Research Spotlight Forum

6.4.19 Quantum Information Sciences

Quantum Information Science at CINT

PRESENTED BY:

Andy Mounce, CINT scientist

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Center for Integrated NanoTechnologies (CINT)

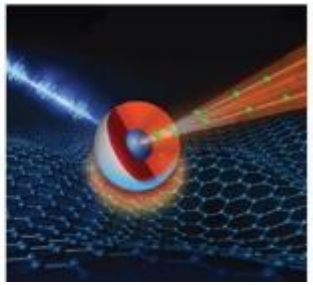
DoE funded nano-science user center

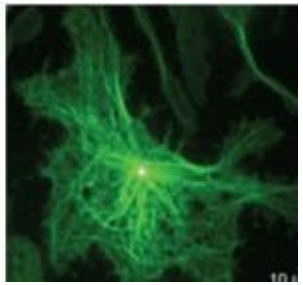
About CINT:

- **Free** access to staff expertise and equipment for open science
- Two proposal calls per year; proposals for short-term projects are accepted continuously
- Simple 2-page proposal
- Proprietary research is possible with full-cost recovery

Research areas:

- **In-Situ Characterization & Nanomechanics –** Developing and implementing world-leading capabilities to study the dynamic response of materials and nanosystems to mechanical, electrical, or other stimuli.
- **Nanophotonics & Optical Nanomaterials –** Synthesis, excitation, and energy transformations of optically active nanomaterials and collective or emergent electromagnetic phenomena (plasmonics, metamaterials, photonic lattices).
- **Soft, Biological & Composite Nanomaterials –** Synthesis, assembly, and characterization of soft, biomolecular, and composite nanomaterials that display emergent functionality.
- **Quantum Materials Systems –** Understanding and controlling quantum effects of nanoscale materials and their integration into systems spanning multiple length scales.





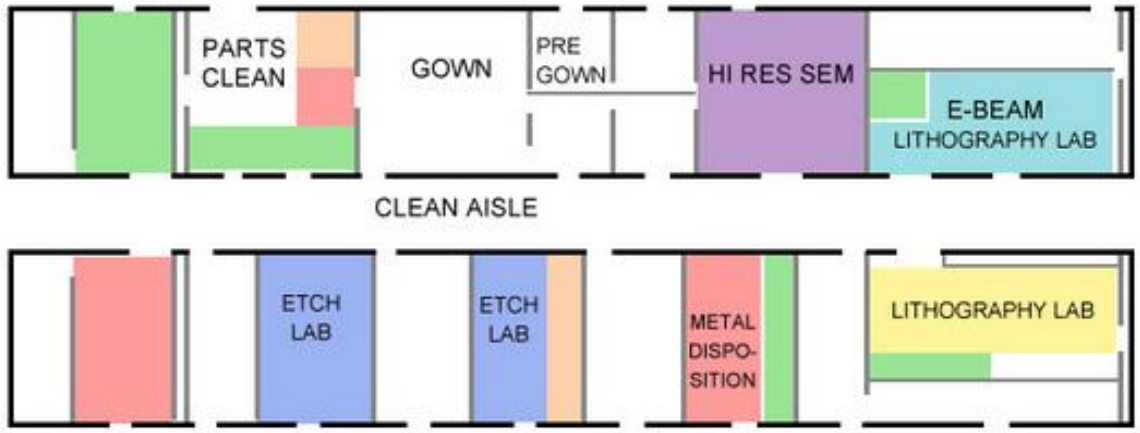
https://cint.lanl.gov
https://cint.sandia.gov
cint@lanl.gov

CINT – General Capabilities

Integration Laboratory:

9000 sq. ft. Class 100 clean room

- Deposition
- Plasma
- E-beam Writer
- Scanning Electron Microscope (SEM)
- Lithography
- Wet Benches
- Metrology



Partnerships:

High Magnetic Field Laboratory

Los Alamos Neutron Science Center

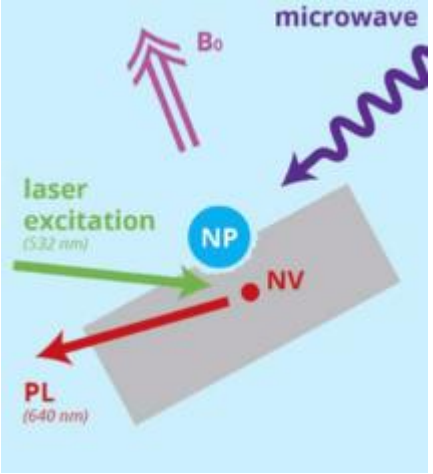
Laboratory for Ultra Fast Materials and Optical Science

