Research Spotlight Forum

6.4.19 Quantum Information Sciences

Overview of QIS Research at Sandia National Laboratories

PRESENTED BY:

Rick Muller, Manager, Quantum Initiatives

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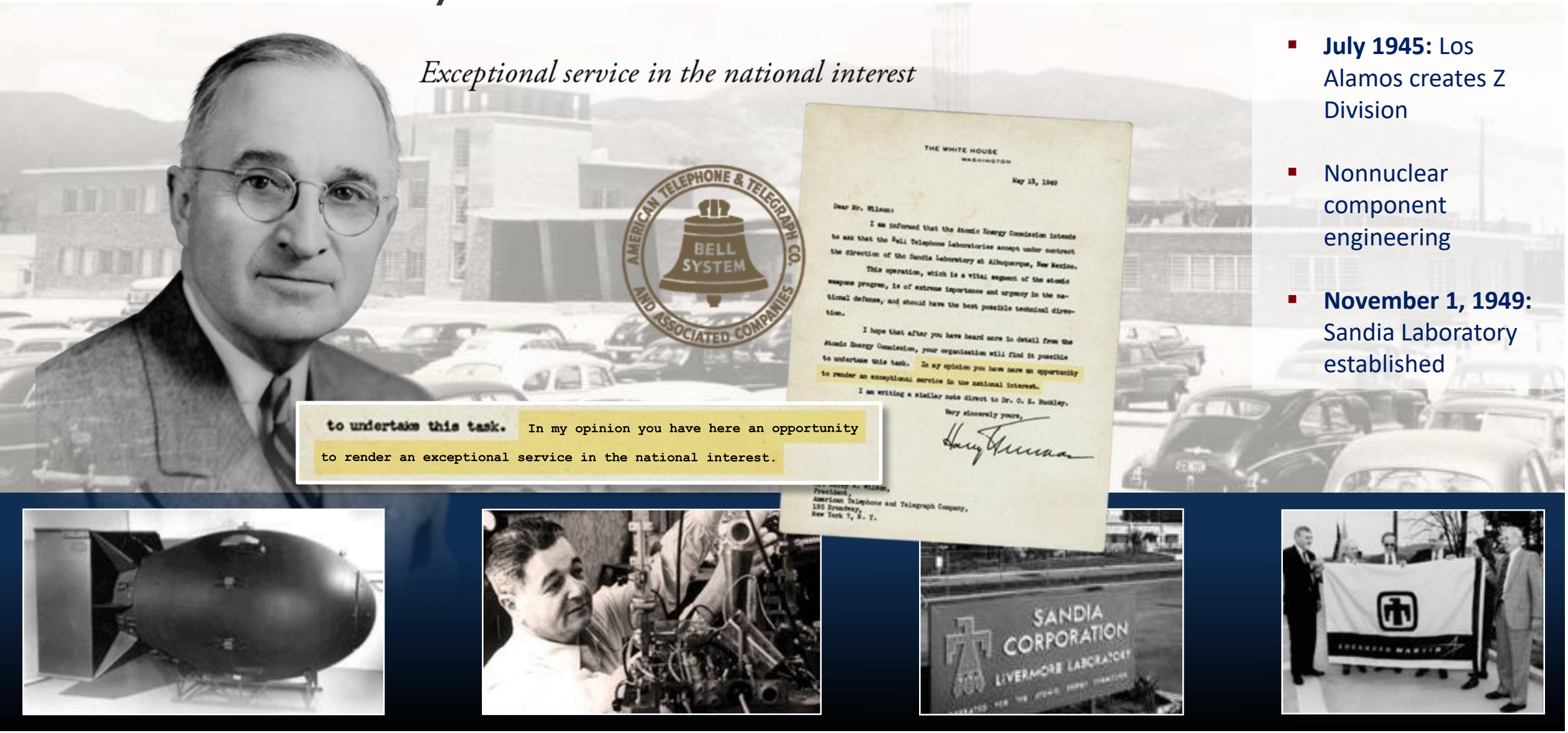
Sandia's history

