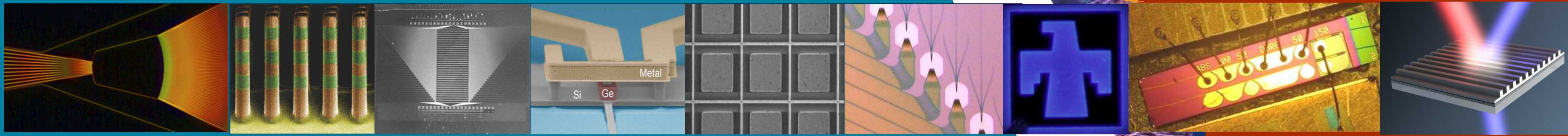
SAND2019-11775C

Exceptional service in the national interest

2019 IEEE Photonics Conference

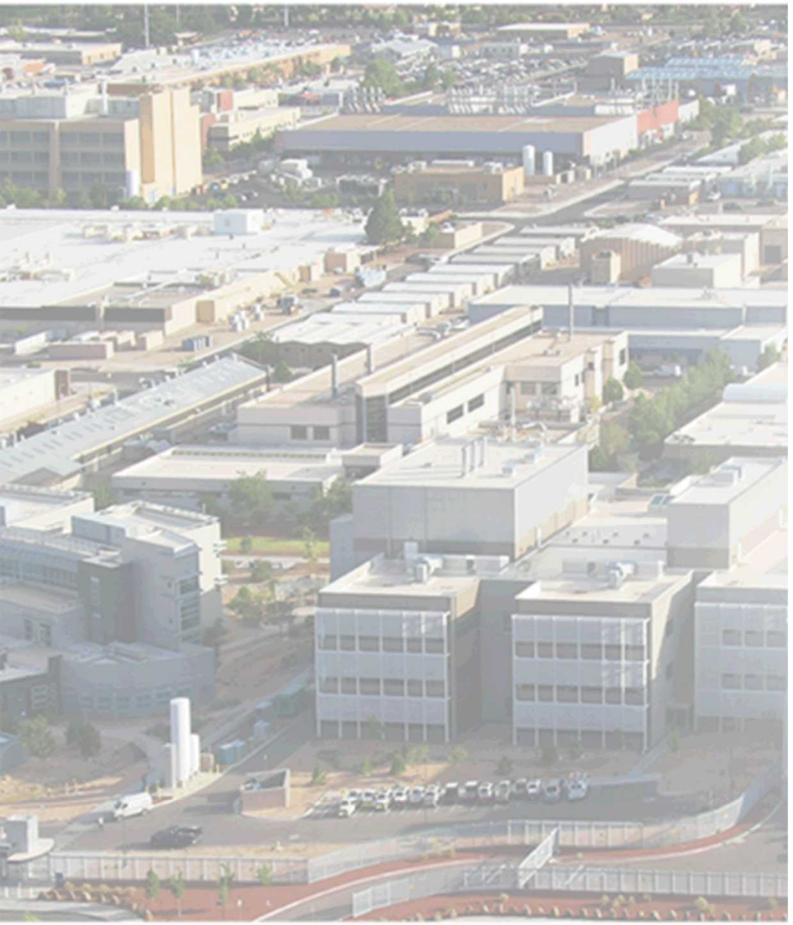


Collaborating with Sandia's National Security Photonics Center

Rick McCormick, Senior Manager, Advanced Semiconductor Technologies

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND2019-5161 C

SANDIA HAS FIVE
PROGRAM PORTF



SANDIA HAS FACILITIES ACROSS THE NATION

Activity locations

- Kauai, Hawaii
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Tonopah, Nevada

Main sites

- Albuquerque, New Mexico
- Livermore, California

SANDIA's MESA COMPLEX

MESA= Microsystems Engineering, Science and Applications

Co-jointed Fab Facility

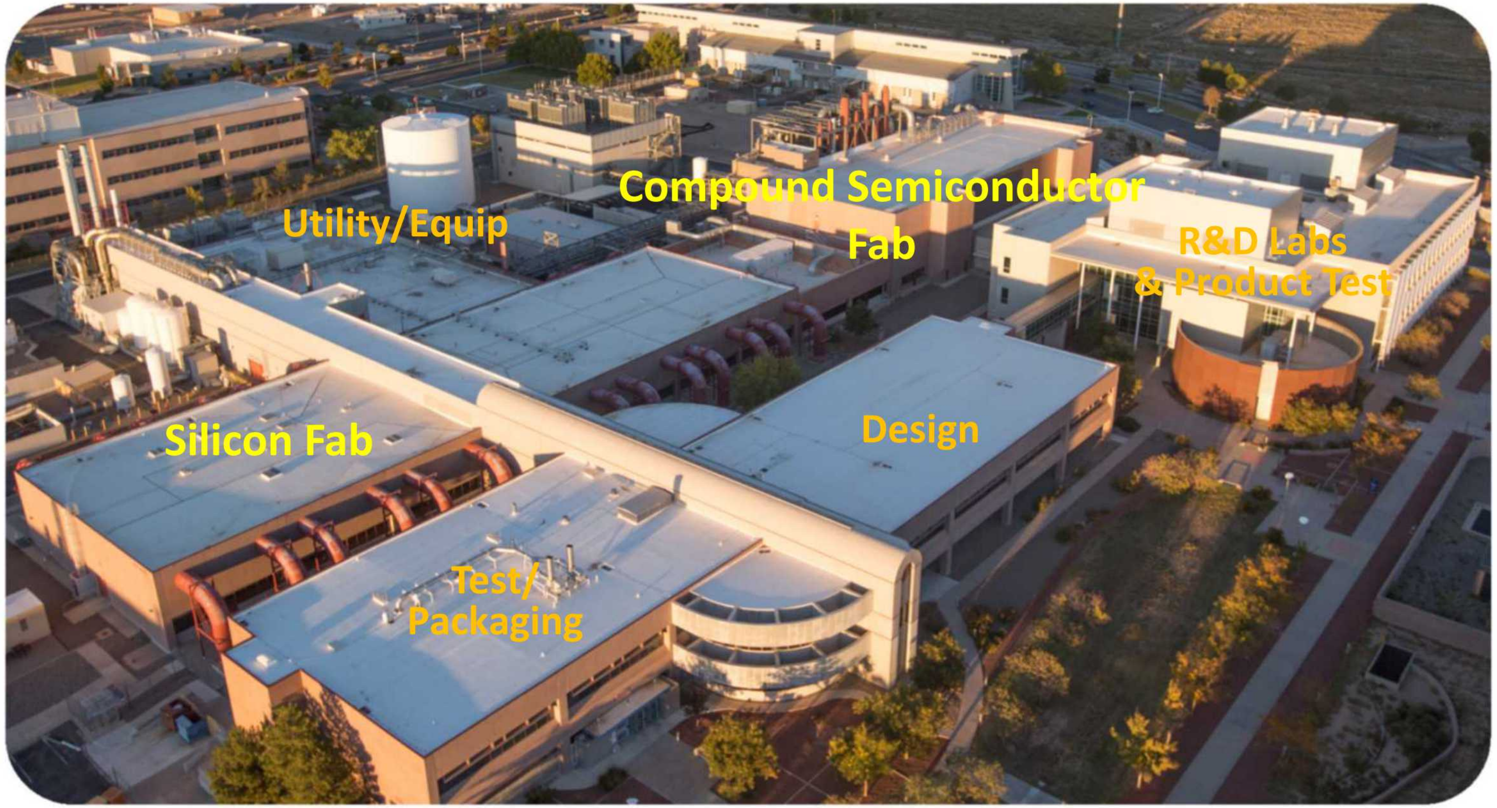
- Silicon Fab
- Compound Semiconductor Fab

Charter:

- design, develop, fabricate, qualify, and produce at low-volume for DOE applications
- conduct leading edge research

Currently dozens of products:

- ASICs, III-V SSICs, MEMS, FPAs, RFICs, Optoelectronics



Co-located R&D and Production

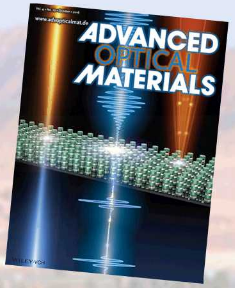
SANDIA's NATIONAL SECURITY PHOTONICS CENTER

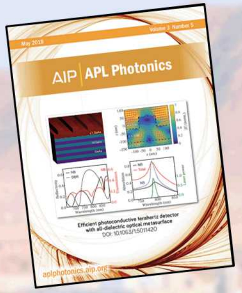
Serve the nation as a center of excellence for national security photonics through scientific excellence and innovations and leading-edge integrated photonics solutions

- >60 photonics staff (plus postdocs and students) with expertise in device design, modeling, simulation, epitaxy, device fabrication, integration, assembly, and test
- Partnership with government agencies, industry, and universities
- Technology transfer to industry
- Areas of interest: communication, sensing, computing, imaging, quantum applications
- Special expertise in harsh environment photonics

2012 R&D 100 50th ANNIVERSARY

Microsystems Enabled Photovoltaics





2016 R&D 100 WINNER

T-QUAKE (Transceiver for Quantum Keys and Encryption)

R&D 100

2009 Ultralow-power Silicon Microphotonic Communication Platform

SANDIA's NATIONAL SECURITY PHOTONIC CENTER

www.sandia.gov/mstc/nspc

A member of AIM photonics

Silicon Fab:
Silicon Photonics

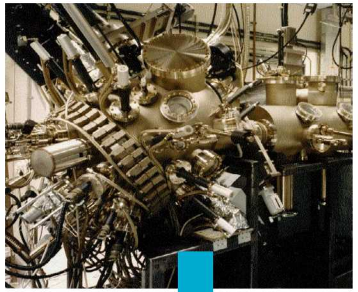
Microfab:
Compound Semiconductor
Photonics

PDK and
Multi-Project Wafers

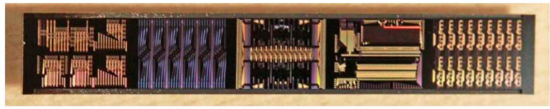
60+ Photonics Staff

Device Design, Modeling, Simulation
Semiconductor Device Fabrication
Microsystem Fabrication
Testing, Rad Effects, Cryo
Reliability

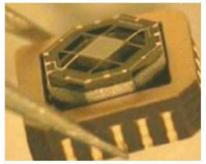
Custom Epitaxial Growth & III-V Devices
(GaAs, InP, GaSb, GaN)
PDK and Multi-Project Wafers (InP)

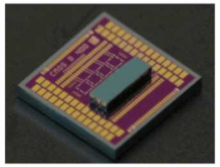


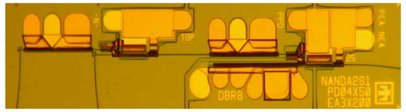
Microsystems and Heterogeneous Integration
(Flip Chip Bonding, micro-optics, assembly, packaging)



Photonic circuits







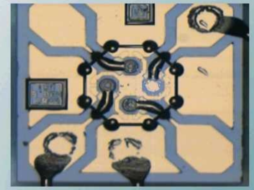
Photonic circuits & Lasers

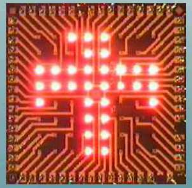
SANDIA's PHOTONIC MICROSYSTEMS

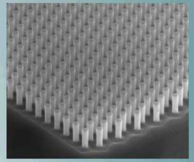
National Capabilities for Advanced Photonics R&D: design, model, fab, package, and test

Materials: Silicon, III-V (Phosphides, Arsenides, Antimonides, Nitrides), Lithium Niobate, Graphene, etc.

