UC SANTA BARBARA

THE Current

March 30, 2026
Sonia Fernandez

Researchers demonstrate integrated stabilized laser chips performing clock and quantum operations on a room temperature trapped ion qubit

In an ongoing effort to bring quantum science out of the tightly controlled lab environment and into the field, researchers from UC Santa Barbara and the University of Massachusetts Amherst have, for the first time, demonstrated a chip-scale, stabilized, visible light laser that drives a trapped ion atomic optical clock and quantum qubit, paving the way toward compact, portable and scalable trapped-ion quantum information systems.

"This work is foundational in that we demonstrated that chip-scale integrated photonic stabilized lasers can be used to connect precision light to one of the narrowest atomic optical transitions that people work with, with the trapped ion itself created on a surface trap chip operating at room temperature," said Daniel Blumenthal, a professor of electrical and computer engineering at UCSB and a senior author of a paper published in Nature Communications.

Miniaturization is the name of the game for Blumenthal's research group, which is working to shrink what are normally large lasers and optical components and often room-sized quantum optical light-matter experiments, down to about the size of a deck of cards. The traditional lasers and other components that power these experiments typically occupy 90% of the setup on table-tops and equipment racks that require hand-tuning and are very susceptible to environmental disturbances. In scaling these components down to the chip and providing room temperature operation, it becomes possible to bring the power and precision of quantum measurement, sensing and computation to more researchers and to a wider variety of experiments, as well as making these technologies more robust and portable.

“These portable quantum circuits can then be located at many places on the Earth and flown in satellites, to the moon, and into space,” Blumenthal said. “The ability to use these precision portable clocks opens a wealth of applications and fundamental science including search for dark matter and dark energy, the mapping of gravity, and measurement of general relativity and the search for fundamental constants, and possible time varying changes in these constants.” Networks of these clocks can sense and measure gravity on Earth and create gravity maps around other solar objects, he added, or sense shifts in geological conditions.

For this project, conducted in collaboration with UMass Amherst electrical and computer engineering professor Robert Niffenegger’s group, the researchers focused on a core aspect of quantum experimentation: the trapping, state preparation and manipulating of the quantum particles — in this case trapped ions — that could then be used for quantum operations. Depending on the experiment, these ions can be used to sense, measure, timekeep and compute to the finest, most precise levels possible.

Lasers are essential to help the ions get into their quantum state and measure and control it. The laser employed by Blumenthal’s group to do this is a visible light Brillouin laser that has such low frequency noise that it enables superior quantum operations compared to traditional lasers. Equally as important, this chip scale Brillouin laser is anchored to a second chip that contains an integrated coil resonator — a technology pioneered by the Blumenthal group — that keeps the laser light in range of the extremely precise strontium clock transition long enough to lock the laser to the ion in a highly sensitive operation that typically requires relatively bulky table top components.

The next pieces to put into place are all of the additional lasers required for state preparation and management (SPAM), clock and qubit control and the “physics package” that houses the surface electrode ion trap.

“If you want scalability or portability with quantum technology, you need the laser systems to all be on chip too,” Nifenegger said. “We could have millions of qubits on one chip in a way that is not possible if you needed rooms full of lasers and optics. If you’re serious about getting to that scale, you have to look at how traditional computers have scaled through integration. That’s the vision we’re following.”

The researchers tested how their design performs key quantum operations, including SPAM and trapped-ion spectroscopy. A qubit is the basic unit of information in quantum computing, similar to a classical computer’s “bit,” however unlike digital bits, which exist in a known state of 0 or 1, a qubit can exist in a combination of both 0 and 1 states simultaneously, giving it the ability to solve far more complex problems in less time than classical computing can typically handle. The challenge is in preserving the very delicate quantum state while the quantum operations are performed.

The researchers were able to demonstrate that they could achieve 99.6% SPAM fidelity with less than half the number of control pulses than required by a table top standard laser, thus reducing the SPAM preparation time and speeding up the eventual computation or sensing time. Their results show the system sets the stage in terms of high-fidelity qubit SPAM required for the next steps toward logical qubits and quantum computing, while further improvements will enable applications in quantum sensing.

This result is the latest in the Blumenthal Lab’s effort to create a complete chip-scale photonic system for quantum experiments that involve trapped ions and neutral atoms, an effort that has been marked with breakthroughs and progress in integrating tiny form factor lasers and the components needed to tune, stabilize and guide the light around in a palm sized device.

“We are only at the beginning of this journey and I am really excited to see how the next several years play out,” Blumenthal said. “Whereas conventional wisdom was that integrated lasers and photonics only enabled portability at the expense of performance, we are today seeing that integration can bring about improved performance. Partnering with physicists will bring about a new era of integrated physics experiments, and it will be exciting times.”

Tags
Quantum Science

Media Contact

Shelly Leachman
shelly.leachman@ucsb.edu
(805) 893-4620

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.