Aluminum ion clock at PTB

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Since 1967 the second is defined via the hyperfine transition in caesium [1]. Modern caesium microwave clocks feature to a fractional frequency uncertainty of 2×10^{-16} and instability of $2.5\times10^{-14}/\sqrt{\tau/1\mathrm{s}}$ [2]. Optical atomic clocks can now surpass this performance by more than two orders of magnitude in stability and uncertainty. The optical clock transition in the aluminum ion has the advantage of a very low sensitivity to Zeeman shifts, black body radiation shifts and has a negligible quadrupole shift. This makes aluminum an excellent clock candidate. However, the doppler cooling and detection transition is in the deep ultraviolet at 167 nm. The aluminum clock at NIST has demonstrated a fractional frequency uncertainty below 10^{-18} [3] and instability of $(2.8\pm0.6)\times10^{-16}/\sqrt{\tau/1\mathrm{s}}$ using correlation spectroscopy [4].

Here we present the results of our aluminum ion clock at PTB. An aluminum ion is co-trapped with a calcium ion in a blade-style linear Paul trap [5]. Calcium is utilized for sympathetic cooling as well as for state readout via quantum logic spectroscopy (QLS) [6]. Electromagnetically induced transparency cooling [5] is employed for ground state cooling, which is mandatory for applying QLS. The calcium ion is used for the measurement of the external fields for most of the systematic frequency shifts due to its larger sensitivity. We determined a preliminary systematic frequency uncertainty of 1.06×10^{-18}. The instability of our clock is $8.1\times10^{-16}/\sqrt{\tau/1\mathrm{s}}$ (see Fig. 1), deduced from a frequency comparison against the strontium optical lattice clock [7]. Preliminary frequency ratio measurements against PTB's strontium lattice and ytterbium ion clocks [8] have been performed at the 10^{-17} uncertainty level.

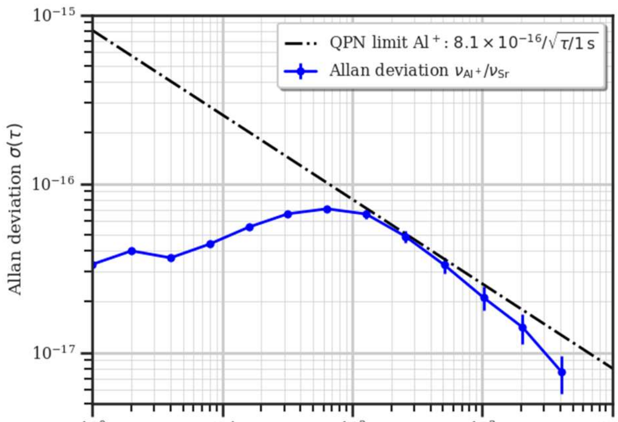

Fig. 1: Fractional frequency instability of the optical frequency comparison between the aluminum ion clock (350 ms interrogation time) against strontium lattice clock.

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