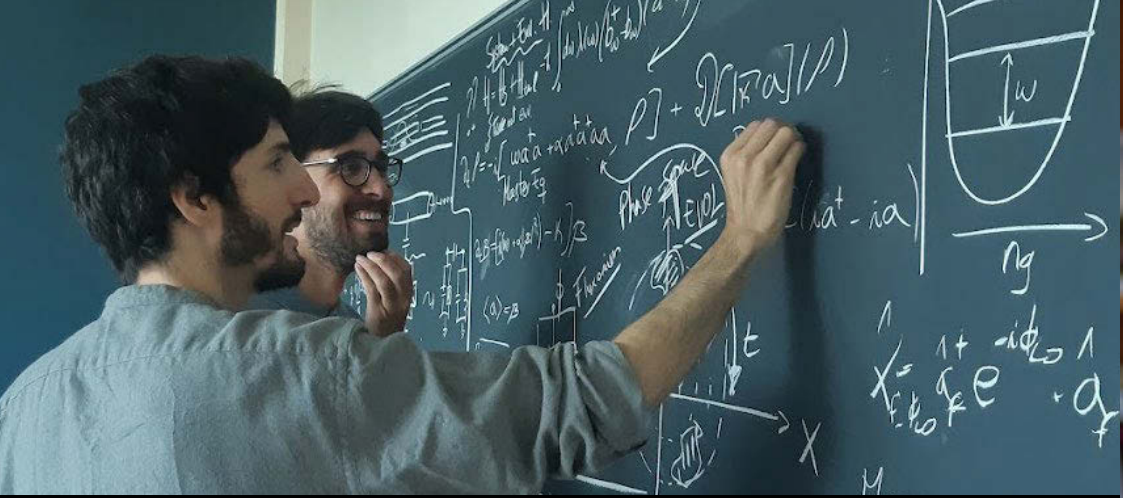


Impact Report

Quantum Systems Accelerator

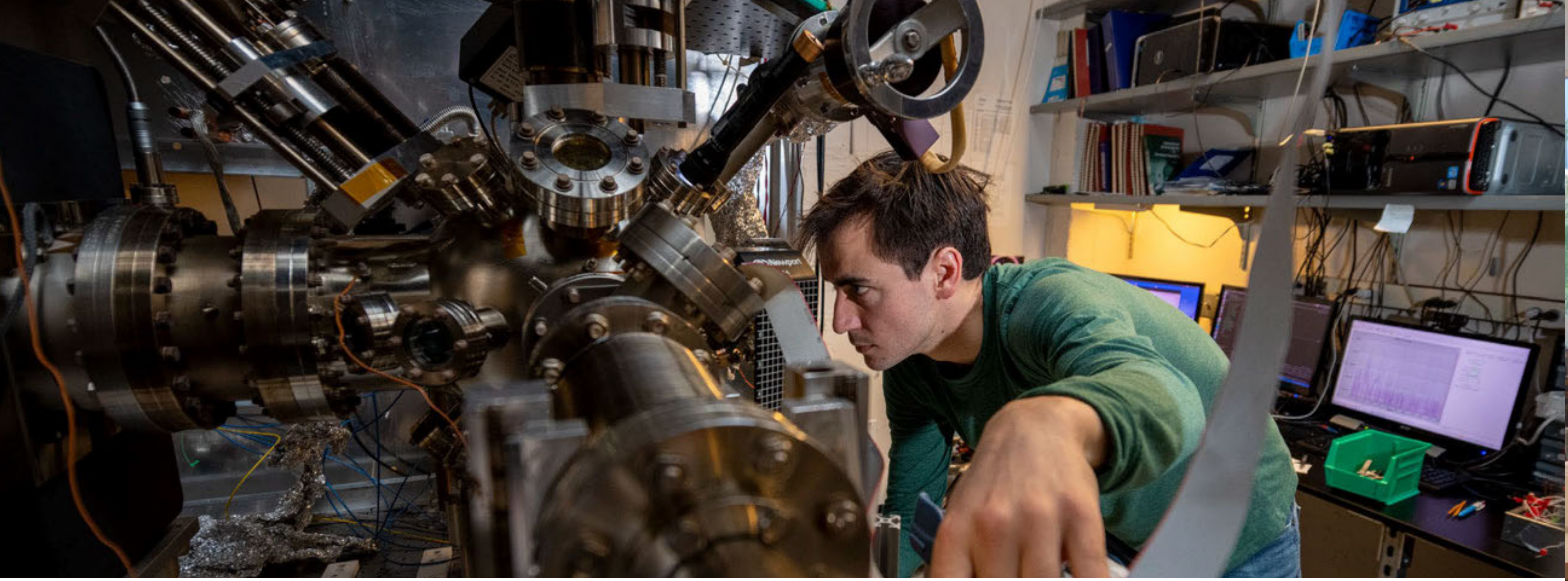
Lawrence Berkeley National Laboratory

Sandia National Laboratories

APRIL 2023

QUANTUM SYSTEMS ACCELERATOR

U.S. DEPARTMENT OF ENERGY | Office of Science



Cover images, counter-clockwise from left: Theorists at work (Credit: Université de Sherbrooke); quality control of quantum processors in clean room (Sandia Labs); Adjoint Professor Ana Maria Rey (UC Boulder); Current page: UC Berkeley's Ben Saarel adjusts settings for trapping ions (Credit: Berkeley Lab)

BERKELEY LAB

Sandia National Laboratories

MIT LINCOLN LABORATORY

Berkeley UNIVERSITY OF CALIFORNIA

MIT

Tufts UNIVERSITY

USC

THE UNIVERSITY OF NEW MEXICO

TEXAS The University of Texas at Austin

UNIVERSITÉ DE SHERBROOKE

Duke PRATT SCHOOL of ENGINEERING

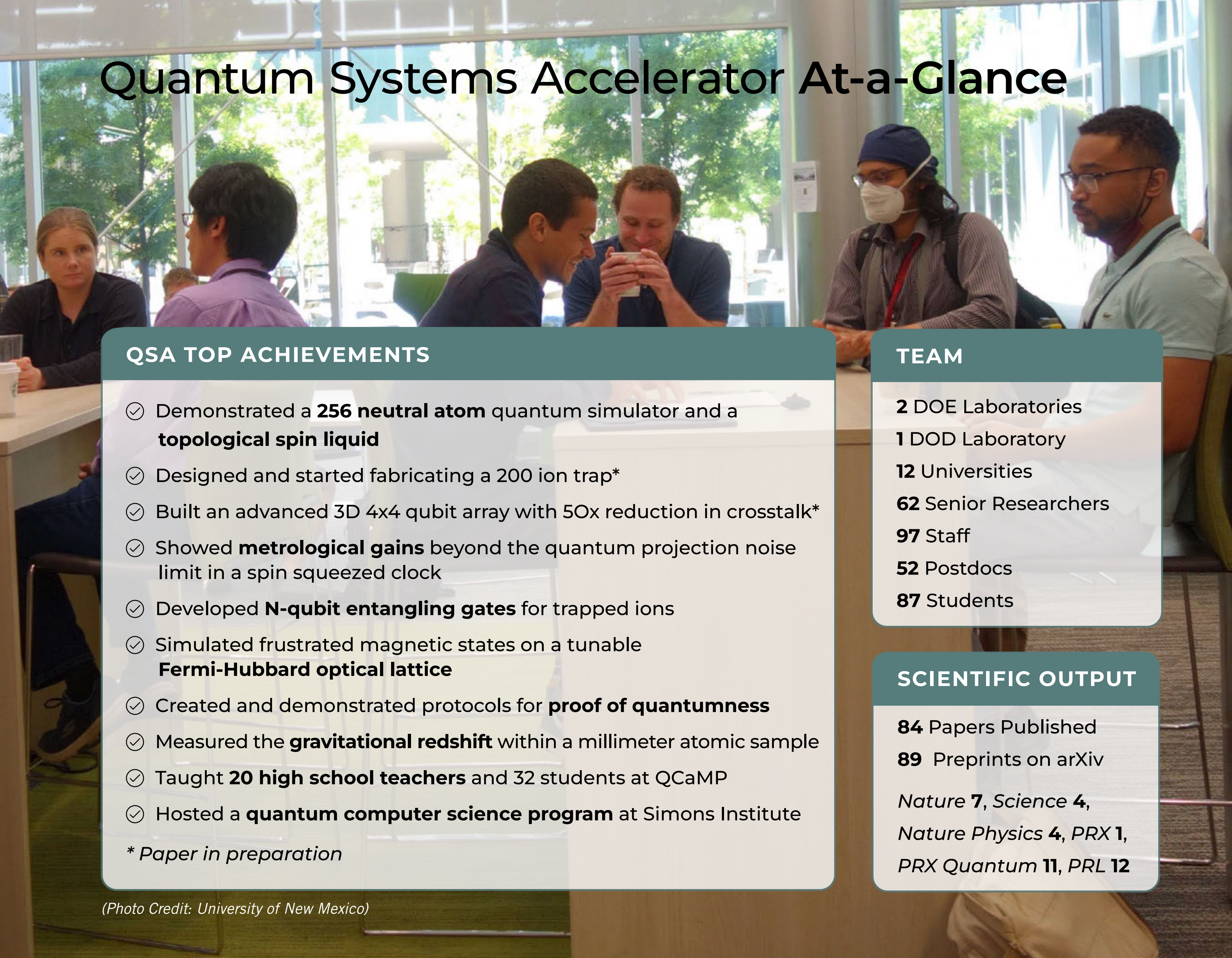
Caltech

HARVARD UNIVERSITY

University of Colorado Boulder

UNIVERSITY OF MARYLAND

Quantum Systems Accelerator At-a-Glance



QSA TOP ACHIEVEMENTS

- Demonstrated a **256 neutral atom** quantum simulator and a **topological spin liquid**
- Designed and started fabricating a 200 ion trap*
- Built an advanced 3D 4x4 qubit array with 50x reduction in crosstalk*
- Showed **metrological gains** beyond the quantum projection noise limit in a spin squeezed clock
- Developed **N-qubit entangling gates** for trapped ions
- Simulated frustrated magnetic states on a tunable **Fermi-Hubbard optical lattice**
- Created and demonstrated protocols for **proof of quantumness**
- Measured the **gravitational redshift** within a millimeter atomic sample
- Taught **20 high school teachers** and 32 students at QCaMP
- Hosted a **quantum computer science program** at Simons Institute

** Paper in preparation*

(Photo Credit: University of New Mexico)

