredder."

- What is it good for?
  - Training for new personnel
  - Handy quick reference for experienced ones
  - Record of "why" decisions
  - Baseline for continuous improvement
  - NB: Not static

TMR Wafer Mapper

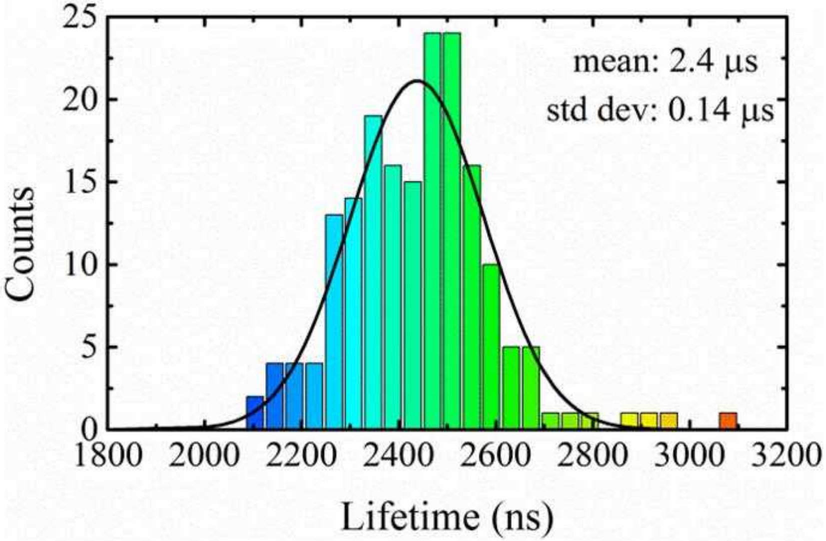




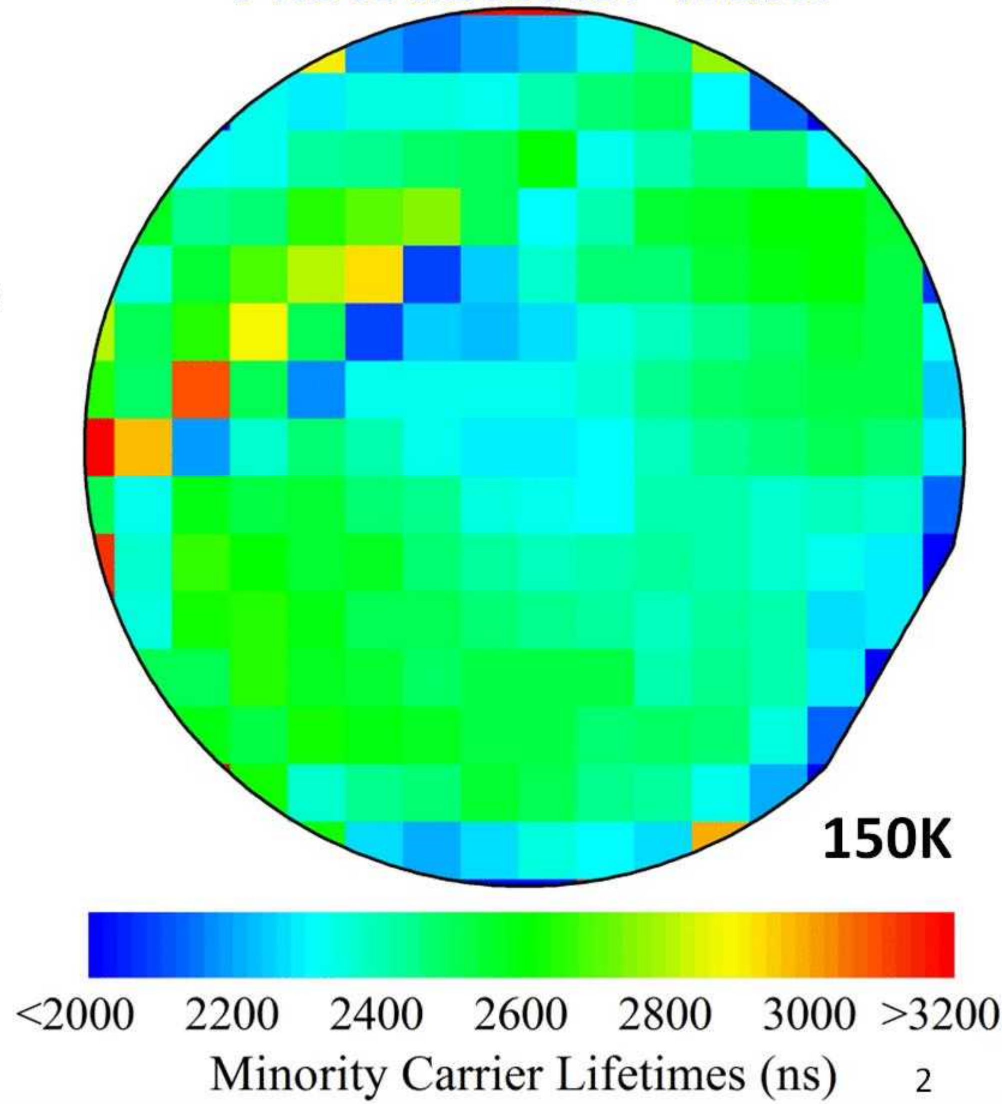
Lifetime Wafer Mapping

- **Non-Destructive**
- **Non-Contact**
- **Provides wafer diagnostics before fabrication**
- **Detector dark current depends on the carrier lifetime!**

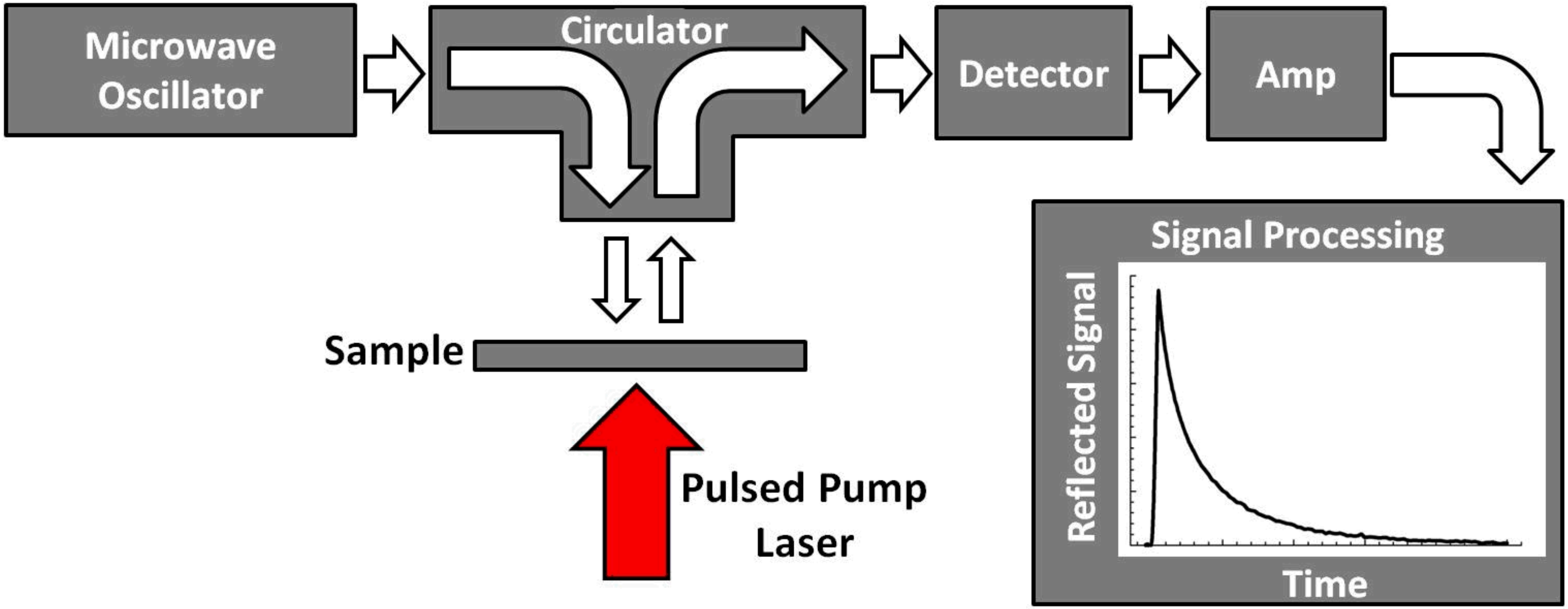
$$J_{Diff} = q\frac{n_i^2 L_{abs}}{N_d \tau_{MC}}$$



3in MWIR Photodetector Wafer



Time-Resolved Microwave Reflectance (TMR)

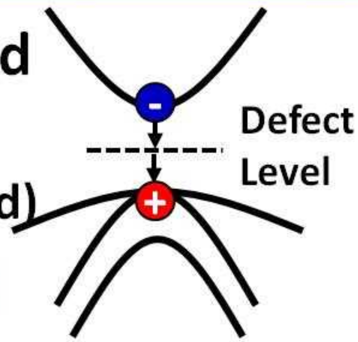


- Pump Pulse excites charge carriers in IR absorber layer, altering the conductivity of the sample
- Microwaves reflected from sample surface detect this change and monitor their decay back to equilibrium (i.e. the carrier lifetime)
- Approximate 10 ns time resolution, fast acquisition/high throughput, and extremely sensitive

Carrier Lifetimes

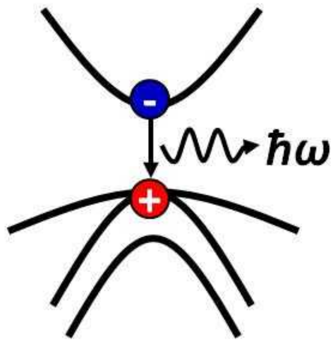
Recombination Mechanisms

Shockley Read Hall (defect mitigated)



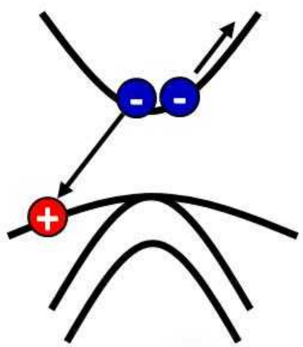
$\tau_{SRH}^{-1} \propto \text{const}$

Radiative (intrinsic)



$\tau_{rad}^{-1} \propto \Delta n$

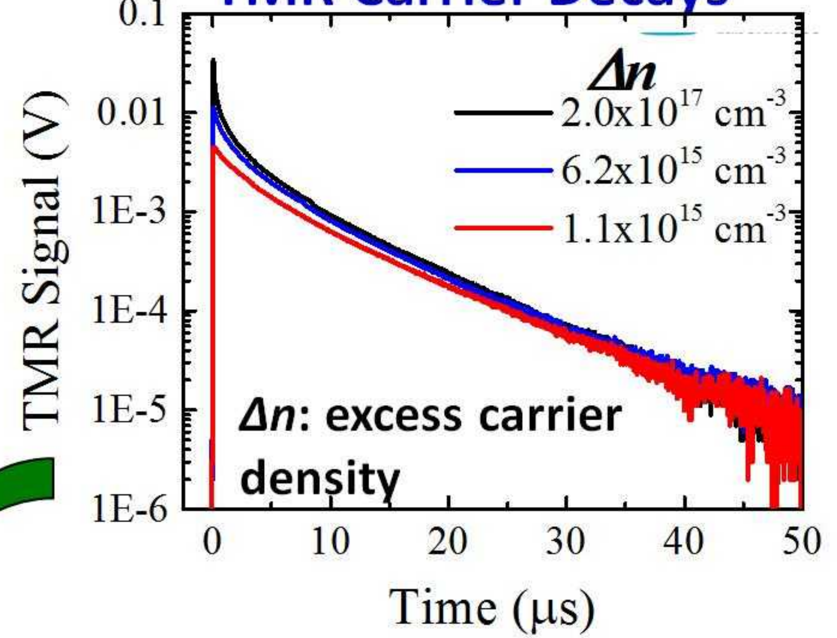
Auger (intrinsic)



$\tau_{auger}^{-1} \propto \Delta n^2$

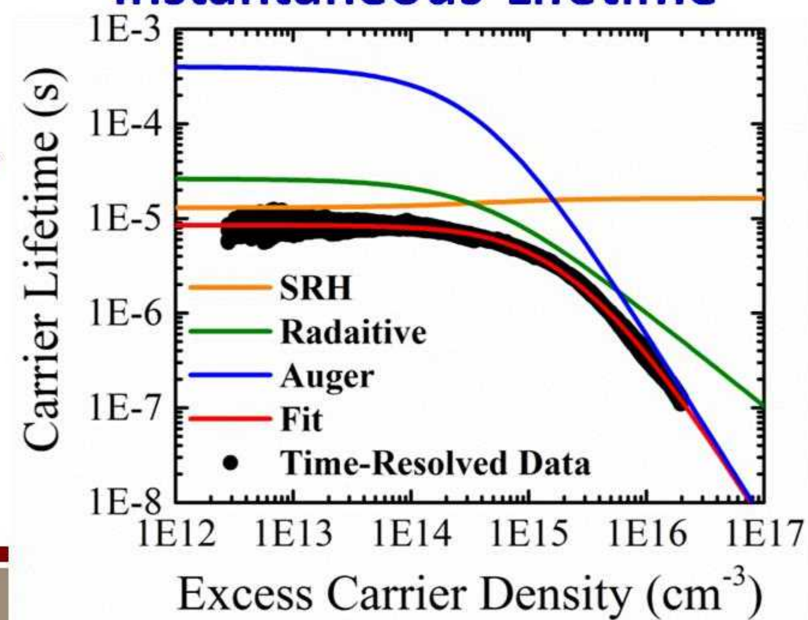
$$\tau_{meas}^{-1} = \tau_{srh}^{-1} + \tau_{rad}^{-1} + \tau_{auger}^{-1}$$

TMR Carrier Decays



Data Transform

Instantaneous Lifetime



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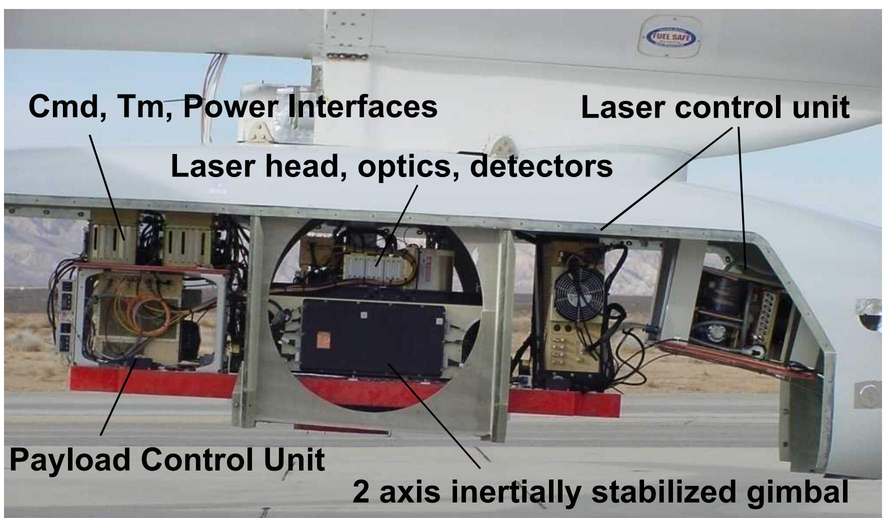
LRS: Aura - Airborne UV LIF lidar System