LANL and Sandia Advanced Computing Resources

Discovery Platforms:

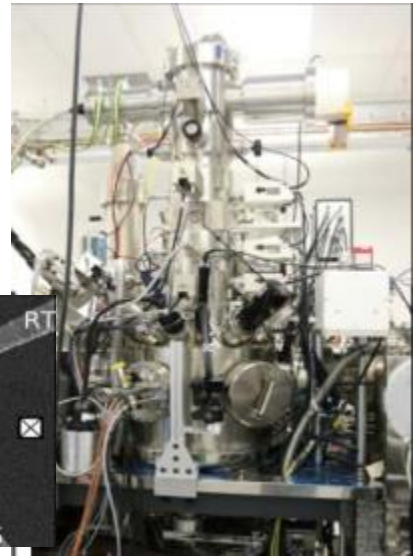
E.x. Quantum Sensed Magnetic Resonance

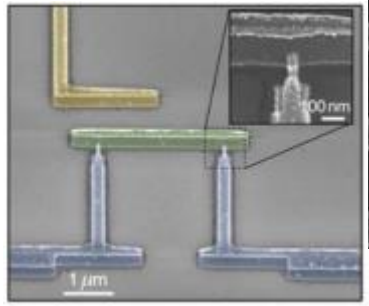
- Custom, qubit based sensors for nano-scale structural and magnetic measurements

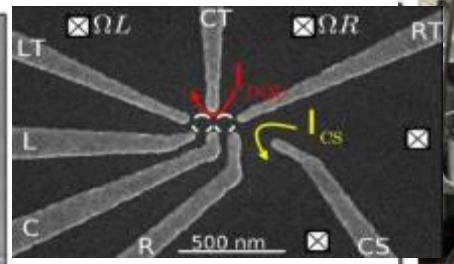


CINT – Quantum Materials: Differentiating Capabilities

Quantum Information Science
- Quantum Transport and qubits
- Quantum Sensing
- Focused ion implantation

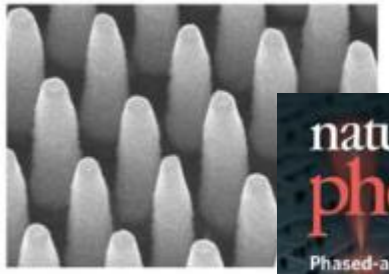


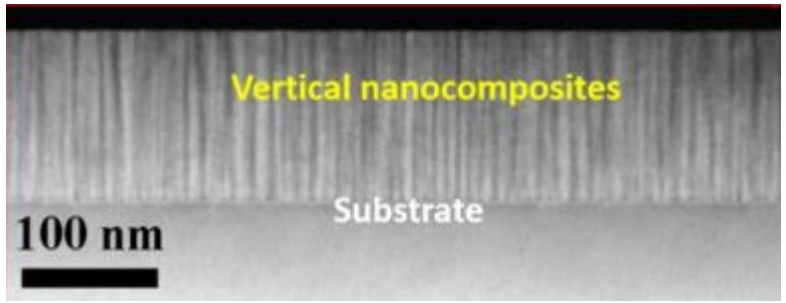


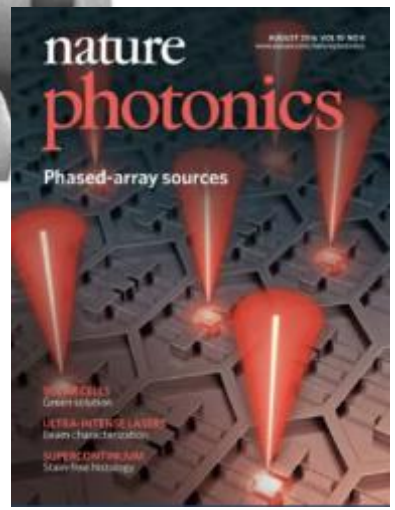


Theory for Correlated Systems
- Techniques for strongly correlated models
- Many-body approaches
- Mean-field modeling for quantum materials

