GPS-free Navigation May Become a Reality Thanks to a Quantum Compass.

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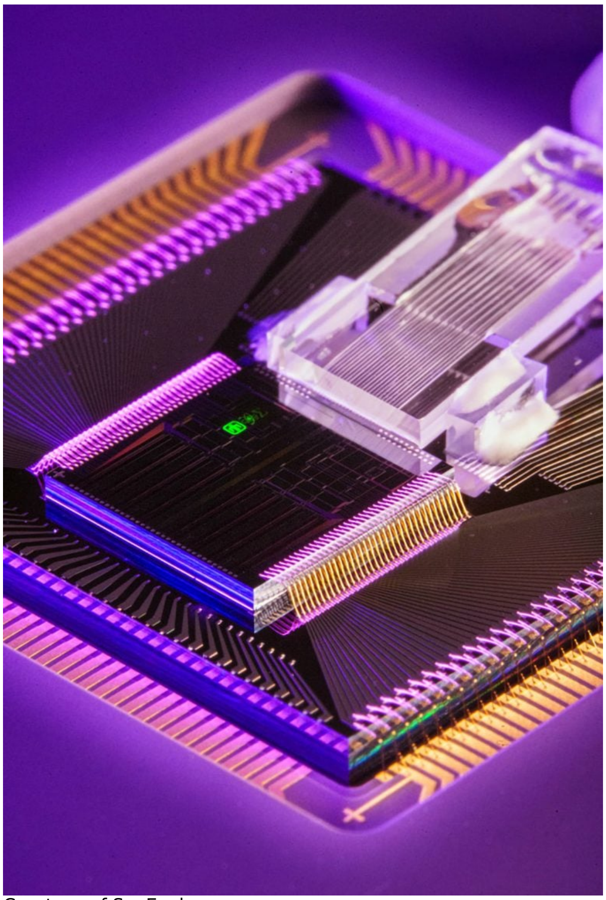
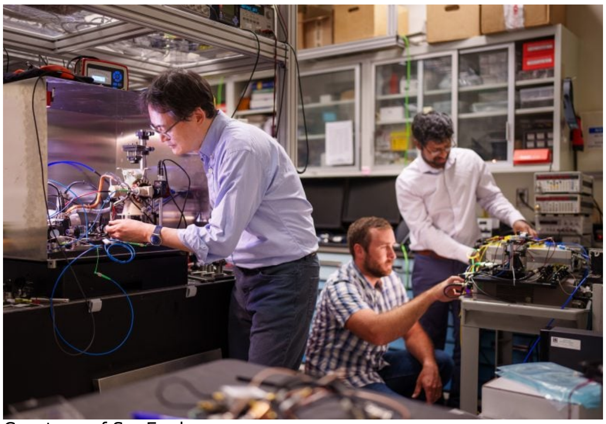


Courtesy of SynEvol
Credit:Craig Fritz

When you disassemble a smartphone, fitness tracker, or virtual reality headset, you'll discover a tiny motion sensor that records the device's position and motion. With GPS assistance, larger, more costly models of the same technology—roughly the size of a grapefruit and a thousand times more accurate—assist in navigating ships, aircraft, and other vehicles.

Scientists are currently working to create a motion sensor that will be so accurate that it will reduce the country's dependency on global positioning satellites. Such a sensor would have filled a moving truck until recently. It is a thousand times more sensitive than modern navigational equipment. However, developments are bringing this technology's size and cost down significantly.

For the first time, atom interferometry—a quantum sensing method that provides incredibly accurate acceleration measurements—has been carried out by Sandia National Laboratories researchers using silicon photonic microchip components. It is the most recent advancement in the creation of a quantum compass that can be used for navigation in the absence of GPS signals.



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The team's research was published, and the journal Science Advances featured a cover story on a novel high-performance silicon photonic modulator—a device that manipulates light on a microchip.

Sandia's Laboratory Directed Research and Development program provided funding for the study. It was partially held at the National Security Photonics Center, a cooperative research facility that creates integrated photonics solutions to challenging issues in the field of national security.

