Development of a Transportable Optical Lattice Clock and Its Applications

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Optical lattice clocks have achieved a fractional uncertainty of 10^{-18} and instability of 10^{-17} at an averaging time of one second, which is more than two orders of magnitude better than the cesium atomic clock that currently defines the second. Such a highly accurate and stable clock is not only important as a time and frequency standard but is also expected to serve as a quantum sensing device. For example, a clock with 10^{-18} uncertainty can measure the gravitational redshift due to a height difference of 1 cm, according to the general theory of relativity, thus making it a high-precision geodetic device. We developed a pair of transportable 18-digit precision optical lattice clocks [1], installed them on the ground and the observatory floor of Tokyo Skytree, and compared their frequencies with 18-digit precision at a height difference of 450 m. As a result, we verified the general theory of relativity with an accuracy of 5 digits, which is comparable to a space-scale experiment [2].

The application to relativistic geodesy requires optical lattice clock networks connected by optical fiber links, as is being demonstrated in Europe [3]. Such optical lattice clock networks can be employed to establish an elevation system and to monitor crustal movement and volcanic activity [4]. For such geodetic applications, it is also essential to develop highly transportable optical lattice clocks that can operate outside the laboratory.

In this presentation, we will introduce the development of transportable optical lattice clocks and their applications to relativistic geodesy. We will also present the development of next generation transportable systems.

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