RESEARCH AND DEVELOPMENT

Quantum Sensors Have Potential to Replace GPS

7/27/2023

By Jan Tegler

iStock illustration

Researchers in government and industry laboratories across the globe are in a race to refine technology and methods for detecting changes in motion and electric and magnetic fields at the atomic level.

Spotting minute changes in the known properties of atoms can yield extremely precise and accurate measurements — a technique known as quantum sensing.

While suitable for a range of applications, quantum sensing for navigation is an area of prime interest for the Pentagon. U.S. warfighters routinely train for operations in GPS-denied environments as realization has grown that technologically sophisticated rivals like China or Russia can corrupt or disable the GPS signals the U.S. military relies upon.

Work done by Naval Research Laboratory research physicist Roger Easton was foundational for GPS, leading to the launch of NTS-2, the first satellite to transmit GPS signals in 1977. Today the NRL's Section Head in Quantum Optics, Adam Black, is among those adapting quantum sensors for an alternative navigation technique that predates GPS — inertial navigation.

"I think that with some of the smallest atomic inertial technologies we might only be a few years out from something like that," Black said, describing quantum inertial measurement units that could be much smaller than the large, fixed equipment currently used for quantum sensing research and development in laboratories.

Inertial navigation employs accelerometers, gyroscopes and a computer — known collectively as an inertial measurement unit, or IMU — to continuously calculate the position, the orientation and velocity of a moving object without the need for external references. In use for military aircraft and weapons guidance since the 1960s, the technology was supplanted by GPS by the early 1990s.

Less vulnerable to disruption than GPS, inertial navigation using quantum sensors is viewed as a way to navigate with similar or better accuracy than GPS when compromised or unavailable.

One of the biggest hurdles to quantum sensing devices that could be used in dynamic environments like military ships, submarines or aircraft is making them small enough and energy efficient enough to be suitable for these platforms. Downsizing the quantum sensors developed so far also diminishes their accuracy and precision. It's a "tradeoff but a tractable challenge" that NRL, the Army and Air Force Research Laboratories and researchers in private industry are working on, Black explained.

"You can imagine a shoebox containing a quantum IMU" with accelerometers and gyroscopes "pretty reasonably," Black told National Defense. "We're not there at the moment. But I think that's within the realm of the physics."

Operating as part of new inertial navigation systems, quantum IMUs would perform the same functions as a classical IMU, "just with better precision and accuracy coming from that sensor for a period of time," he added.

Dr. Gerald Borsuk, associate director of research for NRL's Systems Directorate, said that a new generation of smaller, precision atomic clocks — devices that are also quantum sensors — could be used to keep time when GPS is denied.

"A GPS sensor can still be used if it has precision time by another source," Borsuk explained.

Atomic clocks that measure time by monitoring the resonant frequency of atoms have been in use since the 1950s. Black described development of miniaturized, high performance microwave atomic clocks and small optical atomic clocks that measure time based on optical frequencies in the hundreds of terahertz, as jam-resistant quantum sensors that could improve GPS resilience.

"People are now taking the more advanced optical atomic clocks and engineering them to have field-able package sizes," he noted.

Development of quantum sensors is often protracted by the need to build physical prototypes for real-world testing. Black said that digital engineering — virtual modeling and simulation — is being applied by the Navy lab and other research groups to speed up the process.

"An example is a recent program we participated in with the Office of Naval Research aimed at putting quantum gravimeters on ships," he revealed.

Black's group at the Naval Research Laboratory took advantage of precise ship motion models to build an atomic physics level model that forecasts how the atoms in gravimeters — sensors that measure acceleration due to gravity — behave without large, heavy stabilization gimbals.

"It turned out that the gravimeters worked just fine as long as you incorporated knowledge of the error sources in the gravimeters and corrected for those," he reported.
"We intend to accelerate progress," Borsuk concluded. "We formed our Quantum Science Institute to focus our efforts to reduce risk to industry to take the results we've created and apply them." ND

Topics: Cyber

Related Articles

Hackers Intensify Fears Of Industrial Espionage

New Rule Forces Contractors to Report Cybersecurity Incidents

Defense Companies Facing Array of New Cyberthreats (UPDATED)

VIEW ALL ARTICLES ▸

Related Events

Cybersecurity 9/22/2023
CMMC Update: Timeline and NIST Rev3 Comments and New Requirements

VIEW ALL EVENTS ▸

Comments (3)

Re: Quantum Sensors Have Potential to Replace GPS

How does this technology compare to the Quantum Photonic Vibrometer developed by Quantum Computing Inc (QUBT)?

David G at 3:49 AM

Re: Quantum Sensors Have Potential to Replace GPS

The SR-71 used an IMU that looked to the stars in IR and compared that to star maps to determine its location and guide the plane to where it was to take pictures and back. It was installed behind the cockpit with a crane after being programmed on the ground. Tech. has changed.

Everett Puterbaugh at 2:21 PM

Re: Quantum Sensors Have Potential to Replace GPS

Inertial navigation systems based on ring laser gyros have been around for a long time and work fine. Once costing upwards of $100k, with today's LED lasers I have to imagine they can build them for a few bucks. Sure, quantum sensors may be a few millimeters more accurate, but this sounds like a "solution in search of a problem."

Johnathan Galt at 1:15 PM