- **Mission applications**
  - **WMD proliferation**
  - **Support to military operations: Standoff detection of biological weapons agents(BWA)**
  - **Bomb damage assessment: BWA production and storage**
- **Airborne requirements drive system design**
  - **Compact integrated system**
  - **Payload Requirements:**
    - **Weight, power, volume efficient**
      (~ 400 pounds, 2000 watts, 20 ft^3)
    - **Hands-off operation**
    - **Ruggedized components**
  - **designed for Predator-class UAV**
  - **flown on Proteus and Egrett aircraft**
- **Major AURA components**
  - **12 watt UV laser**
  - **30 cm composite telescope**
  - **GPS aided Inertial Navigation and Pointing with automated target acquisition and tracking**
  - **Laser, optics, & detectors on pointing gimbal**
  - **Real-time onboard processing**

LRS: Ares & B70 – mobile LIDAR systems

Develop and field test LIDAR systems

B70: lidar laboratory on wheels

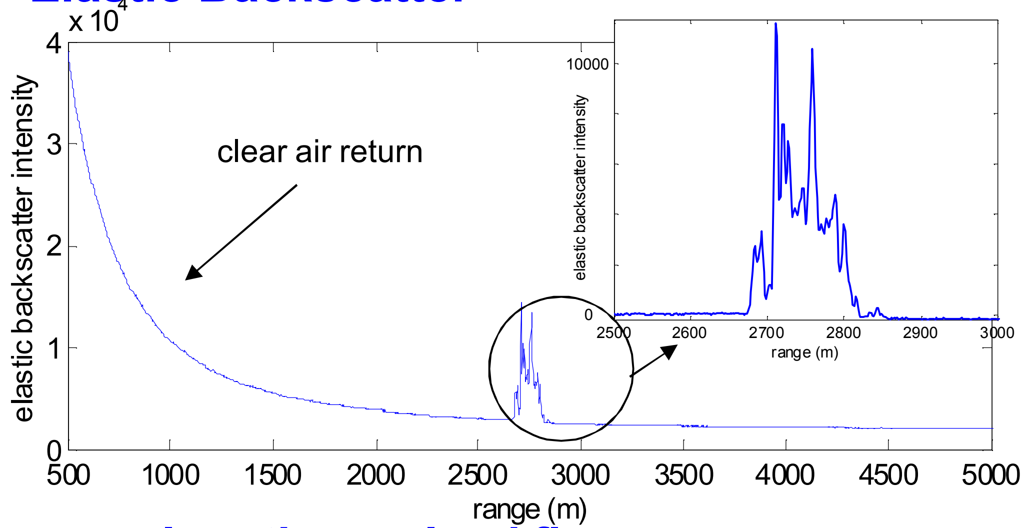
Ares: bio-aerosol standoff detection system in a van

Target phenomenology, signatures, and cross sections

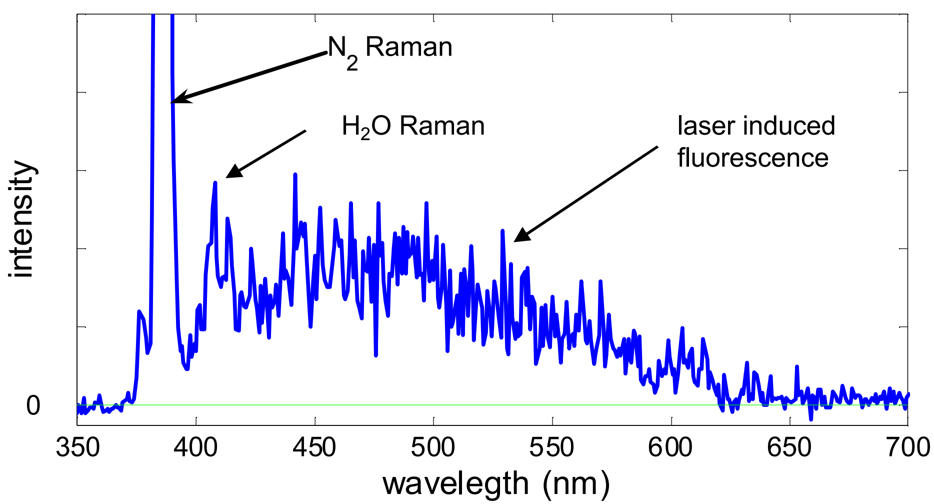
- UV LIF signatures of bio materials and interferrants
- fluorescence and backscatter cross sections
- methods for measuring BWA cross sections

Wavelength-resolved fluorescence and elastic backscatter provide complementary information about the target

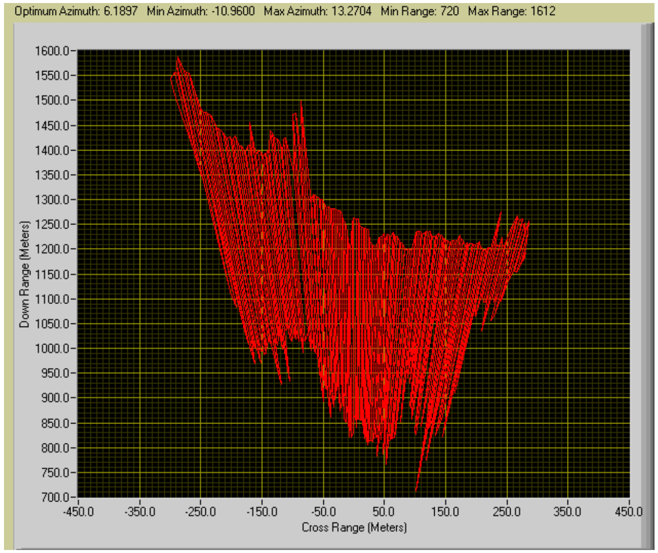
Elastic Backscatter



wavelength-resolved fluorescence



- Elastic backscatter at 355 nm used to detect aerosol clouds
- Algorithms determine the location and size of clouds



- This cloud was identified as BG with high confidence after comparison to database spectra
- Test log confirms BG + kaolin release

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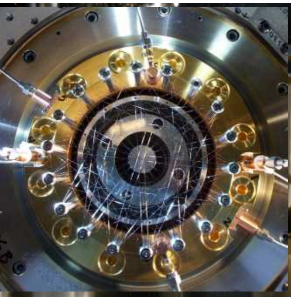
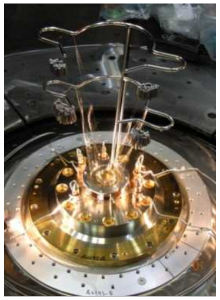
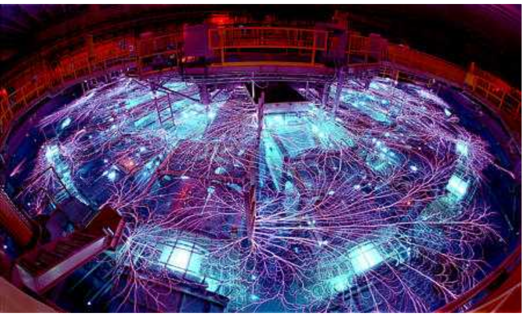
LRS: Tailored Application Platforms







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Exceptional service in the national interest

High Energy Density Science

Breakout Session #2

M. E. Cuneo, D. B. Sinars, G. A. Rochau,
M. Knudson, B. Jones, M. Herrmann, C. Nakhleh

mecuneo@sandia.gov

Defense Science Study Group
Sandia National Laboratories
June 20th, 2013

U.S. DEPARTMENT OF ENERGY

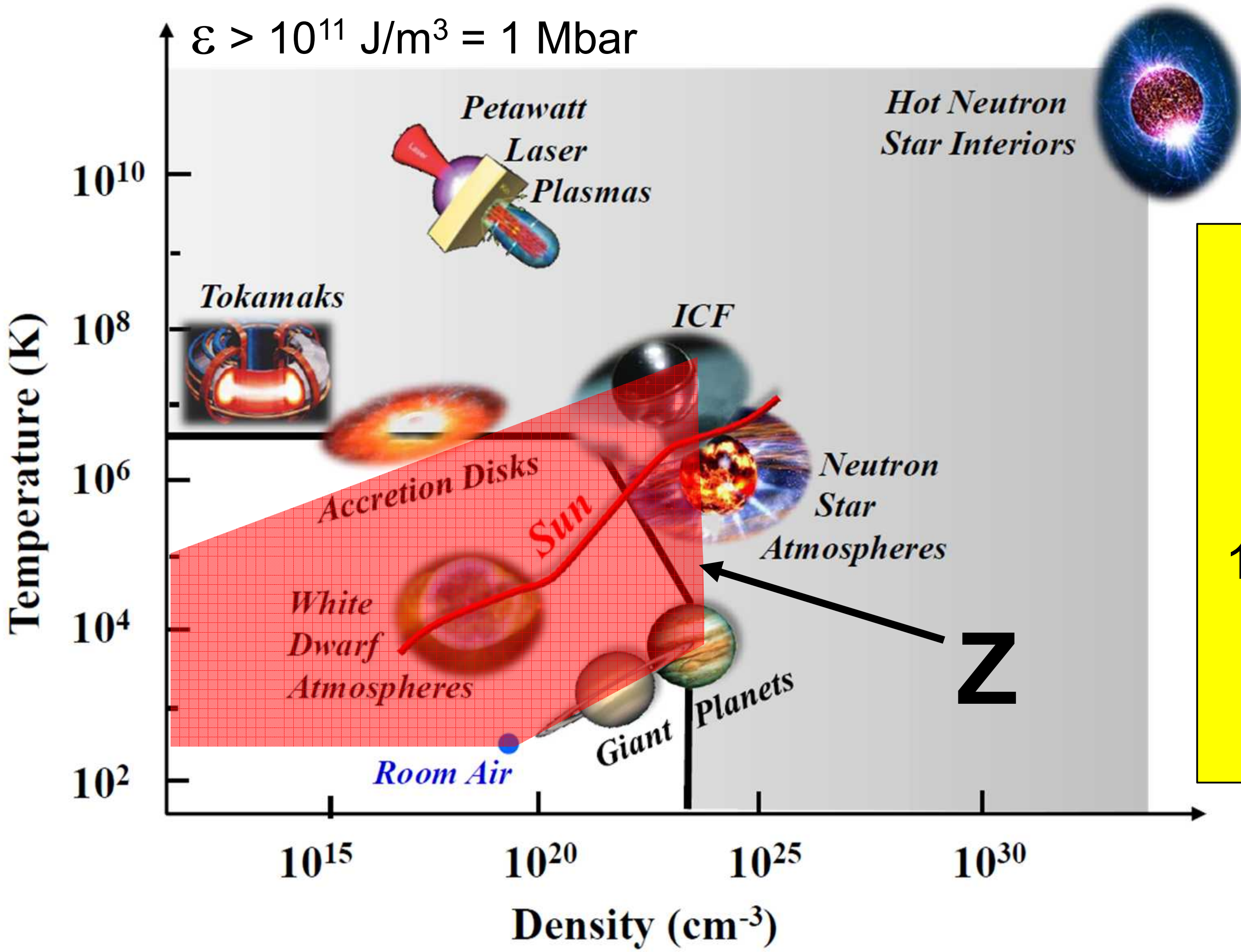
NNSA National Nuclear Security Administration

SAND2013-4973C

High energy density is defined, somewhat arbitrarily, as a pressure of 1 Mbar

High Energy Density Regime

$\varepsilon > 10^{11}$ J/m^3 = 1 Mbar



Pressure is equivalent to energy density

1 Mbar =
1.01e6 atmospheres =
1.e11 Pascals =
100 GPa =
1.e11 J/m^3

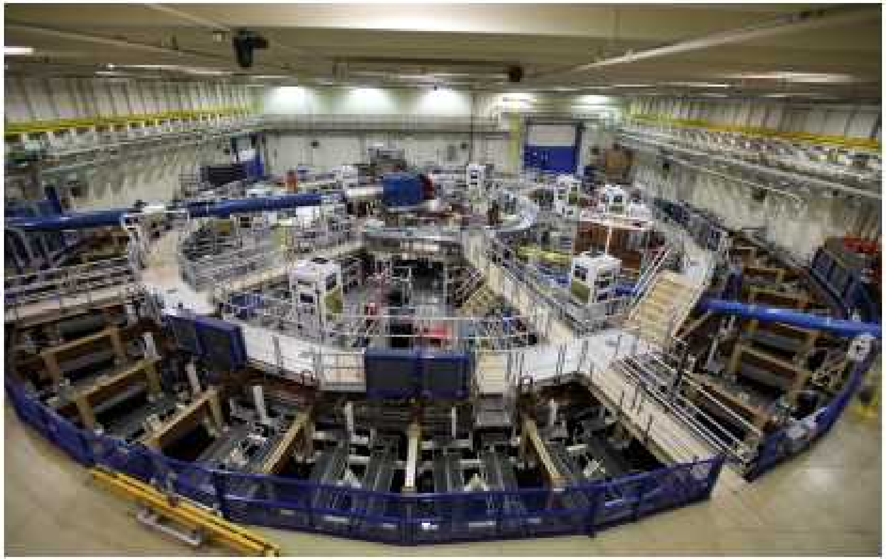
figure courtesy of G. Rochau

What are our most important near-term and long-term missions?

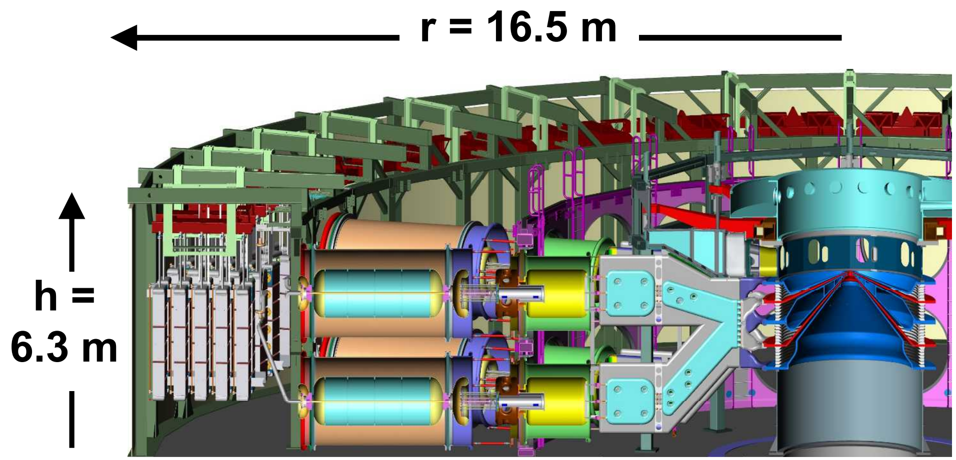
- Near term and long-term: stewarding, certifying the stockpile in the absence of Underground Tests (UGT)
  - Certify that the non-nuclear components (e.g. arming, firing, fuzing) will work as intended even in hostile environments with severe radiation threats
  - Certify that the non-nuclear components and nuclear explosive package (NEP) will work as intended, with material re-use, new processes, new materials

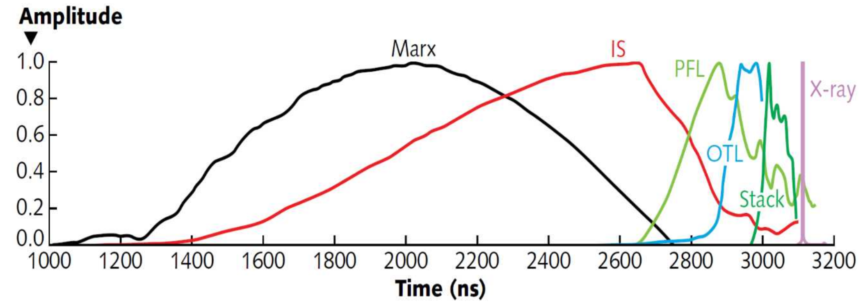
- Long term: fusion ignition for AGT
  - Can we achieve fusion ignition in the laboratory?
    - Can we make this easier to achieve?
  - Can we achieve high fusion yield in the laboratory?
    - What are the requirements? Driver size?

