Optical Clock Based on the $^{171}Yb^+$ Octupole Transition with Uncertainty at the 10^{-18} Level

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We aim at realizing a very accurate optical clock that uses the electric octupole transition $^2S_{1/2}(F = 0)\rightarrow{}^2F_{7/2}(F = 3)$ of a single laser-cooled $^{171}Yb^+$ ion at 467 nm as a reference. This transition has a natural linewidth in the nHz range, and a low sensitivity to frequency shifts induced by electric and magnetic fields[1]. Both characteristics are advantageous for the realization of an optical clock, but because of the extremely small oscillator strength of the transition its excitation requires high spectral power density. The required intensity in turn introduces a significant light shift of the transition frequency.

To avoid the light shift, we have implemented the Hyper-Ramsey excitation scheme (HRS)[2] with a pulse sequence that is tailored to produce a resonance signal that is immune to frequency shifts during the interrogation pulses. In the HRS, the effect of the light shift on the spectrum is compensated by introducing a frequency step of the probe light during the interrogation pulses and an additional pulse cancels the linear dependence of the resonance frequency on the necessary compensation frequency step. Our experiments demonstrate a suppression of the light shift by four orders of magnitude and immunity against its fluctuations[3]. For the operation as a frequency standard, we have implemented a servo system that controls the size of the frequency step in the HRS by comparison to interleaved Rabi interrogation at the same intensity. In this way, slow variations of the light shift will not degrade its suppression. We estimate the systematic uncertainty due to the light shift from the probe laser to be below 2×10^{-18}.

Recently, we have inferred the differential polarizability of the octupole transition from light shift measurements with lasers at various NIR wavelengths. Improved knowledge of the thermal radiation emitted by the ion trap and its mounting structure has been obtained from measurements with thermal sensors and finite element modeling[4]. Taken together, this allows us to correct the blackbody radiation shift with a fractional uncertainty of less than 4×10^{-18}, which constitutes the leading contribution to the total systematic uncertainty of 5×10^{-18}.

This work is partly funded by the EMRP project SIB04 Ion Clock. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

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