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Transportable optical lattice clocks to test and use gravitational redshift

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Abstract

Clocks are devices to share time using ubiquitous oscillatory phenomena in nature. We once relied on astronomical observations, and today we use far regular oscillations of cesium atoms to define the international system of unit (SI) for time, i.e., the SI second. Recent optical atomic clocks have demonstrated more than 100-fold improvement over cesium clocks, leading to a redefinition of the second in the future. This extreme precision, in turn, allows clocks to investigate relativistic spacetime curved by gravity, where clocks serve as gravitational potential sensors. Roles of the clocks are rapidly changing from those supposed previously.

An “optical lattice clock” proposed in 2001 benefits from a low quantum-projection noise by simultaneously interrogating a large number of atoms trapped in optical lattices. About a thousand atoms enable such clocks to achieve 10-18 instability in a few hours of operation. This superb stability is especially suitable for relativistic geodesy, where gravitational redshift between the clocks resolves a centimeter height differences.

We overview the progress of optical lattice clocks and address recent topics including 1) transportable optical clocks operated at a broadcasting tower, TOKYO SKYTREE, to test gravitational redshift and 2) an on-vehicle optical clock and its applications.