TEAM

2 DOE Laboratories
1 DOD Laboratory
12 Universities
62 Senior Researchers
97 Staff
52 Postdocs
87 Students

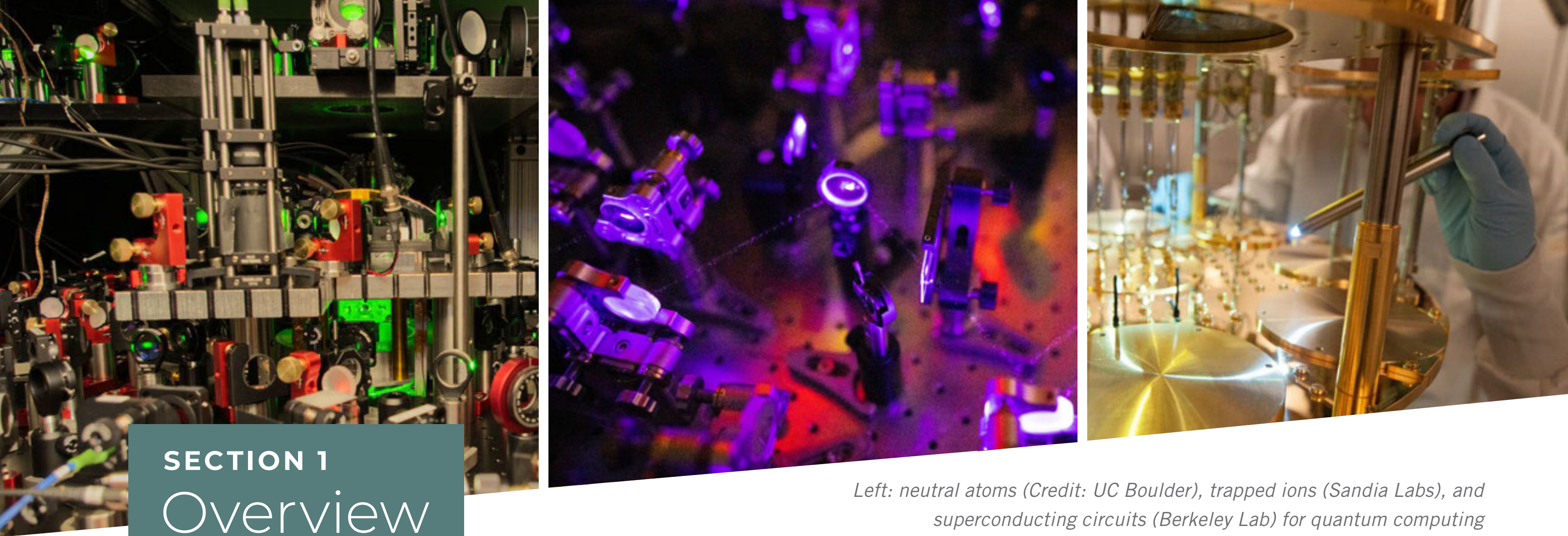
SCIENTIFIC OUTPUT

84 Papers Published
89 Preprints on arXiv

Nature **7**, *Science* **4**,
Nature Physics **4**, *PRX* **1**,
PRX Quantum **11**, *PRL* **12**

Contents

Researchers advance benchmarking and applications for quantum devices (Credit: U Sherbrooke)



Left: neutral atoms (Credit: UC Boulder), trapped ions (Sandia Labs), and superconducting circuits (Berkeley Lab) for quantum computing

SECTION 1

Overview

The Quantum Systems Accelerator (QSA) is a U.S. National Quantum Information Science Research Center established in August 2020 and funded by the Department of Energy (DOE) Office of Science. QSA is composed of 15 partner institutions—universities and national laboratories—bringing together pioneers of many of today's unique quantum information science (QIS) and engineering capabilities. Led by Lawrence Berkeley National Laboratory (Berkeley Lab), with Sandia National Laboratories (Sandia Labs) as the lead partner, 250+ QSA researchers are catalyzing U.S. leadership in a fast-growing field that seeks solutions to the Nation's and the world's most pressing problems by harnessing the laws of quantum mechanics.

As part of its mission to explore the technologies required to bridge the gap between today's NISQ (Noisy Intermediate-Scale Quantum) systems and those that will be fully fault-tolerant and capable of impactful science applications, QSA leverages state-of-the-art existing national facilities and the DOE's robust history of pushing the frontiers of basic science and scientific computing. QSA also collaborates with various industry and academic partners worldwide while preparing the Nation's increasingly diverse quantum workforce, starting as early as high school.

Since its founding, QSA has co-designed powerful programmable quantum prototypes that maximize the performance of current noisy quantum hardware in three major platforms: neutral atoms, trapped ions, and superconducting circuits. Furthermore, it has advanced the algorithms and platform-specific applications specifically constructed for near-term, imperfect hardware for scientific computing, materials science, and fundamental physics. These scientific achievements will continue accelerating the technology transfer from labs and universities to the marketplace and prepare the Nation's workforce and industry to harness the capabilities of quantum computing.

Leadership

Rick Muller, Director

Spanning a career of two decades at Sandia National Laboratories, Rick Muller is the Senior Manager of Sandia's Advanced Microsystems Group. Muller directs the QIS and technology program, which develops key technologies for quantum computing, quantum sensing, neuromorphic computing, and other novel computing technologies. Previously, Muller served as a distinguished member of the technical staff in Sandia's Computational Materials and Data Sciences Division and supported the Joint Program Office for the U.S. National Strategic Computing Initiative. Muller has a doctorate in computational chemistry and materials science from Caltech.

Bert de Jong, Deputy Director

Bert de Jong is a senior scientist at Berkeley Lab leading the Applied Computing for Scientific Discovery Group. de Jong is the director of the quantum computing team (AIDE-QC), a multi-institution effort developing solutions in open-source computing, programming, and simulation environments for the large diversity of quantum computing research at DOE. He has leadership roles in multiple DOE funded quantum information science projects, the DOE Advanced Scientific Computing Research (ASCR) Exascale Computing Project NWChemEx, the SPEC Computational Chemistry Center, and AI-driven Rare Earth and Carbon Capture research projects. Prior to joining Berkeley Lab, de Jong spent 14 years in various leadership roles at Pacific Northwest National Laboratory. de Jong earned his doctorate in theoretical chemistry at the University of Groningen.

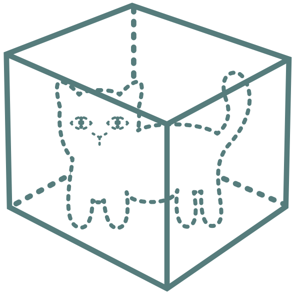


Illustration of Schrödinger's cat thought experiment, famous in quantum physics

Science and Technology Coordinators and Advisors



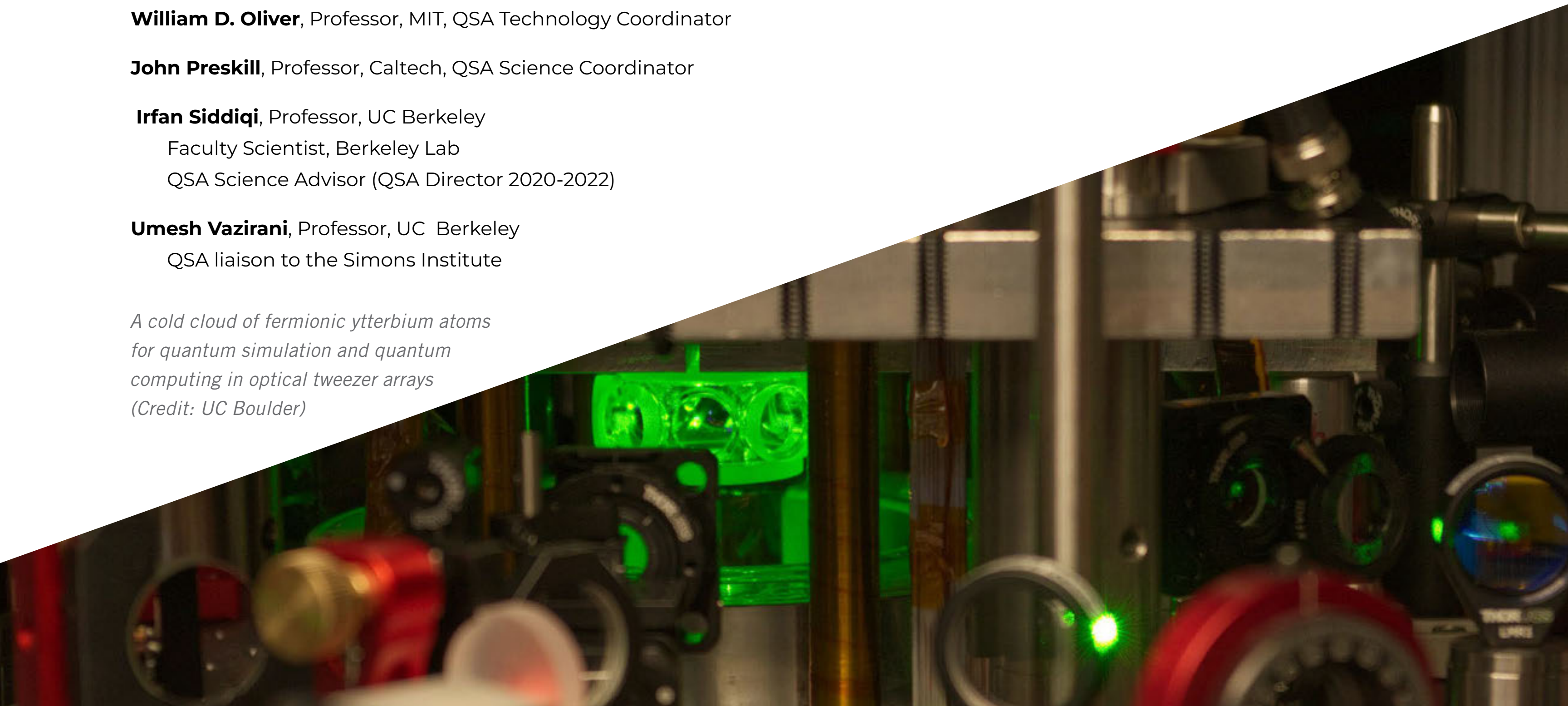

In addition to an external advisory and international coordinator board that helps leverage the collective expertise, QSA has pioneers in senior advisory roles.

William D. Oliver, Professor, MIT, QSA Technology Coordinator

John Preskill, Professor, Caltech, QSA Science Coordinator

Irfan Siddiqi, Professor, UC Berkeley
Faculty Scientist, Berkeley Lab
QSA Science Advisor (QSA Director 2020-2022)

Umesh Vazirani, Professor, UC Berkeley
QSA liaison to the Simons Institute



A cold cloud of fermionic ytterbium atoms for quantum simulation and quantum computing in optical tweezer arrays (Credit: UC Boulder)

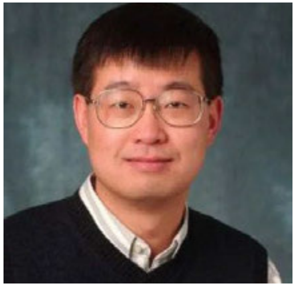
Research Thrust Leads

QSA has unique opportunities to contrast how different platforms perform on different applications by developing prototypes for the three leading quantum technologies. Furthermore, QSA's fundamental science activities are based on three major research thrusts aligned with the technical areas of interest: **Algorithms & Applications, Programmable Quantum Systems, and Integrated Quantum Engineering**.

Each QSA research thrust lead sets the high-level direction and vision of their respective scientific and technical programs, providing intellectual leadership, managing staff, and facilitating integration.

