URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Comparison of two ^{171}Yb^{+} single-ion optical frequency standards with a millihertz uncertainty

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^{171}Yb^{+} possesses favorable properties for a trapped ion optical frequency standard, including long trapping times and a non-degenerate ground state $^2S_{1/2}$(F=0). Two reference transitions in Yb^{+} are suitable for the realization of optical frequency standards: the $^2S_{1/2}(F=0)\rightarrow{}^2D_{3/2}(F=2)$ electric quadrupole (E2) transition at 436 nm and the $^2S_{1/2}(F=0)\rightarrow{}^2F_{7/2}(F=3)$ electric octupole (E3) transition at 467 nm [1]. The significantly higher sensitivity of the E2 transition to field induced frequency shifts permits the sensitive diagnosis of systematic effects on the same ion and a precise correction of the E3 transition frequency.

We employ two ^{171}Yb^{+} single-ion optical frequency standards that differ significantly with respect to trap geometry, control software and interrogation sequence [1,2]. The relative systematic uncertainty of the clocks referencing the E3 transition has been evaluated to less than 4×10^{-18} [1]. In a long-term comparison of the two clocks for a period of seven months with a duty cycle of up to 95 % per day, we found an agreement of the measured 642.121 THz transition frequencies to better than 2 mHz. This corresponds to a relative frequency offset of 2.8×10^{-18}, measured with a 2.1×10^{-18} statistical uncertainty.

Due to the electronic structure of the $^2F_{7/2}$ state, the E3 transition frequency is very sensitive to violations of Local Lorentz Invariance. The two clock ions are confined in separate ion traps with quantization axes aligned along nonparallel directions. Hypothetical Lorentz symmetry violations would lead to sidereal modulations of the frequency offset. From the absence of such modulations at the 10^{-19} level we deduce stringent limits on Lorentz symmetry violation parameters for electrons in the range of 10^{-21}, improving previous limits by two orders of magnitude [3].

Beside the use of ^{171}Yb^{+} single-ion clocks in metrology and basic research, they are also investigated for wider applications within a pilot project for quantum technology supported by the German Federal Ministry of Education and Research. Together with 6 industrial partners, 2 universities and a research institute, we are developing a robust, high-availability and easy-to-use optical clock based on the E2 transition, which can be operated outside of specialized laboratories [4].

1. N. Huntemann, C. Sanner, B. Lipphardt, Chr. Tamm, and E. Peik, “Single-Ion Atomic Clock with 3×10^{-18} Systematic Uncertainty”, Phys. Rev. Lett. 116, 063001 (2016).

2. C. Sanner, N. Huntemann, R. Lange, Chr. Tamm, and E. Peik, “Autobalanced Ramsey Spectroscopy”, Phys. Rev. Lett. 120, 053602 (2018).

3. C. Sanner, N. Huntemann, R. Lange, Chr. Tamm, E. Peik, M. Safronova, and S. Porsev, “Optical clock comparison test of Lorentz symmetry”, arXiv:1809.10742

4. www.opticlock.de