According to Sandia scientist Jongmin Lee, "when GPS signals are unavailable, accurate navigation becomes a challenge in real-world scenarios."

These difficulties present threats to national security in a conflict area since electronic warfare forces have the ability to block or spoof satellite communications, interfering with army movements and activities.

Quantum sensing provides an answer.

"These cutting-edge sensors provide unmatched accuracy in measuring acceleration and angular velocity by harnessing the principles of quantum mechanics, enabling precise navigation even in areas denied GPS service," Lee stated.

An atom interferometer is usually a modest room-sized sensor system. To be more exact, a quantum inertial measurement unit, or full quantum compass, would require six atom interferometers.

However, Lee and his group have been able to lessen the device's size, weight, and power requirements. An avocado-sized vacuum chamber has already taken the place of a big, power-hungry vacuum pump, and multiple parts that were previously painstakingly put across an optical table have been combined into one stiff device.

The novel modulator serves as the focal point of a microchip laser system. It would take the place of a traditional laser system, usually the size of a refrigerator, because it is robust enough to withstand strong vibrations.

In an atom interferometer, lasers serve many purposes. The Sandia team employs four modulators to change the frequency of a single laser so that it can serve various purposes.

However, sidebands—unwanted echoes—that are frequently produced by modulators must be reduced.

By reducing these sidebands by an astonishing 47.8 decibels, a measurement that is frequently used to characterize sound strength but is equally applicable to light intensity, Sandia's suppressed-carrier, single-sideband modulator produces a nearly 100,000-fold decline in light intensity.

Scientist Ashok Kodigala of Sandia remarked, "We have drastically improved the performance compared to what's out there."

Cost has been a significant barrier to the deployment of quantum navigation systems, in addition to size. Each atom interferometer requires a laser system, and modulators are necessary for laser systems.

According to Lee, the cost of a single full-size, commercially available single-sideband modulator is more than $10,000.

Reduced costs are achieved by shrinking large, costly components into silicon photonic chips.

"On a single 8-inch wafer, we can make hundreds of modulators; on a 12-inch wafer, we can make even more," Kodigala stated.

Furthermore, "This sophisticated four-channel component, including additional custom features, can be mass-produced at a much lower cost compared to today's commercial alternatives, enabling the production of quantum inertial measurement units at a reduced cost," according to Lee, because they can be made using the same method as almost all computer chips.

The research team is looking into applications for the technology outside of navigation as field deployment approaches. By sensing the minute changes these make to Earth's gravitational field, researchers are examining if this could aid in the location of subterranean cavities and resources. Additionally, they see applications for the optical components they created, such as the modulator, in optical communications, quantum computing, and LIDAR.

"I find it incredibly thrilling," Kodigala remarked. "Miniaturization is progressing quickly for a wide range of applications."

Kodigala and Lee are the two members of a multidisciplinary team. Experts in nuclear physics and quantum mechanics make up one half of the group, which includes Lee. The other half, including Kodigala, are experts in silicon photonics; picture a microchip with light beams passing through its circuitry in place of electricity.

At the Microsystems Engineering, Science, and Applications complex at Sandia, where researchers design, manufacture, and test chips for use in national security applications, these teams work together.

Quantum sensing scientist at Sandia Peter Schwindt said, "We have colleagues that we can go down the hall and talk to about this and figure out how to solve these key problems for this technology to get it out into the field."

The team's ambitious goal is to transform atom interferometers into a portable quantum compass, which will allow them to close the gap between university basic research and tech businesses' commercial development. An effective instrument for GPS-denied navigation could be an atom interferometer, a well-established technique. The goal of Sandia's continuous work is to increase its fieldability, stability, and profitability.

To create new technologies and assist in the introduction of new goods, the National Security Photonics Center works with academics, government organizations, small and medium-sized enterprises, and industry. To further its goals, Sandia has hundreds of granted patents and several more that are being pursued.

Schwindt remarked, "I'm passionate about seeing these technologies used in practical ways."

The same enthusiasm is shared by Michael Gehl, a scientist at Sandia who works with silicon photonics. He remarked, "It's fantastic to see our photonics chips being used for practical applications."