Applications & Algorithms Lead Birgitta Whaley with early-career researchers (UC Berkeley)






Algorithms & Applications

Birgitta Whaley
UC Berkeley

Mikhail Lukin
Harvard University

Programmable Quantum Systems

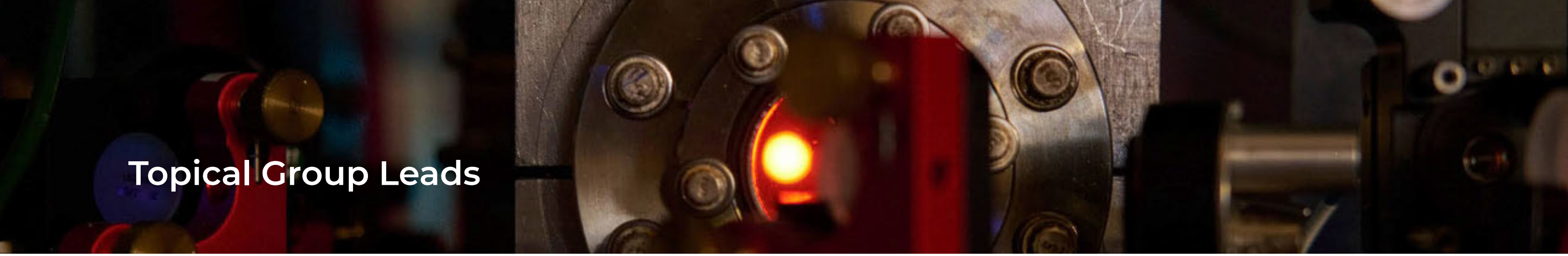
Jun Ye
UC Boulder

Dan Stick
Sandia Labs

Integrated Quantum Engineering

Mollie Schwartz
MIT Lincoln Laboratories

Christopher Monroe
Duke University



Topical Group Leads

E8 titanium experiment (Credit: UC Berkeley)

QSA has nine topical science groups straddling multiple research thrusts to facilitate co-design. Group leads coordinate specific research milestones within and across the topical groups' projects.

Algorithms & Applications

Topical group: NISQ Algorithms

Akimasa Miyake
University of New Mexico

Topical group: NISQ Algorithms

Peter Love
Tufts

Topical group: Extensible Quantum Systems

Andrew Landahl
Sandia Labs

Topical group: Benchmarking & Characterization

Tim Proctor
Sandia Labs

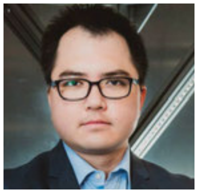
Programmable Quantum Systems

Topical group: Neutral Atoms

Kang-Kuen Ni
Harvard University

Topical group: Neutral Atoms

Adam Kaufman
University of Colorado Boulder



Topical group: Superconductors

Long Nguyen
Berkeley Lab

Topical group: Trapped ions

Dan Stick
Sandia Labs

Integrated Quantum Engineering

Topical group: Materials

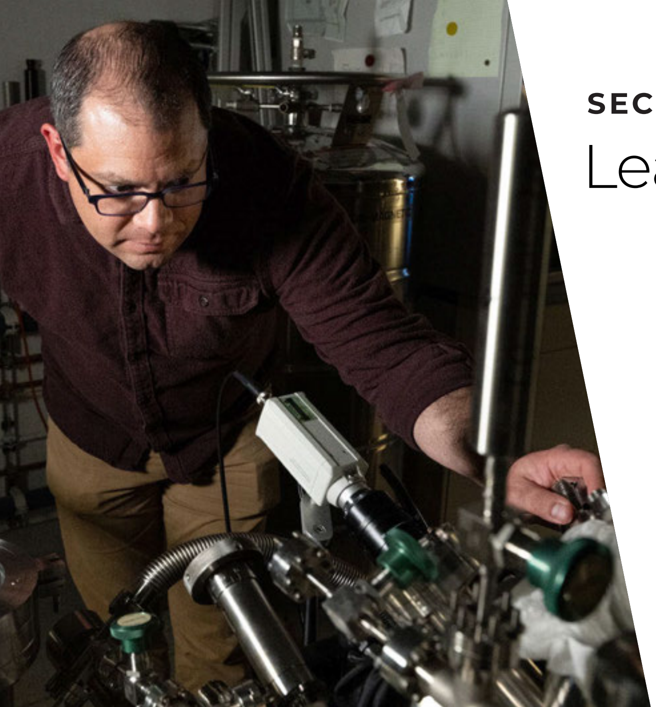
Sinéad Griffin
Berkeley Lab

Topical group: Materials

Mike Lilly
Sandia Labs

Topical group: Integration and Controls

Matt Eichenfield
Sandia Labs
University of Arizona



John C. Thomas (Credit: Berkeley Lab)

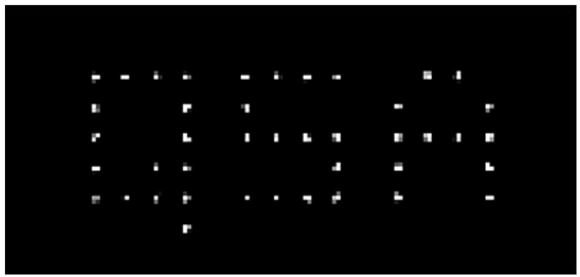
SECTION 2

Leading with Science and Innovation

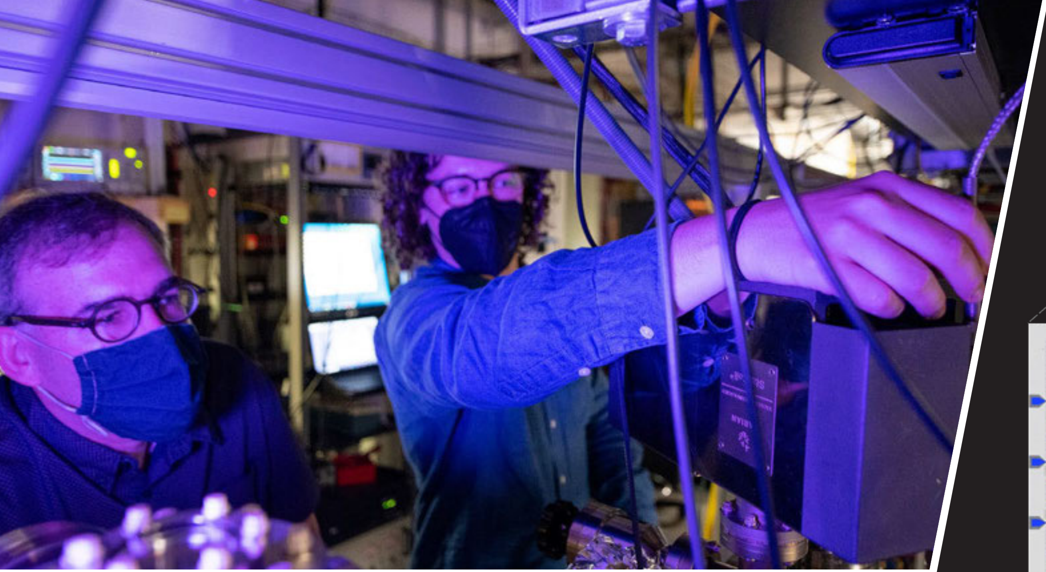
"QSA has a science-first approach to research and development that aligns with U.S. government policy and complements industrial efforts, so QSA develops quantum systems based on published basic scientific research that groups worldwide can reproduce and leverage."

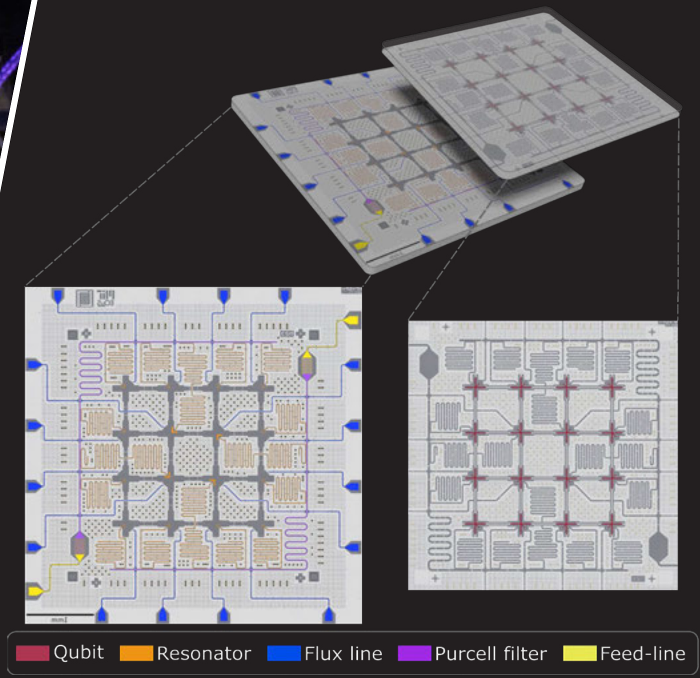
RICK MULLER, *Sandia National Laboratories*
QSA Director

The NISQ era describes the field's current imperfect hardware, where the stability of quantum processors and the coherence time of quantum bits (qubits) are short-lived. Errors and decoherence decrease the system's ability to perform useful computations. Thus, a key challenge is simultaneously manipulating the quantum states of a growing number of qubits with precision on such short timescales. However, a mismatch exists between state-of-the-art NISQ applications – quantum algorithms – and the available quantum technology. Algorithms are platform-agnostic and intended for ideal, error-corrected devices. In contrast, even the most advanced quantum hardware runs only a limited number of gates with modest fidelity. Quantum applications require many entangled qubits and high-fidelity logical gate operations.



Two-dimensional arrays of individually focused laser beams arranged images of 42 atoms (Credit: Harvard University)





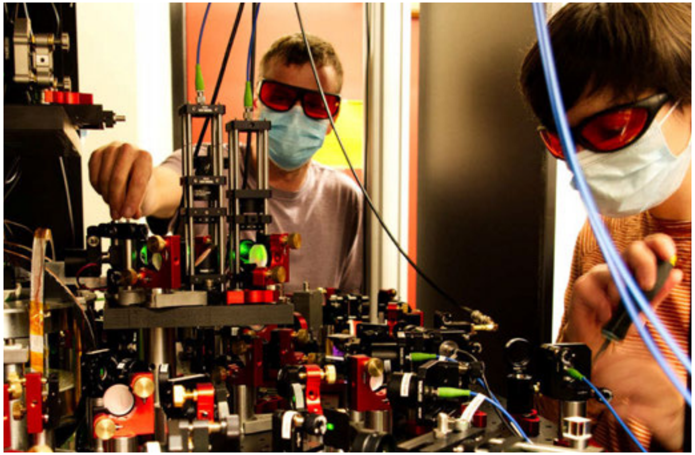
Dan Stamper-Kurn and Scott Eustice in the E8 Ultracold Atomic Physics lab (Credit: UC Berkeley); Right: False-colored optical images of the interposer and the qubit layers in 3D rendering of 16-qubit chip (Credit: MIT)

QSA seeks to demonstrate quantum computational advantage by developing platform-specific and noise-aware algorithms with varying degrees of noise protection. To accomplish this task, QSA leverages today's NISQ systems and co-designs the hardware and software across the different platforms.