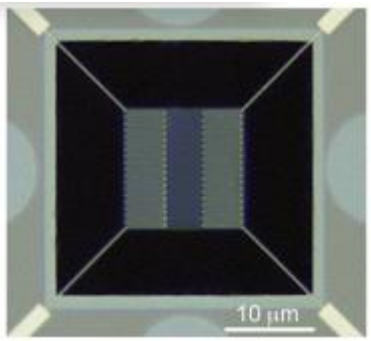
Materials synthesis
- Ultra-High Mobility MBE
- Complex Oxide PLD
- CVD Nanowire Growth

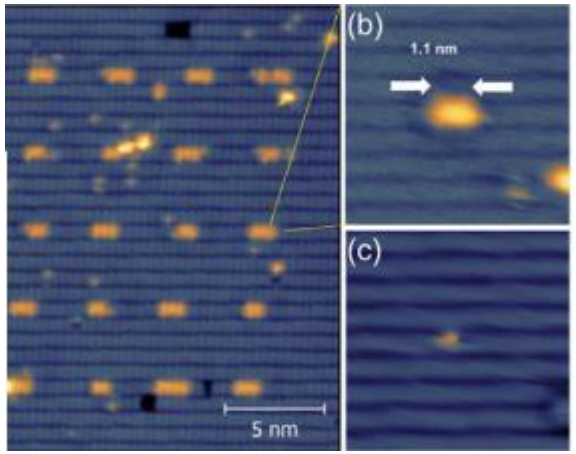






Forefront Lithography
- Atomic-Precision Lithography
- Nanoscale devices





CINT – Quantum Materials: Human Resources

Sandia

Mike Lilly – Lead
Q Transport/
Q Sensing

John Reno
III-V MBE

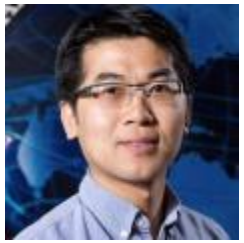
John Nogan
Integration
Lab Manager

Tom Harris
Thermal/Elec.
Transport

Andy Mounce
Q. Sensing
Spin Resonance

Los Alamos

Jinkyoung Yoo
CVD nanowire
& thin film



Aiping Chen
Nanocomposite
synthesis

Dimitri Yarotski
Spetroscopy
Scan Probe

Jianxin Zhu
Theory

Stuart Trugman
Theory

Sandia Affiliates

Ed Bielejec
Ion Implant

Ezra Bussman
STM
Atomic Manuf.

We Pan
Topological QM

Tzu-Ming Lu
Single *e* transport

Other

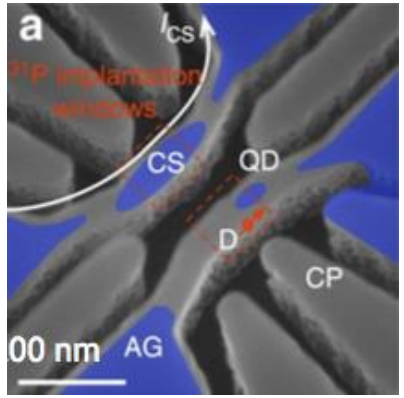
- 4 technologists
- 2 CINT postdocs (+ others)
- 1 UNM student

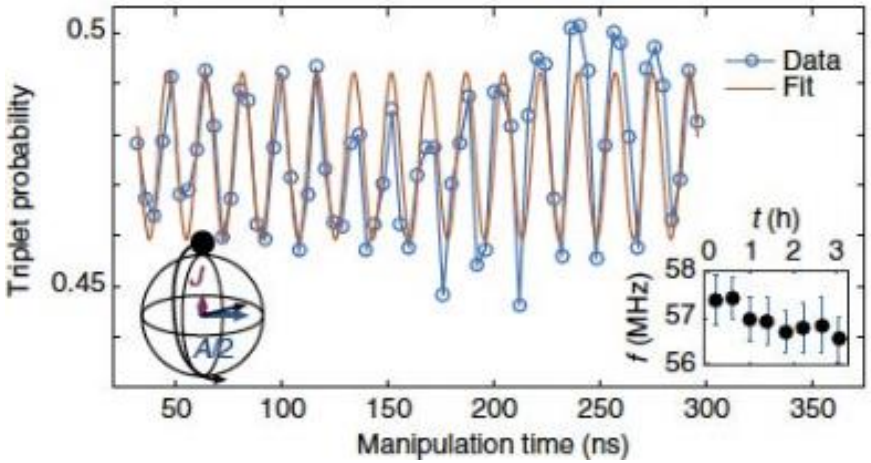
Current Work in Quantum Information Sciences

