Research Spotlight Forum

SAND2019-6170PE

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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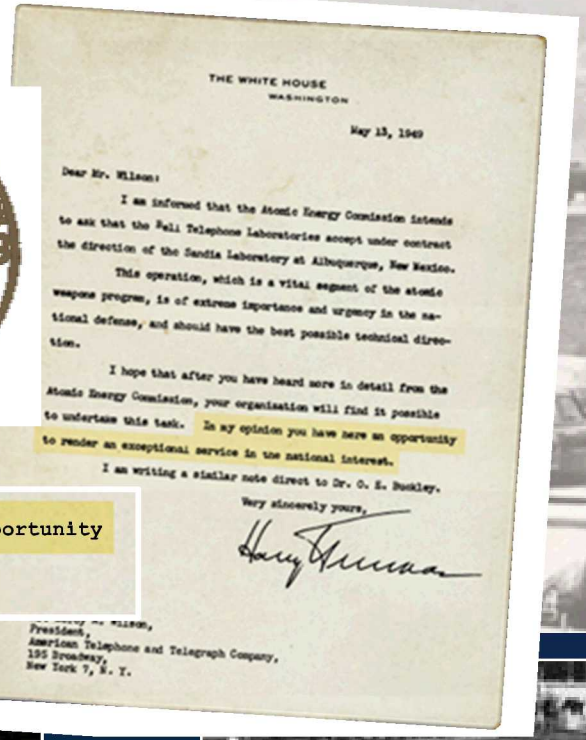
SAND2019-xxxx

Sandia's history

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,

Harry Truman

President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

to undertake this task. 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

Quantum Information Sciences is Important at the National Level

National Quantum Initiative

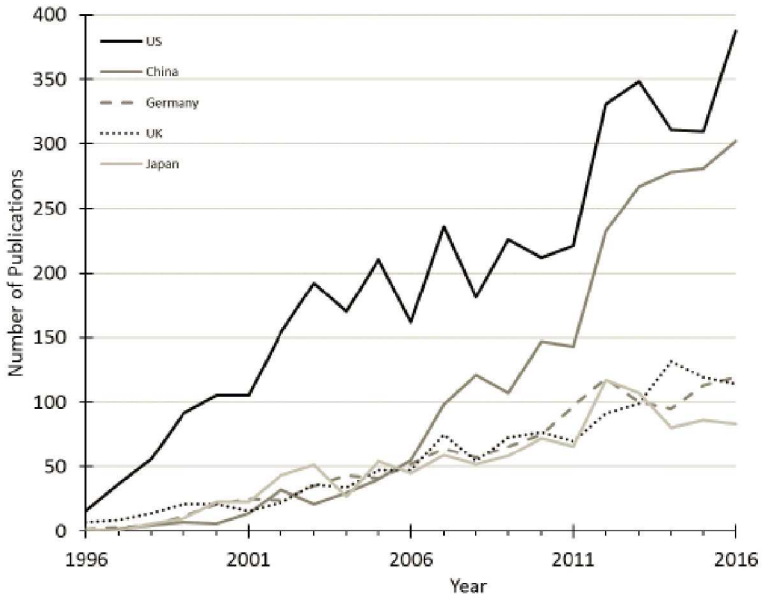
- QIS has important implications for US National and Economic Security
- The rest of the world is investing heavily in QIS: US cannot outspend the world.
- Create an all-of-government approach to coordinate US research in QIS

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



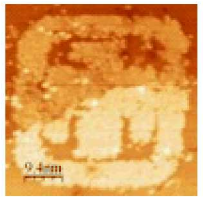
Fabrication and Characterization Capabilities