Co-design is at the heart of QSA's mission to accelerate progress from discovery to prototype development and applied research. The impact of innovation in one of these platforms informs others, and it can optimize the overall result of the application and the overhead on quantum algorithm design across the Center, perhaps even across different technologies. In addition to gains in prototype development since QSA's founding, significant progress has been reported in all technical areas currently being advanced at QSA.

"QSA is outlining a path beyond NISQ-era proof-of-concept demonstrations toward extensible, impactful, general-purpose quantum computing. For example, several new algorithms have been developed for different systems, as well as novel schemes for digital and analog simulation and performance benchmarks."

BERT DE JONG, *Berkeley Lab, QSA Deputy Director*

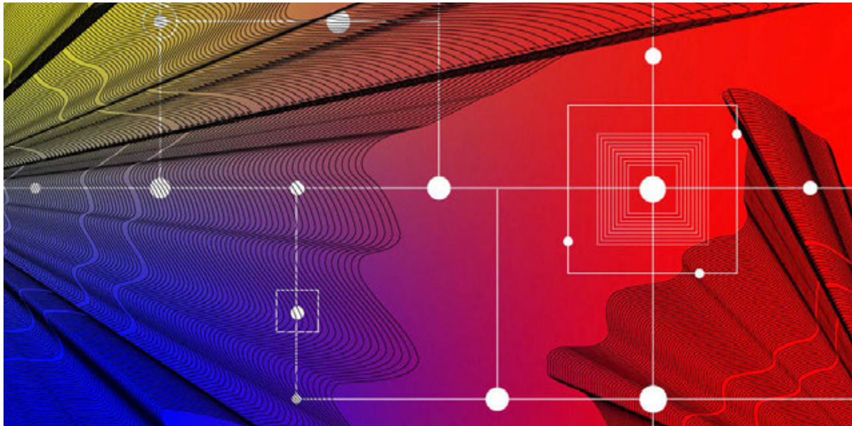


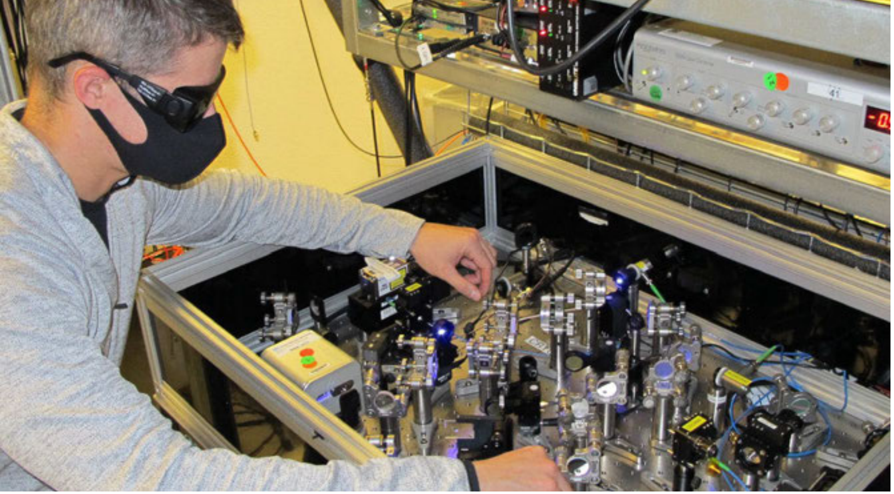
Alec Jenkins and Joanna Lis align laser light onto a quantum system of neutral atoms (Credit: UC Boulder)

Algorithms & Applications: One of the critical open questions with imperfect hardware is whether practical quantum advantages can be obtained for relevant scientific applications and what level of error mitigation would be required if such gains are possible. QSA investigates to what extent specific quantum platforms are valuable for particular quantum applications and how to accelerate the development of platform-specific applications. For example, nuclear magnetic resonance (NMR) is a key structural characterization technique in biology, chemistry, and materials science to gather information on local magnetic fields around atomic nuclei. However, zero-field NMR's computational simulation is limited by the exponentially large state-space required to interpret the nuclear spin system for large molecules, proteins, and protocols. Therefore, these simulations are ideal for tackling with a quantum computer. An interdisciplinary collaboration led by **QSA researchers at MIT, Harvard, and Duke** demonstrated a zero-field NMR digital quantum simulation experiment on a trapped-ion processor, computing the zero-field NMR spectrum of the methyl group of acetonitrile for the first time. This pioneering work with zero-field NMR paves the way for developing new platform-specific applications that seek practical quantum advantage from near-term quantum devices with an impact on other fields.

Programmable Quantum Systems: A key component of more powerful quantum machines is a qubit system with several control knobs and long-lived coherence. Progress in all three QSA hardware platforms — neutral atom, trapped ion, and superconducting circuit — has been made in realizing new robust functionality. For example, trapped-ion systems that exceed 50 ions will require new technologies to deliver and control the optical and electrical control signals. QSA's "Enchilada Trap," led by Sandia Labs and Duke University, will be capable of storing and transporting 200 ions. Sandia Labs fabricates, packages, tests, and delivers the ion traps to QSA collaborators. In support of this effort, Sandia is currently manufacturing a first-generation trap that uses <100 control signals and has completed the final design that uses >300 electrical controls, the most for any ion trap used to date.

Researchers executed several quantum circuits on different physical platforms to analyze cross-platform fidelities (Credit: U Maryland)



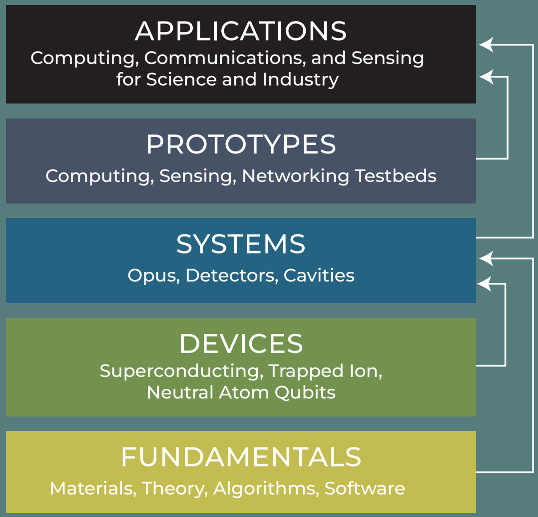


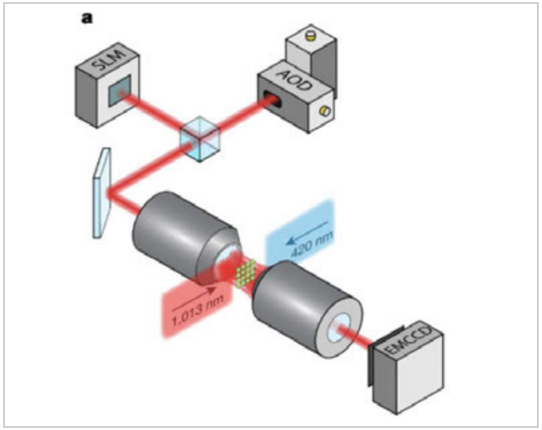
Researcher adjusts settings for trapped-ion systems (Sandia Labs)

Integrated Quantum Engineering: Pairing new algorithms and quantum systems with advanced classical controls requires identifying the high-level criteria for the electronic control hardware. Electronic controls must be scalable and support high-fidelity gates. QSA researchers are thus designing and building cutting-edge hardware to control their experimental systems while liaising with computer scientists and engineers developing high-performance electronics for classical systems. For example, quantum metrology is one of the most important applications for quantum systems, and correspondingly, metrology concepts advance quantum processors and engineering. QSA's Ye group at UC Boulder and JILA used a high-fidelity atomic clock to measure the frequency gradient across a millimeter-scale atomic cloud consistent with the gravitational redshift predicted by general relativity. This experiment marks the first time that the gravitational redshift has been observed in a single atomic sample, as well as the smallest distance over which such a measurement has been made, representing a new era in optical lattice clocks.

The DOE has defined the Quantum Science and Technology Innovation Chain as a ladder or maturation of technologies from **Fundamental Science** to **Devices**, to **Systems** to **Prototypes** to **Applications**. QSA focuses on the quantum systems midway up this ladder, which are robust enough to be programmed and applied to meaningful problems, yet agile enough to be varied and explored in multiple qubit platforms. QSA's ongoing prototype and science efforts aspire to develop hardware ranging from 10-200 physical qubits for up to 1000-qubit quantum simulations.

Science & Technology Innovation Chain



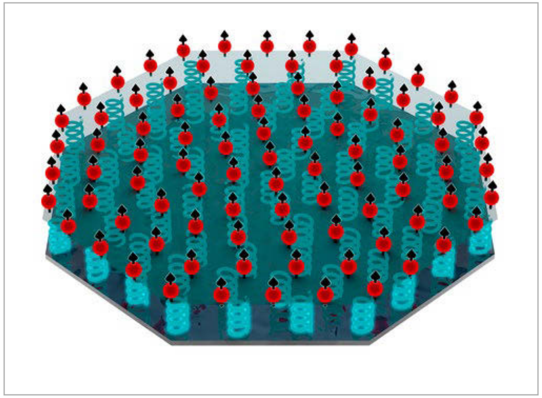


Experimental platform with a 2D array of optical tweezer traps (Credit: Harvard)

256-atom programmable quantum simulator

The QSA neutral atom team members with the Lukin, Greiner, and Vuletic research groups at Harvard and MIT trapped over 250 atoms in dense arrays using reconfigurable atomic tweezers, which by some measures, is the largest programmable quantum processor demonstrated to date. This platform has been used to implement quantum simulations of exotic topological matter and mathematical optimization problems. Controlling this many atoms represents a significant improvement over current NISQ limitations in the number of qubits, quantum coherence, and their flexibility and reconfigurability. QSA was a major contributor to a series of experiments conducted using this system, along with several other agencies. Specifically, QSA supported experimental upgrades resulting in this early achievement, which satisfied a QSA milestone to realize a 200-atom processor enabling the QSA-led next generations of neutral atom platforms. Furthermore, it advances QSA's current plans to integrate advanced optical controls, pushing this capability forward significantly.