1. Qubits in Semiconductors
2. Atomic Scale Fabrication
3. Focused Ion Beam Implantation
4. Quantum Sensing using Nitrogen Vacancies in Diamond

Quantum Dots in Semiconductors Support: Mike Lilly, Tzu-Ming Lu

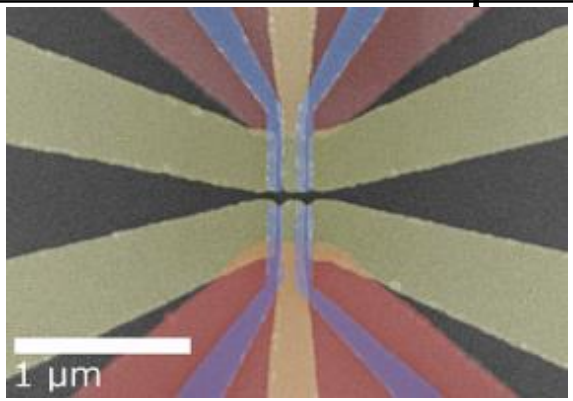
^{31}P Donors in Si





Harvey-Collard, et al., Nature Comm. (2017)]
Harvey-Collard, et al., Phys. Rev. X (2018)
CINT user projects M. Pioro-Ladrarie, M. Carroll

New Platforms: Ge hole quantum dots



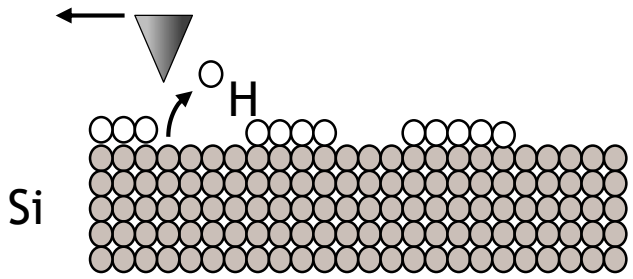
CINT user Dwight Luhman (Sandia)

CINT's role:

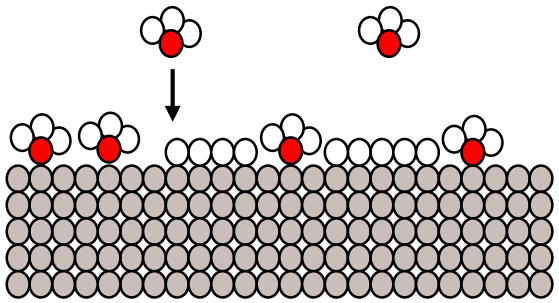
- Fabrication of Ge devices at integration lab
- Cryogenic capabilities:
  - 2x 50mK dilution fridge
  - 1x 300mK 3He fridge
  - 1x 1K pot
  - Several 4K Dewar 'dipper' probes
- Electronics and wiring for low noise measurements
- Cyrogenic amplification

