高精度・光格子時計の実現と物理探索

Development of highly accurate optical lattice clocks and a quest for related physics

Objectives

時計遷移のシュタルクシフトをキャンセルする光格子に捕獲されたおよそ 100 万個の原子を用いた原子時計—光格子時計—による 18 桁の周波数計測の実現可能性を実験的に評価する。超高安定な時間・周波数計測が可能にする新しい物理現象を、異種・同種原子による光格子時計の比較と通した物理定数の恒常性の検証、ファイバーリンクを用いた高精度原子時計の遠隔地比較によって探索する。

Optical lattice clocks utilize millions of atoms trapped in light-shift-free optical lattices, which provide a new avenue to study highly accurate and stable frequency measurements. We explore the novel physics related to such precision measurements, including relativistic geodesy utilizing two long-distant optical lattice clocks connected by an optical fiber and search for constancy of physical constants by comparing two optical clocks made of different atomic elements.

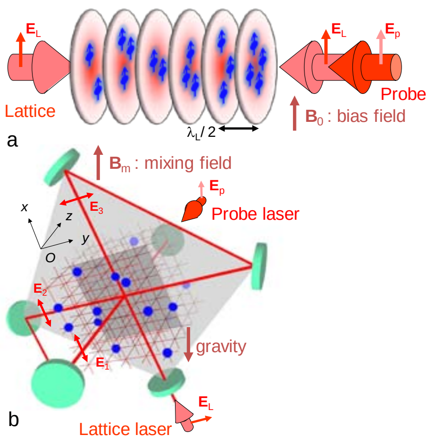

Fig. 1: Geometries for optical lattice clocks.
a) 1D optical lattice clock with spin-polarized fermions relying on the Pauli blocking of collisions.
b) A 3D optical lattice suppresses the bunching of bosonic atoms.

Achievements

- 光格子の幾何学的形状、被観測原子の量子統計性から光格子時計の究極の実現手法を議論した。
- 異種同位体を用いた、2 台の光格子時計の比較により、国際原子時(TAI)を超える精度で、時間比較を実現した。
- 東大—産総研間で光ファイバーリンクを実現し、光格子時計を TAI に基づき評価した。
- 原子と光格子の多重極相互作用を考慮した、魔法波長の厳密な定義を与えた。

- Realizations of optical lattice clocks are discussed in view of the lattice geometry and the quantum statistics (and resultant spins) of interrogated atoms.
- We performed comparisons between two optical lattice clocks and demonstrated the clock performance which exceeded the International Atomic Time (TAI).
- Optical fiber link of the clocks was established between Tokyo-Tsukuba to evaluate the Sr based optical lattice clock frequency based on TAI.
- We discussed the exact definition of the magic wavelength, which is the central concept for the optical lattice clocks, by taking multipolar atomic-lattice interactions into account.

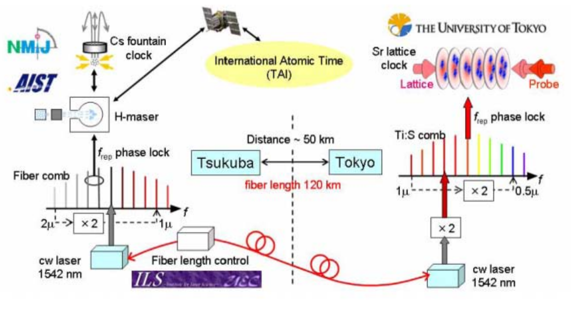

Fig. 2: Remote frequency transfer using optical fiber connecting Tokyo and Tsukuba.

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