Nature 595, 227–232 (2021)

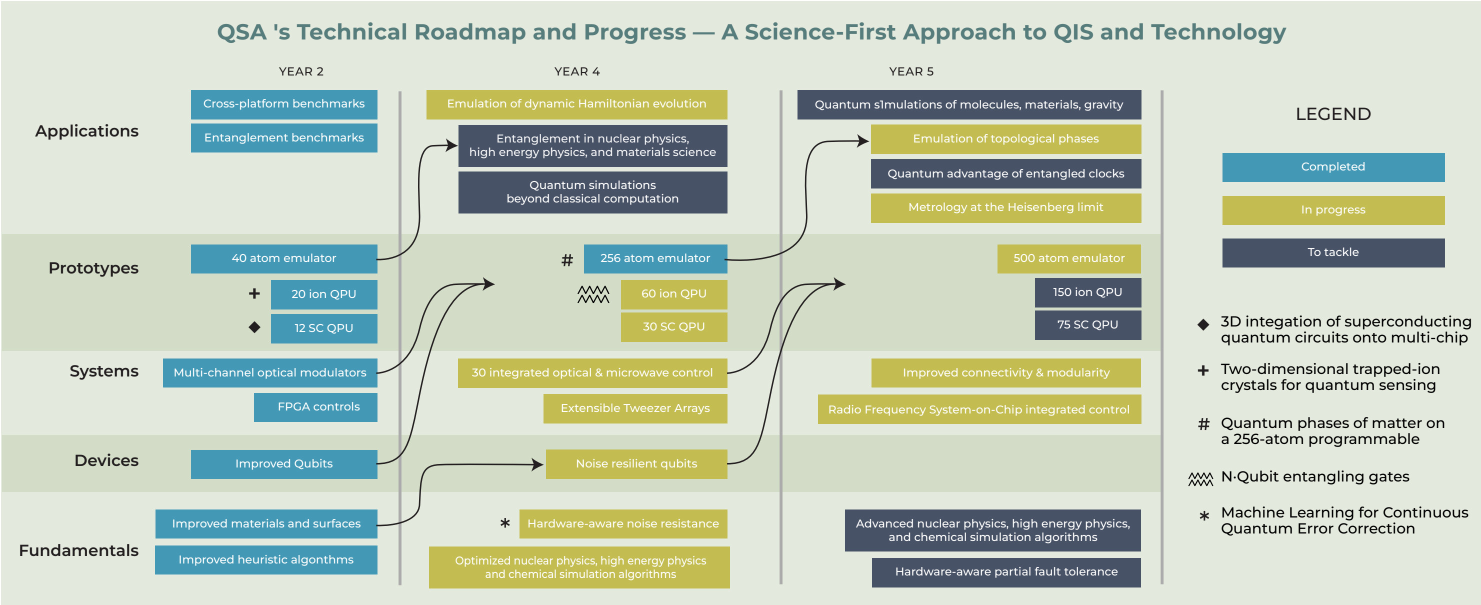


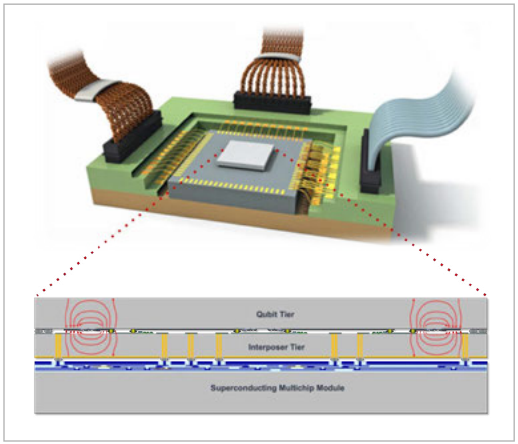
NIST quantum sensor made of trapped beryllium ions self-arranged into a 2D crystal (Credit: UC Boulder/JILA/NIST)

Two-dimensional trapped-ion crystals for quantum sensing

The QSA program harnesses quantum systems for advancing metrology and, correspondingly, metrology concepts for advancing quantum processors. An interdisciplinary team of scientists, including the UC Boulder team developed a quantum sensor composed of roughly 150 beryllium ions trapped in a two-dimensional crystal. The sensor uses quantum entanglement in a fully controllable, ultracold atomic system to achieve world-record sensitivities to electric fields that exceed the standard quantum limit – the measured noise levels set by quantum mechanics that typically set the limit for sensor performance. By overcoming such potential noise sources at the tiniest scales, the sensor opens the possibility of using trapped-ion systems to explore dark matter, among other advanced applications.

Science 6 Aug 2021 Vol 373, Issue 6555





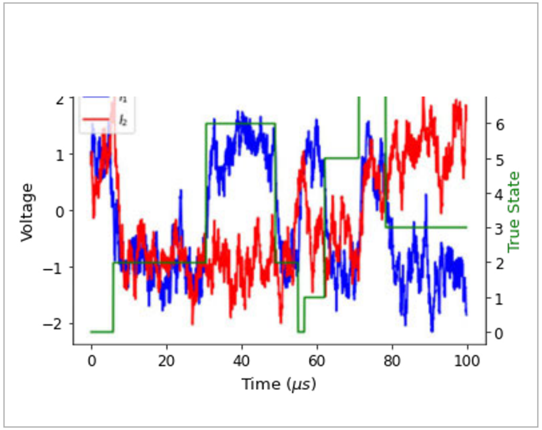
Schematic of MIT Lincoln Laboratory's 3D integration capability (Credit: MIT / MIT Lincoln Laboratory)

3D integation of superconducting quantum circuits

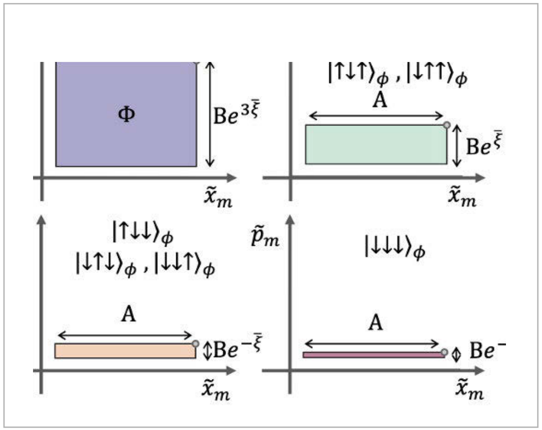
As part of the Center's collaborative efforts to push the technical limits of next-generation superconducting qubits and co-design qubits, controls, and their applications, the QSA team at MIT and MIT Lincoln Laboratory is extending the design and application space of 3D integration capability for superconducting qubits. Developing superconducting processors with 3D integration enables high connectivity and I/O routing while maintaining qubit coherence. The MIT Lincoln Laboratory 3D integration capability consists of multiple functional layers for the qubit, an interposer, and an I/O routing layer. The first QSA-funded devices have now been designed, fabricated, and integrated supporting QSA's technical roadmap to accelerate discovery and prototype development for extensible quantum computing. Experiments with 9-qubit and 16-qubit arrays are currently underway with the first publications on calibration and entanglement propagation in preparation.

Barrett, Cora N. et al., (in preparation)

Karamlou, Amir, et al., (in preparation)



Example of filtered qubit parity traces (Credit: UC Berkeley)



Protocols for entangling three ions (Credit: Duke University)

Machine learning for continuous quantum error correction

QSA investigates methods to quantify, characterize, and reduce the noise in quantum computing operations. Researchers at UC Berkeley designed a new machine learning (ML) protocol to extract errors detected by continuous quantum error correction (CQEC) signals. In CQEC, the quantum system is continuously monitored for errors, such as a qubit flipping between 0 and 1. The resulting signals contain information about the system's errors, but this information is hidden by noise. Therefore, extracting the relevant information accurately and efficiently is crucial to mitigate quantum errors in real time.

The ML algorithm can extract errors more accurately than current real-time methods and perform similarly to the best theoretical decoder by training on data from a superconducting quantum processor. These advancements toward real-time error correction are critical for the path to extensible quantum computers.

2022 *New J. Phys.* 24 063019

N-qubit entangling gates

Programmable quantum circuits of multi-qubit entangled gates are building blocks of quantum computers. Therefore, QSA researchers at Duke University, in collaboration with other agencies, leveraged advances in trapped-ion systems to codesign a novel and single-step protocol for generating N-qubit entangling gates between trapped ions. By using state-dependent, spin-squeezing approaches to combine multiples of these operations into a single step, circuit depth decreases, speeding up gate execution before decoherence reduces the fidelity of the results. The N-body entangling gate allows the implementation of an N-Toffoli gate that is expected to be an important element in quantum adders and multipliers, Grover searches, and variational quantum algorithms. Furthermore, by codesigning platform-specific applications, QSA opens the door for the design of new applications that can specifically use such operations to accelerate quantum simulation.

***Phys. Rev. Lett.* 129, 063603 – 4 August 2022**

To access QSA's robust archive of publications, visit: Publications

SECTION 3

Ecosystem Stewardship

QSA seamlessly integrates the broad research network from its 15 members into a cohesive, collaborative Center that propels the field forward in new ways. To build a connected, engaged, and diverse research community, QSA frequently engages with industry, government labs, and international research programs with a commercial focus on the quantum industry, including the Quantum Economic Development Consortium (QED-C), National Institute of Standards and Technology (NIST), and Federal Laboratory Consortium in the United States. In addition, QSA has hosted and co-organized industry-focused roundtables and events to hear directly from leaders and investors in major publicly traded companies and innovative startups such as IBM, Intel, IonQ, Keysight Technologies, Toptica Photonics, Q-CTRL, and Bleximo.

To accelerate the research, development, and adoption of quantum technologies, QSA developed a **Partnerships and Intellectual Property (IP) portal**. This is a public-facing online portal in the members' One-Stop Quantum Shop. It is a novel avenue to seamlessly highlight available IP opportunities and promote unique tech transfer capabilities with industry and the growing community.

First virtual industry roundtable in 2021 (Credit: Berkeley Lab)

"The QSA ecosystem vision extends beyond research and development to bring core technologies to market by working in sync with industry, regional economic development offices, and other national and international offices of sciences and user facilities to leverage each party's scientific breakthroughs and best practices."

DAVID KISTIN, *Sandia Labs, QSA Ecosystem Associate Director, Industry Engagement Lead*

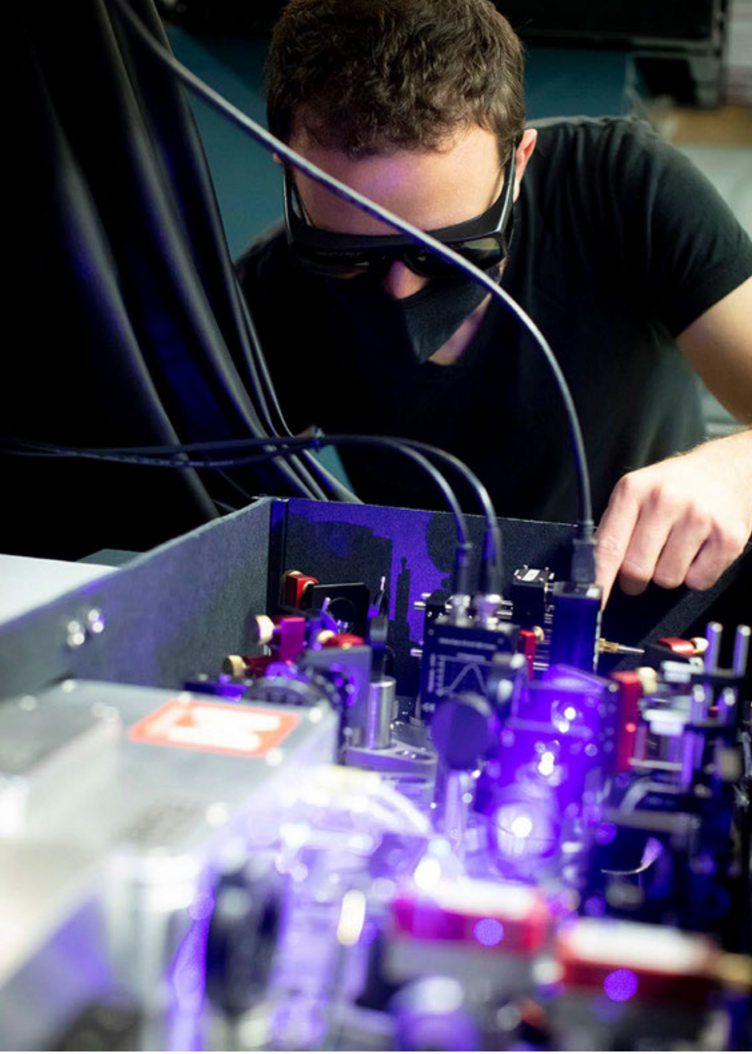
Clockwise from left: Prithviraj Prabhu (USC), Élie Genois (U Sherbrooke), Ross Shillito (U Sherbrooke), Giulia Semghini (Harvard), and Michael Kreshchuk (Berkeley Lab)

Workforce Building

A commitment to diversity, equity, and inclusion at all participation levels is paramount to QSA, informing the Center's vision and mission that champions innovation, engagement, representation, and psychological safety for everyone. Therefore, as it prepares the next generation of scientists and engineers, QSA established an Inclusion, Diversity, Equity, Accountability, and Solutions working group early in its foundation, composed of QSA members and diversity, equity, and inclusion subject matter experts.