Pulsed-power generators provide an energy-rich platform for high energy density experiments



- 21 MJ stored at 85 kV
- 26 MA into low impedance loads
- 33 m diameter footprint
- Facility refurbished completed in 2007 at a cost of ~4$/J
- Compact ~ 10,000 ft^2





- High energy density achieved through multiple stages of spatial and temporal pulse compression
- EM energy/volume increased by a factor of ~10^{17} down to size of r=1 cm, h=1 cm.

Axial Imaging and Thermometry (AXIAT)

Deliverable:

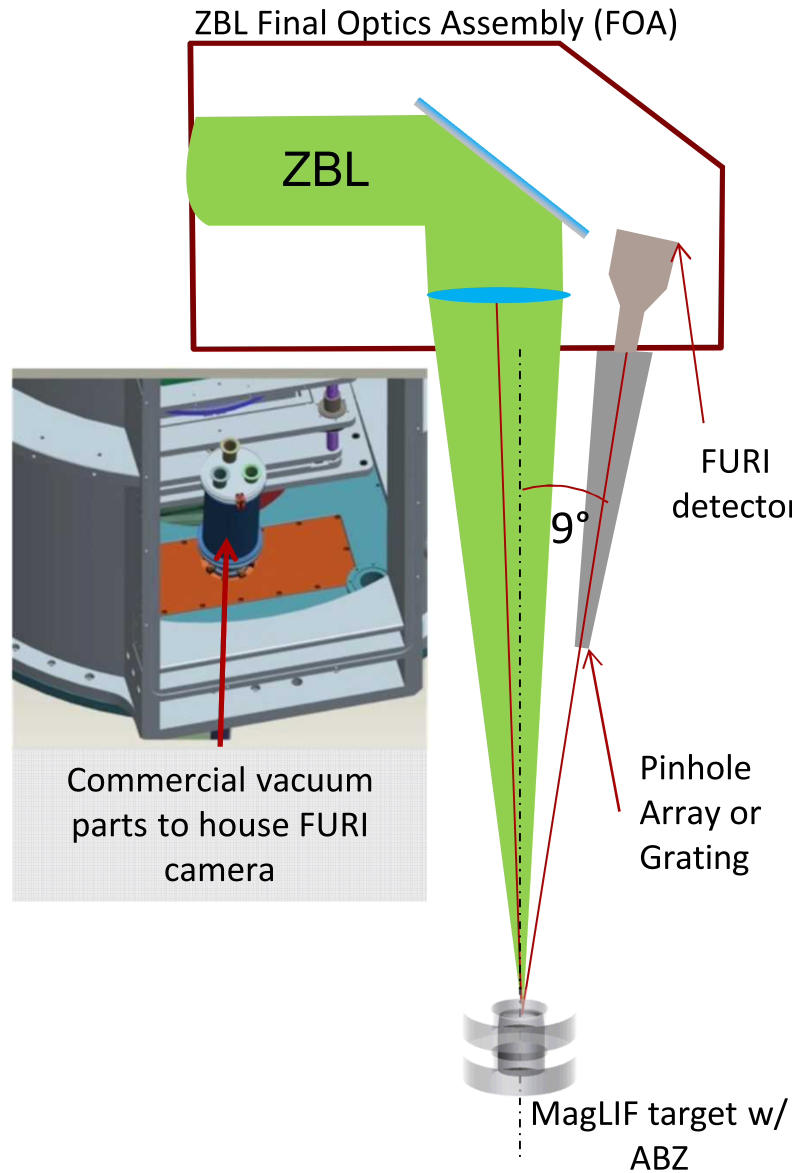
$k_B T_{e,i}(r,z,t)$ during and shortly after laser irradiation

Technique:

Time-gated x-ray emission spectroscopy & pyrometry of Ne tracer gas

Implementation:

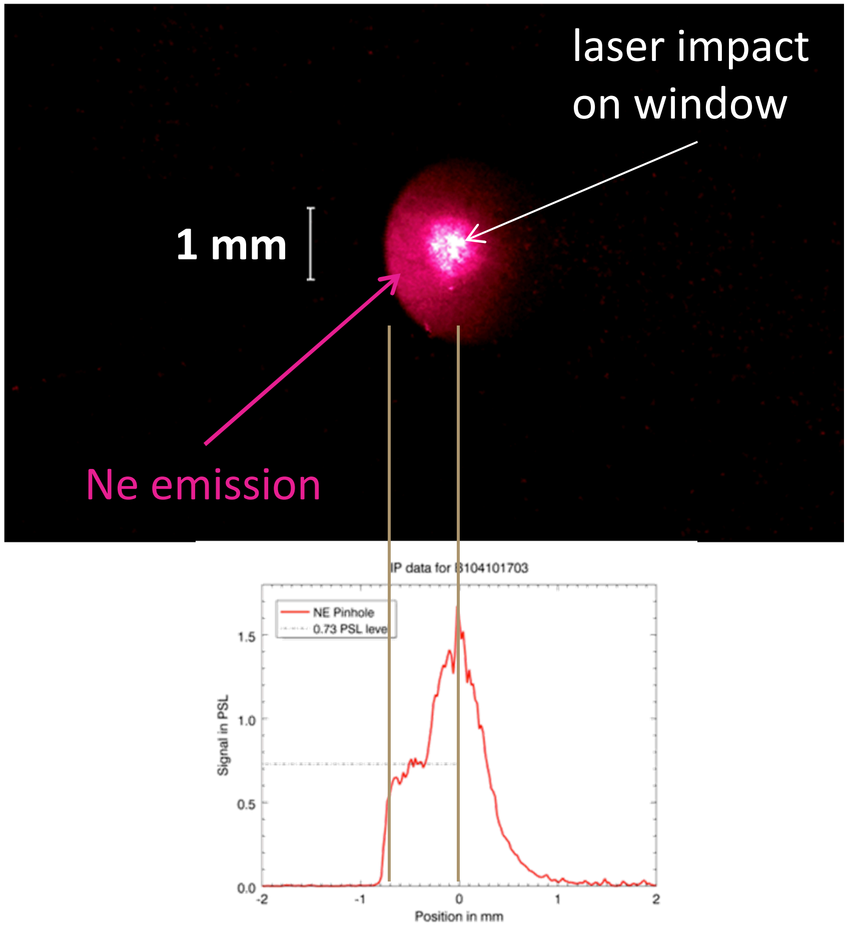
1. Field X-ray pinhole camera in FOA (FURI)
2. Assess temperatures based on Ross-filtered images from 1
3. Field spectrometer in FOA to measure plasma temperature from H- and He-like ion line ratios (FURI)
4. Benchmark detectors with blastwave experiments in PECOS target chamber (FURI, HIPPOGRIFF)



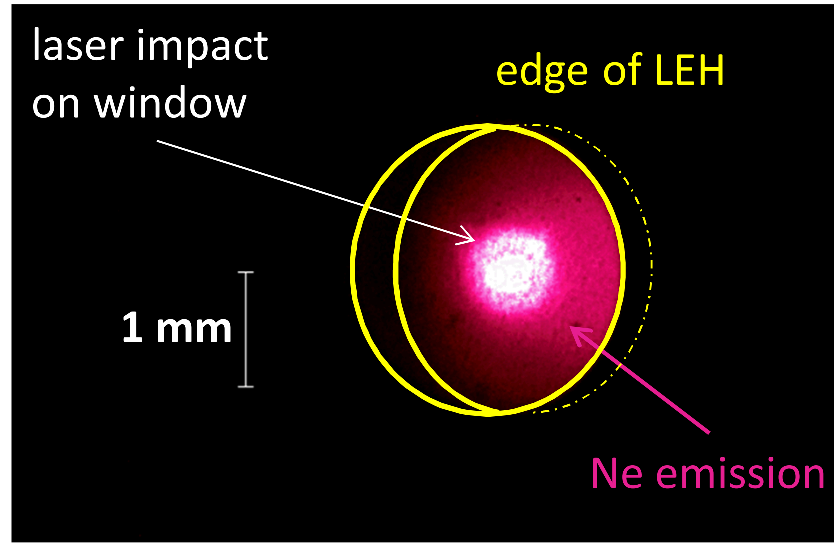
Commercial vacuum parts to house FURI camera

Neon Emission on ZBL shot B14101703 (270 torr Ne)

North-East Viewport



North-West Viewport



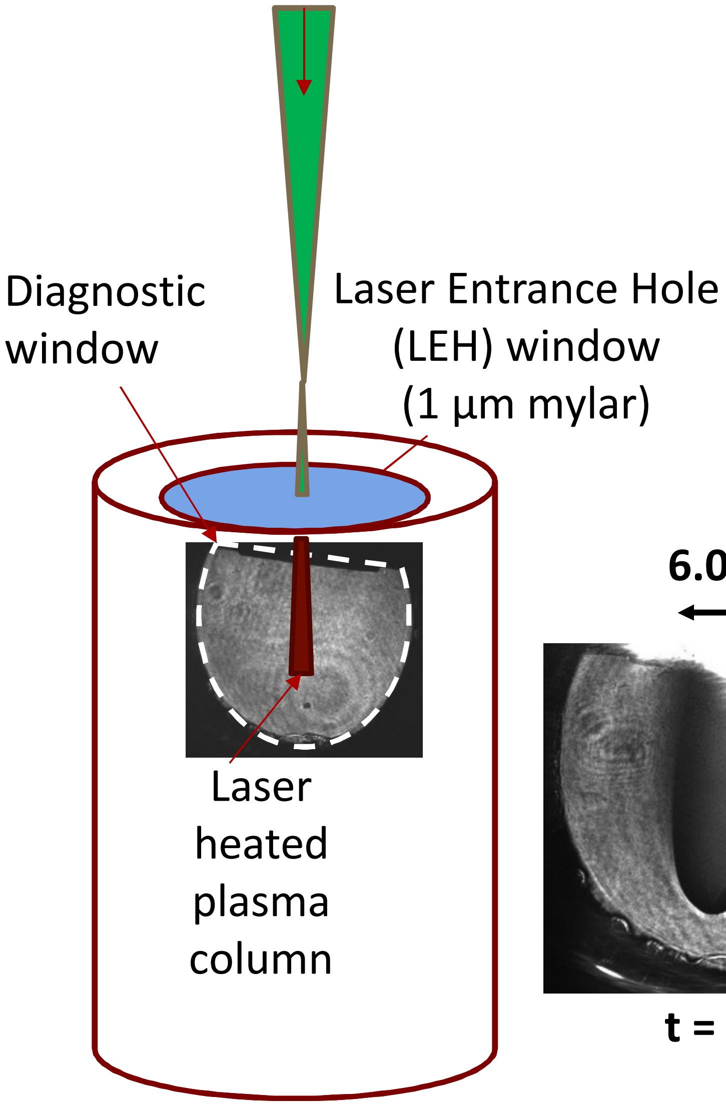
Signal estimate:

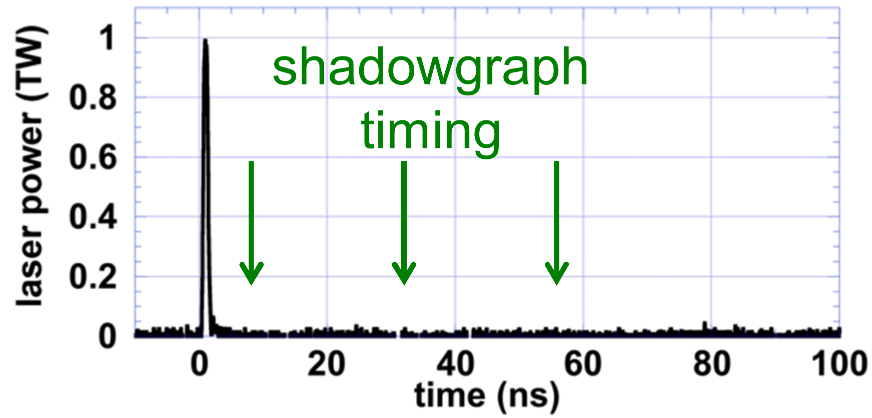
Laser pulse:	0.5ns (pre) + 2ns (main)
Pulse duration behind window:	≈1ns
Ne radiance (300 eV):	2×10^{10} W/cm^2/sr
IP response:	1.8×10^{-4} PSL/phot.
Filter transmission:	0.28

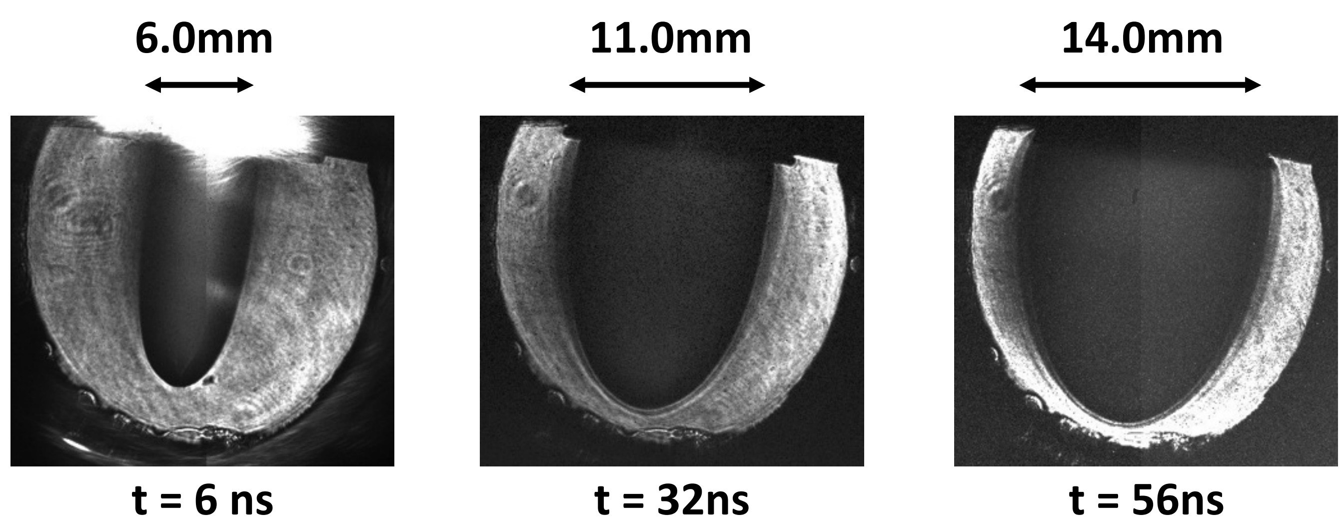
Prediction for IP signal at $kT_e > 200$ eV: **1-2 PSL**

