Tiny optical frequency clock measures time accurately to 270 quintillionths of a second

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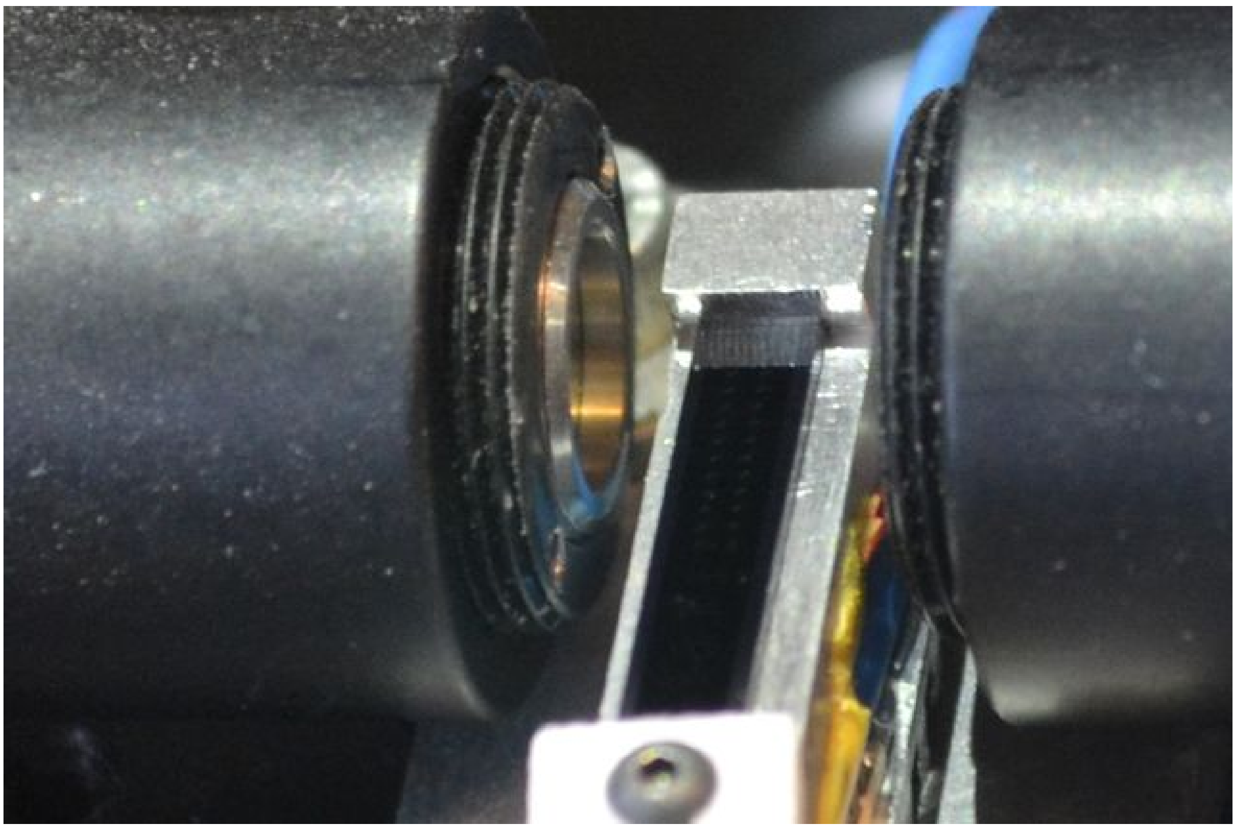

The optical clock developed by UCLA Engineering researchers is the small black strip between the two black cylinders.

Researchers at the UCLA Henry Samueli School of Engineering and Applied Science have created an optical clock that's just 1 cubic centimeter—small enough to fit on a standard silicon chip—and can track time intervals with precision to 270 quintillionths of second. (One quintillionth is equivalent to 1 times 10 to the negative 18th power, or 0.000000000000000001.)

Today's most accurate clocks, atomic clocks, are used to keep time for the Internet and satellite communications, and help astronomers detect Earth-like planets beyond our solar system. Their accuracy—to "only" within a tenth of trillionths of a second, or 1 times 10 to the negative 13th power—is based on the naturally occurring frequencies of atoms that respond to radiation. The atomic frequencies can be expressed as a "frequency comb," a series of evenly spaced vertical lines of light produced by the atoms under radiation into microwave frequencies that are accessible to the electronic instruments that ultimately turn those readings into accurate measurements of time.

Previous optical clocks were much larger than the new one developed at UCLA: They used large fiber lasers that needed to be housed in equipment about the size of a desktop computer. The UCLA team was able to shrink the mechanism significantly to 1 cubic centimeter by using a process similar to how silicon chips are made. The new clock's precision approaches the world's best frequency standards.

The clock could lead to more precise measurements of space and time, an area known as attosecond physics, and could have applications in optical, wireless and space-based communications. For example, it could be used to measure the movement of atoms, or to discern the movement of distant objects far beyond our solar system.

"If incorporated with other technologies into infrared telescope observatories, this device can enable the detection of Earth-like planets and celestial objects 100 times smaller than that, which was previously impossible," said Shu-Wei Huang, a UCLA Engineering scientist and the project's lead author. The research was published in *Science Advances*. Chee Wei Wong, a UCLA associate professor of electrical engineering, is the project's principal investigator.

"Measuring the time it takes for a pulse of light to reflect from an object and return back to us also tells us a distance," Wong said. "This could help in precision laser distance ranging, such as in sensing for self-driven automobiles and aerial vehicles."

Wong said the laser clock could help generate ever-shorter pulses of light, which would be useful for watching the motion of electrons or detecting trace hazardous materials from faraway distances.

The new clock could also help further refine the absolute value of "fundamental constants," numbers that are thought to be same throughout the universe—for example, the strength of electromagnetic interactions between electrons and other elementary particles.

Wong said because the clock is cast on a silicon chip, it is more reliable than the previous, larger model, which required additional stabilization and control electronics to work.

The paper's other authors are Jinghui Yang of UCLA, Mingbin Yu and Dim-Lee Kwong of Singapore's Institute for Microelectronics , and Bart McGuyer and Tanya Zelevinsky of Columbia University.

More information: S.-W. Huang et al. A broadband chip-scale optical frequency synthesizer at 2.7 x 10-16 relative uncertainty, *Science Advances* (2016). DOI: 10.1126/sciadv.1501489

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