



Quantum New Mexico Symposium

LANL's role in the 'Second Quantum Revolution'

John Sarrao

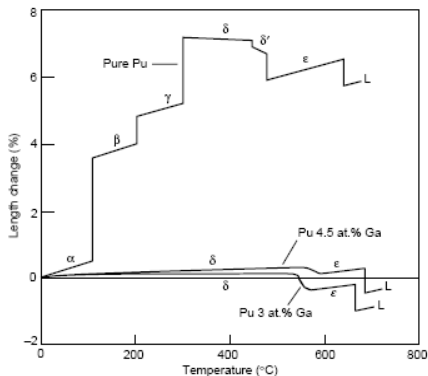
Deputy Director, Science, Technology & Engineering

March 31, 2022

LA-UR #

Pre-history: Quantum Matter is central to nuclear weapons

Plutonium: Superconductivity

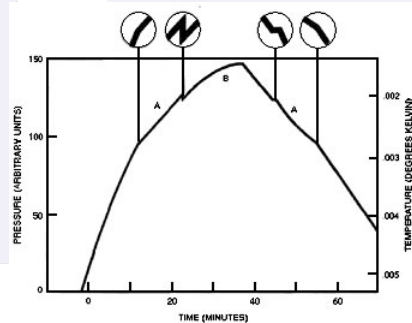


Adding small amounts of gallium dramatically changes plutonium's behavior: from cast iron to aluminum

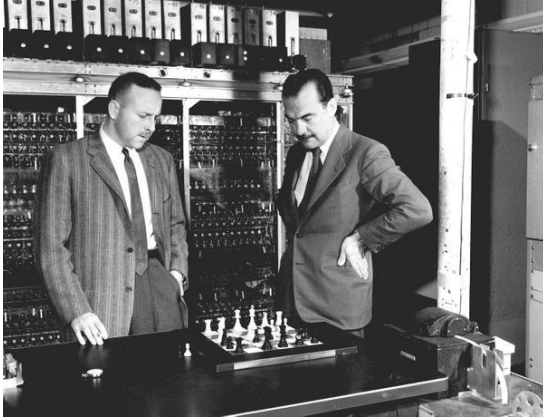


“The magnetism of superconductivity ... electrons should not be blamed for the misdeeds of their nucleus...”
Stephen Julian, Physics World, February 2003

Tritium: Superfluidity



Los Alamos has always strived to be at the frontier of computing



Richard Feynman

On quantum physics and computer simulation

... there is plenty of room to make [computers] smaller. ... nothing that I can see in the physical laws ... says the computer elements cannot be made enormously smaller than they are now. In fact, there may be certain advantages.
—1959

The next question was what are the limits in computers due to quantum mechanics? ... What I hoped to do was to design a computer in which I knew how every part worked with everything specified down to the atomic level. In other words I wanted to write down a Hamiltonian for a system that could make a calculation. Then I could calculate the various effects of the limits due to quantum mechanics.

Feynman, R. 1983. Tiny Computers Obeying Quantum Mechanical Laws. Talk delivered at Los Alamos National Laboratory. Published in *New Directions in Physics: The Los Alamos 40th Anniversary Volume*. 1987. Edited by N. Metropolis, D. M. Kerr, and G.-C. Rota. Orlando, FL: Academic Press, Inc.

LANL's history in quantum computing (~2000)



LANL has been a world leader in quantum information science since the late 90s



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Liquid-state NMR simulations of quantum many-body problems

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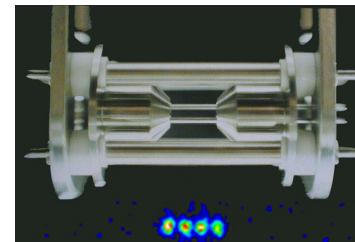
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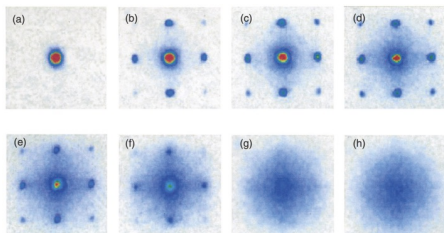
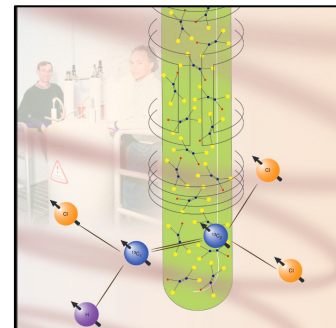
⁴Mathematics and Computer Sciences Division, National Institute of Standards and Technology, Boulder, Colorado 80305, USA