Sources

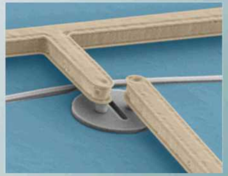

Single-Frequency Tunable VCSELs

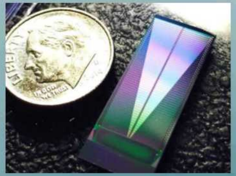

High Efficiency VCSELs

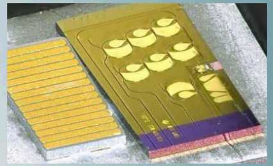

Nanowire Laser

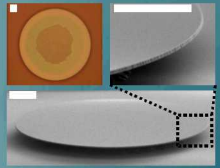

High power GaAs laser

Control / Manipulation

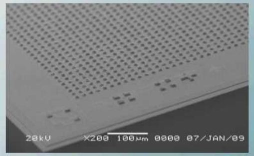

Resonant Optical Modulator/Filter

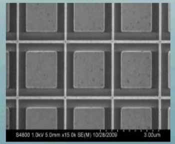

Array Waveguide Grating Channelizing Filter

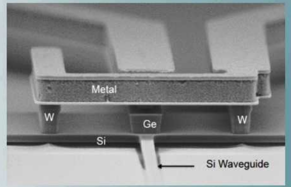

RF Channelizing Filter


LiNbO3 Freq. Converter

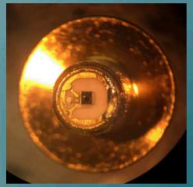
Detection


Infrared Detector


Plasmonic Perfect Absorber



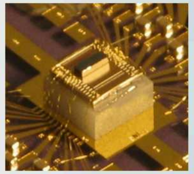
Germanium Detector on Silicon


X-ray Detector

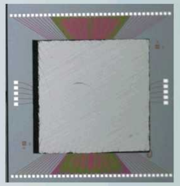
Chip-scaled MicroSystems

Heterogeneous Integration

III-V on CMOS

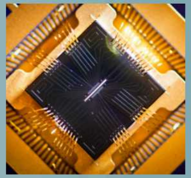


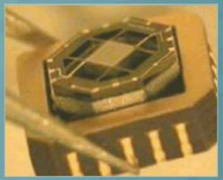
CMOS on Si Photonics

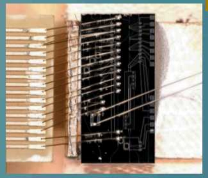

High-speed Optical Transceivers

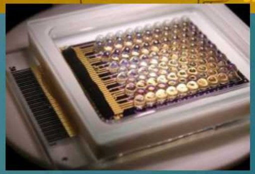
nBn on CMOS

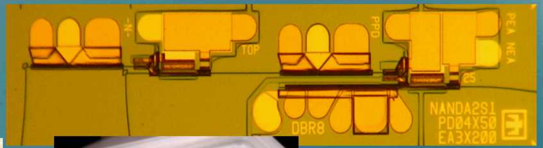

IR Focal Plane Array w/ ROIC


Quantum Surface Ion Trap


Atomic Clock


Quantum Key Distribution Transceiver


Photovoltaics w/ microlenses

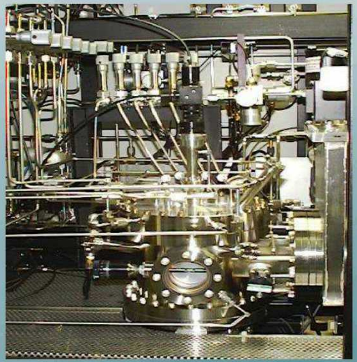

High-speed All-Optical Logic

III-V OPTOELECTRONICS CAPABILITIES

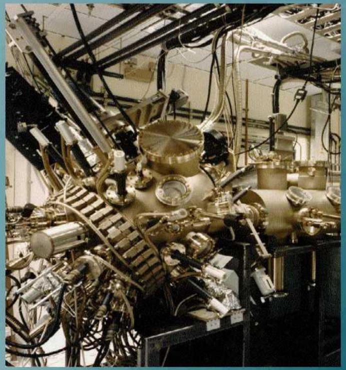
Custom, trusted, low-volume, high-reliability products for harsh environments when industry is unwilling or unable to deliver

Custom Epitaxial Growth

<u>6 MOCVD tools:</u>
As, P, Sb, Ga, In, Al, Zn, Si, Te, N, H_2

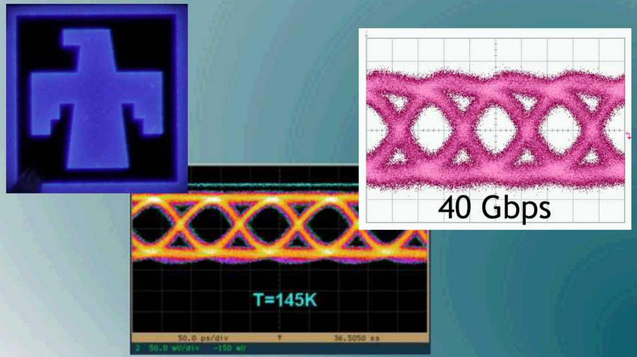


<u>6 MBE tools:</u>
Sb, Ga, As, In, Al, Si, Be,Te,N, H_2



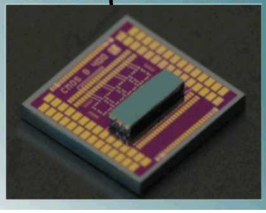
Device Design, Fabrication, and Characterization

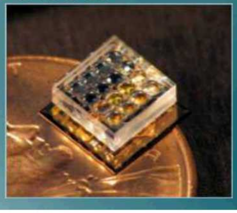
- Device design, modeling, simulation
- TRL 1-6+: create, develop, prototype
- Fabrication: 16,600 sq. ft Class 10/100 Cleanroom
- Optical Comm testing to > 40 Gbps
- Cryo-testing
- Reliability and Rad Effects
- 8 Optoelectronics Laboratories



Microsystem Heterogeneous Integration

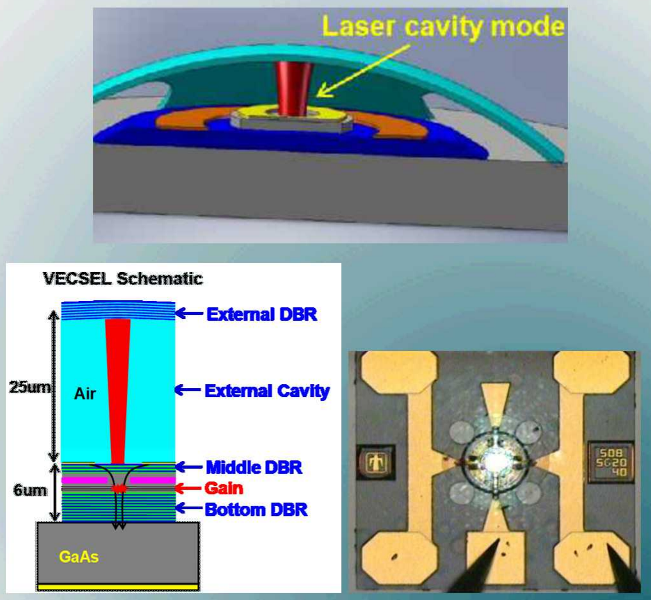
- Flip chip bonding
- Wafer level oxide bonding
- solder dam and bumps
- Grind, thin and polish
- Substrate removal
- Epoxy underfills
- AR coatings
- Micro-optics: diamond turning and molding
- Active alignment
- Dicing, scribe and break
- Full productions toolset & multiple R&D toolsets





SANDIA's VCSEL RESEARCH and GaAs CAPABILITY

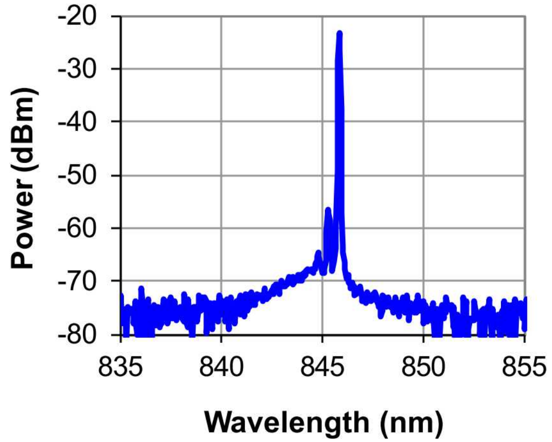
VCSEL



Narrow Line Width VECSEL

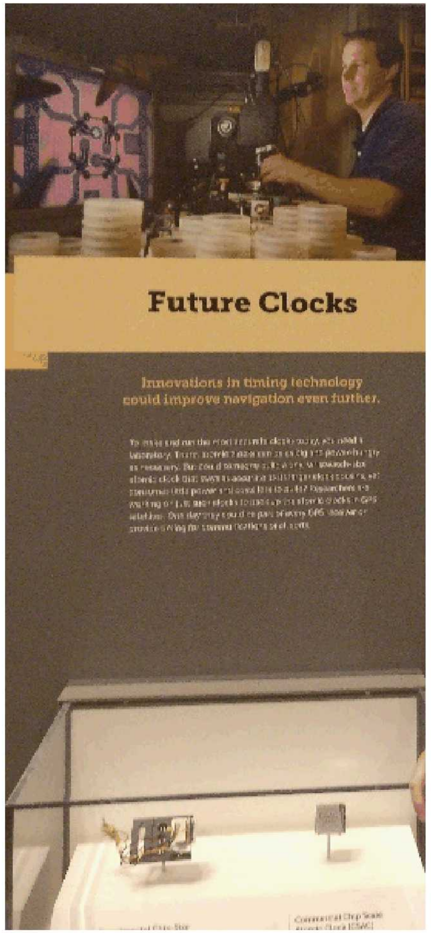
Sandia develops custom VCSELs & Photodiodes for emerging applications

- Innovative VCSEL research since 1990 with on going R&D and production
- Special VCSELs developed for atomic clocks
  - Narrow linewidth (<10MHz)
  - Technology transferred: Commercialized as a chip scale atomic clock, now manufactured Microsemi.
  - Current work focuses on VECSELs
- Custom VCSELs for high speed, high efficiency, cryogenics, and sensing



Chip Scale atomic clock technology transferred to industry

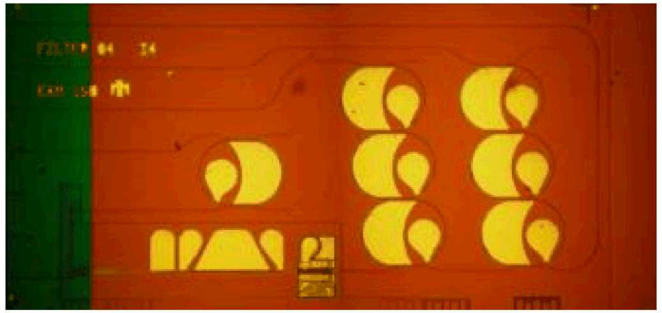
Smithsonian Air and Space Museum Exhibit
(Sandian Darwin Serkland (poster))



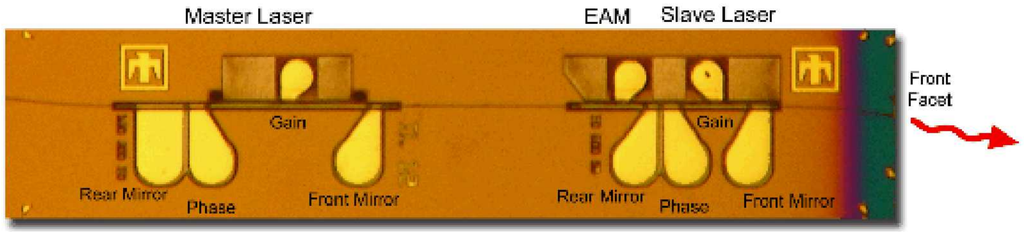
SANDIA's InP PIC CAPABILITY

InP-based Photonic Integrated Circuits

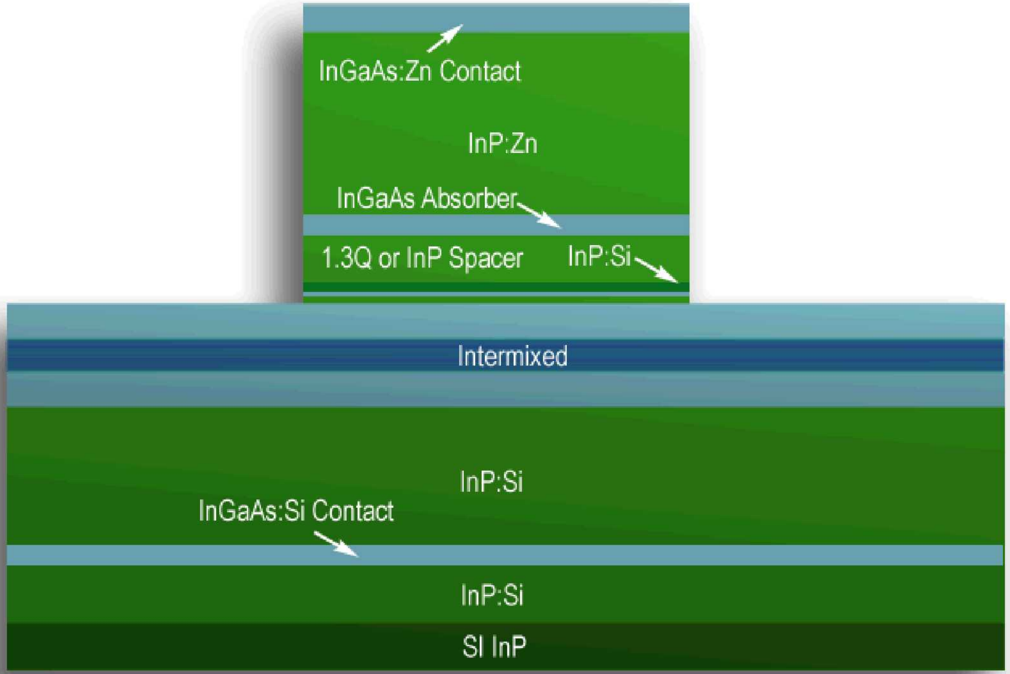
- Multiple band-edges by quantum-well-intermixing and/or regrowth
- Single and/or multiple epitaxial regrowth(s)
- Top-side n-type and p-type contacts
- Ridge, buried, and/or deep etch waveguide architectures



