【Grant-in-Aid for Specially Promoted Research】
Science and Engineering (Mathematics/Physics)

Title of Project : Investigation of novel engineering and scientific applications of ultra-precise optical lattice clocks

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Research Project Number : 16H06284 Researcher Number : 30233836
Research Area : Mathematical and Physical Sciences
Keyword : Quantum Electronics

【Purpose and Background of the Research】

Accurate atomic clocks not only support the foundations of sciences but also have an immense impact on applications in modern society, including positioning with Global Navigation Satellite System and synchronization of high-speed communication networks. The optical lattice clock, which we proposed in 2001, has so far achieved the relative uncertainty of 10^{-18}. Such optical clocks have surpassed the uncertainty of Cesium clocks that define the second of the International System of units (SI) by two orders of magnitude, which initiated the discussions toward the redefinition of the second.

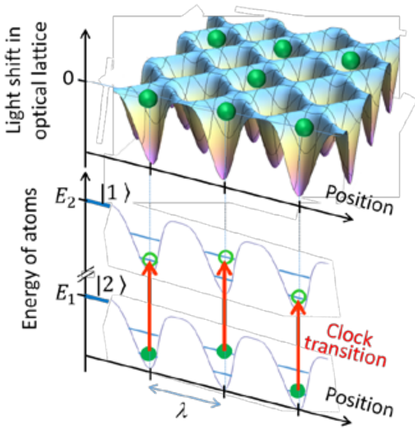

Figure 1: Schematic diagram of an optical lattice clock. Atoms are confined in an optical lattice, where the light shift perturbations on the clock transition is eliminated by tuning a lattice-trap laser to the magic frequency.

【Research Methods】

The project shall demonstrate a new concept of "operational magic frequency" that reduces the fractional uncertainty of the total light shift to less than 10^{-18} by including the higher-order light-shift perturbations. We will apply this new protocol to Sr, Yb, Hg, and Cd based optical lattice clocks to establish a highly precise clock network as shown in Fig. 2. With these clocks, we experimentally discuss the most suitable atomic elements for the future clock and demonstrate frequency ratio measurements with an uncertainty of 10^{-19}.

【Expected Research Achievements and Scientific Significance】

High-performance optical lattice clocks will impact on discussions toward the redefinition of the SI second. On the other hand, such clocks will function as probes 1) to explore "new physics" by investigating the stability of the fundamental constants and anisotropy of space and 2) to develop the "relativistic geodesy" that relies on the gravitational red shift, both of which will drastically alter the existing methodologies.

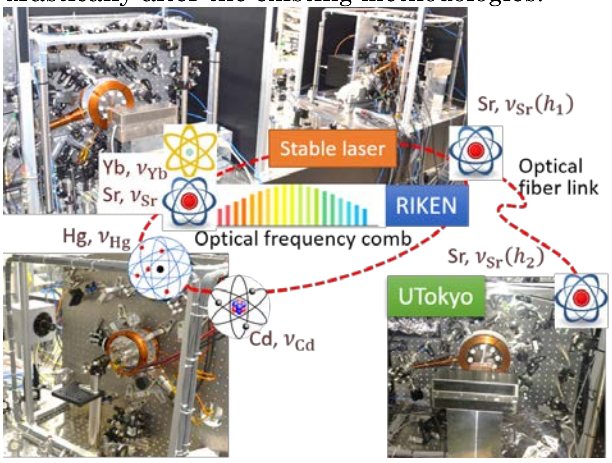

Figure 2: Establish optical lattice clocks consisted of different atomic elements. Frequency ratios of such clocks may probe the stability of the constants.

【Publications Relevant to the Project】

・H. Katori, Optical lattice clocks and quantum metrology, Nature Photon. 5, 203 (2011).
・H. Katori, et al., Strategies for reducing the light shift in atomic clocks, Phys. Rev. A 91, 052503 (2015).

【Term of Project】 FY2016-2020

【Budget Allocation】 452,600 Thousand Yen

【Homepage Address and Other Contact Information】

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