Toward a Mercury Optical Lattice Clock: Spectroscopy of the Clock Transition in Fermionic Isotopes

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Abstract— **In this paper, we report on development on an optical lattice clock using neutral mercury. Laser spectroscopy of the clock transition in fermionic isotope has been performed, which is an important step in this project.**

The performance of optical atomic clocks is improving at a high pace. Optical clocks are now surpassing atomic fountain clocks based on microwave transition [1-4]. Optical lattice clocks using strontium atoms have demonstrated uncertainties at the 10^{-16} level [3]. At this level of uncertainty, the blackbody radiation shift is the largest correction and the largest contribution to the strontium clock uncertainty and it will be a severe limitation at the 10^{-17} level. Owing to its low sensitivity to blackbody radiation [5], mercury has the potential to achieve uncertainty in the low of the 10^{-18} and to compete with the best single ion optical clocks [1]. In this paper, we report our work toward the realization of an optical lattice clock using mercury, including the first laser spectroscopy of the clock transition.

While implementing magneto-optical trapping (MOT) of neutral mercury using a 254nm laser source based on Yb doped thin disk laser, we have developed an ultra stable laser source at 265.6 nm for probing the 1S0-3P0 clock transition. This laser source is based on a Yb doped DFB fiber laser at 1062.5 nm stabilized to a reference 10 cm vertically mounted Fabry-Perot cavity with fused silica mirrors. This laser is linked to LNE-SYRTE primary reference using a Ti:Sa based optical frequency comb. Comparisons between this ultra stable laser source and a 1 GHz reference derived from a cryogenic sapphire oscillator has shown a short term instability of 6 parts in 10^{15} at one second, limited by the 1 GHz signal and a mid term instability below 2 parts in 10^{15} up to 1000 s, after a predictable linear drift of -50 mHz at 1062.5 nm is removed. This system is ready for highly stable optical to microwave measurements, limited only by the microwave standard at the level of few parts in 10^{14} at 1 s. Using this clock laser system, we have performed the first direct laser spectroscopy of the 1S0-3P0 clock transition at 265.6 nm in fermionic isotopes of mercury. Spectroscopy is done on a cold atom sample released from the MOT with a retro reflected vertical probe beam. In this geometry, the Doppler-free recoil doublet is resolved. Absolute frequency measurement of the clock frequency in both fermionic isotopes is performed with a fractional uncertainty of about 5.10^{-12}, improving previous indirect knowledge of the transition frequency by more than 4 orders of magnitude [6].

Finally, work is on going toward the realization of a dipole lattice trap at the magic wavelength of mercury, which is expected to be at 360 nm [5].

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