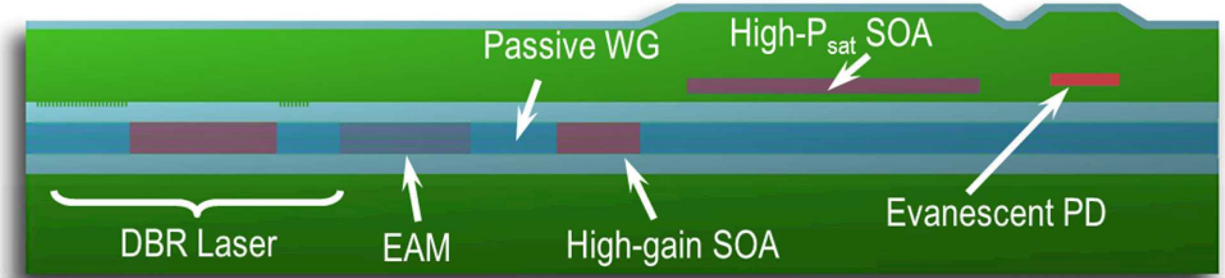
RF-Optical Channelizing Filter
1-20 GHz RF on C-Band Light



On-Chip Injection Locking
Enhanced Modulation > 50 GHz, C-Band



Device Cross-section (Lateral)



Device Cross-section (Longitudinal)

SANDIA's InP 'Design-Guided' Multi-project Wafer Runs

3 tier offering at 1550 nm

- Tier 1: one regrowth
- Tier 2: 2 regrowths – adds High P_{sat} optical amplifier
- Tier 3: Full custom process –

Unique features of Sandia's InP MPW runs

- Trusted, ITAR-Controlled, limited access (classified) facility
- Radiation-Effects aware designs and components
- Harsh Environment & Cryogenic Photonics

Example InP PICs Demonstrated

- RF Optical channelizing filters
- All-optical Logic (AND, NOT)
- Transceivers (tunable laser integrated modulators/amplified PD)
  - Modulator – electro-absorption or Mach-Zehnder
  - Receiver – optically amplified, high input saturation power
- Optical heterodyne
- Injection locked lasers
- AWG, TIR turning mirrors, low divergence waveguides

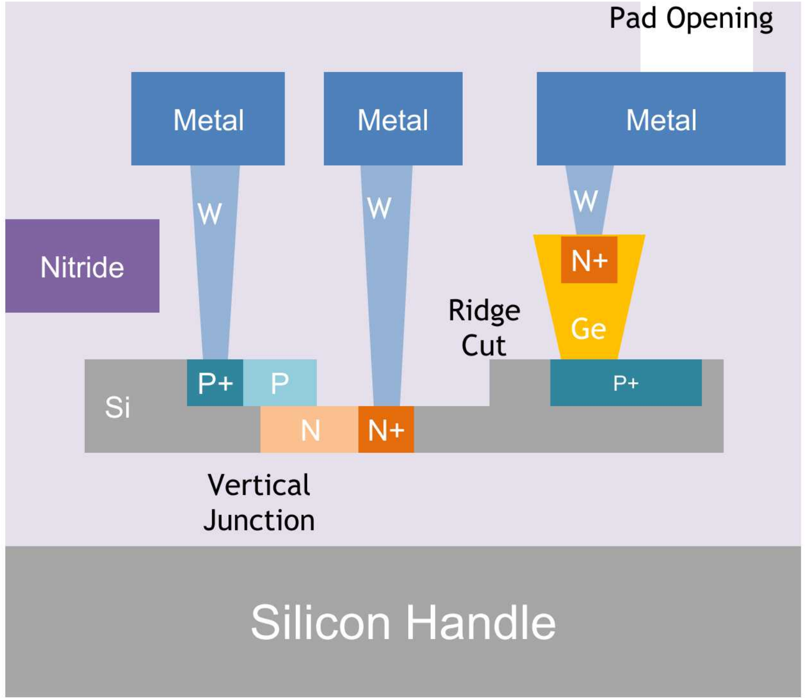
For more information:
email photonics@sandia.gov

Process		Tier 1	Tier 2	Tier 3
Description		One MOCVD regrowth	Two MOCVD regrowths	Full custom process
Lasers	Tunable (~5 nm)	YES	YES	YES
	Tunable (~40 nm)	YES	YES	YES
SOA	High Gain (dB/cm)	400	400	400
	High P_{sat}	NO	YES	YES
Detectors	R (A/W)	0.8	0.8	0.8
	P_{in} saturation (dBm)	15	15	15
	Bandwidth (GHz)	> 20	> 40	> 40
Wave-guide	Propagation Loss (dB/cm)	< 2	< 2	< 2
	Turning mirror loss (dB)	N/A	< 0.5	< 0.5
EA-Modulator	Length (µm)	125	125	125
	Efficiency (dB/V/cm)	800	800	800
	Loss (dB)	< 1	< 1	< 1
	Bandwidth (GHz)	> 20	40	40
MZ-Modulator	Electrode Length (µm)	250	250	250
	Efficiency (V_{π})	2	2	2
	Loss (dB)	~1	~1	~1
	Bandwidth (GHz)	> 20	> 20	> 40
Phase Modulator	Length (µm)	200	200	200
	Efficiency (°/V)	20	20	20
	Loss (dB)	< 1	< 1	< 1
	Bandwidth (GHz)	> 20	> 20	> 40

Inaugural Device Library

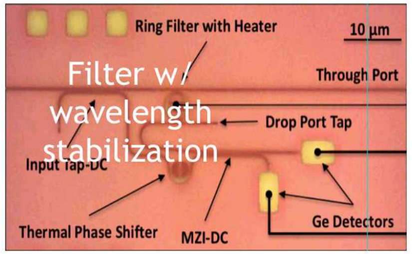
SILICON PHOTONICS CAPABILITIES

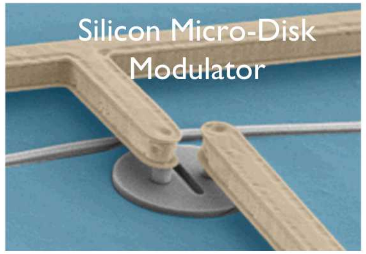
- Leverage existing CMOS infrastructure (200mm SOI)
- Low Power, High Speed Devices
- Low Loss Optical Waveguides (<0.1 dB/cm)
- Two waveguide interconnect layers:
  silicon and silicon nitride
- Selective Area Germanium Epitaxy for PIN/APDs
- 39 issued patents

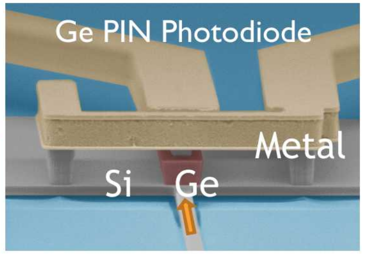


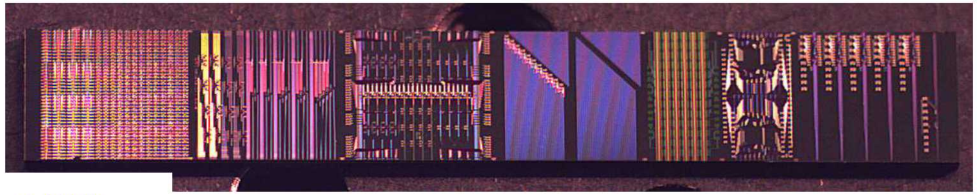
Multi-project wafer runs

- Collaborative and custom work within or outside of MPW
- Academia, industry, other government entities
- Typical block size: 4 mm x 26 mm
- Three Deliverables:
  1) passive (Si+SiN), 2) Passive+ Active,
  3) Passive+ Active+ Germanium









For more information:
email photonics@sandia.gov

Image of MPW run, supporting Columbia, U of AZ, UC Berkeley, UCSD & Caltech

SNL SILICON PHOTONICS LIBRARY

(1st Rev. in Synopsis Optodesign Software)

22 Passive Devices

- Si rib and ridge waveguides (including transitions, auto routing, phase aware routing)
- Nitride waveguides (si to nitride transitions)
- Si rings [6] (standard, adiabatic, cascaded)
- Grating couplers (1D & 2D)
- Edge couplers (silicon, SiN)
- Waveguide crossings (nitride over silicon)
- Beam splitters (amplitude and polarization, MMI, adiabatic and directional couplers)

20 Active Devices

- Disk modulators (different size, dopants)
- Disk modulators and filters with heaters (int. & ext.)
- Ring modulators (adiabatic)
- Thermal phase shifters
- Thermal and electro-optic traveling wave MZM
- Ge PIN detectors

Design Tools & Features

- Design Guide
- Library (GDS/Scripted)

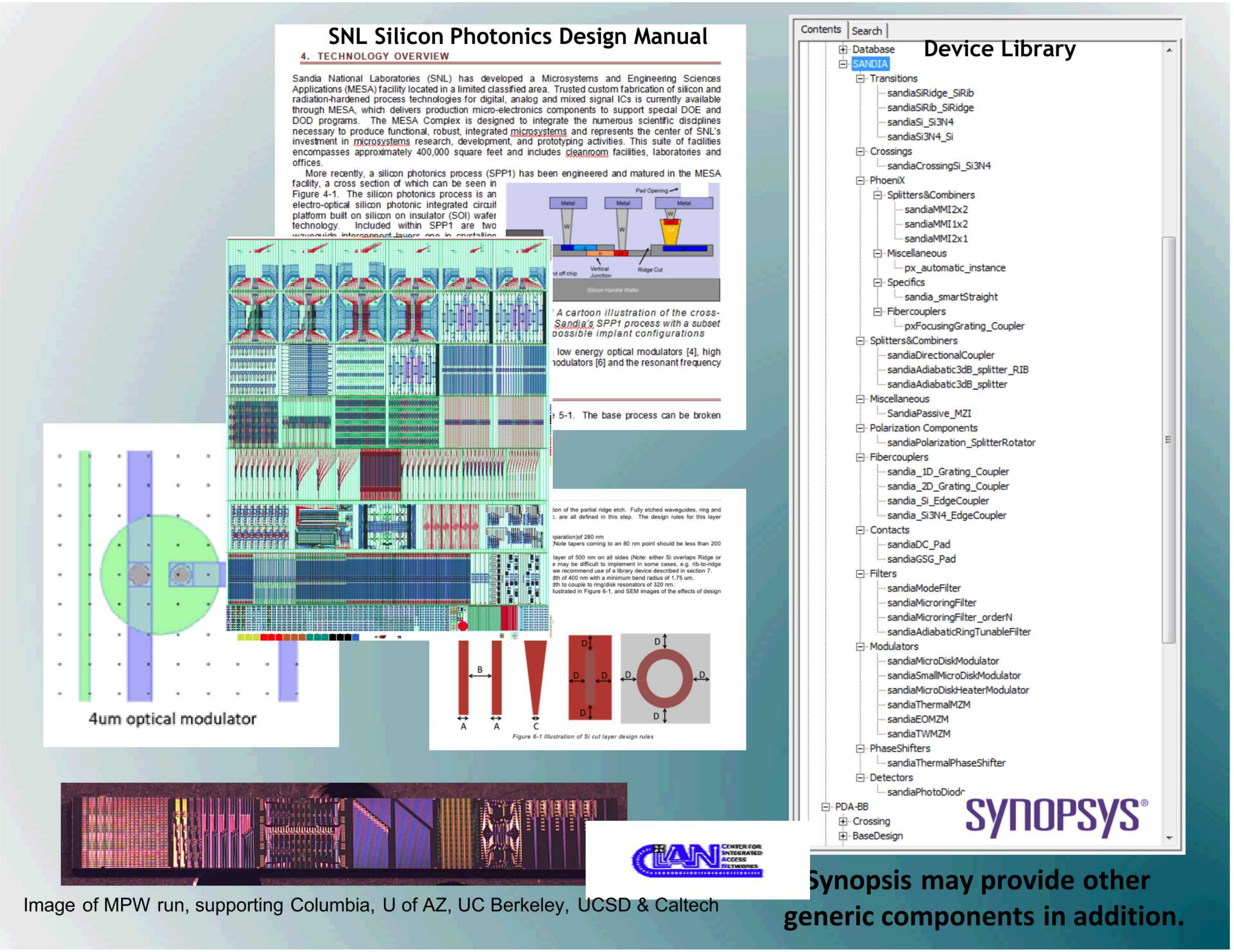
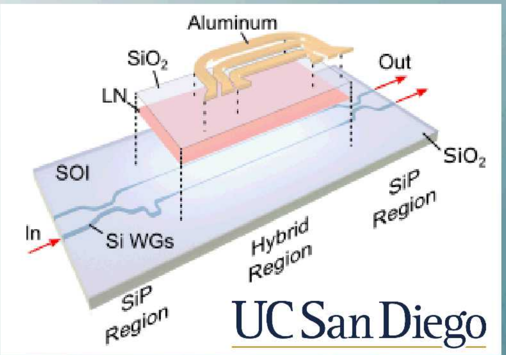


Image of MPW run, supporting Columbia, U of AZ, UC Berkeley, UCSD & Caltech

Synopsis may provide other generic components in addition.