Measurement (corrected for fading): **1.6 PSL**

Laser launches cylindrical blast wave

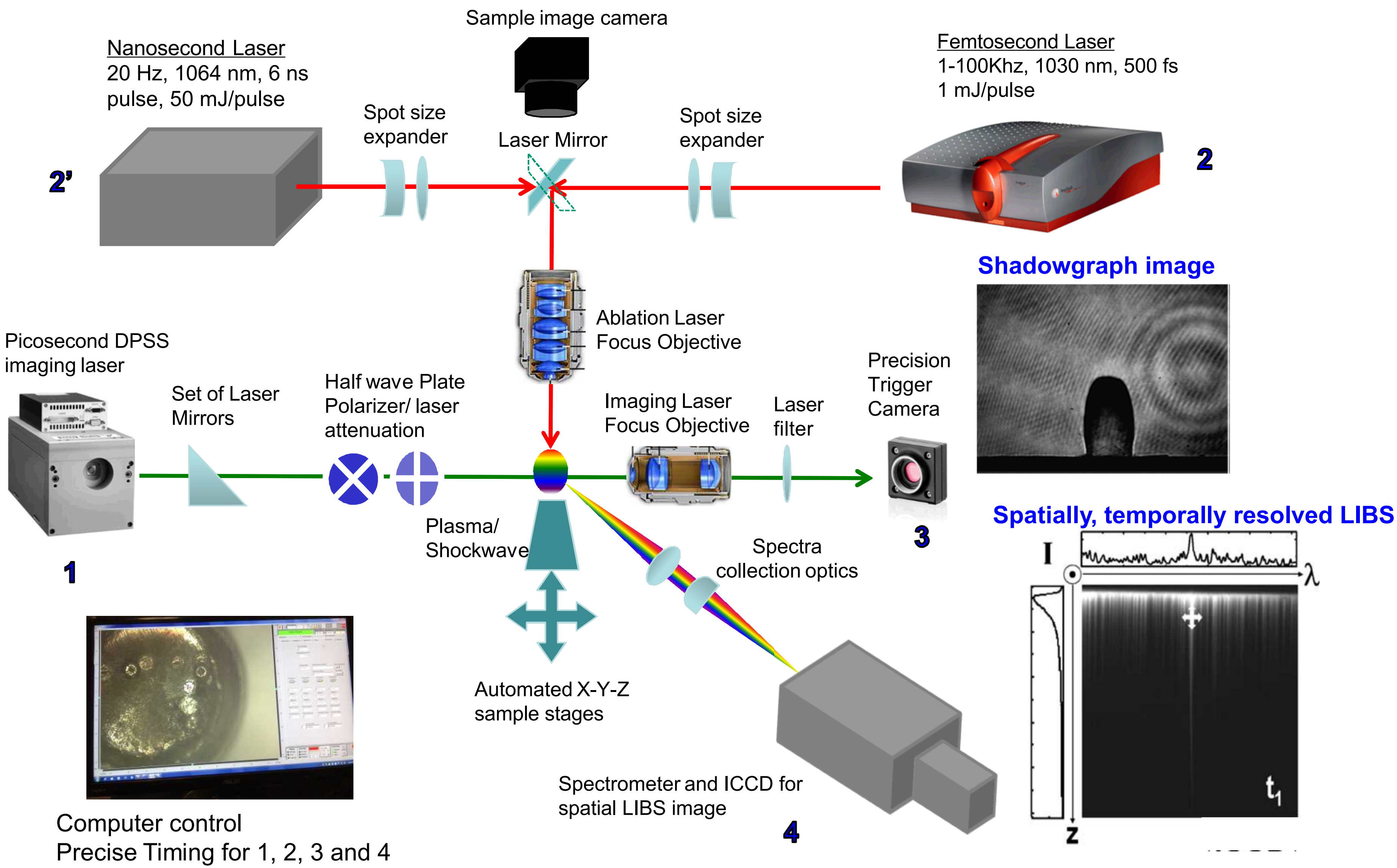




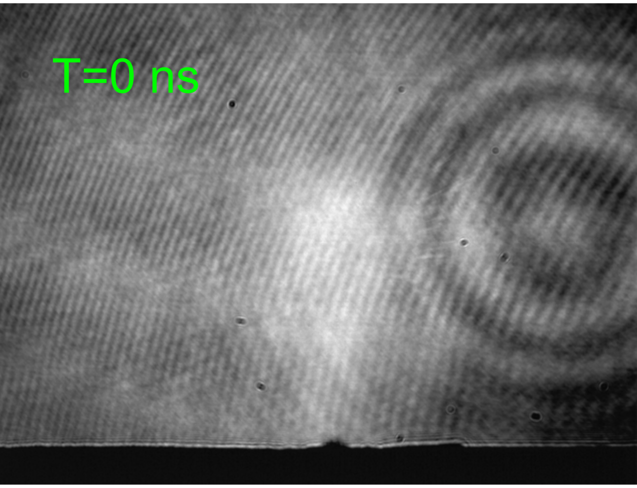


ZBL: 1.8kJ/2ns, 300J prepulse, 1 mm dia., focus at window **Target:** 1 µm-thick Mylar LEH, 247 Torr neon gas fill

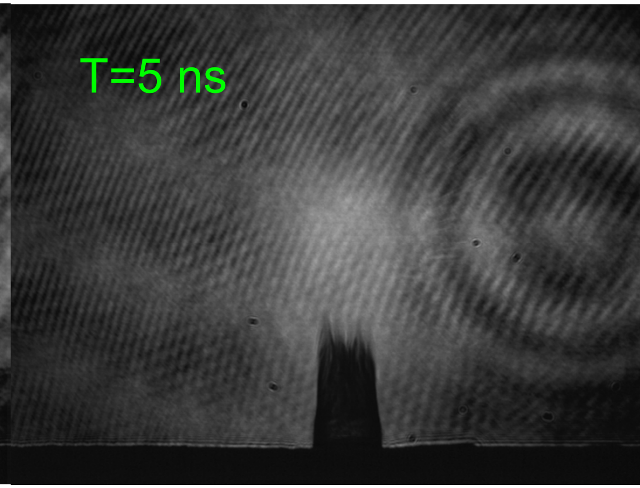
Shadowgraph/LIBS system at SNL



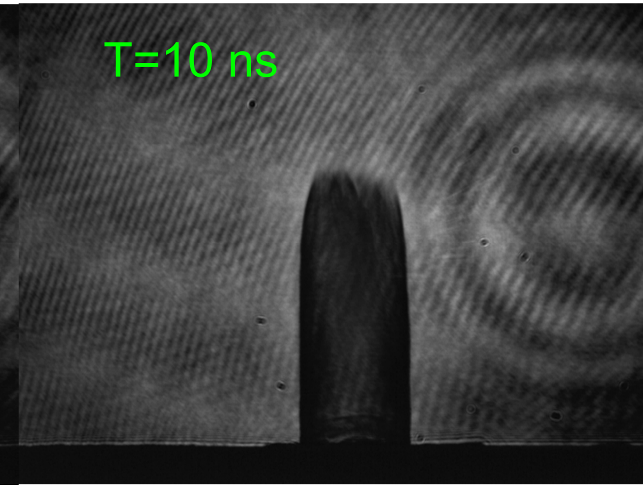
Shadowgraphs of Mg Ablation in Ar



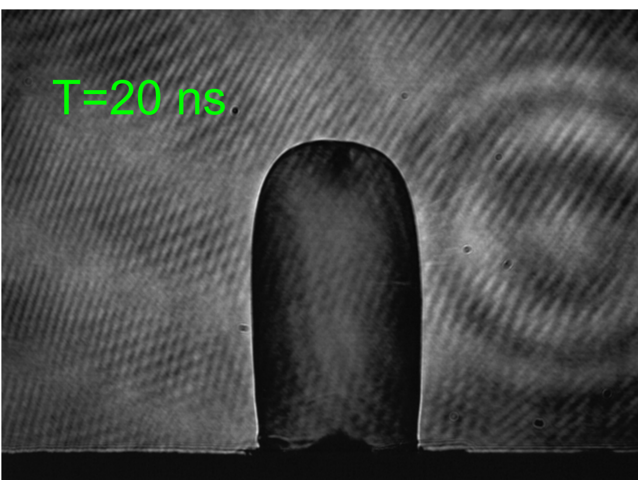
MginAr dt -5ns337shot.png



MginAr dt -1ns325shot.png



MginAr dt 5ns318shot.png



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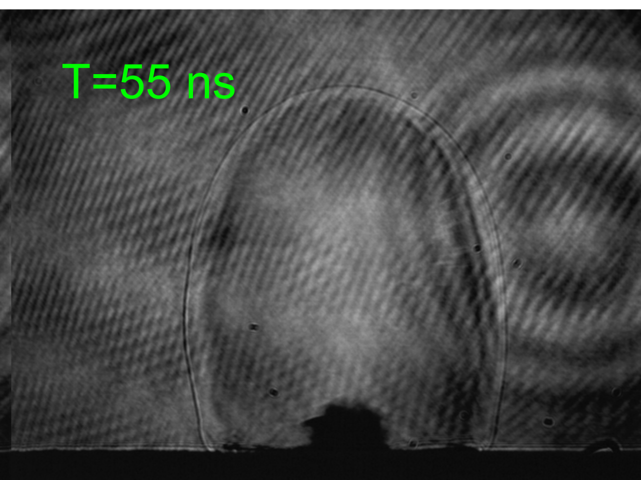
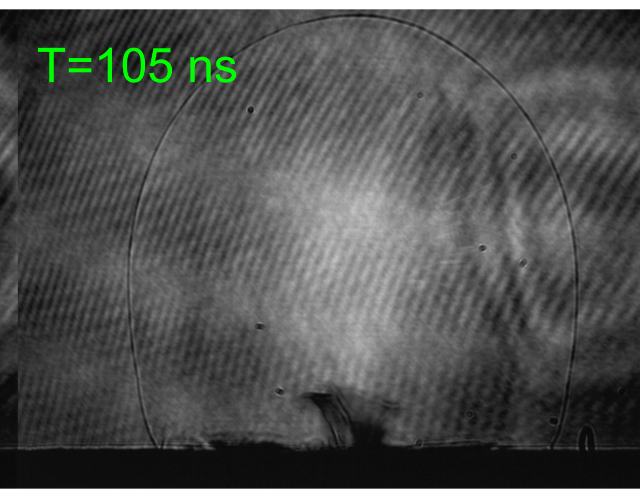
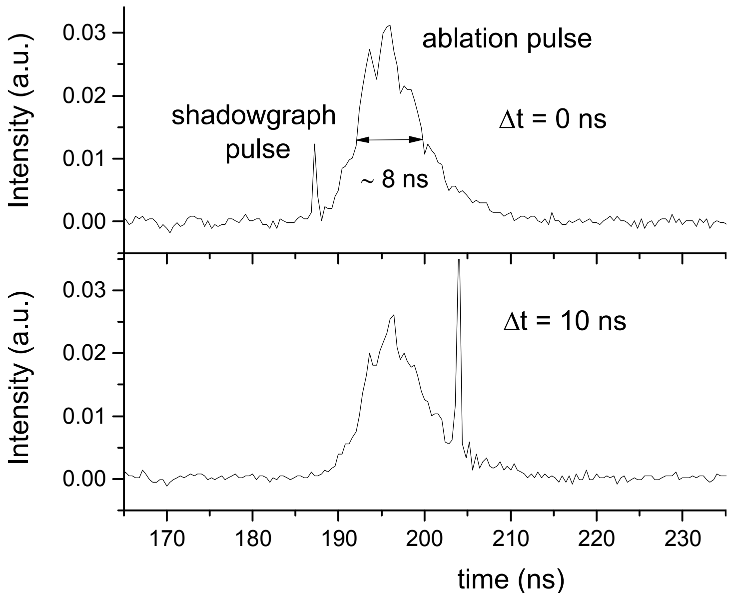


MginAr dt 50ns192shot.png

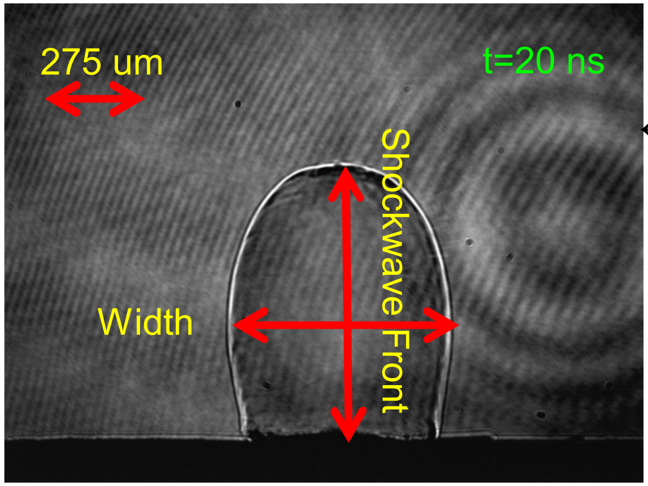


MginAr dt 100ns188shot.png

Shadowgraph imaging



← Shadowgraphs taken at varying delays of probe laser to pump laser for different shots in the same spot



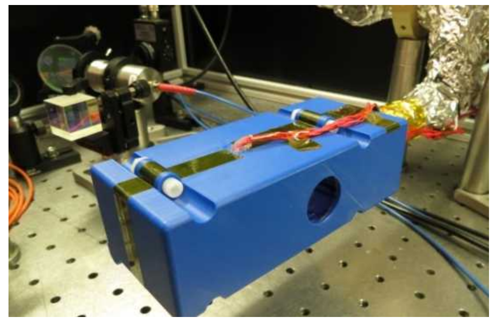
← Measure position of shockwave front and width at each delay time (spatially calibrated images)

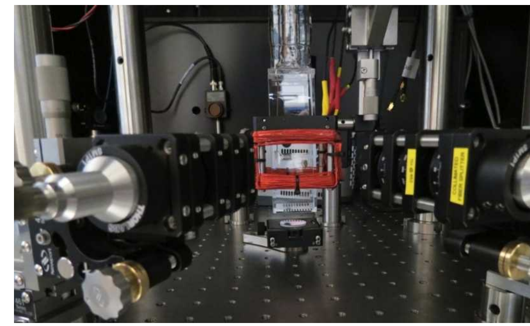
← Stability and repeatability of the shadowgraph taken at same delay of probe laser to pump laser for different shots in the same spot (delay 118 ns for Mg ablation)

Exceptional service in the national interest

Sandia National Laboratories

Funded by DARPA: The views expressed are those of the author(s) and do not reflect the official policy or position of the Department of Defense or the U.S. Government. Distribution "A": Approved for Public Release, Distribution Unlimited