- **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

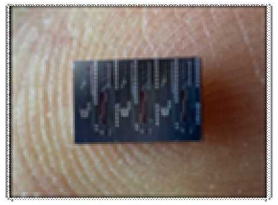
MESA

CINT

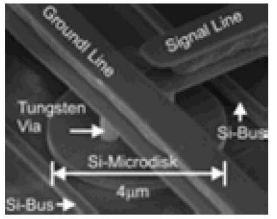
Atomic Precision Fab @ CINT



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



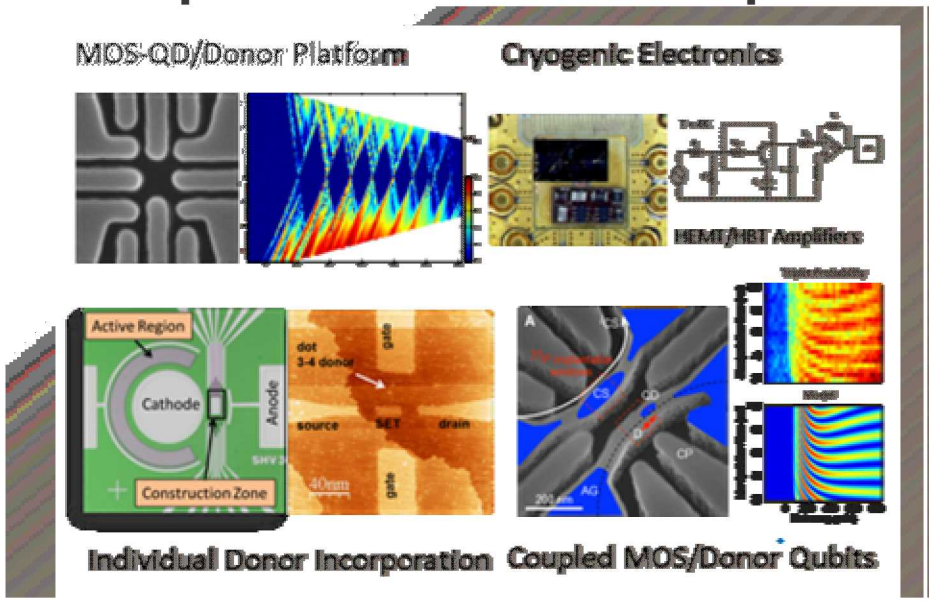
World-first chip scale Si photonics quantum transceiver

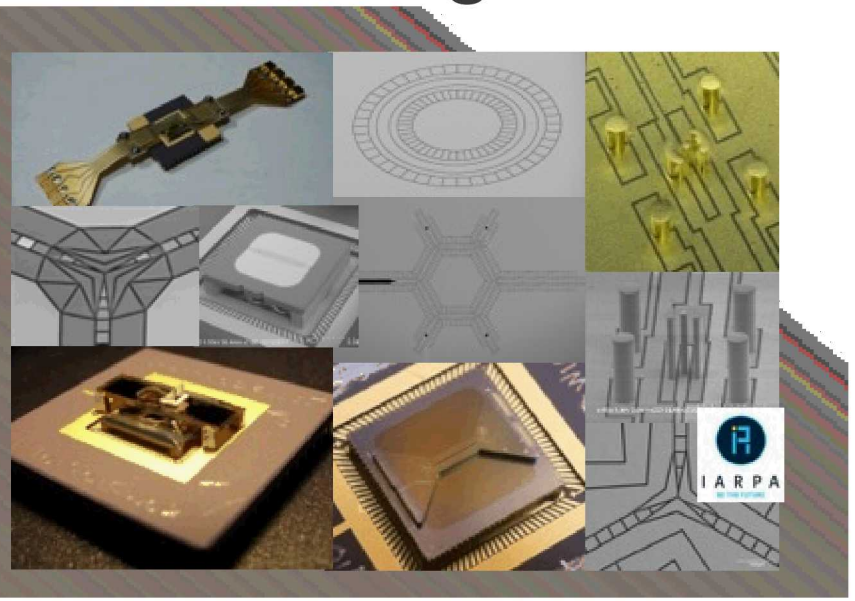


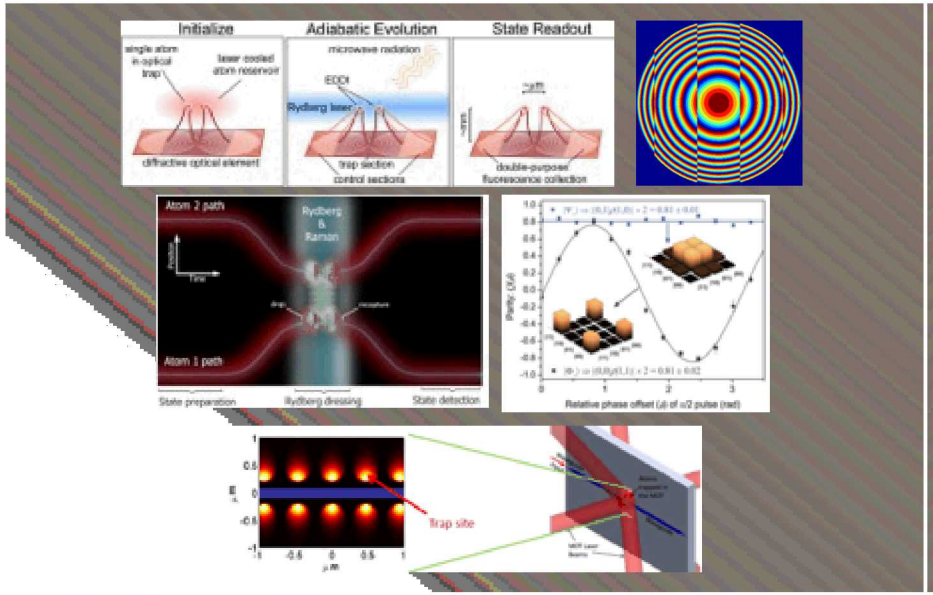
Si Photonics resonant optical modulator/filter

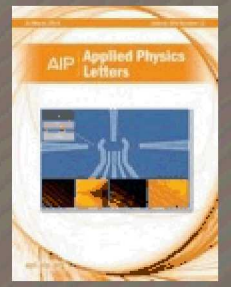
Co-location with Si foundry: industrial fab rigor, defect reduction (function and performance), semiconductor yield engineering - ***QIS program accelerator***