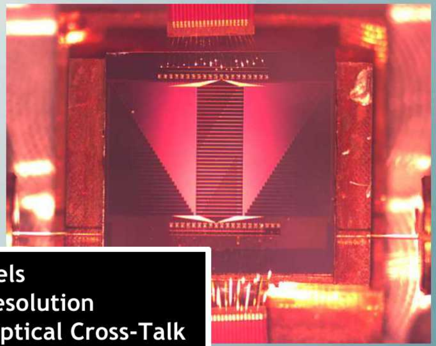
INTEGRATED SILICON PHOTONICS for RF SIGNAL PROCESSING

Optics Express 26 (18), 23728-23739, July 2018

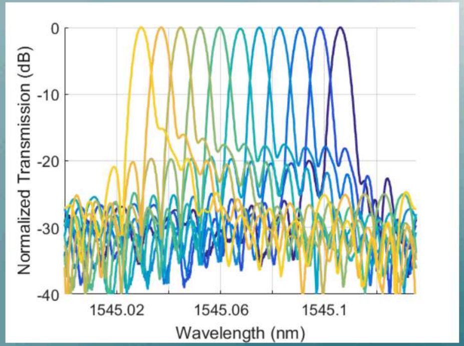


Lithium Niobate on Silicon
100+GHz Bandwidth demonstrated

Optics Express 25 (6), 6320-6334, Mar. 2017



11 Channels
<1 GHz Resolution
<-15 dB Optical Cross-Talk
1.1 cm² Total Area

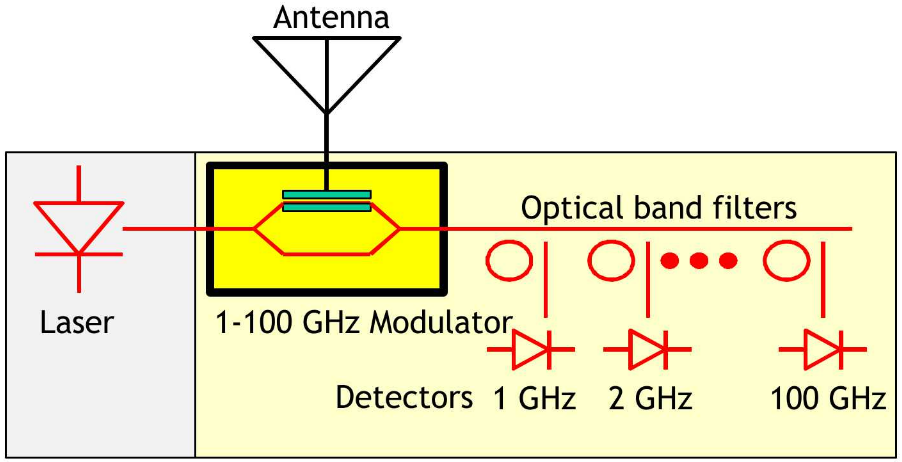


1st Demo of 1GHz RF Channelization in a Si Photonics Array Waveguide Grating

Photonic processing of RF signals provides significant reduction in SWAP-C for high frequency applications (>40 GHz)

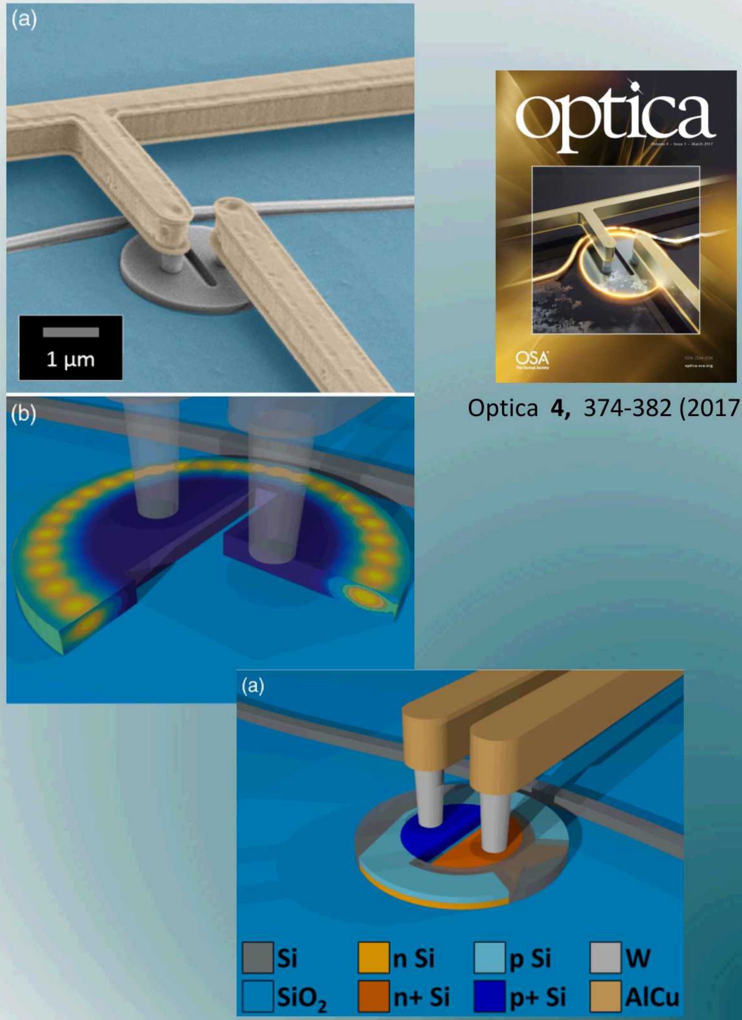
Applications in space and avionic platforms for electronic warfare and situational awareness

- Frequency up/down-conversion
- Antenna remoting
- RF over fiber
- Wide-band channelization
- Low loss RF delay lines



Example integrated wide-band channelizer

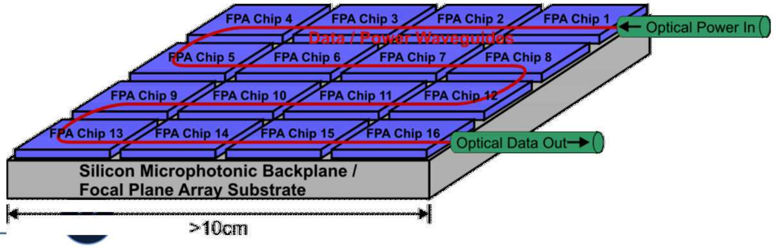
CRYOGENIC OPTICAL INTERCONNECT

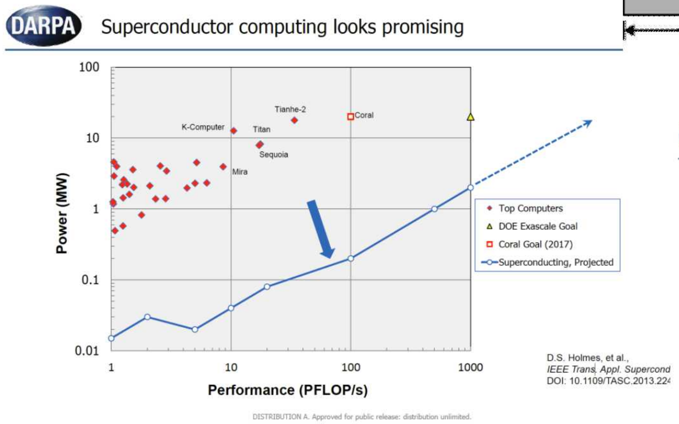


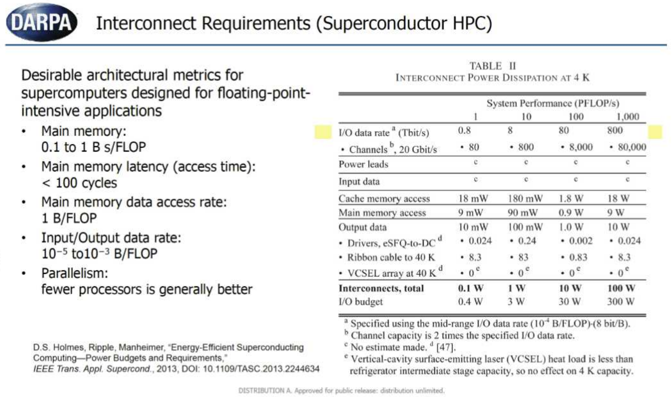
Optica **4,** 374-382 (2017)

High-speed low-power resonant modulator operating at cryogenic temperatures (50K, 4K, and below)

- Superconducting Computing
- Optical backplane for focal plane array







DARPA

Interconnect Requirements (Superconductor HPC)

Desirable architectural metrics for supercomputers designed for floating-point-intensive applications

- Main memory: 0.1 to 1 B s/FLOP
- Main memory latency (access time): < 100 cycles
- Main memory data access rate: 1 B/FLOP
- Input/Output data rate: 10^{-5} to10^{-3} B/FLOP
- Parallelism: fewer processors is generally better

D.S. Holmes, Ripple, Manheimer, "Energy-Efficient Superconducting Computing—Power Budgets and Requirements," *IEEE Trans. Appl. Supercond.*, 2013, DOI: 10.1109/TASC.2013.2244634

TABLE II
INTERCONNECT POWER DISSIPATION AT 4 K

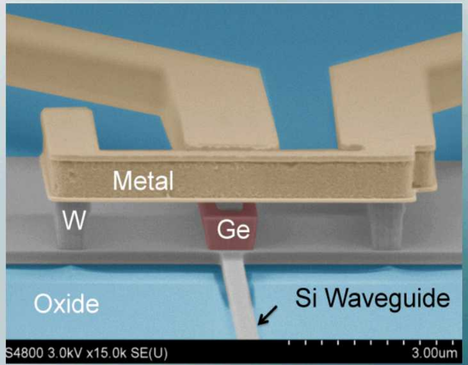
	System Performance (PFLOP/s) 1	10	100	1,000
I/O data rate [a] (Tbit/s)	0.8	8	80	800
• Channels [b], 20 Gbit/s	• 80	• 800	• 8,000	• 80,000
Power leads	c	c	c	c
Input data	c	c	c	c
Cache memory access	18 mW	180 mW	1.8 W	18 W
Main memory access	9 mW	90 mW	0.9 W	9 W
Output data	10 mW	100 mW	1.0 W	10 W
• Drivers, eSFQ-to-DC [d]	• 0.024	• 0.24	• 0.002	• 0.024
• Ribbon cable to 40 K	• 8.3	• 83	• 0.83	• 8.3
• VCSEL array at 40 K [d]	• 0 [e]	• 0 [e]	• 0 [e]	• 0 [e]
Interconnects, total	**0.1 W**	**1 W**	**10 W**	**100 W**
I/O budget	0.4 W	3 W	30 W	300 W

[a] Specified using the mid-range I/O data rate (10^{-4} B/FLOP)·(8 bit/B).
[b] Channel capacity is 2 times the specified I/O data rate.
[c] No estimate made. [d] [47].
[e] Vertical-cavity surface-emitting laser (VCSEL) heat load is less than refrigerator intermediate stage capacity, so no effect on 4 K capacity.

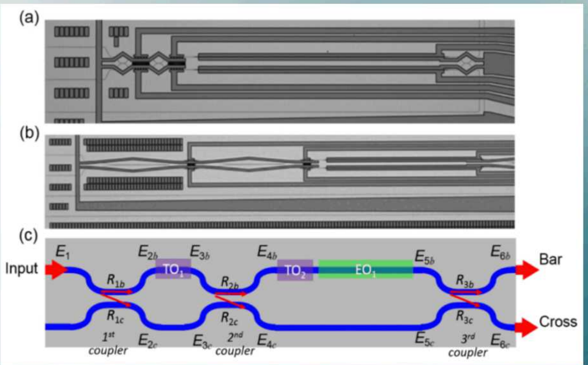
DISTRIBUTION A. Approved for public release: distribution unlimited.