"At QSA, we continuously discuss how to create the training opportunities today for tomorrow's diverse quantum workforce. For this effort, the IDEAS (Inclusion, Diversity, Equity, Accountability and Solutions) Advisory Council continuously provides strategic insights into data-driven diversity research and best practices, thus providing practical guidance to QSA activities, especially for the outreach and retention efforts for early-career researchers in the Center."

KRISTIN BALDER-FROID, *Berkeley Lab*
QSA Ecosystem Deputy



"The opportunity at the **QSA/JSTI** summer camp inspired me to continue building my knowledge in quantum computing and quantum mechanics, which I had already been curious about. I have conducted a second research project this year investigating hybrid quantum-classical machine learning architectures. I think the field is exciting, and there's so much more that I want to learn. The extended mentorship with QSA researchers influenced and inspired me in the right direction to learn more about quantum computing."

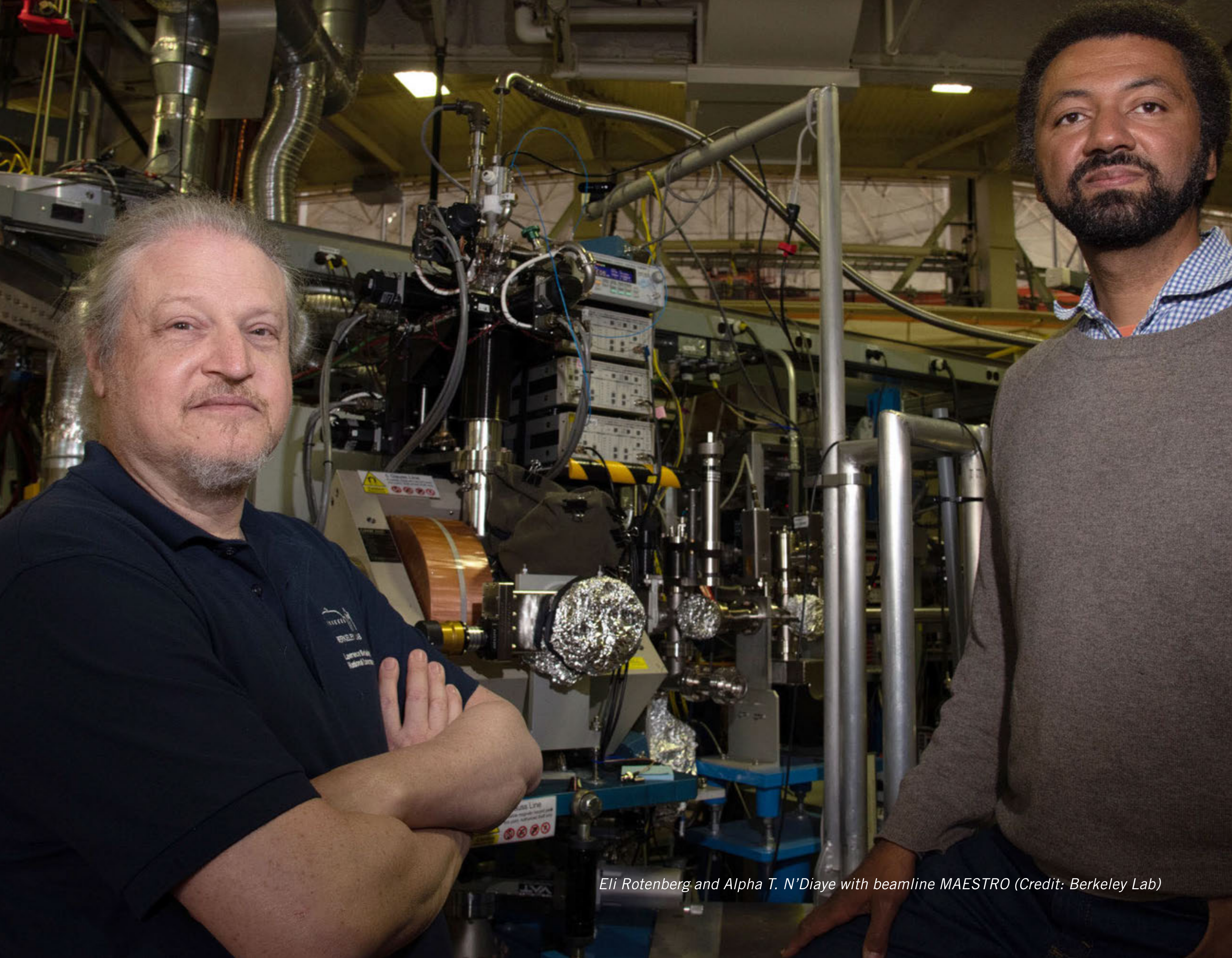
GALILEA RODRIGUEZ, *Student*
Harmony Science Academy El Paso, Texas

Dolev Bluvstein controls entanglement of Rydberg atoms (Credit: Harvard); Right: Institutional Lead Ivan Deutsch & his research group (Credit: UNM)

"The recently established peer to peer mentoring network among QSA members and students, as well as content and communications engagement engagement efforts in different languages and the Center's online portal, the One-Stop Quantum Shop, helps to foster a research climate of inclusion and strengthens career skills and interpersonal relationships."

KELLI HOWIE, *Sandia Labs*
QSA IDEAS Lead

Top: Sinéad Griffin (far right), materials topical group lead with research collaborators (Credit: Berkeley Lab); Mohammad Hafezi & Beini Gao filming recent advances in QIS (Credit: University of Maryland)



Eli Rotenberg and Alpha T. N'Diaye with beamline MAESTRO (Credit: Berkeley Lab)

Megan Ivory, program manager for high school summer camps (Credit: Sandia Labs)

"QSA's workforce development activities are designed to engage the workforce across the full education spectrum, from high school through postdoc, helping build the quantum-ready workforce of tomorrow. Furthermore, by continuing to work with students across the five National QIS Research Centers, we reach a broad audience and collaborate in preparing programming and materials that meet student needs. Finally, in every iteration of career fairs and outreach efforts, we learn how to strengthen recruitment, retention, promotion, and cultures of inclusion, especially in communities underrepresented in the field."

JAKE DOUGLASS, *Sandia Labs*

QSA Operations Deputy, Workforce Development Lead

SECTION 4

Five National QIS Research Centers (NQISRCs)

QSA is one of the five **U.S. National QIS Research Centers** funded by the DOE Office of Science. Each of the National QIS Research Centers (NQISRCs) is led by a national laboratory, so that – coupled with the DOE's research portfolio – the quintet collaboratively builds and stewards the QIS ecosystem with the government, industry, and academia. For example, the NQISRCs Executive Council identifies the areas around which the Centers can coordinate and collaborate. Working groups composed of leads from each Center support the Executive Council. Former QSA Director Irfan Siddiqi was chair of the NQISRCs Executive Council in FY2022. The widely attended 2022 and 2021 virtual QIS career fairs were organized in collaboration with the NQISRCs. The diverse composition of students and postdoctoral researchers who participated in the career fairs demonstrates the significant anticipated national impact of the NQISRCs on national security, economic competitiveness, and the U.S. continued leadership in quantum information science.

SECTION 5

QSA by the **Numbers**

Scientific Output

84 Published papers

Nature **7**
Science **4**
Nature Physics **4**
PRX **1**
PRX Quantum **11**
PRL **12**

89 Preprints on arXiv

2 Intellectual Property

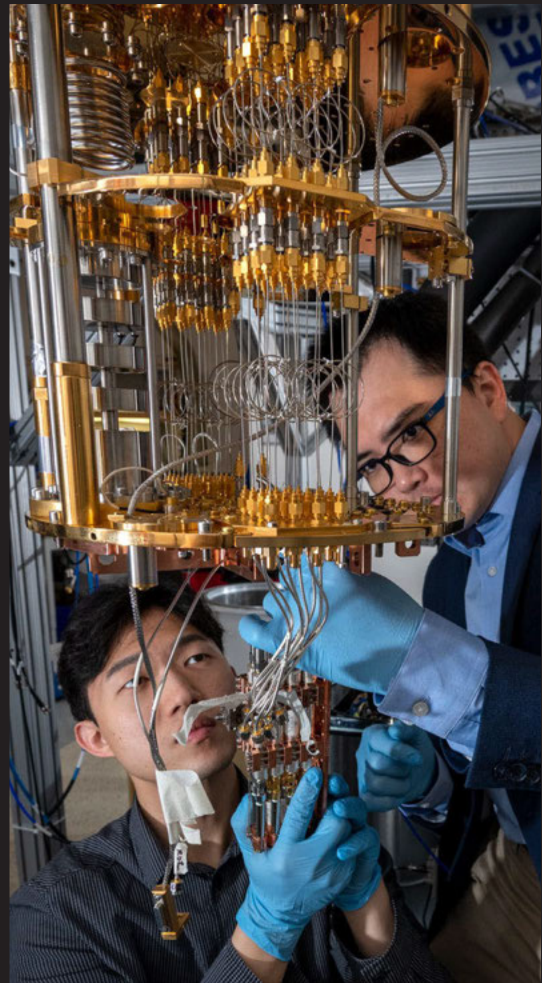
1 Patent Application Pending
1 Partnerships and Intellectual Property public-facing portal

15 Team of 15 partners

2 DOE Laboratories
1 DOD Laboratory
12 Universities

Staff Count

62 Senior Researchers
67 Staff
52 Postdocs
87 Students (graduate & undergraduate)



UC Berkeley's Linus Kim (left) and Berkeley Lab's Long Nguyen (Credit: Berkeley Lab)

