Optical Frequency Standard with Ytterbium Single Ion

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The largest frequency shift that contributes to the systematic uncertainty of many atomic frequency standards is the interaction of the thermal blackbody radiation with the atomic eigenstates. Presence of two ultra narrow optical transitions in the same thermodynamic environment makes possible implementation of so called "synthetic" frequency standard with suppressed blackbody radiation (BBR) frequency shift[1]. In ^{171}Yb ion at room temperature the residual BBR shift is estimated to be on the order of 10^{-18} for the "synthetic" frequency which is a combination of the octupole (467 nm) and the quadrupole (436 nm) optical transition frequencies. Thus, the "synthetic" frequency standard based on $^{171}Yb^{+}$ can be practically immune to the blackbody radiation shift. We report on the progress in development of a highly accurate optical frequency standard based on the single ion of ytterbium-171 at the Institute of Laser Physics, Novosibirsk.

Miniature endcap trap is used for capturing and retaining the single ion by means of a quadrupole radio frequency potential. Endcap trap design has advantage of better optical access which can be exploited for multi beam 3D laser cooling of the ion.

The quasicycling $^2S_{1/2}$ (F=1) $\rightarrow$ $^2P_{1/2}$ (F=0) electric dipole transition with natural linewidth of 23 MHz at 370 nm is used for Doppler cooling and detection of the ion. Doppler cooling of the ion is performed with the help of a frequency modulated radiation of the diode laser resonantly frequency doubled in a nonlinear crystal. Up to 100 μW of the UV light is available for the ion cooling.

Narrow line probe laser is constructed to excite the ion clock transition. The linewidth of the free-running laser is decreased to ~ 1 Hz by the Pound-Drever-Hall frequency stabilization to a high-finesse Fabry-Perot etalon made of ultralow expansion (ULE) glass. The etalon is mounted on a spring suspension inside a thermostabilized vacuum chamber to suppress length fluctuations and thermal drift.

[1]V. I. Yudin, et al., Atomic clocks with suppressed blackbody radiation shift, Phys. Rev. Lett., 107, 030801, 2011