Atomic Scale Fabrication, Support: Ezra Bussmann

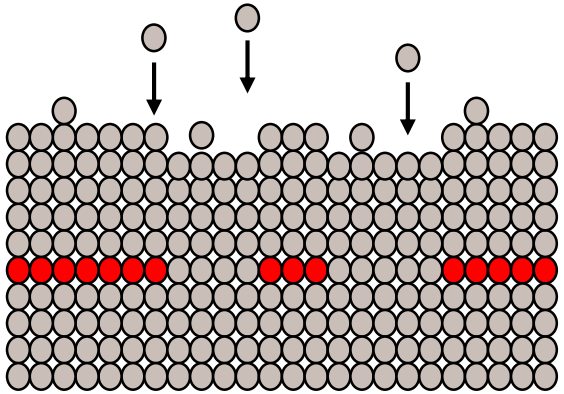
1) Pattern Hydrogen w/ STM tip



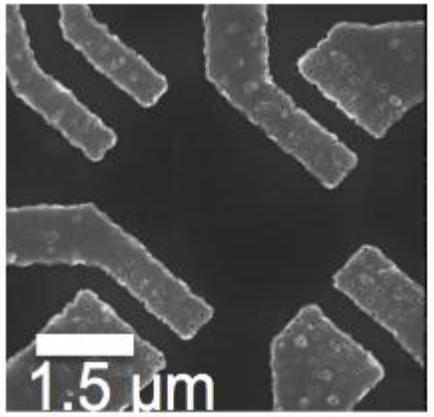
2) Dope with Phosphorus

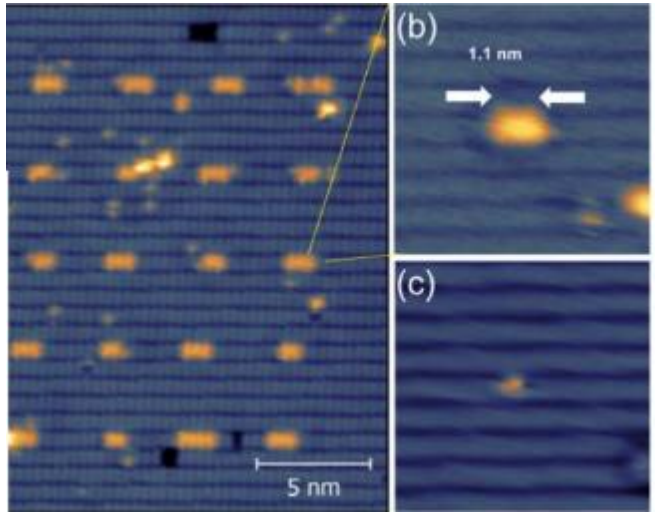


3) Add Si via Epitaxy



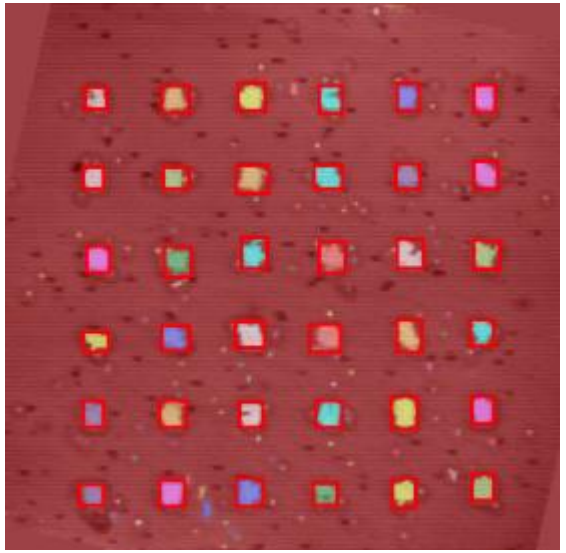
4) Make Device





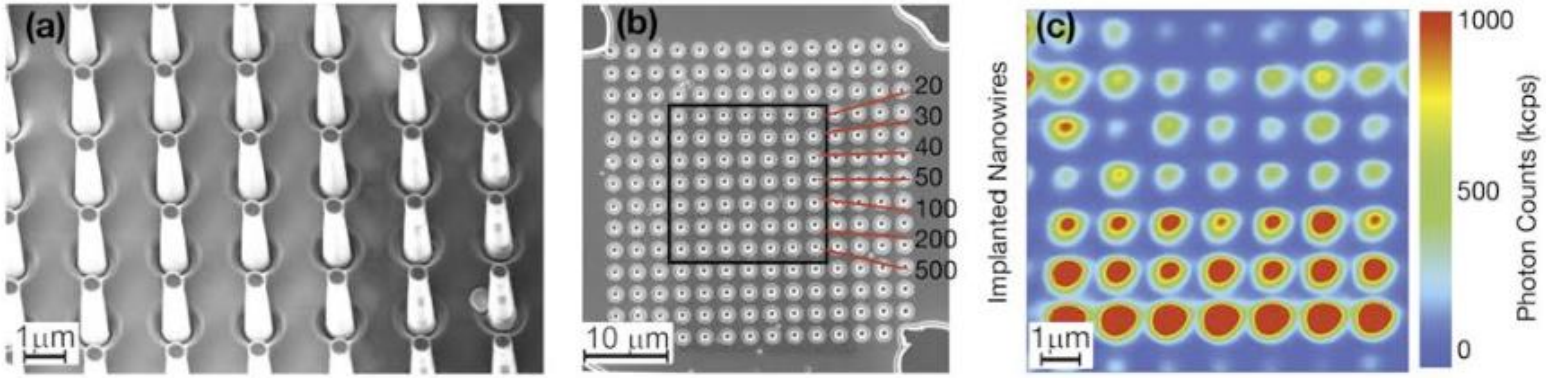
CINT's role:

- Make artificial atomic layer structures
- STM for material surface analysis
- Feature detection and advanced measurement algorithms



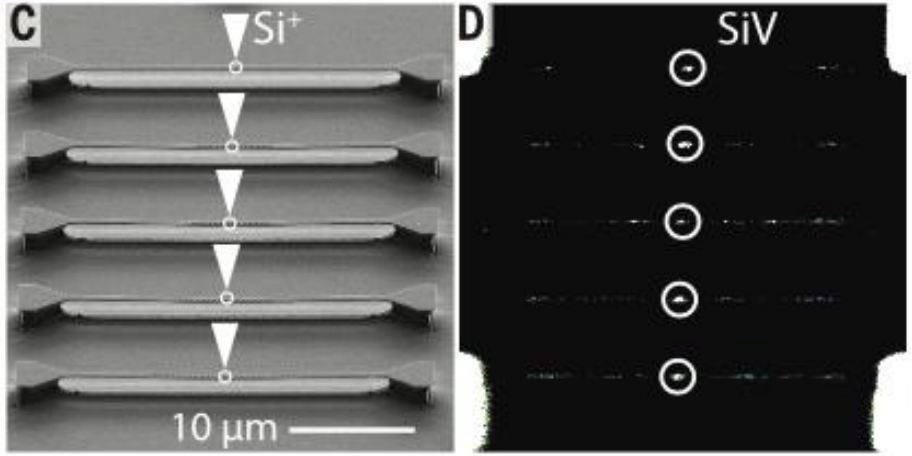
Focused Ion Beam Implantation: Ed Bielejec

Ion implantation into diamond pillars for color center QIS



User project with E. Bielejec, SNL

L. Marseglia, et al., Optics Express (2018)
A. Sipahigil, et al., Science (2016)
T. Schroder, et al., Nat Comm. (2017)

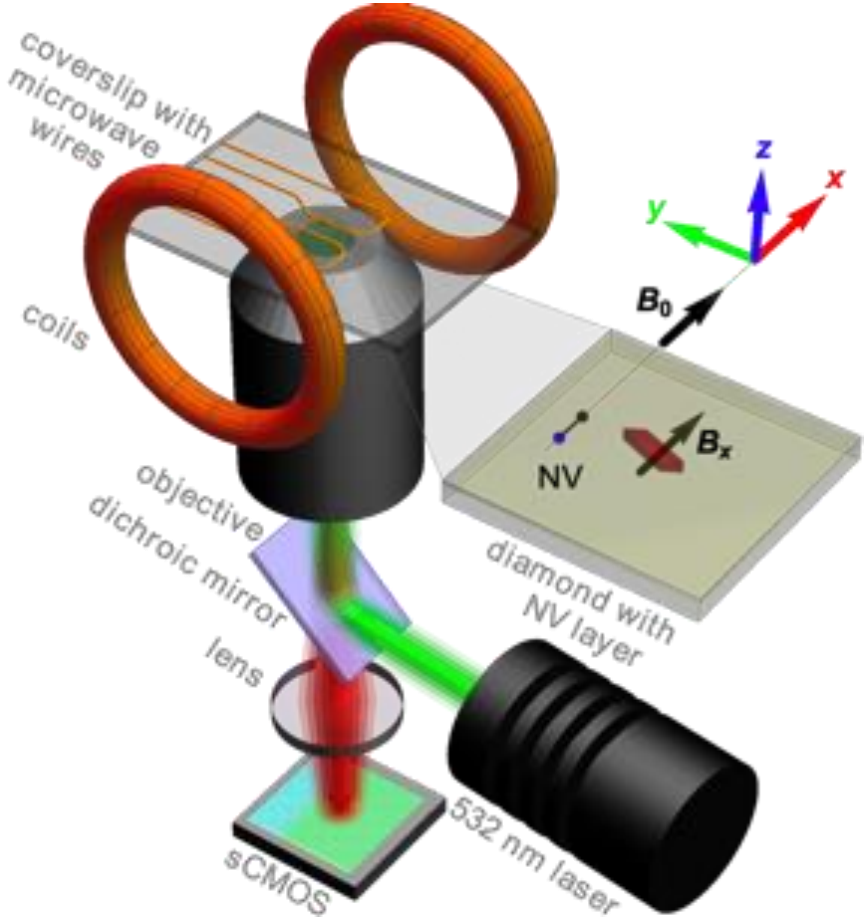


(1) Vary dose
(2) Vary energy
(3) Vary ion species

New FIB source for low energy/high resolution implantation

Quantum Sensing: Andy Mounce

Use the nitrogen vacancy center in diamond's extreme sensitivity to magnetic fields to measure magnetic properties of quantum materials



