World's first compact and robust high-precision optical lattice clock with a 250L volume successfully developed

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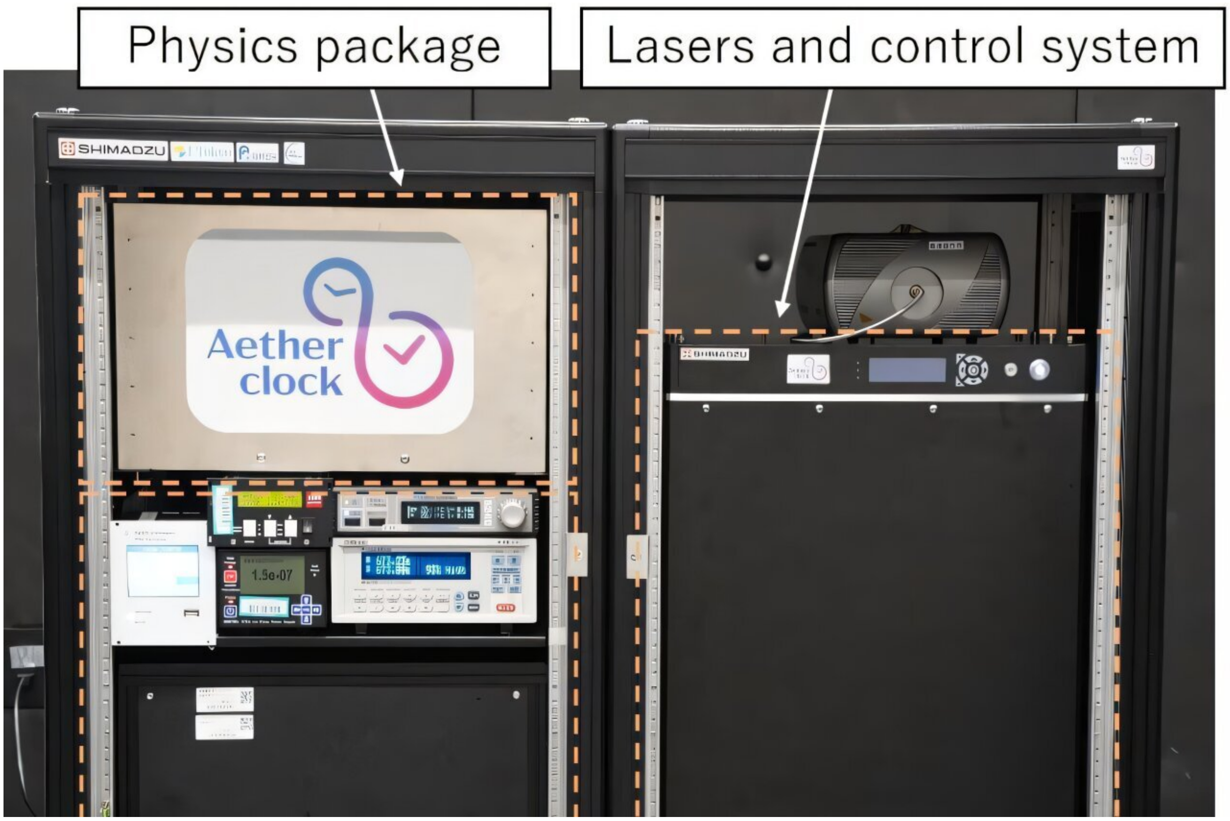

A compact optical lattice clock with a volume of 250 liters has been developed. The system includes a physics package for conducting spectroscopy on the clock transition within a vacuum chamber, lasers for manipulating atoms, a control system for clock operation, and an optical cavity that serves as a frequency reference for the lasers. Laser-cooled atoms are trapped in the optical lattice, and the clock transition frequency is measured with high precision in a lowtemperature blackbody radiation shield. Credit: Shimadzu Corporation

An optical lattice clock is a type of atomic clock that can be 100 times more accurate than cesium atomic clocks, the current standard for defining "seconds." Its precision is equivalent to an error of approximately one second over 10 billion years. Owing to this exceptional accuracy, the optical lattice clock is considered a leading candidate for the next-generation "definition of the second."

Professor Hidetoshi Katori from the Graduate School of Engineering at The University of Tokyo has achieved a milestone by developing the world's first compact, robust, ultrahigh-precision optical lattice clock with a device capacity of 250L.

As part of this development, the physics package for spectroscopic measurement of atomic clock transitions, along with the laser and control system used for trapping and spectroscopy of atoms, was miniaturized. This innovation reduced the device volume from the traditional 920 to 250 L, approximately one-quarter of the previous size.

The miniaturization of the optical lattice clock, which enhances its portability, enables its use for relativistic sensing using the general theory of relativity in various installation environments.

For instance, the optical lattice clock can monitor plate movements with centimeter-level precision, track vertical crustal shifts caused by volcanic activity, and accurately observe elevation changes in the Earth's crust over timescales ranging from hours to years. Additionally, it can facilitate the development of ultrahigh-precision elevation measurement and positioning systems.

Therefore, the optical lattice clock is anticipated to serve as a foundational infrastructure for future societal needs, contributing to a wide range of research fields and practical applications.

This research was performed in collaboration with Senior Researcher Masao Takamoto from the RIKEN Center for Advanced Photonics along with Shimadzu Corporation and JEOL Ltd.

This research was conducted as part of the JST Mirai Program (Large-scale Type) under the technology theme "Ultrahigh-precision time measurement technologies leading to a new time-business." The research development project is titled "Space–time information platform with a cloud of optical lattice clocks."

This research project aims to establish a next-generation platform for ultrahigh-precision space-time information through network deployment and social implementation of "optical lattice clocks."

The goal of this project is to create an ultrahigh-precision cloud clock environment by linking optical lattice clocks that will improve the accuracy of the atomic clocks used in the Global Navigation Satellite System (GNSS) by more than 1,000-fold, thereby enabling faster, larger capacity communications and more advanced location information services.

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