Exceptional service in the national interest



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

Quantum Information Sciences is Important at the National Level

National Quantum Initiative

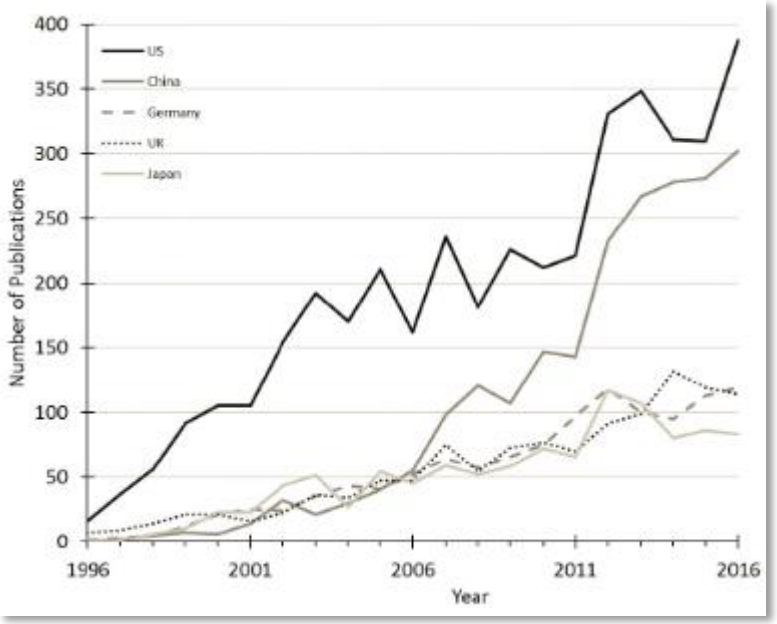
- QIS has important implications for US National and Economic Security
- The rest of the world is investing heavily in QIS: US cannot outspend the world.
- Create an all-of-government approach to coordinate US research in QIS

Bill H.R. 6227

- Unified version of House and Senate Bills
- DOE ($125M/yr), NIST ($80M/yr), NSF ($50M/yr) funding
- Signed by POTUS 12/21/2018
- Authorized but not Appropriated

Opportunities:

- NSF: Quantum Leap Challenge Institutes call open
- NIST: Quantum Economic Development Consortium (QED-C) underway
- DOE Quantum Centers RFI out, FOA expected 2020



SNL QIS Strengths: Fabrication and Characterization

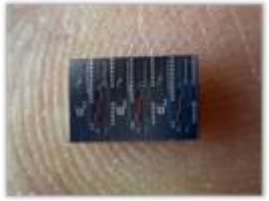
- **MESA Fabs**: Trusted design, fabrication, packaging, testing – underpinning Quantum Info at Sandia
  - Silicon Fab: CMOS process, custom technologies (e.g. ion traps, Si quantum dots, Si photonics)
  - MicroFab: III-V compound semiconductor fab
  - *Wafer-level to die-level processing*
- **Center for Integrated Nanotechnologies (CINT):** *a DOE User Facility*
  - Integration Lab: Clean room with E-beam lithography, photolithography, deposition/etch, SEM/FIB
  - Characterization Lab: SEM/TEM, STM, Si qubit characterization/measurement, transport
- **Special Capabilities:**
  - Atomic Precision Fabrication (CINT): H-lithography for ultimate scale quantum dots and digital electronics
  - Si Photonics: devices thru CMOS integration, cryo SiP
  - Failure analysis: CMOS, superconducting electronics
  - Ion Beam Laboratory: nanoImplanter
- **Materials Science:** creation/synthesis, prototyping processes, measurements, characterization, modeling

MESA

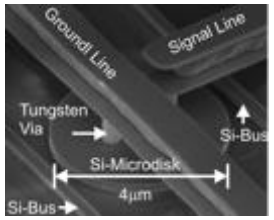
CINT

Atomic Precision Fab @ CINT

World-smallest Sandia "nanologo," at 0.7 nm precision.