D. Scott Holmes DARPA MTO Program Manager
2nd Photonics and Electronics Technology for Extreme-scale Computing (rePETE) Workgroup presentation 2019-05-02

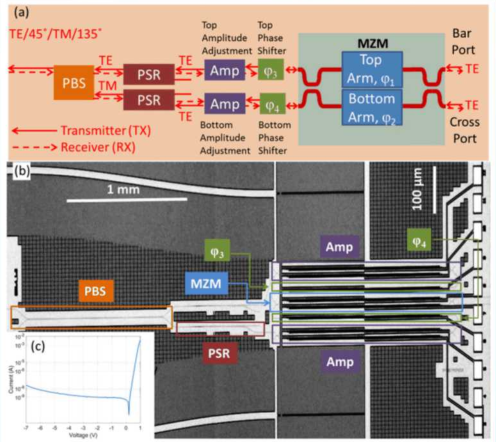
INTEGRATED PHOTONICS for QUANTUM COMMUNICATION



Geiger-mode APD
for single photon detection



High-speed (10GHz) high-extinction ratio (>65dB)
silicon amplitude modulator for CV QKD & Q-Sensing

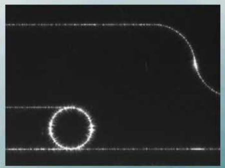


2016 R&D 100 WINNER

T-QUAKE
(Transceiver for
Quantum Keys
and Encryption)

Phys. Rev. X 8 (021009), 1-12, April 2018

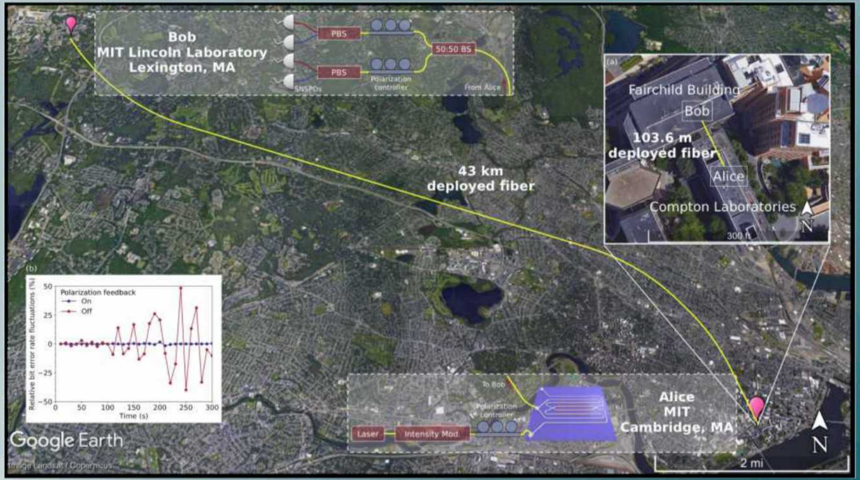
Sandia's silicon, III-V, alumina, lithium niobate heterogeneously integrated photonic platforms enable compact microsystems for telecom. and visible wavelengths



Alumina ring
filter /waveguide
for visible
wavelength

Many foundational building blocks for advancing quantum science have been or are being developed

- detectors, modulators, frequency converter, amplifiers, optical transceivers, etc.



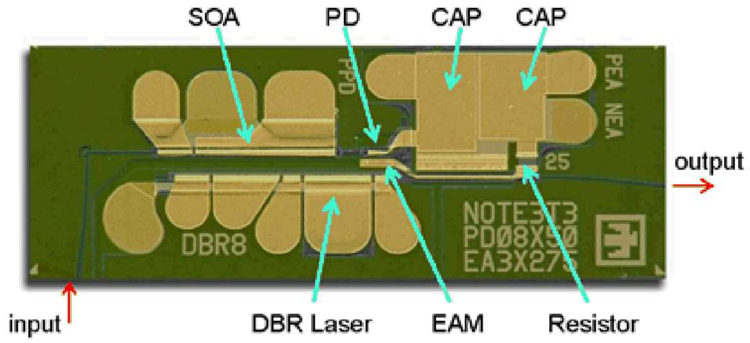
MIT LINCOLN LABORATORY

High-speed polarization-based DV QKD
field tests (BB84) demonstrated

FedBizOpps Announcement: Technology Commercialization Opportunity:
Partnership Opportunity for On Chip QKD Technology Development:
16_462 9/29/2016

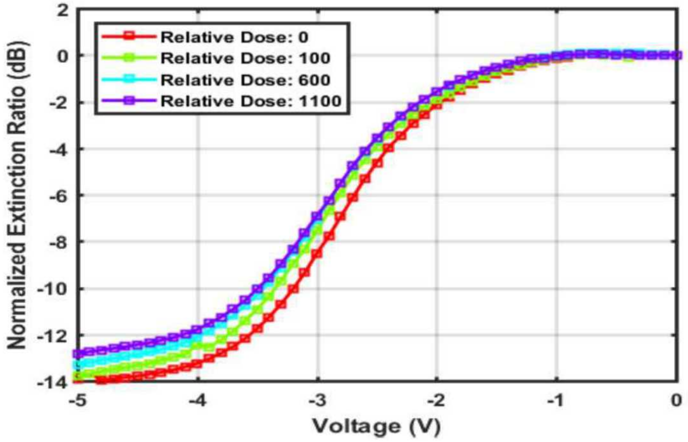
InP Photonic Integrated Circuit Radiation Testing & IBL Capability

- Individual Component Measurements
  - The Ion Beam Laboratory allows us to simulate radiation exposure through ion and electron bombardment with beam sizes small enough to interrogate individual components during operation.
    - Photonics with on-board III-V lasers can be operated easily
    - For photonics without on-board lasers like SiPh modulators, we developed a single mode optical feedthrough for the IBL tools.
- Example Measurements under 1.5 MeV He Ion Bombardment:



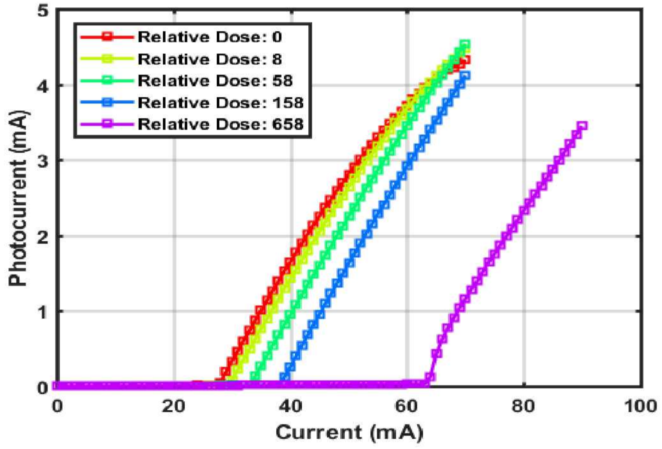
Single mode photonic feedthrough

Integrated Electroabsorption Modulator

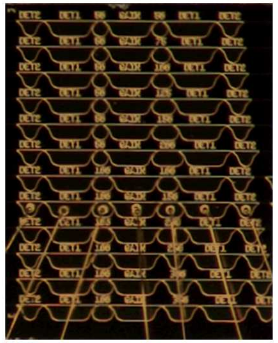


Example of minor degradation

InP DBR Laser



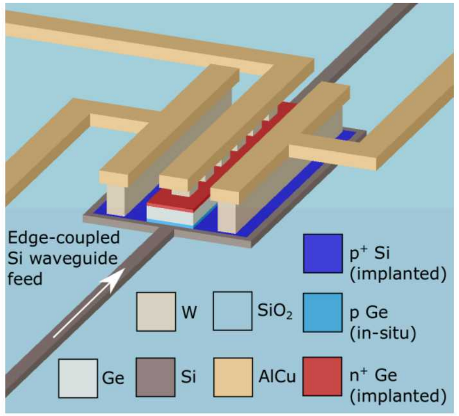
Example of some degradation of threshold and L-I

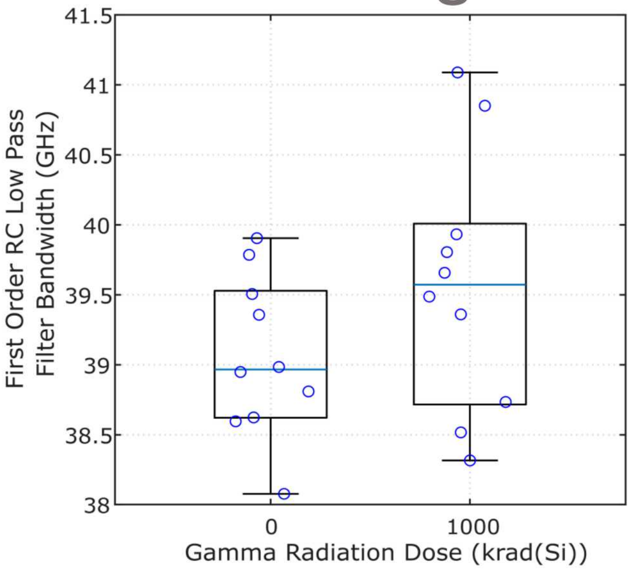


Test Structures

Silicon Photonics Radiation Testing Example – Total Dose response

Ge PIN Diode

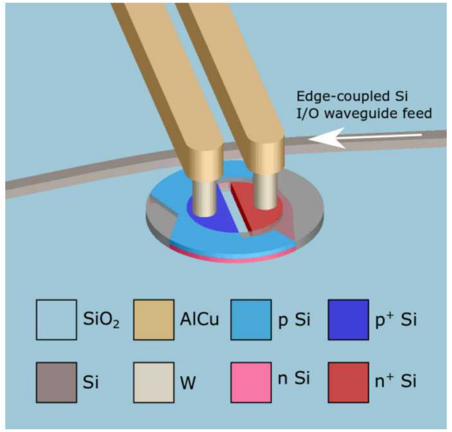


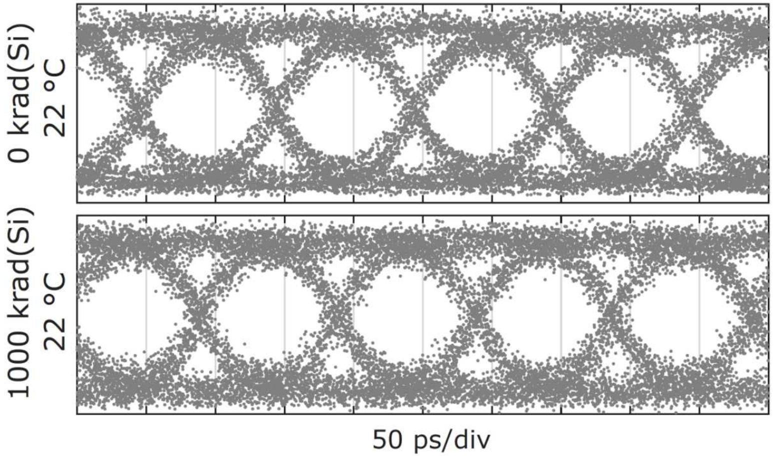


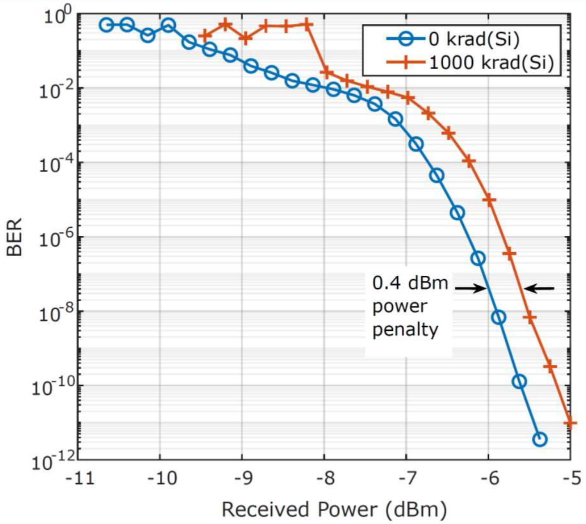
Upon a TID of 1 Mrad(Si) ^{60}Co @ 130 rad(Si)/s, the bandwidth of the Ge PIN photodiode is unaffected and the bandwidth of the Si disk modulator decreases by 6%

The modulator eye diagram remains clean and open with a small received power penalty of 0.4 dBm.

