Development of an Optical Atomic Clock for Fundamental Science Experiments

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Atomic clocks having unprecedented accuracy are realized either by probing forbidden optical transitions of: neutral atoms localized in an optical lattice or a single atomic ion trapped in an electrodynamic trap. The tick rate of such clocks is influenced by unimaginably tiny perturbations of the energy states associated with clock transitions of the atoms. The resulting change in tick rates of the clocks could even be caused by variations of the fundamental constants, breaking of fundamental symmetries, millimeter-scale gravitational red-shifts, gravitation waves, cosmic microwave background, and so on. Thus, the intercomparison of the geographically distributed ultra-stable, highly accurate atomic clocks acts like "networked quantum sensors" and are used to explore the foundations of science, geodetic measurements, and testing the general theory of relativity.

At the Precision & Quantum Measurement laboratory (PQM-lab: https://pqmlab.iucaa.in/), IUCAA we are developing an optical clock based on trapped ytterbium-ions. For this, a single ytterbium-ion will be trapped in an indigenously developed precision ion trap and the ion will be cooled to sub-mK temperature using the laser cooling technique. The laser-cooled and confined ytterbium-ion will then be used to probe its highly forbidden electric octupole (E3) transition at 642 121 496 772 645.15 Hz, with few tens of mHz accuracy for the realization of the optical clock. For exciting the clock transition, an ultra-stable laser having sub-Hz line-width at 467 nm wavelength will be required. This will be produced by referencing a commercial laser to an indigenously developed reference optical resonator (Fabry-Pérot cavity). To make use of our clock, the ultra-stable nearly monochromatic photons need to be disseminated through coherent optical fibers to geographically distributed locations. For that, active phase noise cancellation of the optical fiber by stabilizing its length will be implemented. For absolute referencing of the communication laser at 1550 nm wavelength, it will be referenced to the optical clock through an intermediate optical frequency comb. At present we are engaged in developing all the required technologies and I shall discuss some of them in the meeting.