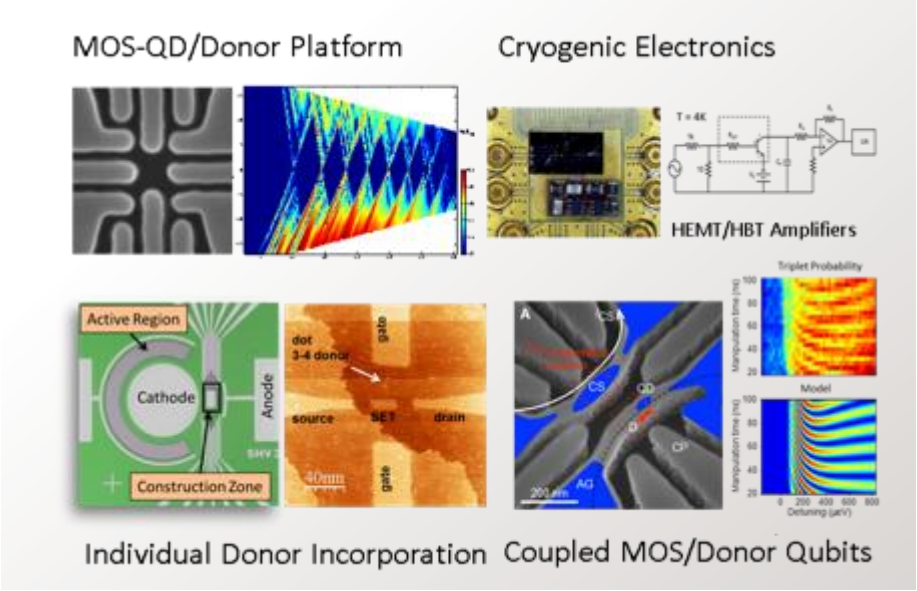
World-first chip scale Si photonics quantum transceiver

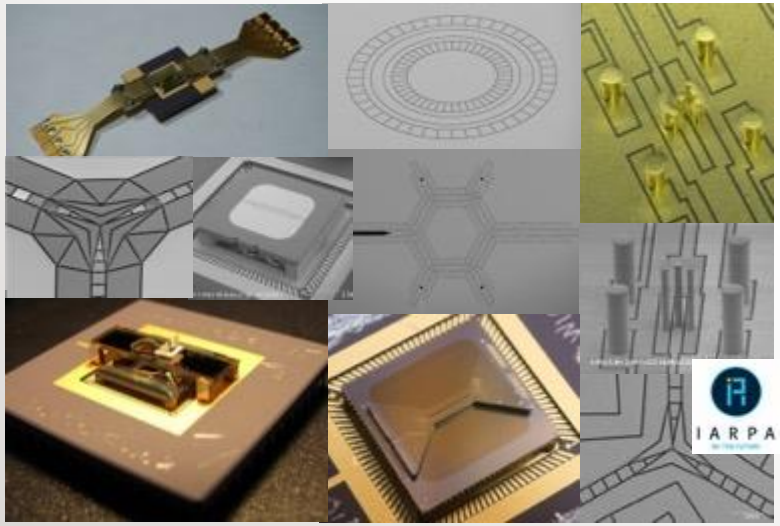


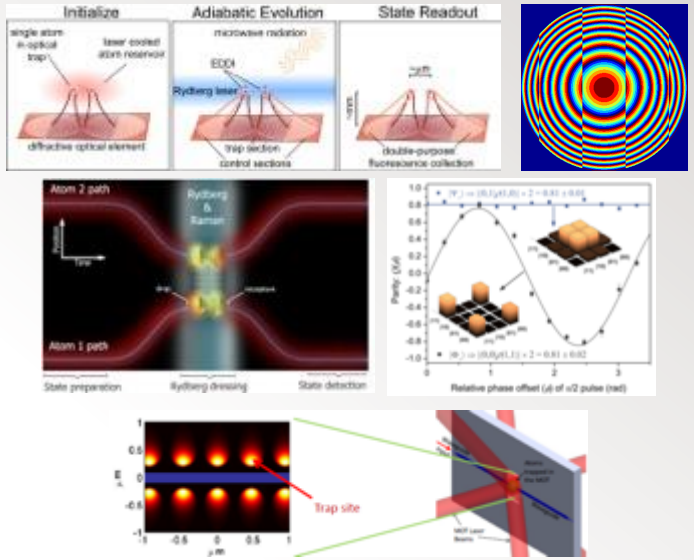
Si Photonics resonant optical modulator/filter