Si Disk Modulator



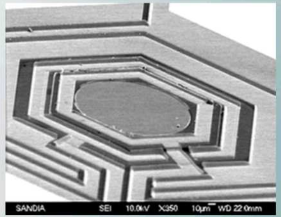
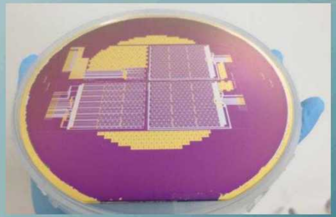
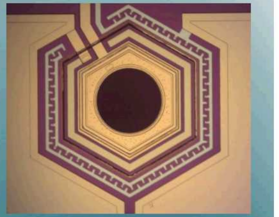




See: G.B. Hoffman, et.al., "The Effect of Gamma Radiation Exposure on Active Silicon Photonic Device Performance Metrics," ***IEEE Trans. On Nuclear Science***, 66(5), pp. 801-809 (May 2019) DOI: 10.1109/TNS.2019.2907582

HETEROGENEOUS INTEGRATION CAPABILITIES

Microsystem-Enabled Photovoltaics

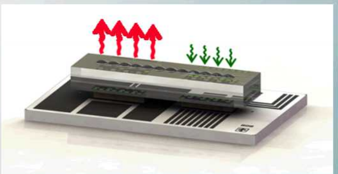
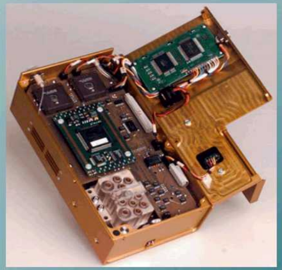
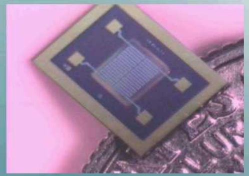
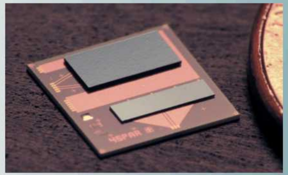
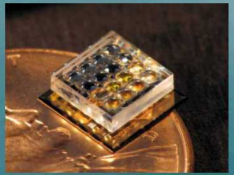




- wafer-level bonding for multi-junction solar cells
- InGaAsP/InP and InGaP/GaAs devices on silicon
- dielectric interfaces with III-V substrate removal
- integration with collection optics

Heterogenerous integration enables miniaturization with independent material and device optimization

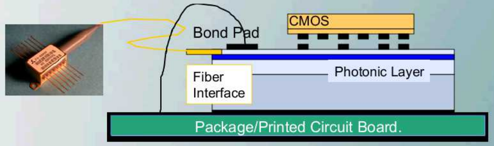
- Integration of $LiNbO_3$ and III-V Lasers on Silicon Photonics
- Non-traditional materials such as Al_2O_3, Epsilon-Near-Zero In_2O_3 and CdO, graphene
- Integration of CMOS with InGaAsP/InP, InGa/GaAs, Silicon Photonics, and other materials

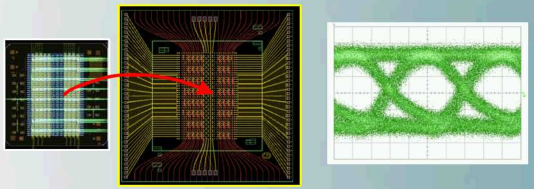
Optical and MEMS-based Microsensors

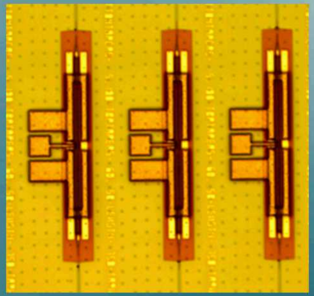






- chemical and bio sensors using MEMS and SAW devices
- g-hard optical microsensors with in-house photonics
- hybrid device integration with custom micro-optics

CMOS / Silicon Photonics / III-V Integration

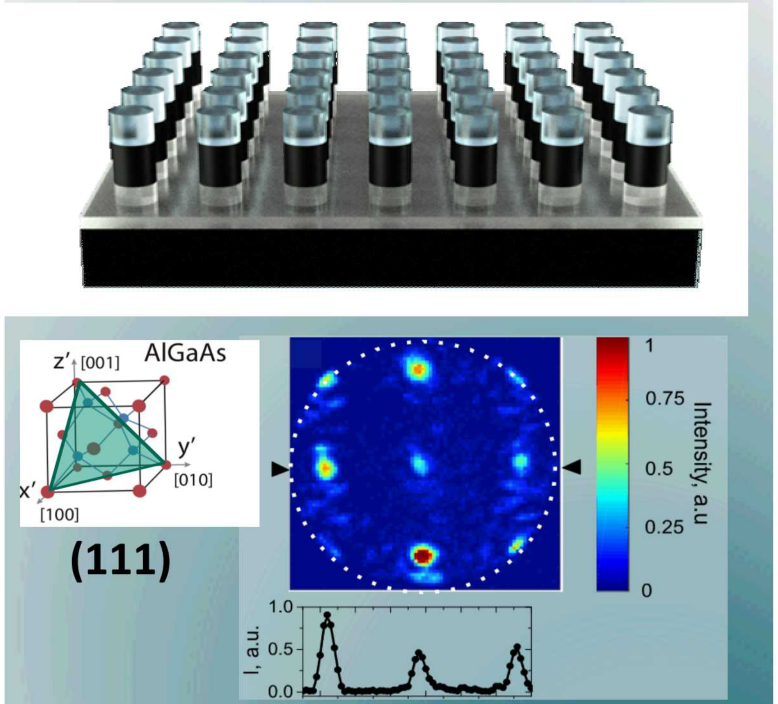




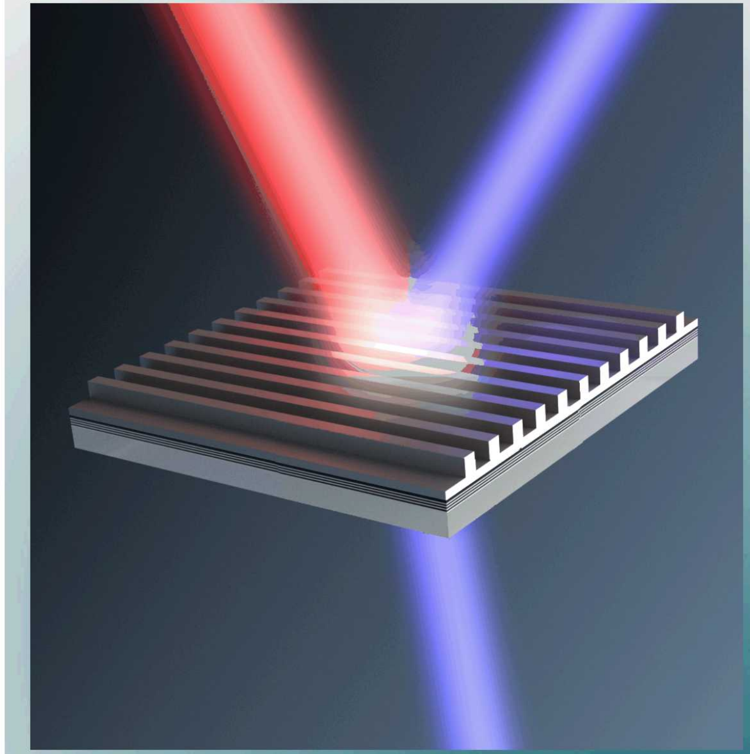

Tx/Rx Si Photonic Chip


- silicon photonics on high-speed silicon ASIC
- independent optimization of electronics & photonics
- Gain and laser sources on silicon

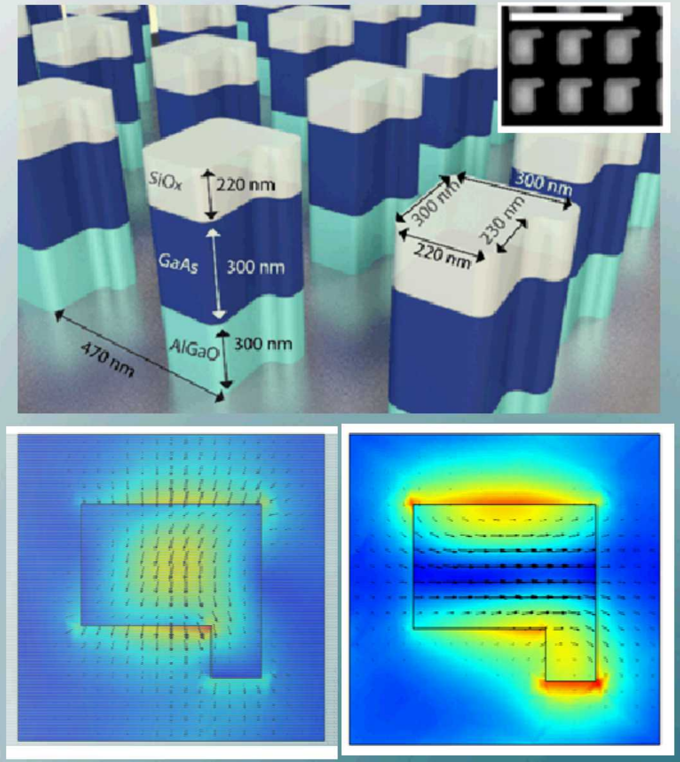
OPTICAL METAMATERIALS RESEARCH



Tailoring Second Harmonic Diffraction in GaAs Metasurfaces via Crystal Orientation

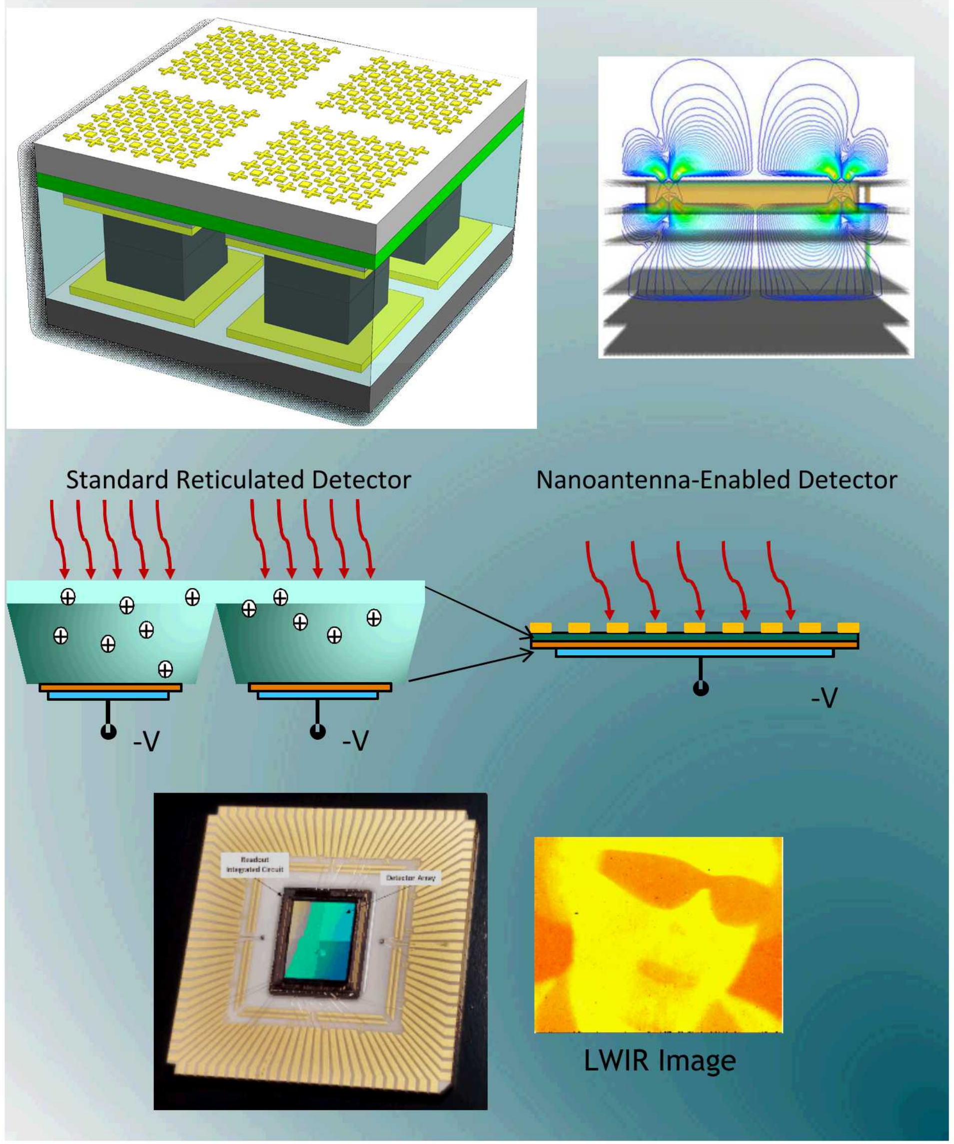


Ultra-thin dielectric-semiconductor hybrid metasurface for broadband and efficient second-harmonic generation