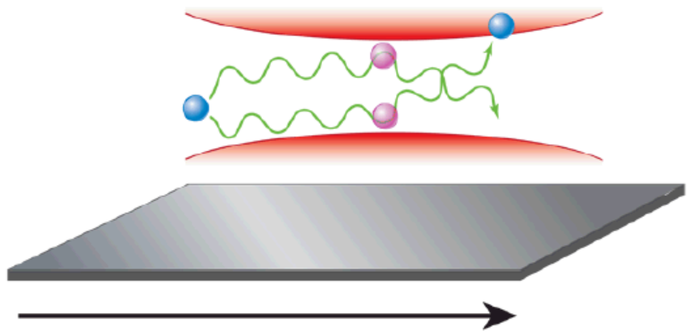


Inertial sensing with atom interferometers

Grant Biedermann

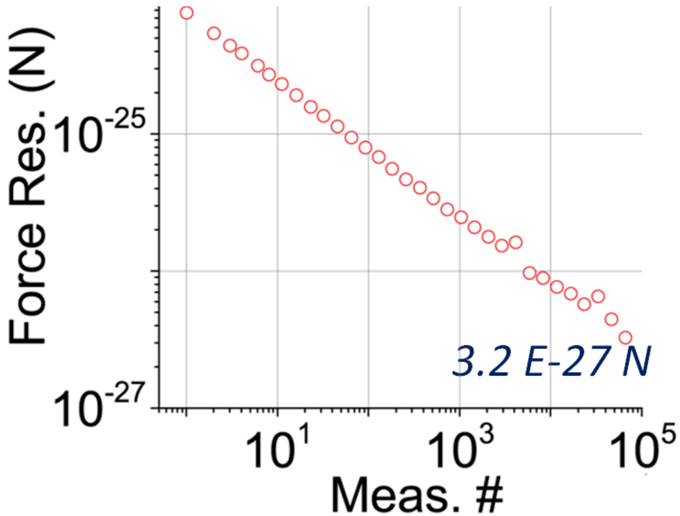
[...] a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin [...] Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Force resolution of a single atom interferometer

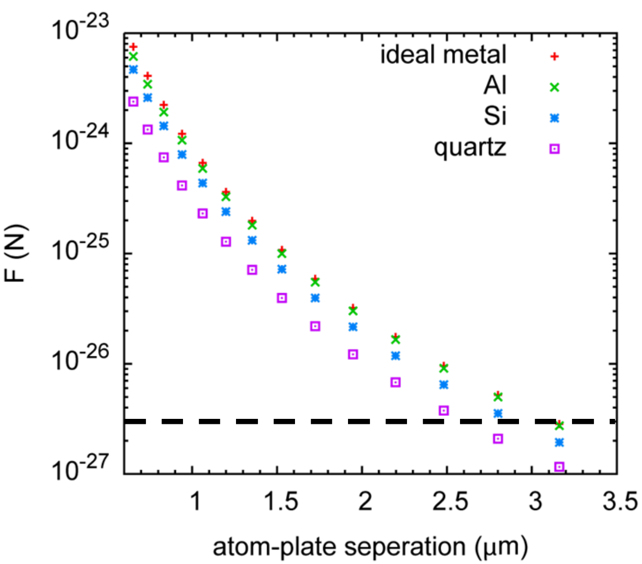


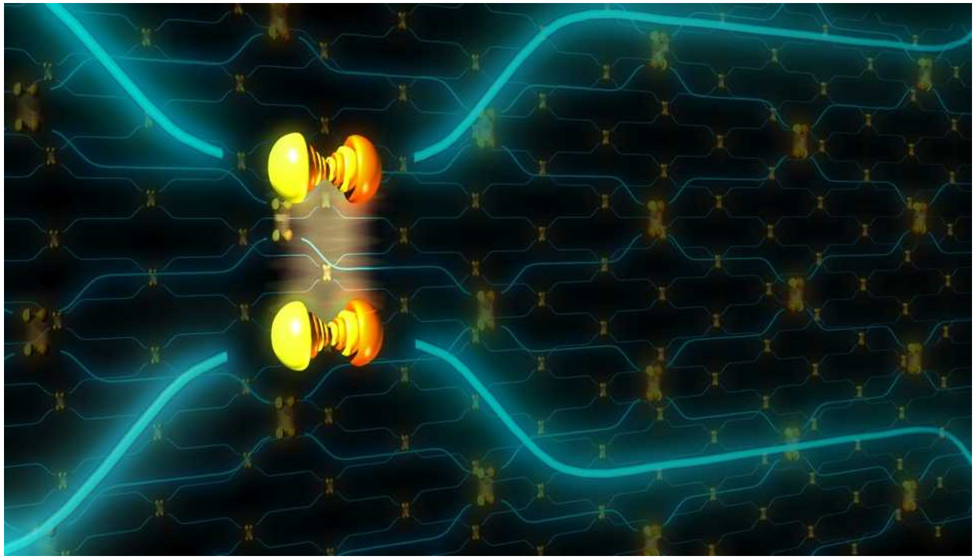
E. Rasel, Physics **5**, 135 (2012)

Parazzoli, et al., Phys. Rev. Lett. **109**, 230401 (2012)



Casimir-Polder force

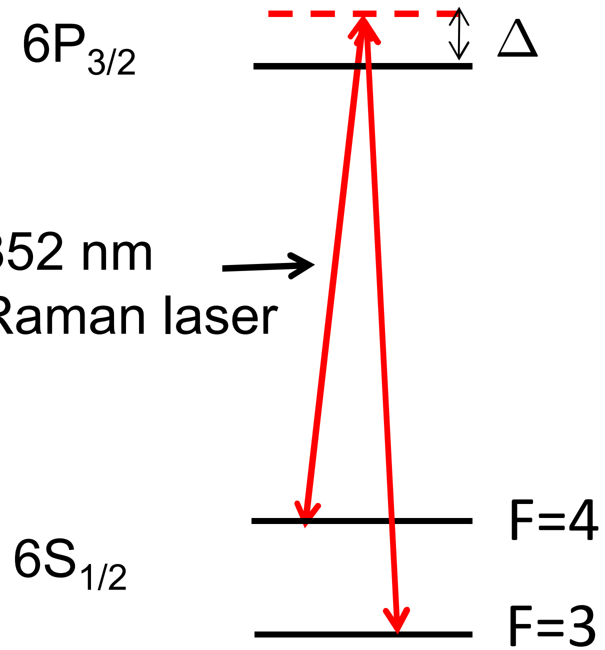




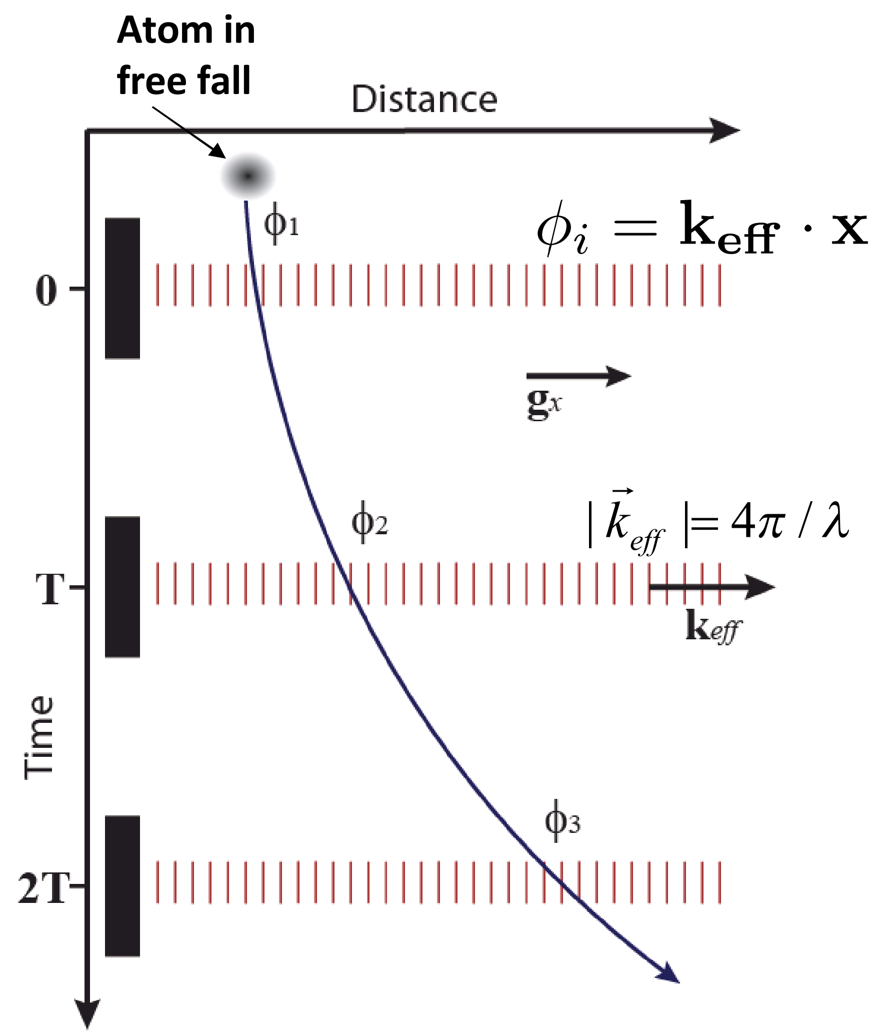
* For cesium 3.2 E-27 N is 1.5 m*g*

Demonstrated entanglement, arXiv:1501.03862

Light-pulse atom interferometry

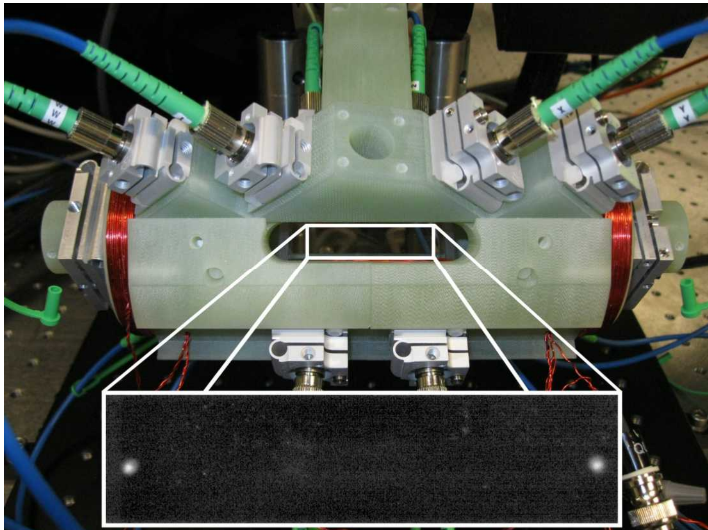


stimulated Raman transition

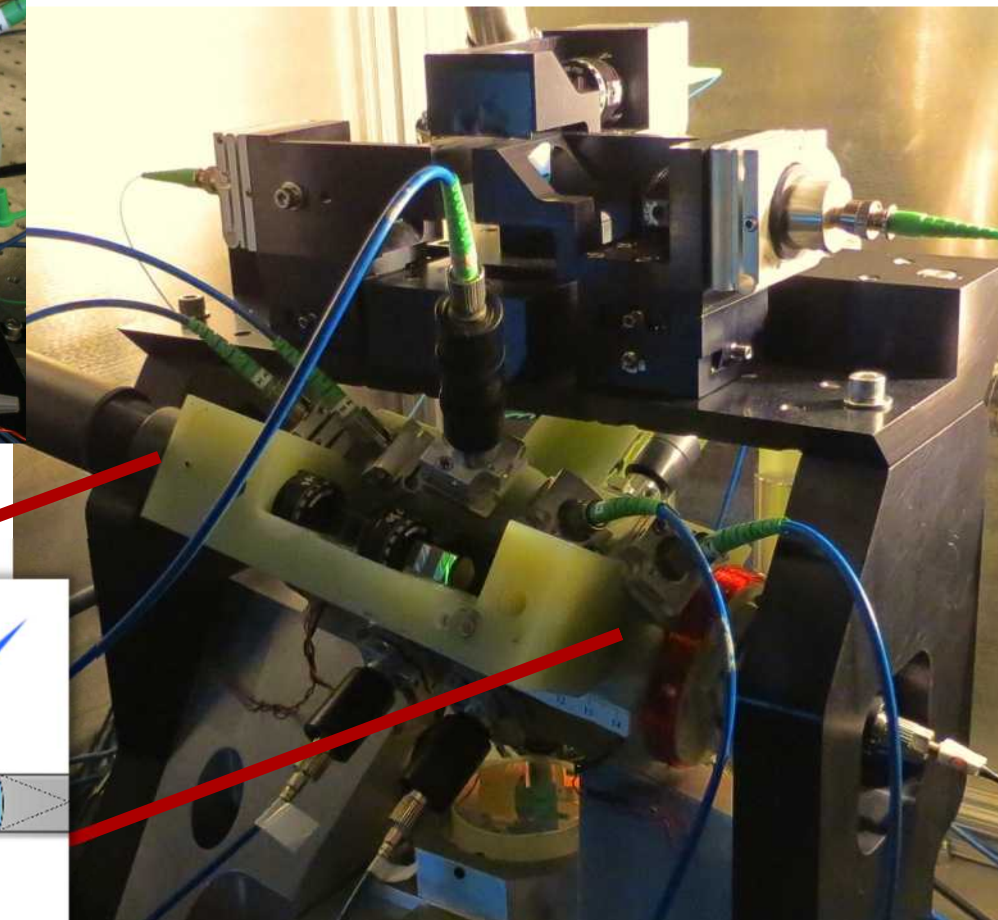


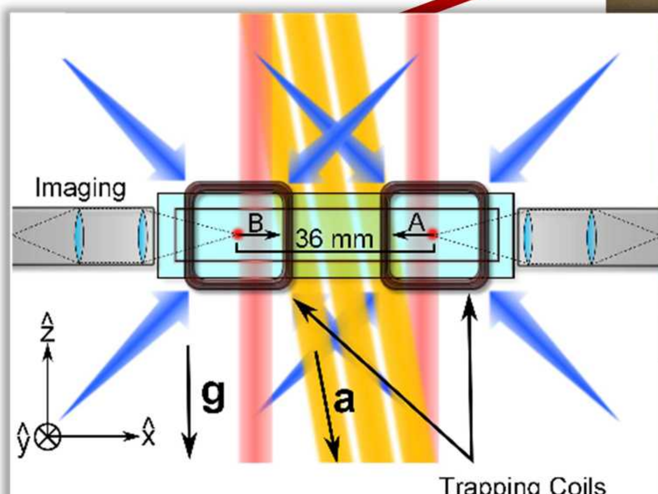
For an atom starting in F=3: $P_{F=4} = \frac{1}{2}(\cos \Delta\phi)$ & $\Delta\phi = \phi_1 - 2\phi_2 + \phi_3$