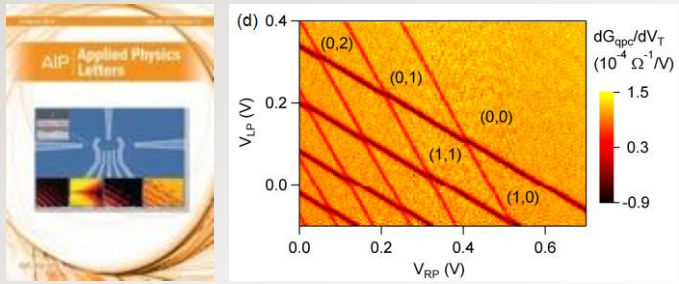
Co-location with Si foundry: industrial fab rigor, defect reduction (function and performance), semiconductor yield engineering - ***QIS program accelerator***

SNL QIS Strengths: Expertise in Multiple Qubit Technologies

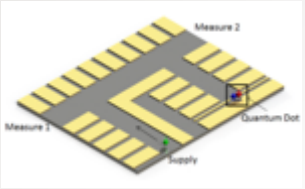




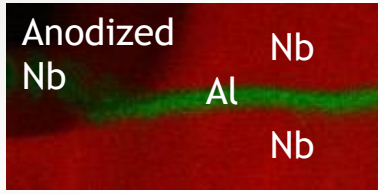




Hole DQD

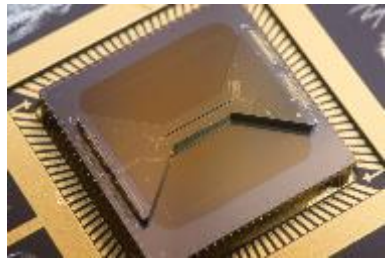


EON Trap



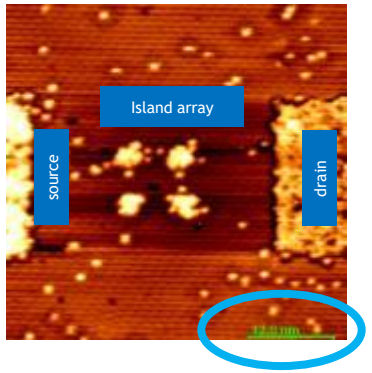
Josephson Junction

New QIS Research Projects

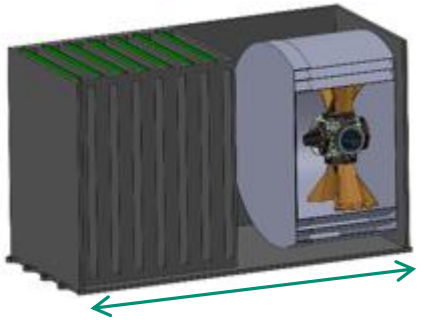


QSCOUT: Use linear ion traps to create an open testbed to understand DOE problems on near-term quantum hardware.
See Dan's talk.

FAIR-DEAL: Apply STM lithography techniques to explore end-of-Moore's law microelectronics issues.