All-Optical Tuning of Fano Resonances in Broken Symmetry GaAs Metasurfaces

NANO-ANTENNA ENABLED FOCAL PLANE ARRAY



Metasurface on Infrared Focal Plane Array

- Reduce dark current and pixel cross-talk
- Increase external quantum efficiency (up to 70%)
- Wavelength tuning by pixel in real time

Licensing Opportunity

- USPTO #: 8,452,134, 8,750,653, and 8,897,609

FedBizOpps Announcement: Technology Commercialization Opportunity: High Quantum Efficiency, Low Dark Current Infrared Detector Architecture - Solicitation Number: 17_486 3/1/2019

Reference

- "Enhanced infrared detectors using resonant structures combined with thin type-II superlattice absorbers," *Appl. Phys. Lett.*, 109(251103), Dec. 2016
- "Tunable dual-band graphene-based infrared reflectance filter," *Opt. Express*, 26,(7) 8532-8541, Apr. 2018
- Military Sensing Symposium Apr 2019

Photonics Partnerships

Examples of industry and academia partnerships

AIM photonics

The University of Arizona

Massachusetts Institute of Technology

Illinois – University of Illinois at Urbana-Champaign

University of Virginia

Raytheon

AFRL – The Air Force Research Laboratory – Lead | Discover | Develop | Deliver

Yale University

Purdue University

The University of New Mexico

parc – A Xerox Company

Georgia Tech Research Institute

JPL – Jet Propulsion Laboratory

stellar science

UC San Diego

blackmore

Lumileds

Teledyne Scientific & Imaging – Everywhereyoulook

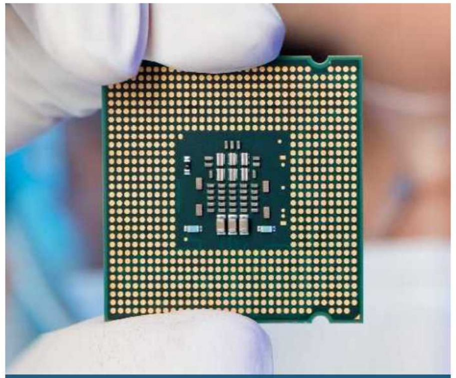
Lockheed Martin

Plasmonics Inc. – Infrared Nanotechnology

HISTORY OF TECHNOLOGY TRANSFER SUCCESS

Cleanroom

Sandia's invention of the original modern-day cleanroom led to $50 billion worth of laminar-flow cleanrooms being built worldwide within only a few years.

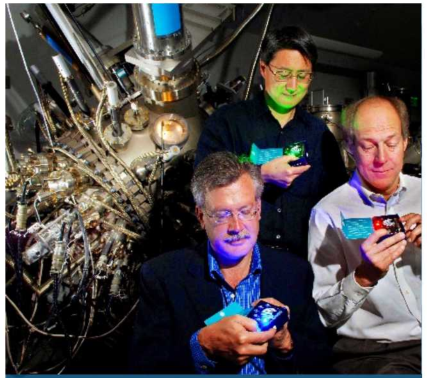


Microelectronics & Semiconductors

Sandia helped revolutionize the semiconductor industry by licensing LIVA/TIVA, VCSEL, EUVL, and 3D-stacking technologies to some of the world's leading semiconductor manufacturing companies.

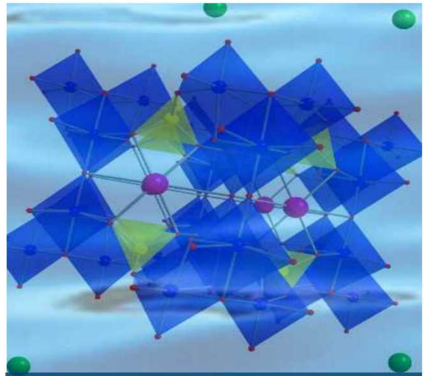
Decon Foam

A Sandia-developed chemistry for neutralization of chem/bio warfare agents that was first used for the anthrax attacks of 2001, is now being used by multiple companies for rapid decontamination applications.



Solid State Lighting

Sandia's early R&D of solid-state lighting has helped establish a global industry for LED/OLED technologies in which improved efficiencies could lead to $120B in estimated annual global energy savings.



Crystalline Silico -titanate (CST)

Sandia's CST technology was used by UOP, LLC to remove radioactive material from more than 43 million gallons of contaminated wastewater at Japan's damaged Fukushima Daiichi nuclear power plant.

Synthetic Aperture Radar (SAR)

Sandia has worked extensively with General Atomics to deploy Sandia's SAR systems for the US military and other customers. One version of the technology has been uncovering IEDs in Afghanistan and Iraq since 2009.

1960s — *1980s* — *1990s* — *2000s* — *2010s*

COLLABORATION WITH SANDIA

Federal agencies can engage in an interagency agreement with NNSA to obtain the Labs' unique services under Sandia's management and operating contract with DOE/NNSA.

Non-federal entities may enter into a variety of technology partnerships agreements with Sandia:

- Commercial License Agreement
  - ~40 Silicon photonics patents
  - >60 III-V patents
  - >15 metamaterials patents
- Cooperative Research and Development Agreement (CRADA)
- Strategic Partnership Projects/Non-Federal Entity (SPP/NFE) Agreement

Collaborate with us!

Visit us:

- On-line: sandia.gov/mesa/nspc

Email contact:

- Photonics@sandia.gov

Career Opportunies for staff and students:

- www.sandia.gov/careers

SANDIA IS A FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTER MANAGED AND OPERATED BY

National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc.: 2017 – present

Government owned, contractor operated

Sandia's Micro & Nano Capability - Strategic National Resource

MESA

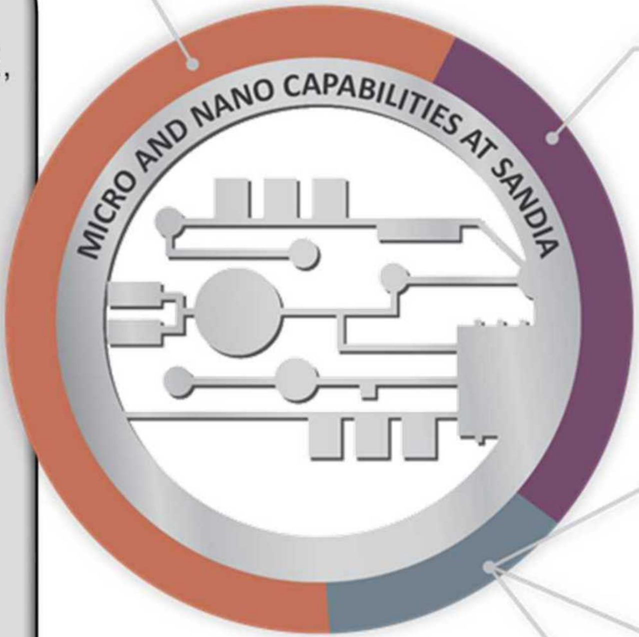
MICROSYSTEMS ENGINEERING, SCIENCE, AND APPLICATIONS

Only source for custom strategic rad-hard microelectronics

Largest Trusted government owned fabrication facility

Charter:

- steward key infrastructure
- design, develop, fabricate, qualify, and produce sub-components for the stockpile
- conduct leading edge research



CDC

COUNTERFEIT DETECTION CENTER

CINT

CENTER FOR INTEGRATED NANOTECHNOLOGIES

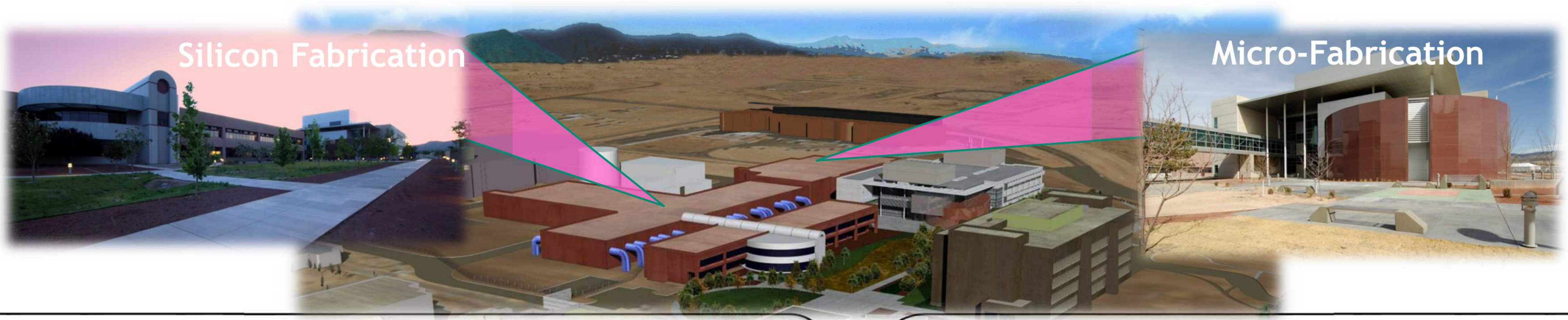
IBL

ION BEAM LABORATORY

ACRR

ANNULAR CORE RESEARCH REACTOR

MESA's Fabs: Co-Located Production and R&D



- Clean room area 34,500 ft2 (11,900 ft2 Class 1)
- 23 laminar flow clean bays
- 3.3V 350nm SOI Rad Hard CMOS (CMOS7) in production
- 3.3/1.8V 180nm SOI Rad Hard CMOS (CMOS8) in development
- Supplier of custom Rad-Hard ICs for life extension programs
- DOD Defense Microelectronics Activity (DMEA) Category1A Trusted Supplier for design, fab, and test
- Micro-Electro-Mechanical System (MEMS)
- Custom Technologies: Ion Traps, Silicon Photonics, AlN Resonators

- Clean room area 30,400 ft2 (14,900 ft2 Class 10/100)
- 6 Class 100 clean bays and 20 Class 10 clean bays
- Reconfigurable tools from wafer pieces to 6" wafers
- III-V compound semiconductor epitaxial growth and circuit fabrication
- Gallium Arsenide & Indium Phosphide HBT production
- Breadth of III/V materials
- Optoelectronics, VCSELs, and photo diodes
- 3D Packaging & Heterogeneous Integration Post-processing hybridization

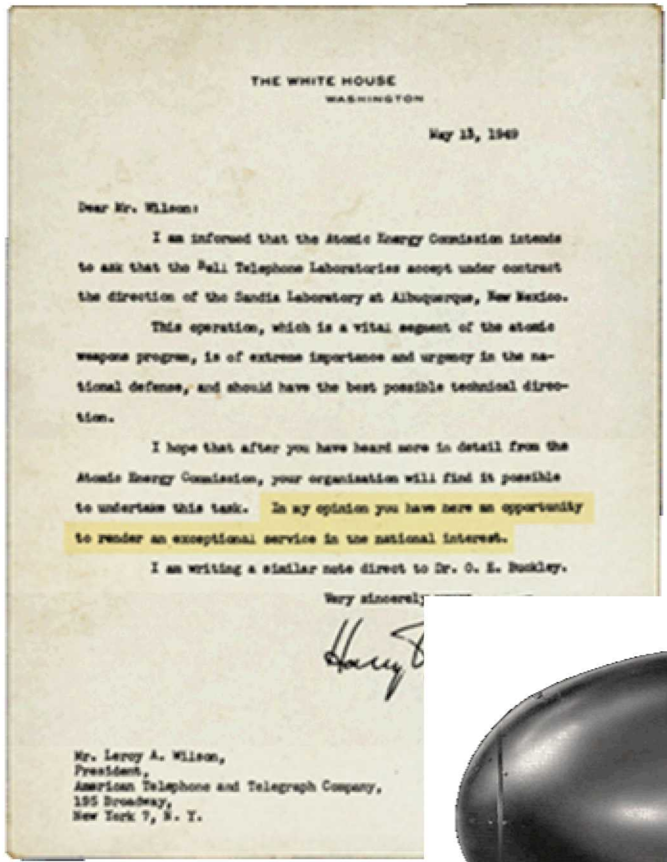
SANDIA ADDRESSES NATIONAL SECURITY CHALLENGES

1950s	1960s	1970s	1980s	1990s	2000s	2010s
Arms race	Cuban missile crisis & Vietnam War	Energy crisis	End of Cold War	Stockpile stewardship	Broader national security	Evolving national security challenges

SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

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

- July 1945
  Los Alamos creates Z Division
  - Nonnuclear component engineering
- November 1, 1949
  Sandia Laboratory established
  - AT&T: 1949–1993
  - Martin Marietta: 1993–1995
  - Lockheed Martin: 1995–2017
  - Honeywell: 2017–present



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.