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Trapped ions

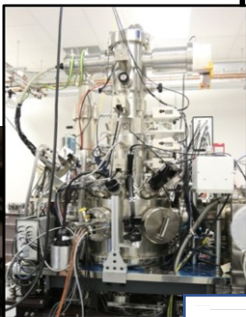
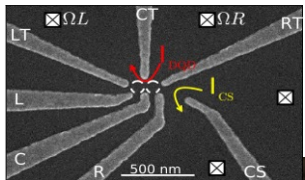


NMR



BECs

The Center for Integrated Nanotechnologies (CINT) hosts forefront quantum research capabilities for users

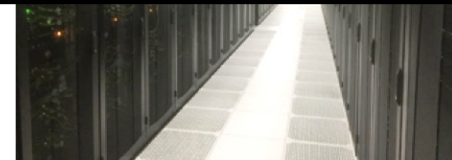


Quantum Information Science

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

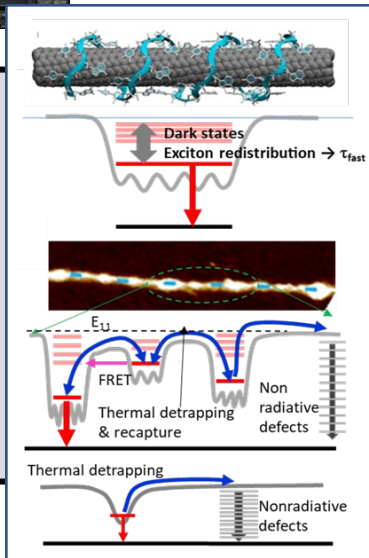
Theory for Correlated Systems

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



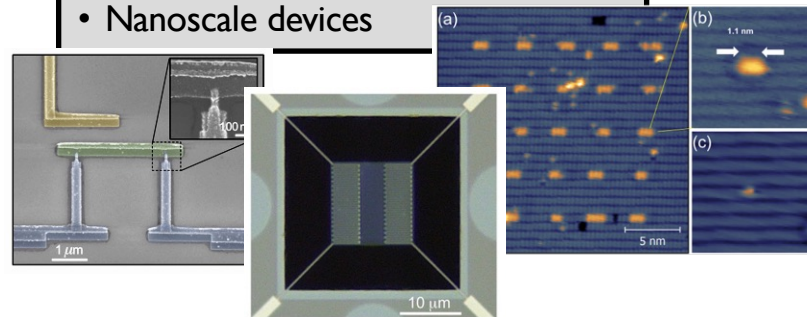
Cutting edge spatial & temporal optical characterization

- Broadband ultrafast spectroscopy
- Broadly tunable Raman probes
- Single nanoelement optical spectroscopy/microscopy
- Scanning near-field optical microscopy: combined optical imaging, spectroscopy, AFM



Forefront Lithography

- Atomic-Precision Lithography
- Nanoscale devices



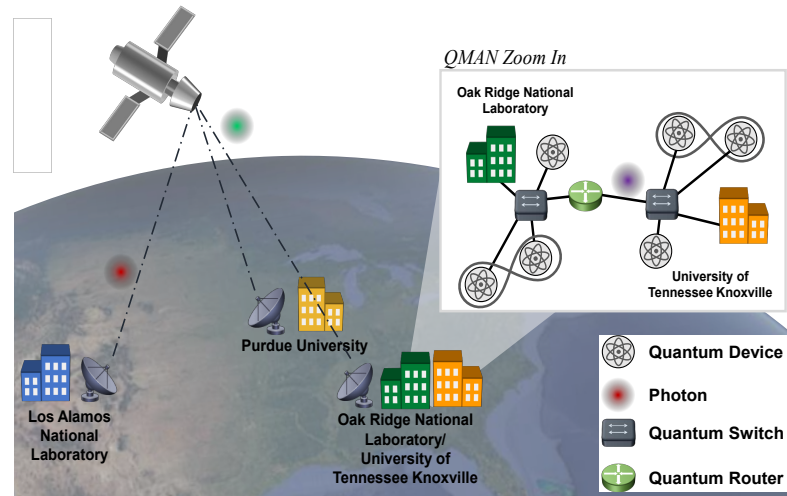
Quantum accelerated internet testbed (QuAINT)