Experiment platform



Picture of interferometer sensor





Angular acceleration and jerks

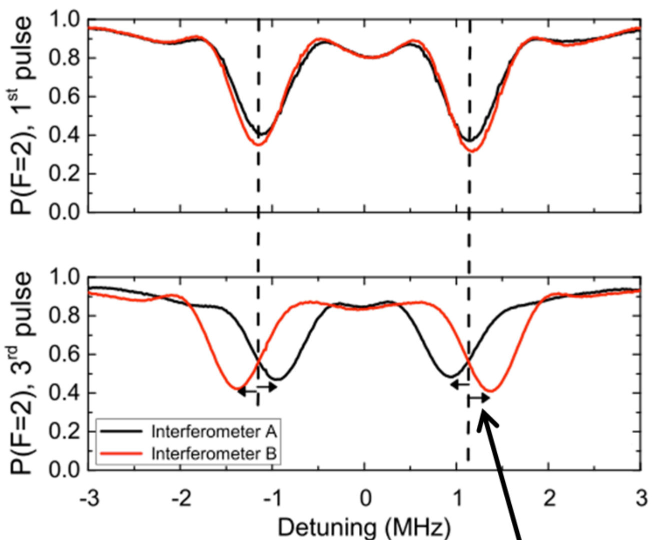
Sandia National Laboratories

Controlling frequency and phase in a dynamic environment

Raman laser frequency scan

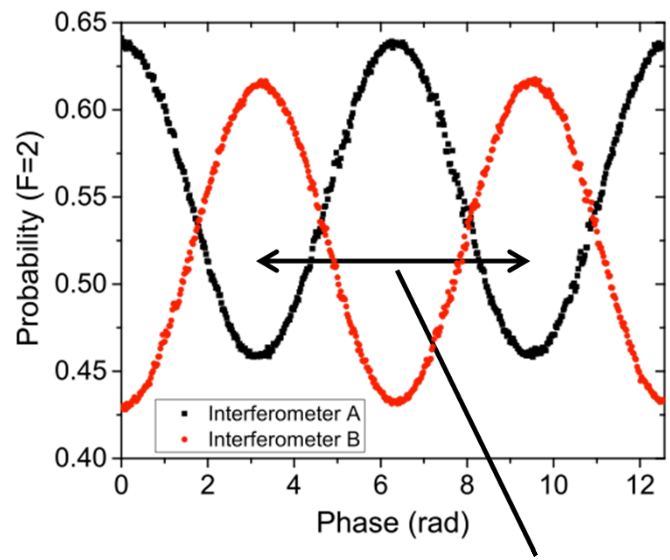
t = 0 ms

t = 10 ms



Significant detuning develops over 10 ms due to gravitationally-driven Doppler shift

Raman laser phase scan



≈ m*g* OR ≈ mrad/s (400 deg/hr)

Small changes in acceleration or rotation during one interferometer cycle cause phase slip

Parametric results of the AlGaInAs quantum-well saturable absorber for use as a passive Q-switch

Daniel A. Bender, Jeffrey G. Cederberg and Gregory A. Hebner

Sandia National Laboratories, Albuquerque, NM USA

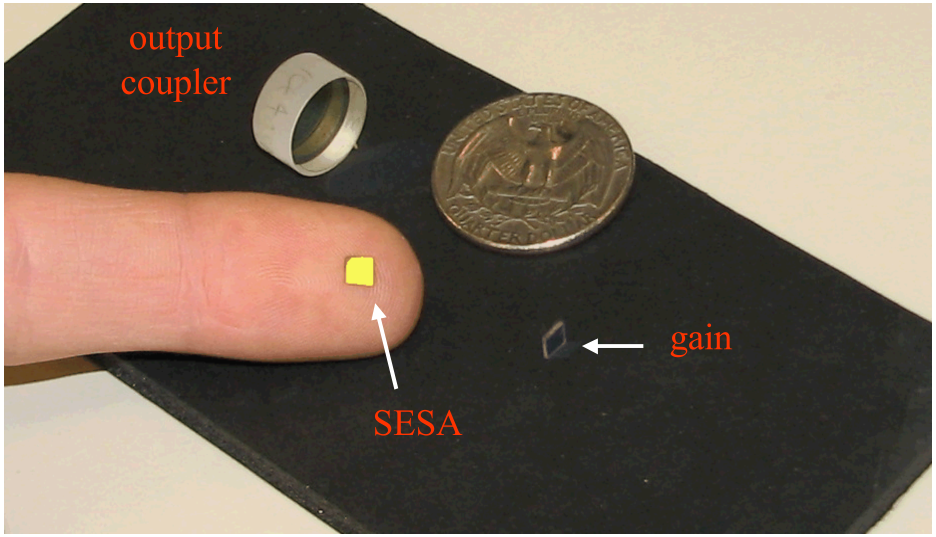
Conference on Lasers and Electro-Optics

May 20, 2010

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

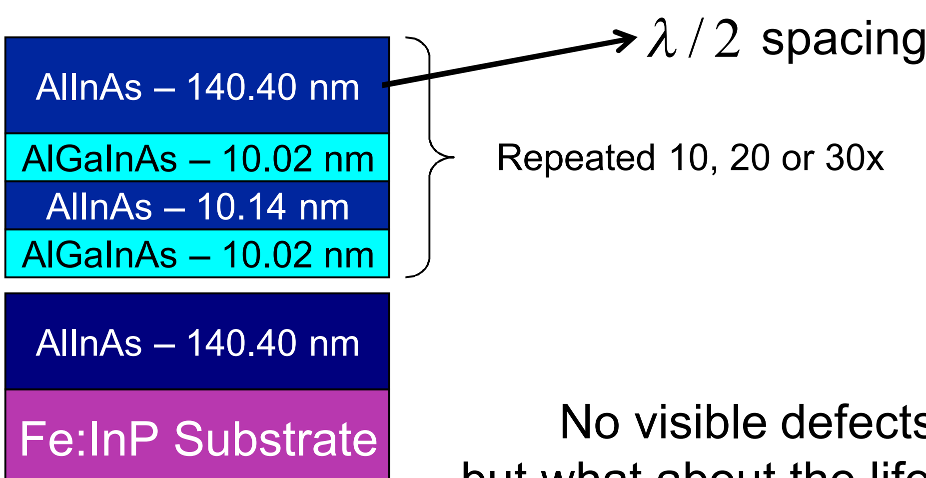
- Characterization of semiconductor saturable absorber (SESA)
  - Growth defects
  - Lifetime
  - Saturation fluence
  - Modulation depth



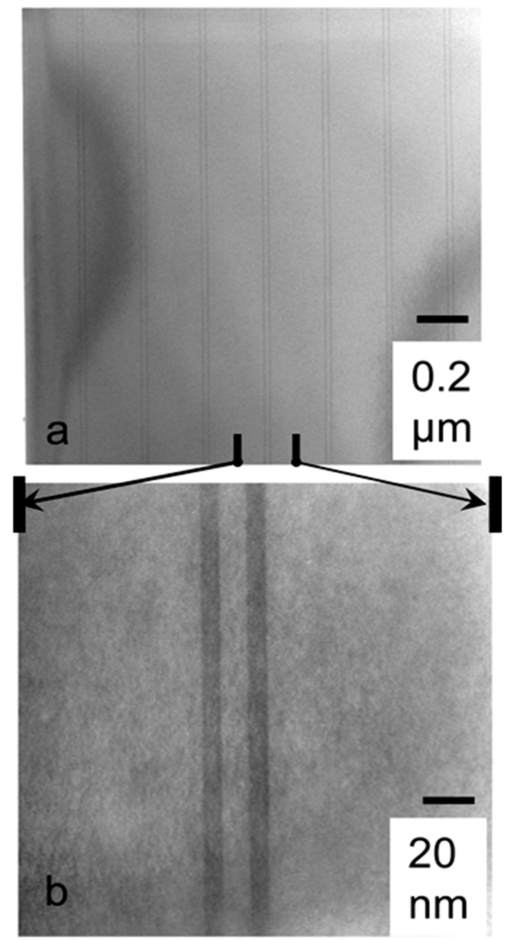
- Laser cavity results
- Laser cavity model

High quality Q-Switch structure

- **AlInAs/AlGaInAs quantum well structure, bandgap = 1064 nm***
- **Latticed matched**
- **Defect-free epitaxy for >6 μm**



Cross-sectional TEM

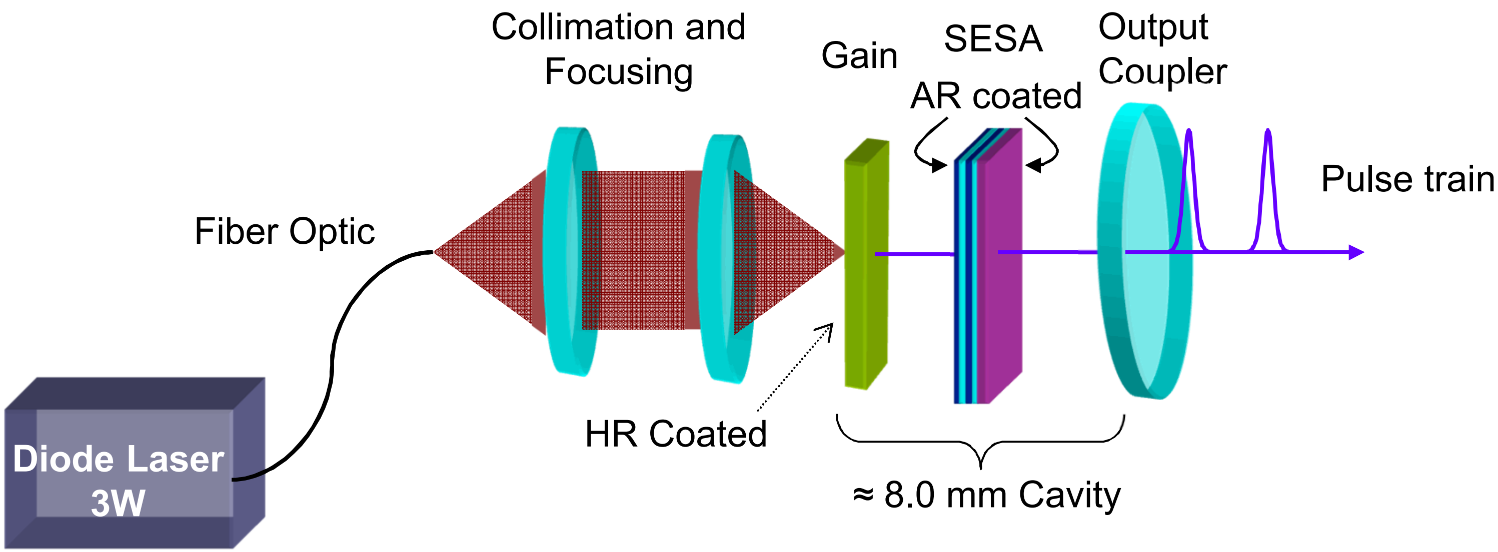


No visible defects,
but what about the lifetime?

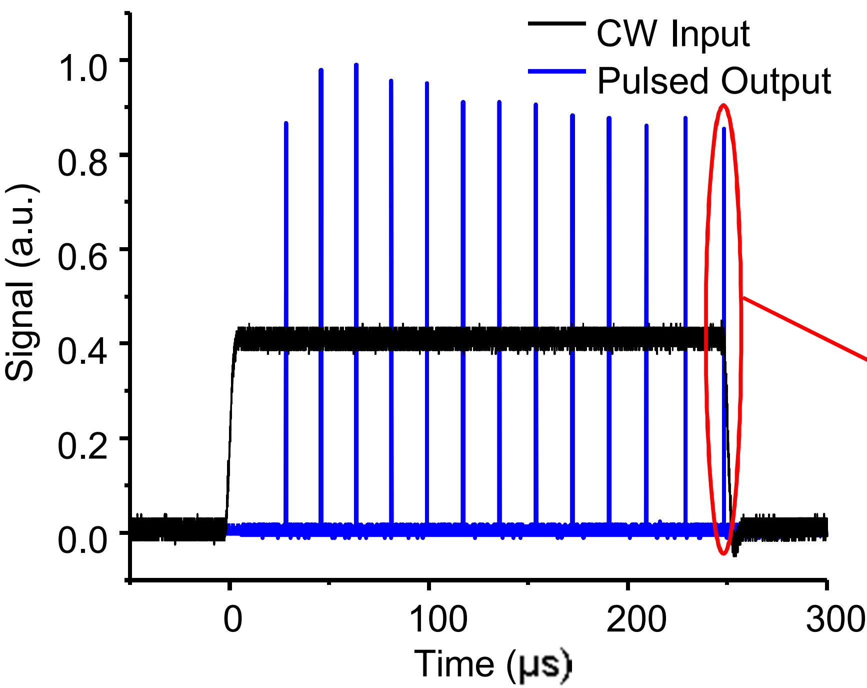
*S. C. Huang, *et. al.*, Opt. Lett., vol. 32, pp. 1480-1482, 2007.

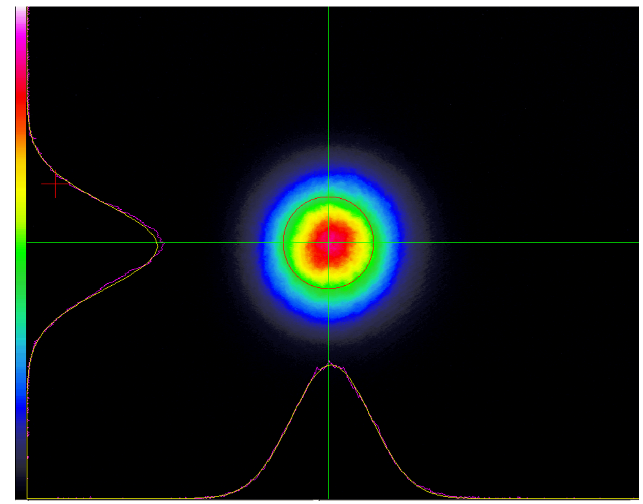
The optical test bed is simple and compact

Cavity Layout:

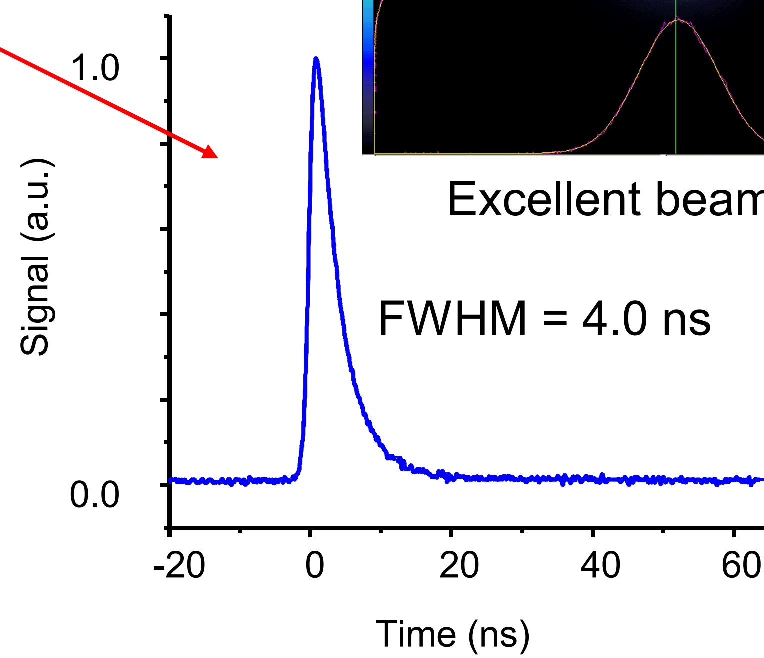


We have successfully produced a passively Q-switch microlaser





Excellent beam quality

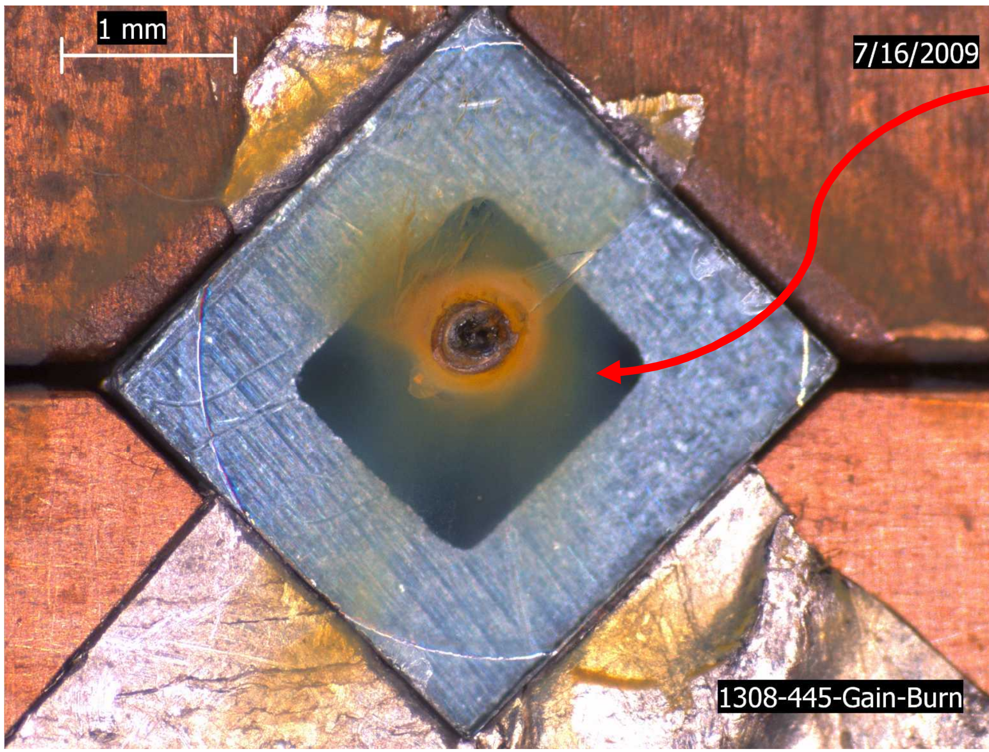


20 QW SESA
ΔT=6%
Rep. rate ≈ 50 kHz

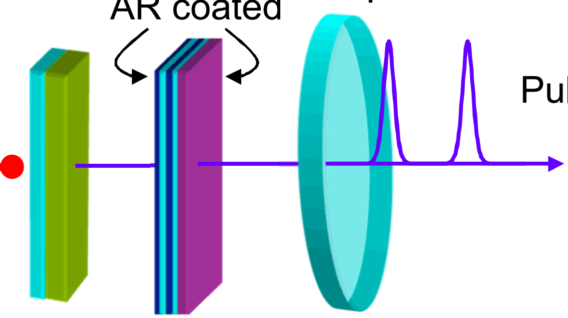
But how robust are they?

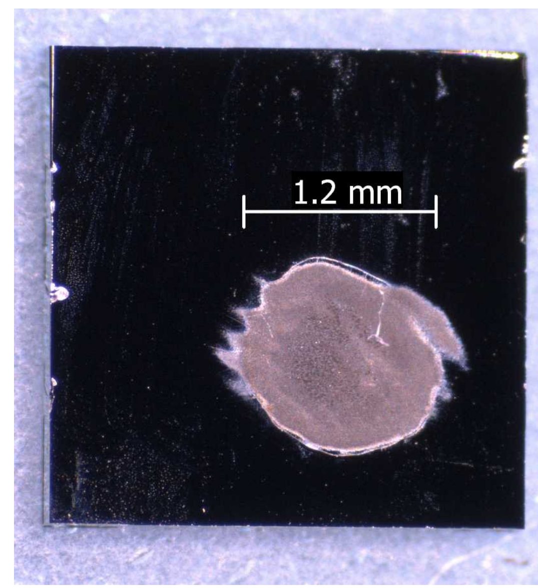
Robust Performance

Gain was burned before SESA was damaged!

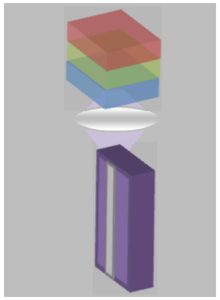


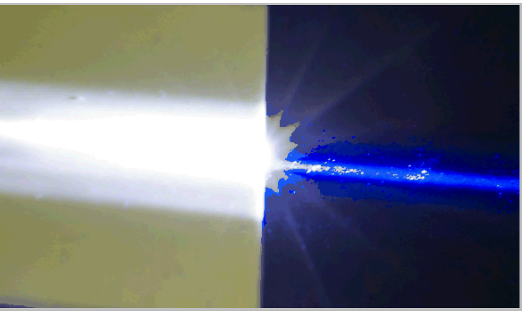
Continuous CW pumping





SESA damage: >8.7 J/cm^2





Sandia National Laboratories

Exceptional service in the national interest

Solid-State Lighting with III-nitride Laser Diodes

Jonathan J. Wierer, Jr. * and Jeffrey Y. Tsao

**jwierer@sandia.gov*

IWN, Wroclaw, Poland 27th August 2014

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

SSLS EFRC

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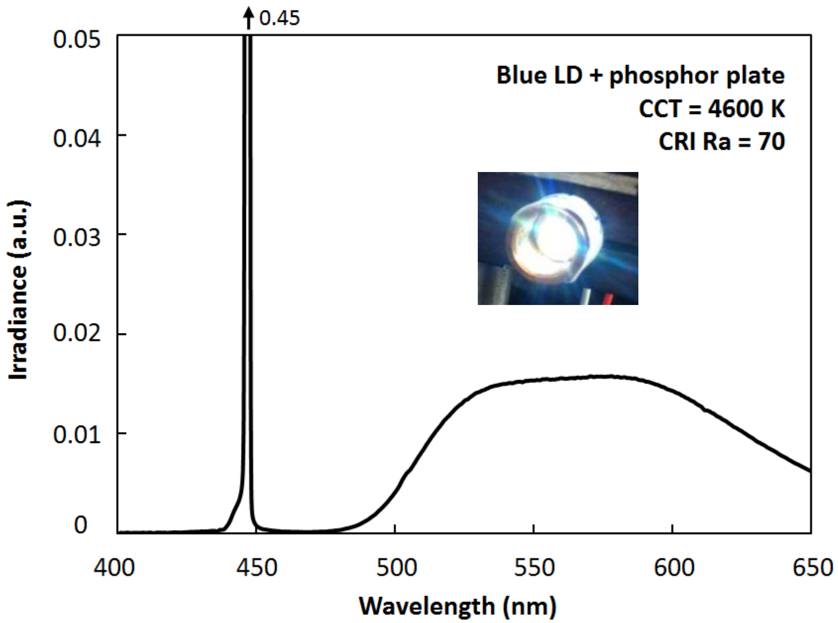
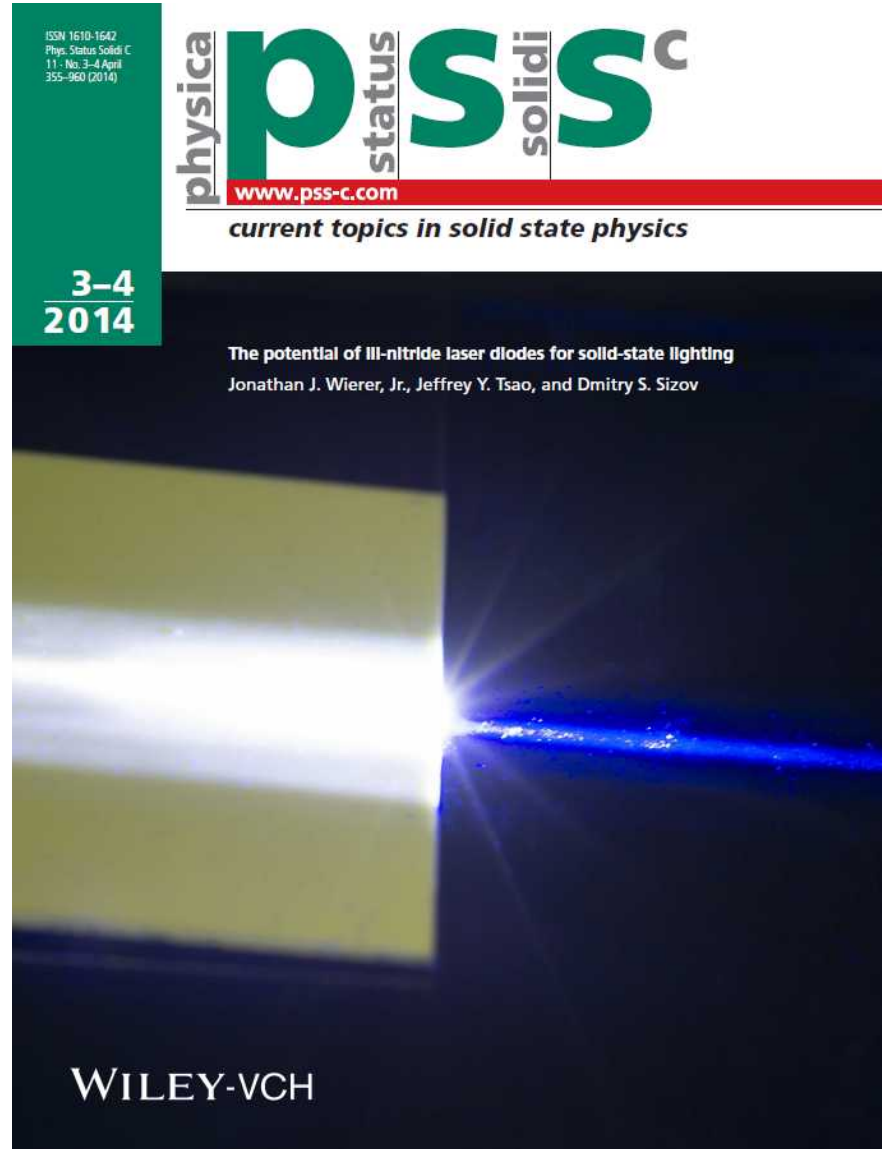
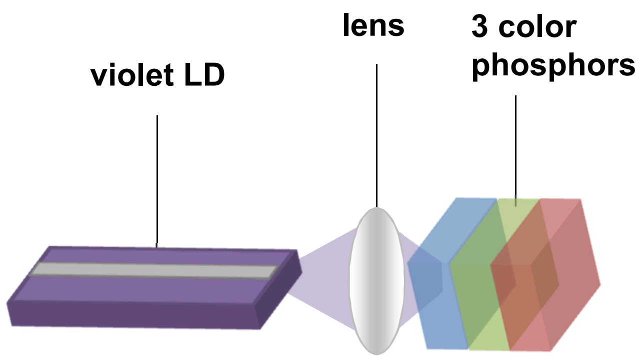
Phosphor converted LD (PC-LD) white

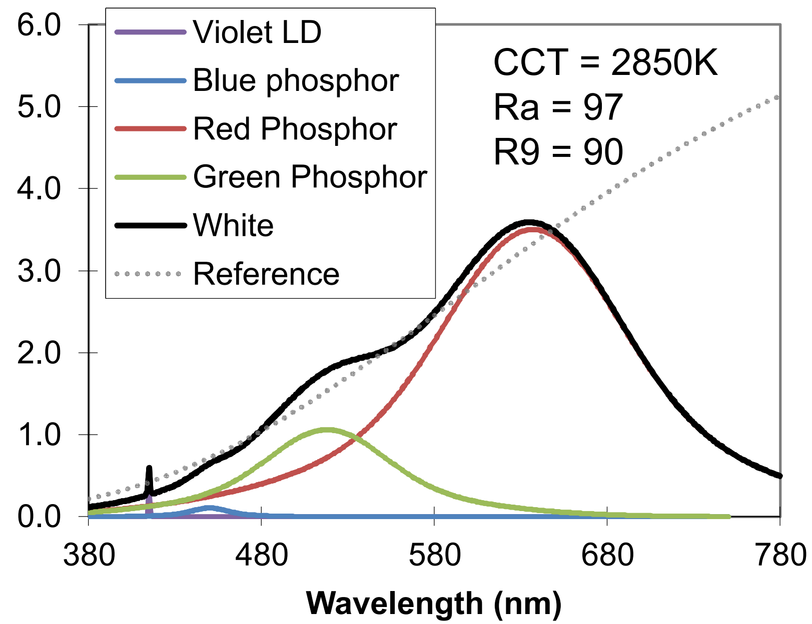




- Commercial blue LD + ceramic phosphor.
- Color temperature and rendering are comparable to PC-LED.
- Blue LDs can be used to produce white light.

Violet pumped PC-LD





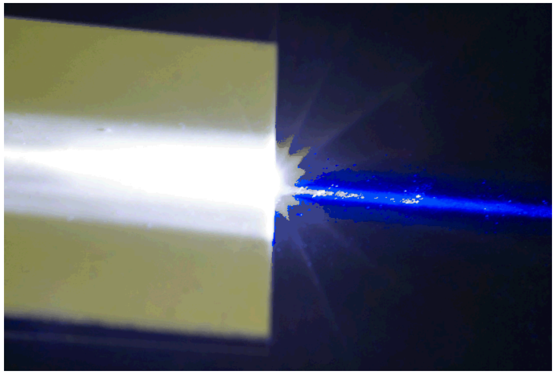
- Simulation of 415nm LD pumping 3 phosphors
  - 450 nm, 518 nm, and 637 nm
- Just like violet PC-LED solution, the violet PC-LD could also produce high color rending white light.
- Phosphor converted solutions cannot chromaticity tune.

Conclusion

- LDs are not affected by efficiency droop after threshold.
  - LDs have higher efficiencies at higher input powers.
  - Modeling suggests LD peak efficiency could match LEDs.
- PC-LDs produce white light with color rendering and temperature similar to LEDs.
- LDs white sources have higher illuminance.

Work was supported by Sandia's Solid-State-Lighting Science Energy Frontier Research Center, funded by the U.S. Department of Energy, Office of Basic Energy Sciences.

Thanks to D. Sizov at Corning Inc. for his contribution on LD efficiency modeling.