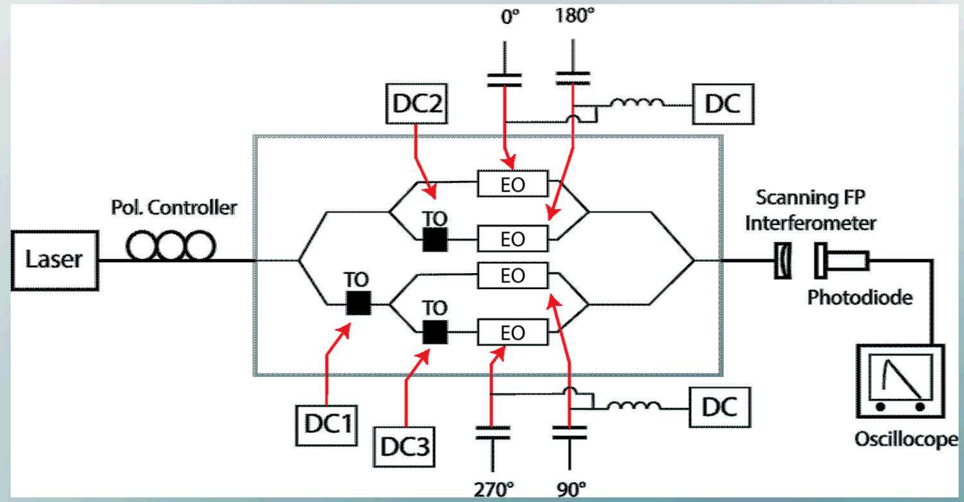
Very sincerely

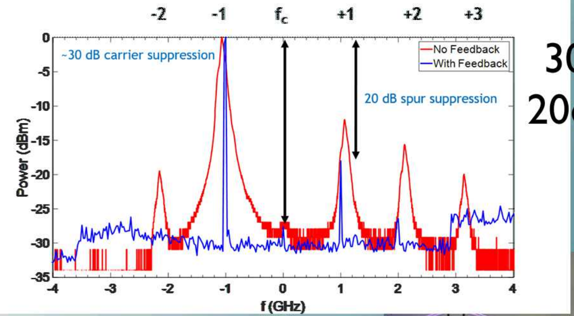
Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

PURPOSE STATEMENT DEFINES WHAT WE DO

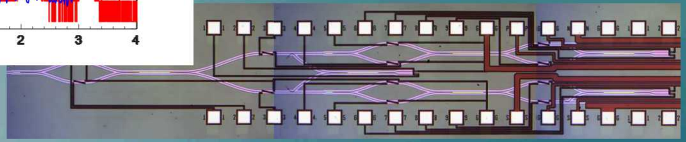
Sandia develops advanced technologies to ensure global peace

SILICON PHOTONICS OPTICAL SINGLE-SIDEBAND MODULATOR





30dB carrier suppression
20dB sideband suppression
with active feedback



Silicon Photonic Single-Sideband Generation
with Dual-Parallel Mach-Zehnder Modulators
(Thur May 9 STh4N.6)

Frequency shifting/conversion for many applications

- high-resolution spectroscopy
- dense wavelength division multiplexed (D-WDM) networks
- atom interferometry / quantum sensing

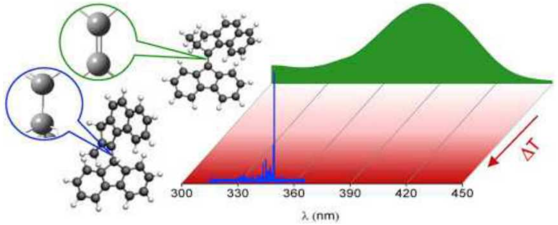


Photo Credit: Tetrahedron, 73(33, pp. 4887-4890, Aug 17, 2017

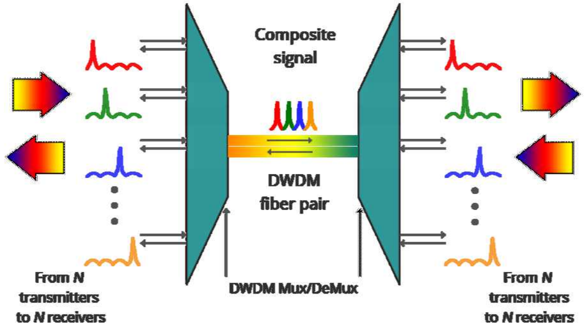


Photo Credit: https://community.fs.com/blog/an-overview-of-dwdm-technology-and-dwdm-system-components.html

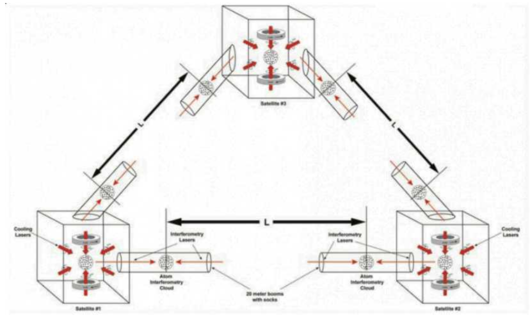
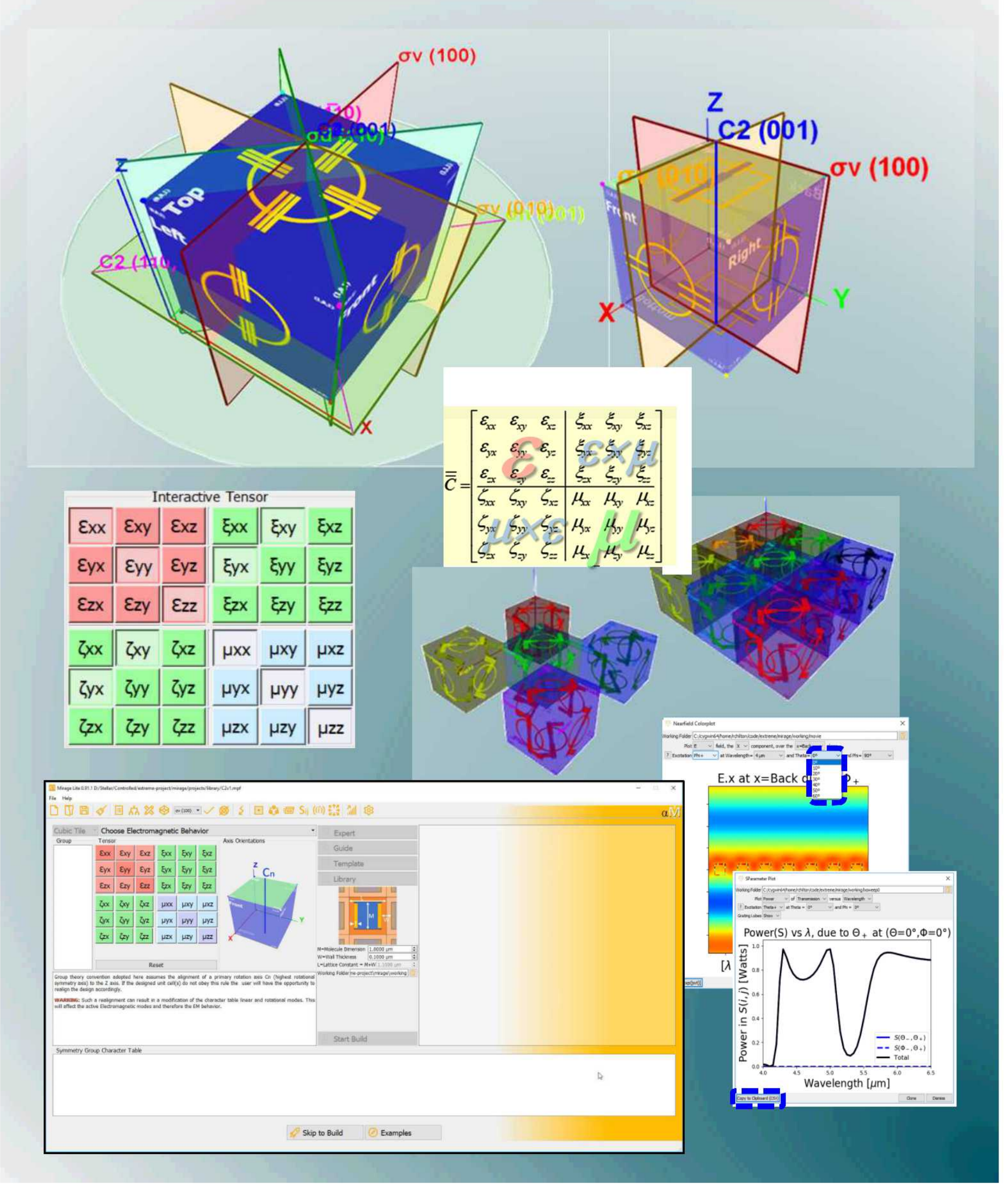


Photo Credit: https://www.nasa.gov/content/atom-interferometry-for-detection-of-gravity-waves-a/

METAMATERIALS SIMULATION – *MIRAGE 1.0*



Multiscale Inversion Rapid Group-theory for Engineered-metamaterials (MIRaGE)

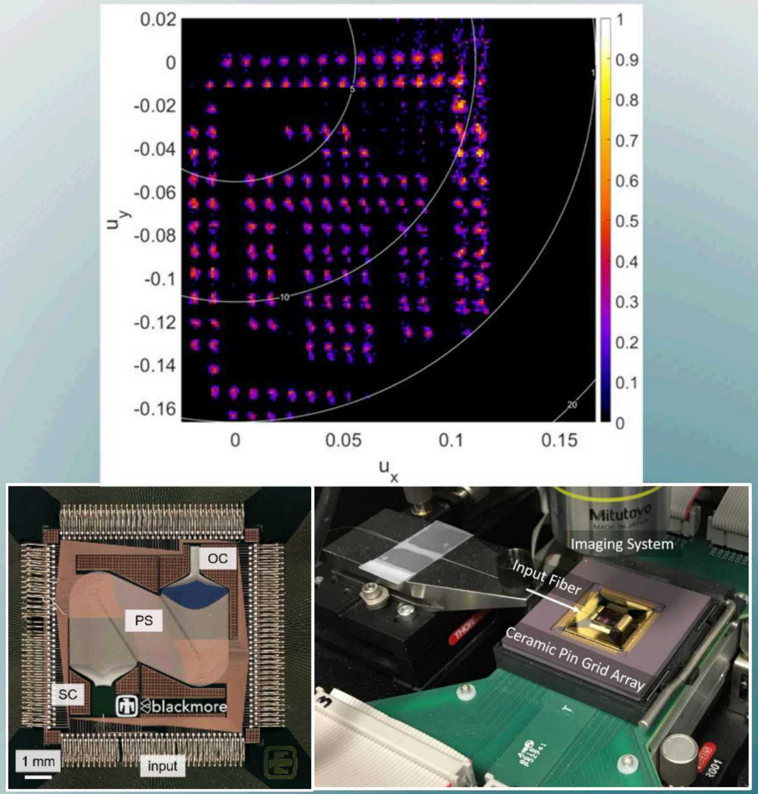
- All-in-one comprehensive simulation tool-set
- Tensor Based Inverse Design Methodology
- Heterogeneous Unit Cell Stitching Capable
- Optimization: geometry, shape, and topology
- Scalable: laptop, desktops and multicore machines
- Designed for novice and expert

Free copy may be available

- Valid research contract with the US government

CHIP-SCALE OPTICAL BEAM STEERING

blackmore



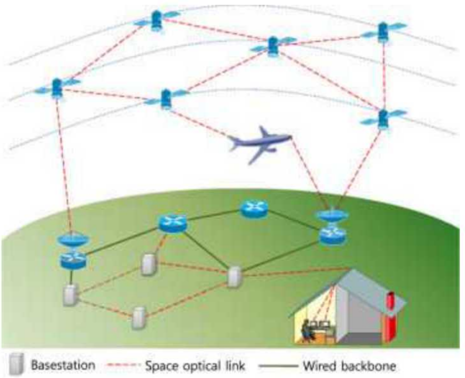
Phase Optimization of Si Photonics
2D Electro-optic Phased Array
(Thur May 9 JTh2A.39)

2D Silicon Photonic Optical Beam Scanner

- Electronic (low-power EO phase shifter) and wavelength steering
- field of view: 24° × 10°; divergence angle: 0.3° × 0.3°
- 256 independent channels with 3-mm pitch
- Area: 750mm x 750mm with high fill factor

Applications

- Imaging and sensing
- Free-space communication



Digital Communications and Networks, 3(2), pp. 67-77, May 2017