Form Factor	Research Enabled
Nano particles	Functionalization of surfaces
Films and devices	Spatial map of magnetism & currents
2D materials	Exploration of new materials
Nanowires	Novel device current imaging
Liquid systems	Configuration and bonding

CINT's role:

- Developing new 'discovery platform' for CINT users
- Current working with Prof. Victor Acosta (UNM) through AA
- Working with UNM student as full time researcher at CINT

FUNDING SOURCES

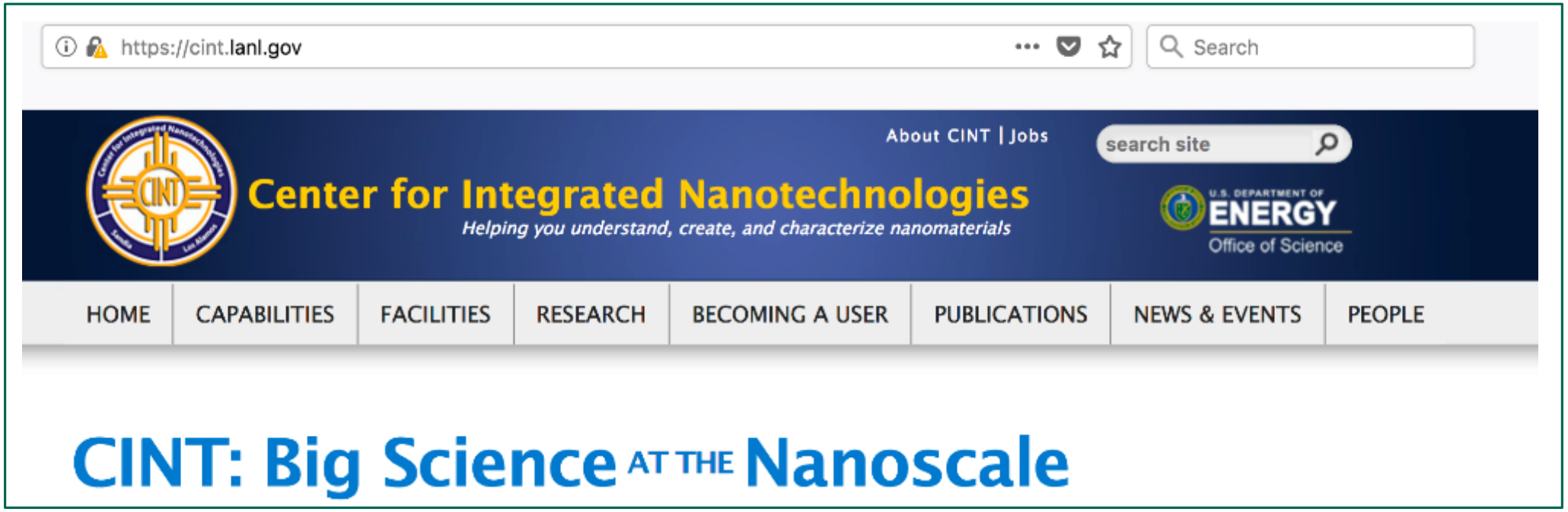
- CINT does not supply PI's with funding, but our resources are free for accepted user proposals

- Department of Energy Basic Energy Sciences

- Laboratory Directed Research and Development (LDRD)
  - Academic Alliance – up to $100k/year to SAA Professor for up to three years
  - ACORNS – up to $80k/year to UNM Professor for up to three years

- Often looking for Postdoctoral Researchers and even Graduate Student Interns

RESEARCH NEEDS



- Visit our website! **cint.lanl.gov**

- Looking for anyone interested in being a CINT user, best to have engaged CINT scientist to help write your 2 page proposal!

- If interested in any of the subjects covered in this presentation contact **amounce@sandia.gov**