4 Industry-Focused Events

with: Simons Institute
Federal Laboratory Consortium
Silicon Valley Leadership Group

2 Virtual Career Fairs

in partnership with NQISRCs

1,000+ attendees
100+ job applications

2 High School Summer Camps

for underrepresented communities

(JSTI & QCaMP)

20 teachers
42 students

2 Novel Programs

with the Simons Institute for the Theory of Computing

Research Pod Program

5 postdocs, **7** students, and **1** senior researcher

Summer Camp

40 researchers-in-residence,
100 workshop participants

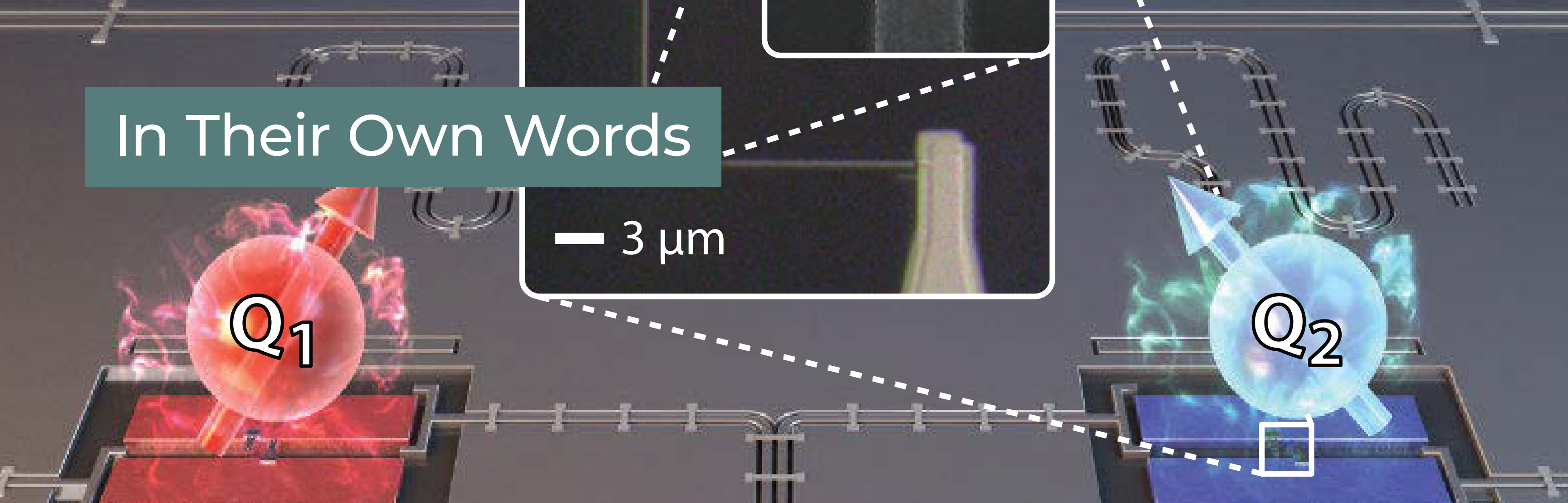
2 Novel Collaboration Tools

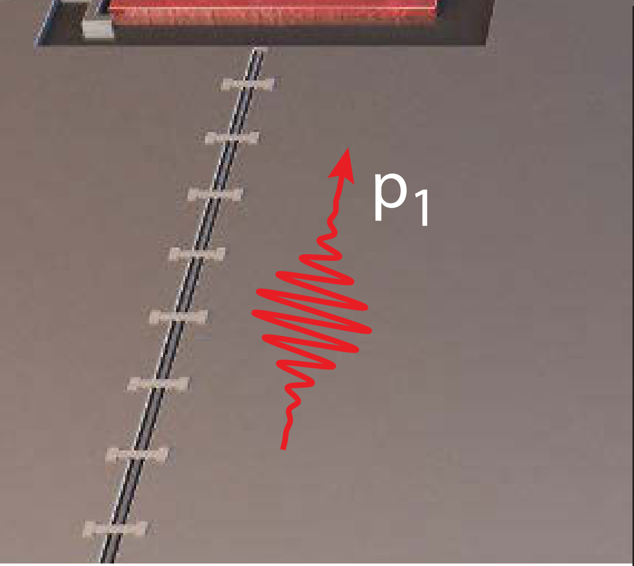
1 Online Community Management System
— One-Stop Quantum Shop (OSQS)

1 Peer-to-Peer Mentoring Network

UC Berkeley's James Analytis (Credit: Berkeley Lab)

In Their Own Words

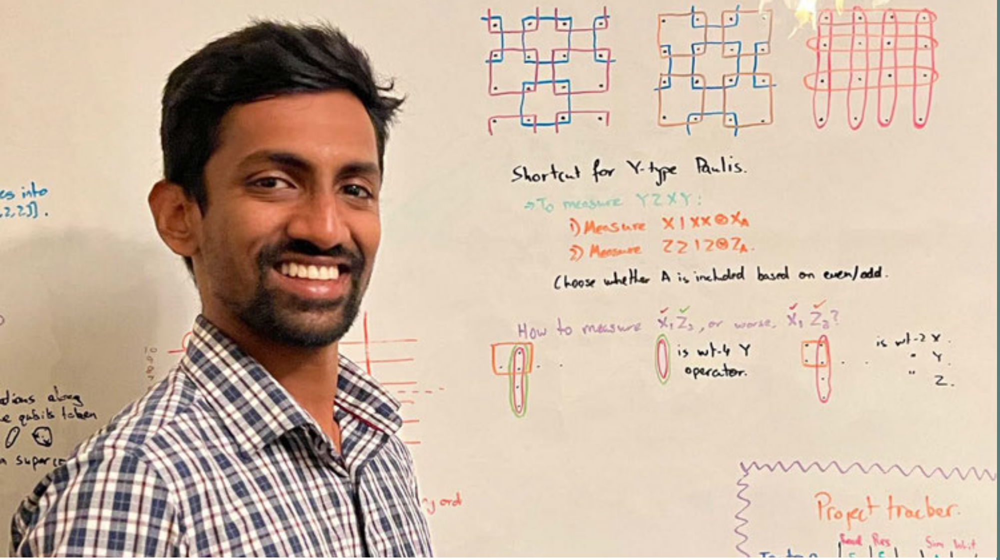




Experimental schematic depicting two single-junction transmon qubits coupled via a shared coplanar-waveguide resonator (Credit: Berkeley Lab)

"While there are many open questions for understanding materials for quantum technologies, discovering new superconductors is one at the top of the list. However, it's a lofty goal! Finding new superconductors amongst the infinite possibilities of chemistries and structures is like finding a needle in a haystack, especially if you are searching compound by compound in the laboratory. Instead, at the QSA, we have been able to combine experiments with theoretical and computational predictions to understand where in this vast landscape we might find superconductors, and hone in on the most promising candidates to accelerate the discovery process."

SINÉAD GRIFFIN, *Berkeley Lab*
QSA Materials Topical Group Lead

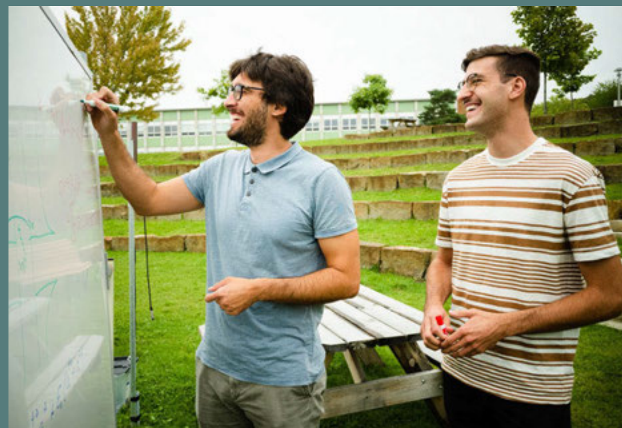


"QSA has helped me by always showing me something new through the biweekly meetings and seminars. In particular, I try to learn more about the experimental aspect of the up-and-coming devices, so that using this experimental knowledge and existing theoretical frameworks, we can make better-informed decisions about what we can do to run quantum algorithms faster or to run them with better error correction. These biweekly meetings are also a great way to meet senior researchers in the field. They explain complex concepts using relatively simple terms, showing us how to effectively communicate science to the public. It gives us something to aspire to."

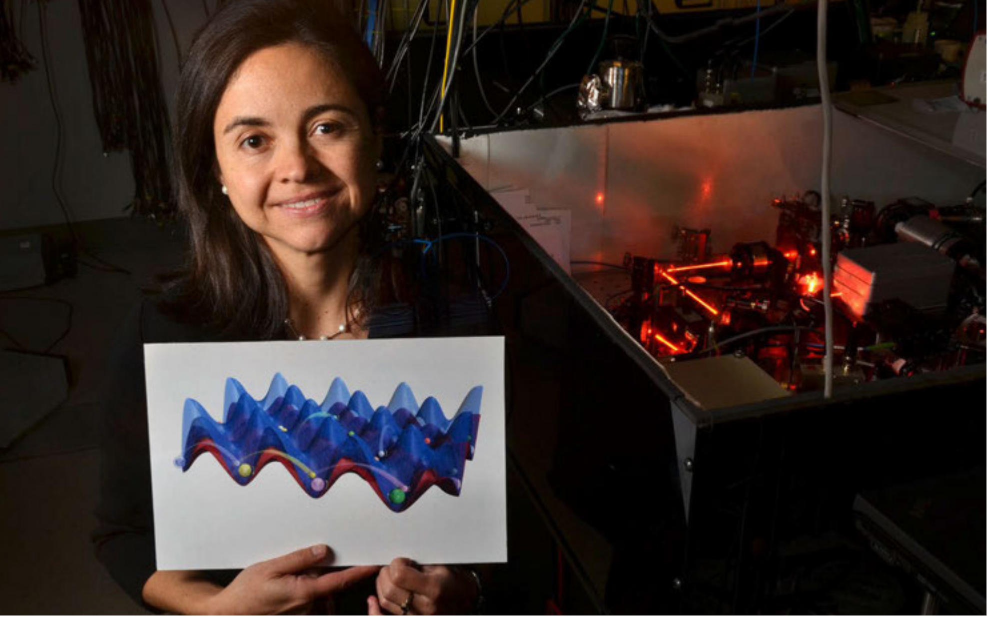
PRITHVIRAJ PRABHU, *Graduate Student University of Southern California*

"Thanks to QSA, I have had greater access to an extensive network of scientists. We had regular joint seminars and discussions and this frequent exchange is really crucial to the type of research and development that we do because it fosters collaborations and inspires new ideas."