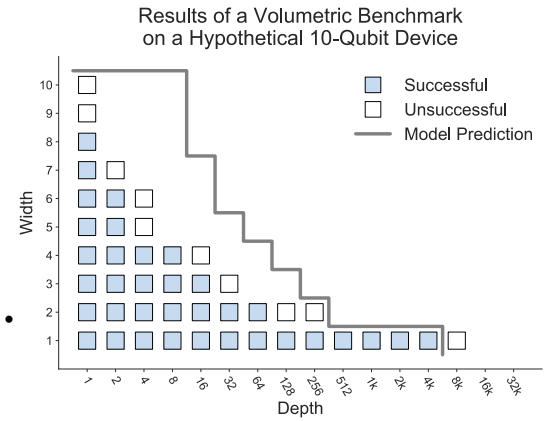


Strategic Inertial Guidance
ΣΙΓΜΑ
with MAtterwaves



SIGMA: Miniaturize trapped atom inertial guidance from laboratory scale to deployable size.
See Shanalyn's talk.

QPERFORMANCE: Explore how quantum processor performance assessment can be assessed and compared.



Sandia Center for Integrated Quantum Sciences

The critical bottleneck to achieving quantum goals is **integration**. CIQS attacks this obstacle by addressing an array of critical S&T challenges:

- How do we simultaneously increase qubit capacity and fidelity?
- Can we integrate multiple qubit technologies to reap the benefits of hybrid devices?
- What efficiencies can be achieved from vertical integration of control stacks?
- What system engineering optimizations can enable key applications?

5 Year Vision: **Integrating Ions and Photons for Science Impact**

- Build on the high fidelity and full connectivity available with trapped ions
- Enable improved devices making use of shuttling and photonics coupling
- Integrate chip-based photonic elements and electronics with existing physics devices.
- Develop algorithms and protocols to deal with connectivity limitations
- Extend to other AMO systems such as quantum sensing with trapped atoms
- ***Driven-by and impacting key science applications***

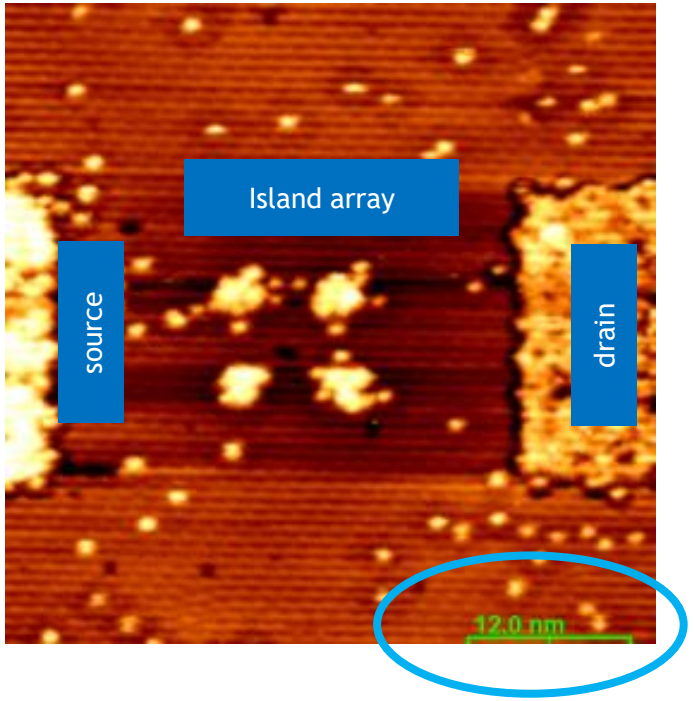
Beyond 5 years:

- Extend capabilities to heterogeneously integrate multiple complementary quantum technologies
- Develop and demonstrate an agile platform for chiplets representing different computing, communications, and sensing capabilities.

Postdocs Wanted!

Sandia has needs for postdocs in QIS:

- Low temperature measurement
- Semiconductor fabrication, measurement, and modeling
- AMO physics
- Modeling of experimental QIS systems
- Quantum algorithms and software

Email quantum@sandia.gov for more information, or search for the current open postings at http://www.sandia.gov:

- 666828 Postdoctoral Appointee - Quantum Computing Theory (CA)
- 667638 Experimental Physicist - Quantum Information Science (early career)
- 667620 Quantum Information Science Postdoctoral Appointee
- 667561 Intern - Quantum Phenomena R&D Graduate Year Round
- 663237 Postdoctoal Appointee – Quantum Algorithms