Conclusion – lasers' wide range of uses

Sandia National Laboratories

- More than 1400 lasers are used across Sandia
  - Materials Characterization
  - Identification and scanning (a,b,c especially)
  - Non-perturbing sampling
  - Fine motion measurement/Control
  - Lighting of the future
- Scaling does matter
  - Some are chip scale
  - Some are large enough to require a large trailer
  - Some take up a whole building
- Location matters
  - Some are in a lab
  - Some are outside, fixed locations
  - Some are outside, mobile

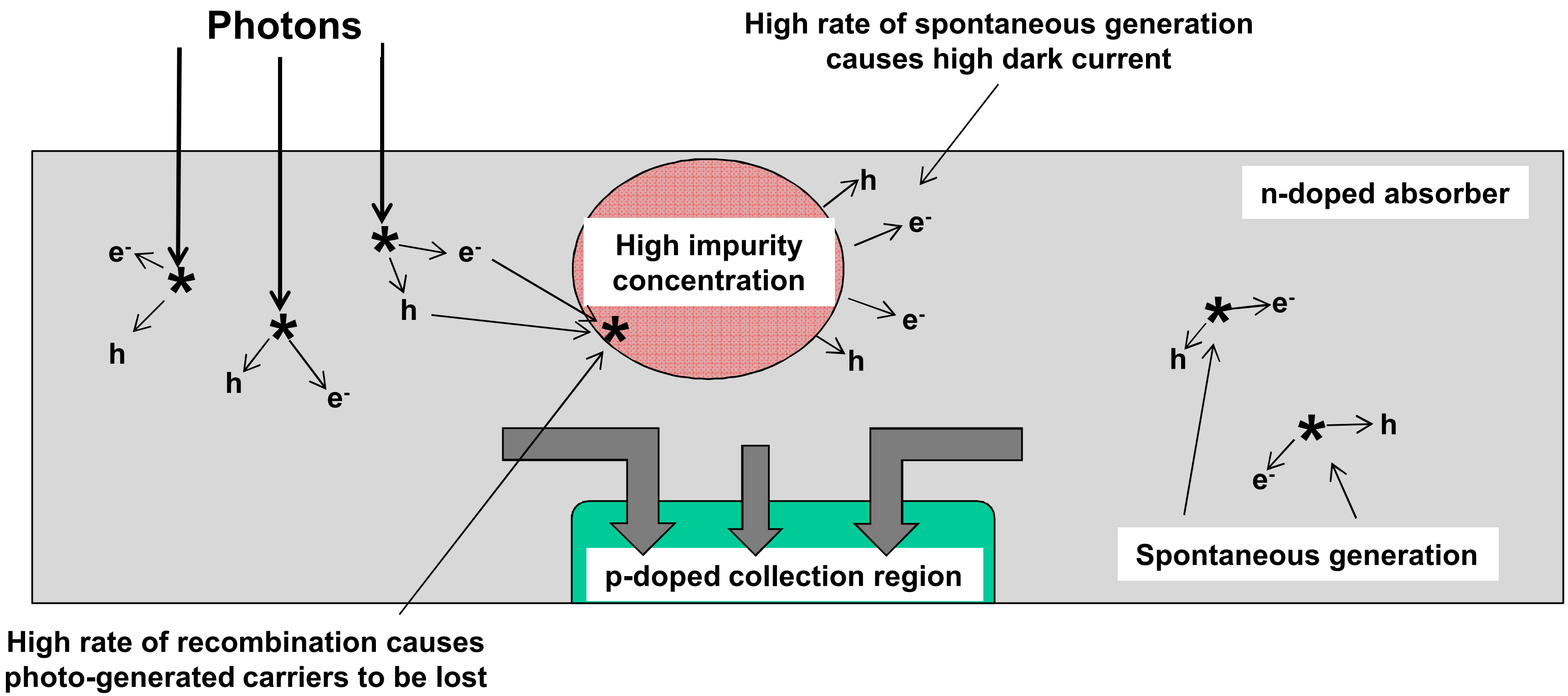
Thanks for listening

- And thanks to so many at Sandia
  - Mendy Brown
  - Alice Sobczak
  - Randy Schmitt
  - Shane Sickafoose
  - Eric Shaner
  - Ben Olsen
  - Olga Spahn
  - Matt Hopkins
  - Grant Biederman
  - Daniel Bender
  - John Wierer
  - …and to the other 12,500+ folks who make Sandia such a treasured place to work

Questions?

Backup Slides

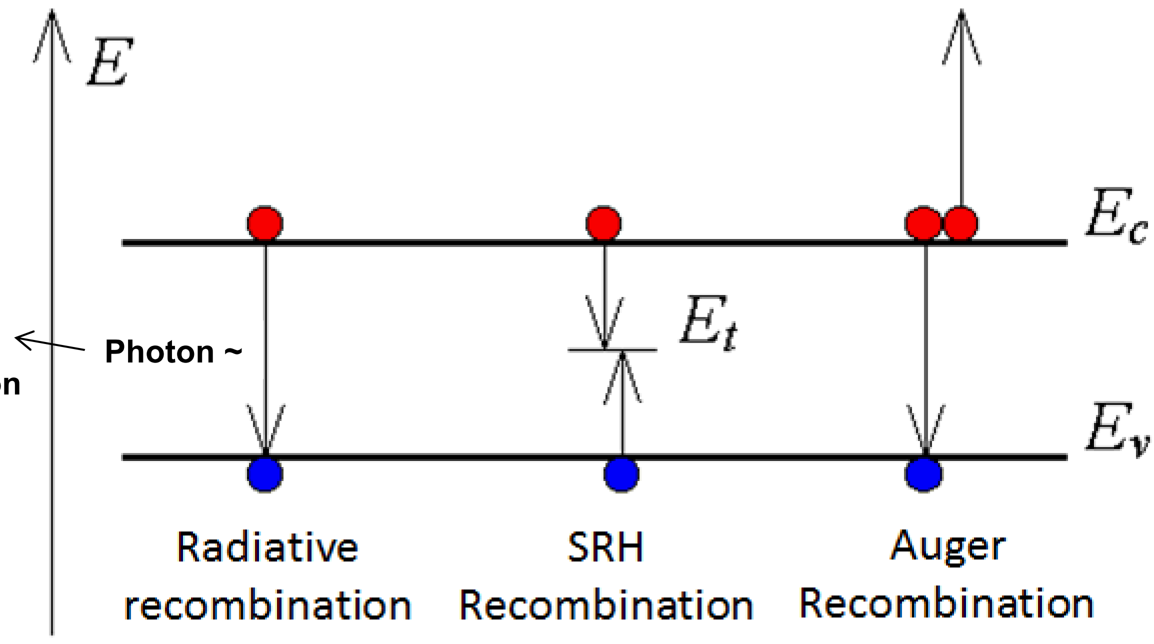
Carrier generation/recombination in a photo-sensitive device



- Carriers generated from photons that are collected are the signal we want
- Carriers spontaneously generated that are collected are dark current
- Carriers generated from photons that recombine contribute to reduced sensitivity

Semiconductor carrier recombination mechanisms

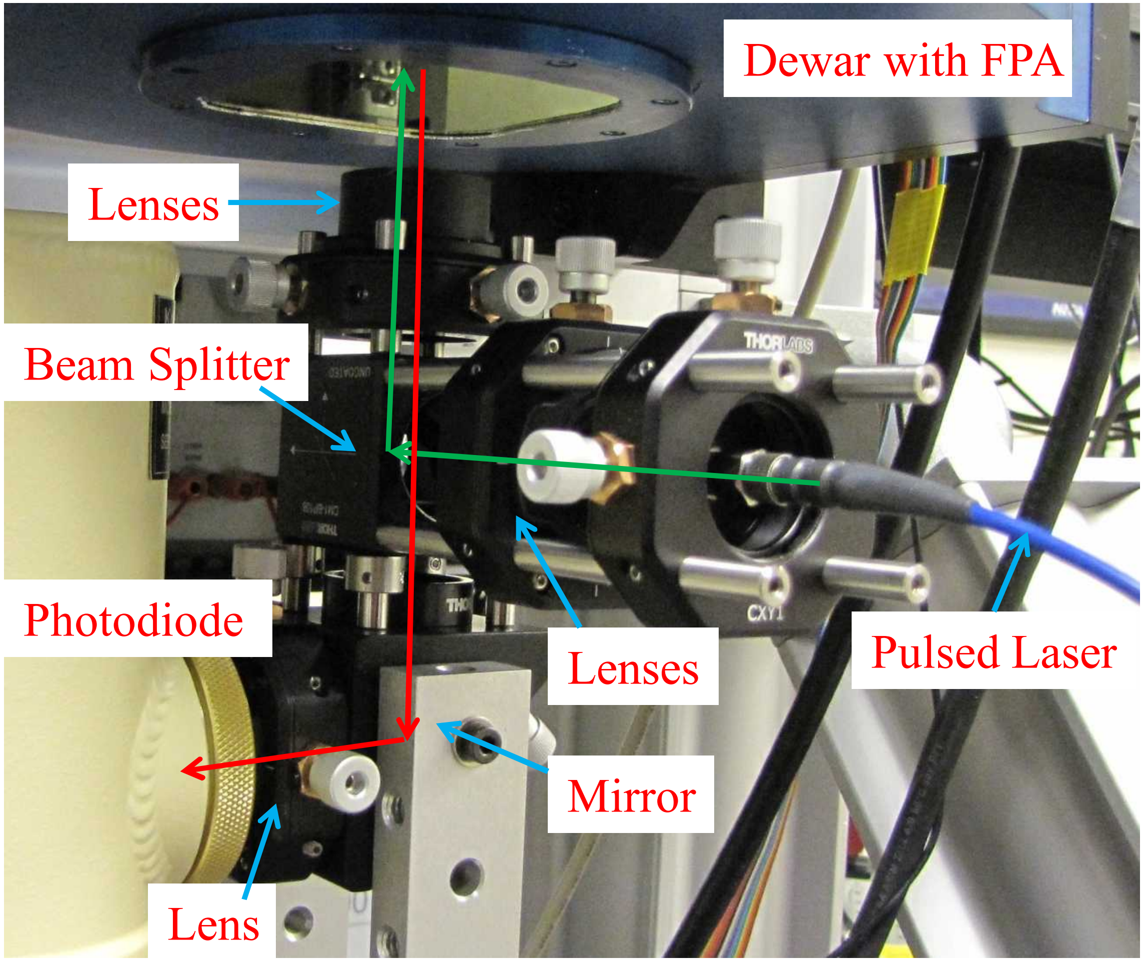
Opportunity to detect photons produced by radiative recombination



- Radiative and auger recombination rates are fixed for a given material composition
- SRH recombination occurs because impurities introduce energy states within the band gap that provide a path for carriers to recombine.
    - The rate varies depending on the impurity concentration(s)

Picture of measurement station

8mm thick silicon window



Kolmar 1mm diameter MCT photodiode

Ekspla OPO laser, tunable from 2500-4450nm

Newport XMS and GTS series stages

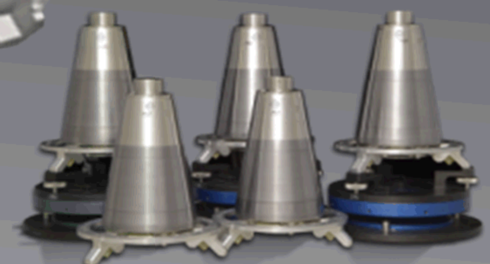
Sandia's Current Nuclear Weapons Activities

Sandia National Laboratories

Warhead Systems Engineering and Integration

Design Agency for Nonnuclear Components

Gas Transfer systems



Arming, fuzing, and firing systems

Safety systems

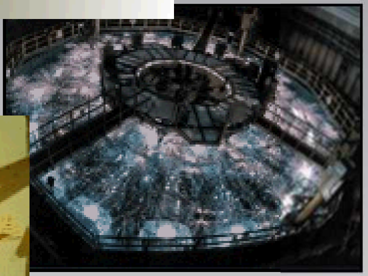
An extensive suite of multi-disciplinary capabilities are required for Design, Qualification, Production, Surveillance, Experimentation / Computation

MESA Microelectronics

Neutron generators

Production Agency

Major Environmental Test Facilities and Diagnostics



Z Machine

Light Initiated High Explosive

Annular core research reactor

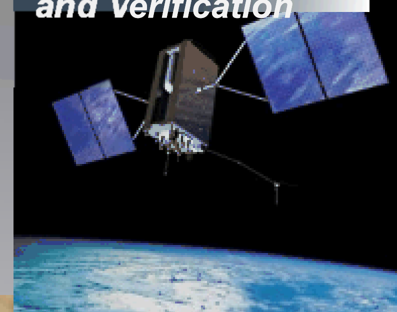
Defense Systems & Assessments Programs

Sandia National Laboratories

Information Operations

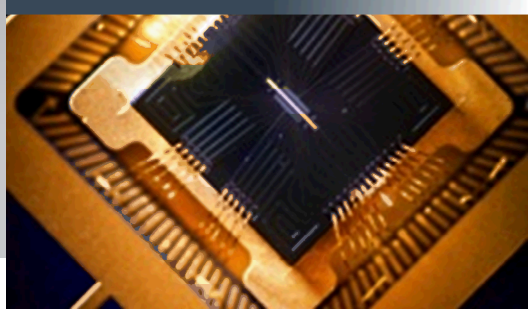
Surveillance & Reconnaissance

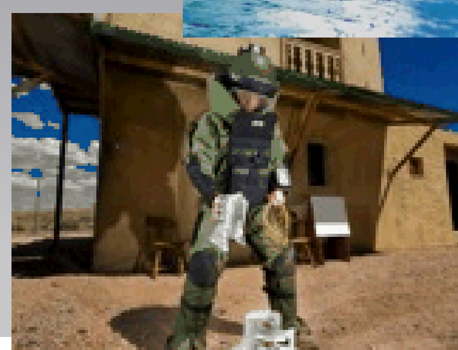
Remote Sensing and Verification



Space Mission

Science & Technology Products





Proliferation Assessment

Integrated Military Systems

UUR

Energy & Climate

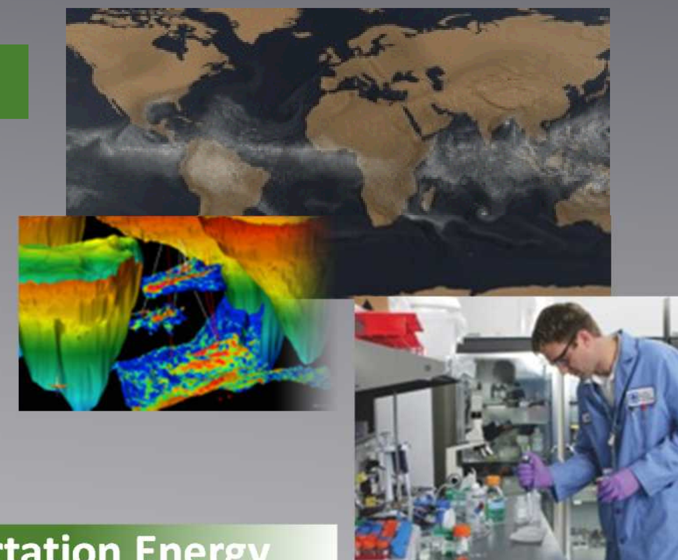
Sandia National Laboratories

Energy Research

ARPAe, BES Chem Sciences, ASCR, CINT, Geo Bio Science, BES Material Science

Climate & Environment

Measurement & Modeling, Carbon Management, Water & Environment, and Biofuels



Nuclear Energy & Fuel Cycle

Commercial Nuclear Power & Fuel, Nuclear Energy Safety & Security, DOE Managed Nuclear Waste Disposal

Renewable Systems & Energy Infrastructure

Renewable Energy, Energy Efficiency,

Grid and Storage Systems

Transportation Energy & Systems

Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology

International, Homeland, & Nuclear Security

Global Security

WMD Counterterrorism and Response

Homeland Security Programs

Cyber and Infrastructure Security

Homeland Defense and Force Protection

Strategic Plan

Sandia National Laboratories

Strategic Objectives

- Deliver with excellence on our commitments to the unique nuclear weapons mission
- Amplify our national security impact
- Lead the Complex as a model 21st century government-owned contractor-operated national laboratory
- Excel in the practice of engineering
- Commit to a learning, inclusive, and engaging environment for our people

Three 1118 business thrust areas

- I. Laser Remote Sensing (LRS)

  Field Testing at long range or lab testing at short range
  esp. chem and bio

- II. IR Detector Physics (IRD)

  Design & Fab the chip scale microelectronic Sources/Sensors

- III. Low Energy Plasma Physics (LEPP)

  Characterize, understand, & predict arcs, breakdown, plasmas
  via non-perturbing laser sensing

All thrusts are related to remote sensing as either

Sources or **Sensors**