GIULIA SEMEGHINI, *Postdoctoral Researcher (Lukin Group), Harvard University*



Adrian Parra-Rodriguez & Élie Genois (Credit: U Sherbrooke)

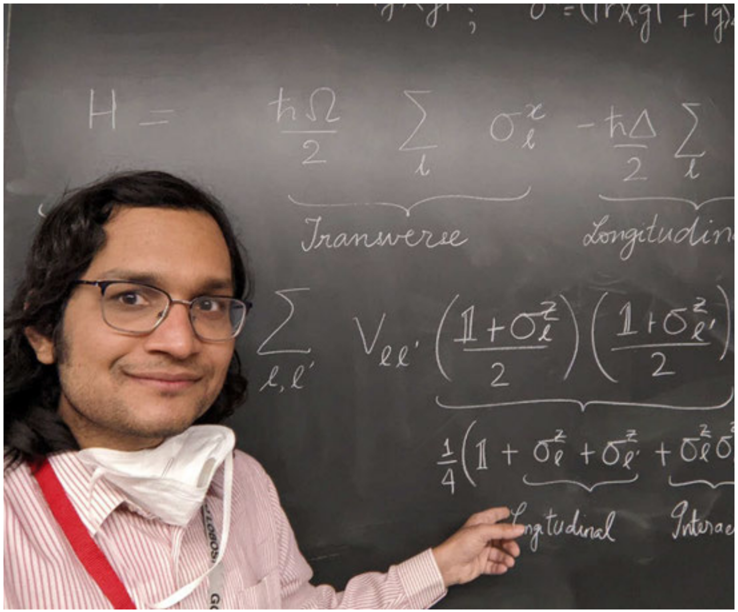


“It is a great pleasure for me to be part of QSA, which includes many researchers working at the frontier of quantum physics and on different systems, including superconducting circuits, trapped ions, and neutral atoms. The most exciting part is how to combine efforts to: understand ways to manipulate and control these systems, conduct calculations that have not been possible to implement with classical approaches, and also to connect the behavior of the microscopic world with the macroscopic one. Such connections could help us answer open questions on fundamental science and solve deep mysteries of our universe.”

ANA MARIA REY, *Adjoint Professor, University of Colorado Boulder, JILA Fellow, NIST Fellow*

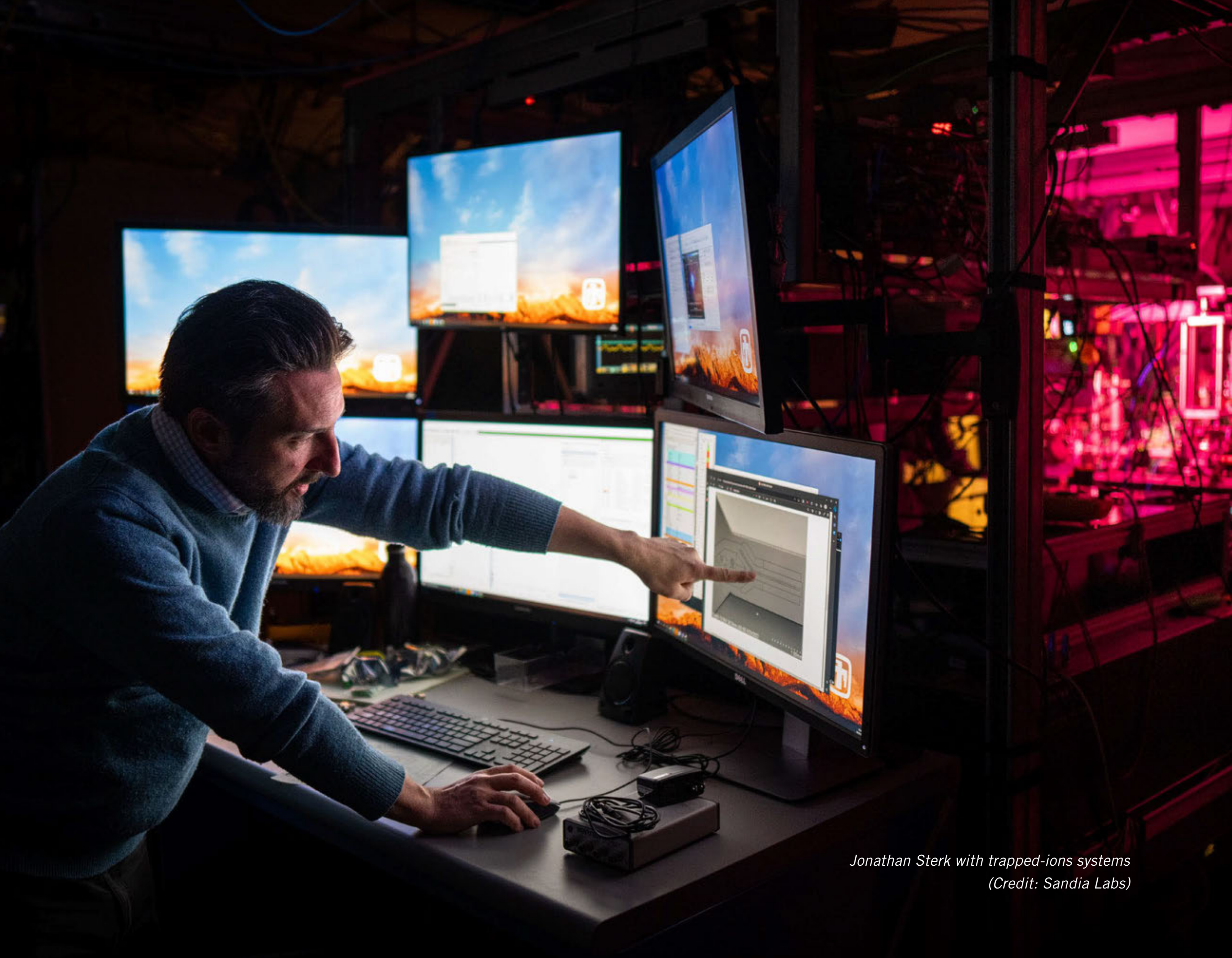
Institutional Lead Alexandre Blais (Credit: U Sherbrooke)

Sandia's Jake Douglass, QSA workforce lead (Credit: Berkeley Lab)



"QSA has a broad community of researchers tackling several problems at the forefront of quantum information science and technology. Regular interactions with the wider community through seminars, panel discussions, and other events have been beneficial for the rapid exchange of ideas among groups and for sharing knowledge regarding solutions to commonly faced problems. I have benefited from these events, as well as from the broader collaborations with QSA researchers. Moreover, the center-wide discussions about common challenges and issues have reduced the duplication of efforts."

ANUPAM MITRA, *Ph.D. Candidate*
University of New Mexico, Deutsch Research Group



Jonathan Sterk with trapped-ions systems
(Credit: Sandia Labs)

For more information about QSA:

Website: **quantumsystemsaccelerator.org**

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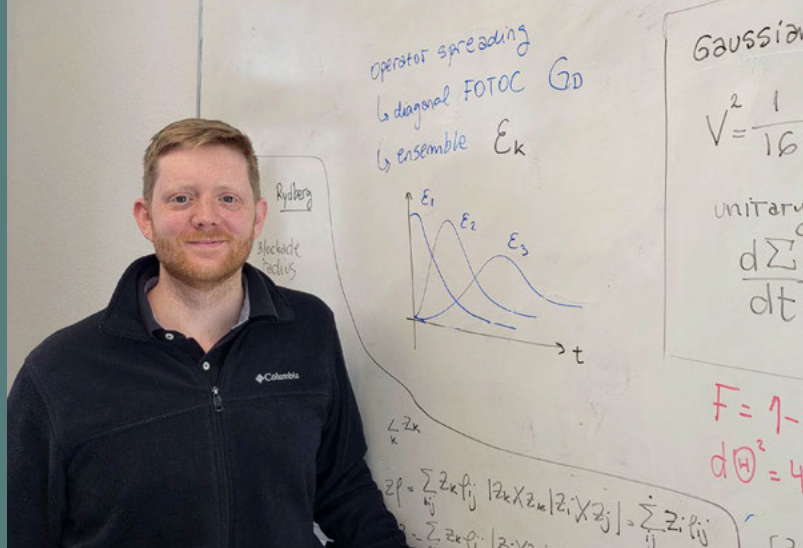
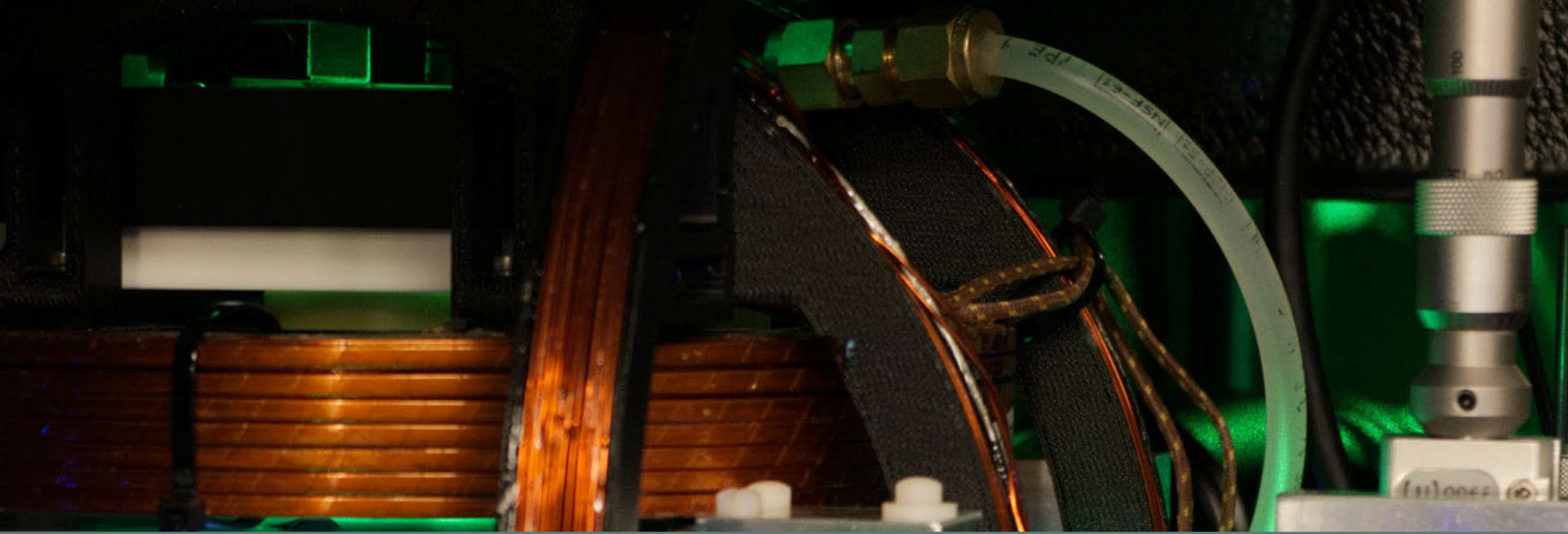


Top: Pablo Poggi and quantum control methods for devices (Credit: UNM); Megan Ivory and students at high school summer camp (Credit: Sandia Labs)



BERKELEY LAB

Sandia National Laboratories

QUANTUM SYSTEMS ACCELERATOR
Catalyzing the Quantum Ecosystem

U.S. DEPARTMENT OF ENERGY | Office of Science

Strontium for quantum-enhanced sensors and implementing quantum algorithms (Credit: UC Boulder)