Objective: Advance the high-priority research directions and milestones identified in the DOE Quantum Internet Blueprint Workshop report.

Approach: Design, develop, and demonstrate a regional-scale intricacy quantum internet testbed along with the required components, subsystems, and control systems. Key technologies include single and entangled photon sources, quantum memory, and quantum processing on frequency modes.

QuAINT builds on efforts that deployed quantum technology on the electric grid

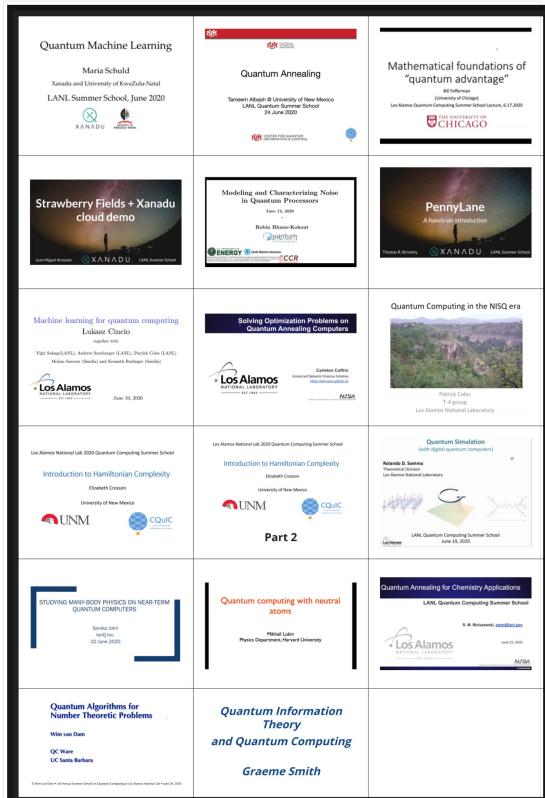
Vision:



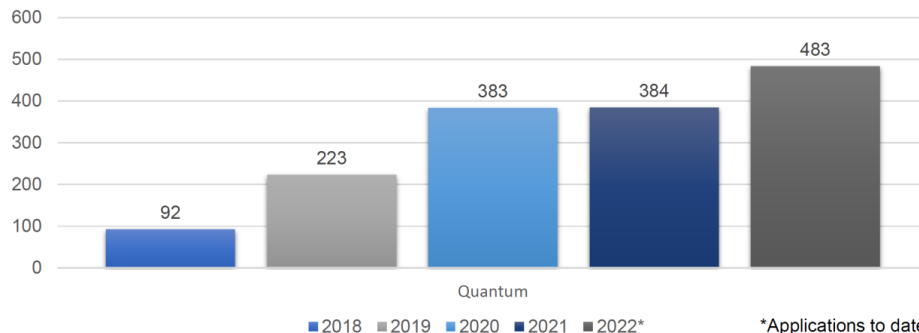
LANL's Quantum Computing Summer School underpins our quantum workforce development strategy

Accepts ~25 students annually through Fellowships

Develops new leaders in theory, application and programming of quantum computers



Student applications by year



LANL is and will continue to be active in the Quantum Community, especially in New Mexico

- A distinguished history and a bright future of partnering with University of New Mexico and Sandia National Laboratories, including through the Quantum New Mexico Institute.
- LANL is a leader of the IEEE Quantum Initiative (QI), IEEE's leading community for all projects and activities on quantum technologies.
- LANL is a leader with the Quantum Economic Development Consortium (QED-C) and was the first National Laboratory to join the QED-C.

New Mexico is *a* and can be *the* Quantum State