Sandia Expertise in Multiple Qubit Technologies

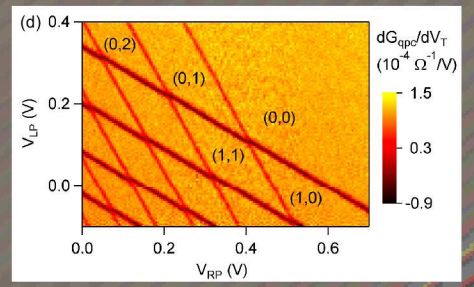


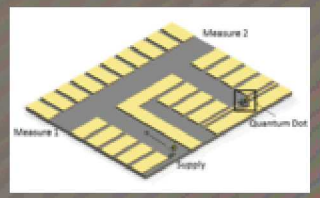




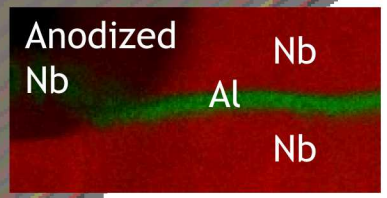


Hole DQD





EON Trap



Josephson Junction

Quantum Scientific Open User Testbed (QSCOUT)

PI: Peter Maunz

DOE/ASCR facility to develop an open quantum testbed with 5-15 qubits realized in trapped-ion technology

Features:

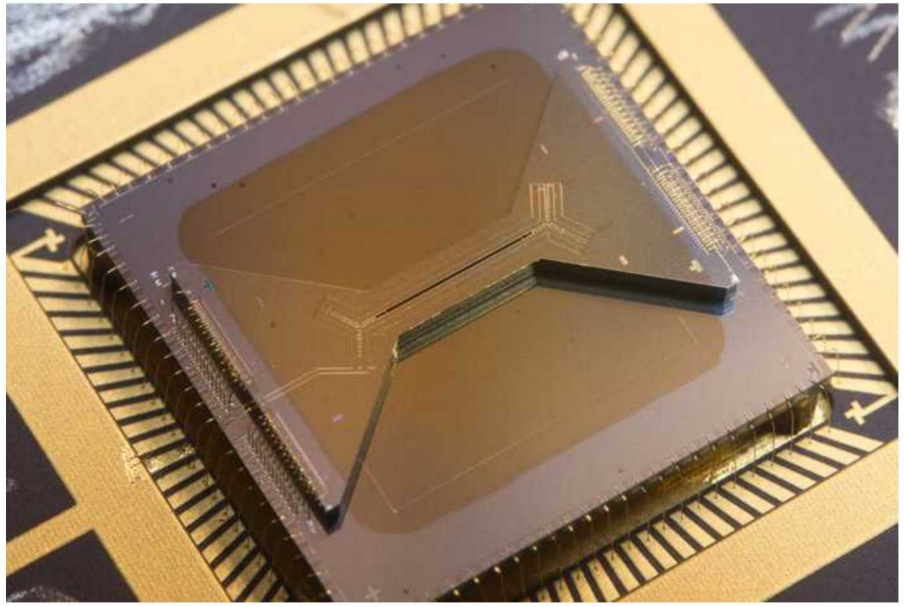
- Low single- and two-qubit error rates ($<10^{-4}$, $<2 \times 10^{-2}$)
- All-to-all connectivity between qubits
- General algorithm execution capability
- Access to all relevant low-level implementation details
- Capability to change low-level gate implementation

Availability:

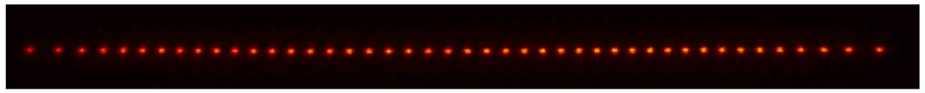
- Available to the DOE Scientific computing community
- First device will come online at end of 2019

User support:

- Exemplar programs and demonstrations
- User workshops and conferences (together with LBNL)



Sandia's High Optical Access (HOA) ion trap



Chain of 44 $^{171}Yb^{+}$ Ions trapped in the HOA trap

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:

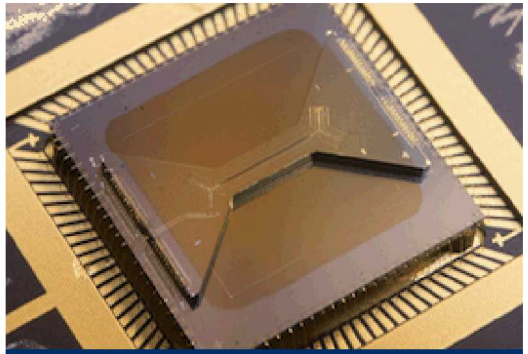
- How do we simultaneously increase qubit capacity and fidelity?
- Can we integrate multiple qubit technologies to reap the benefits of hybrid devices?
- What efficiencies can be achieved from vertical integration of control stacks?
- What system engineering optimizations can enable key applications?

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