Recent Progress on the VTT MIKES $^{88}Sr^+$ Optical Ion Clock

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We present recent progress on the VTT MIKES optical clock based on a single $^{88}Sr^+$ ion. The ion is trapped in a radiofrequency (rf) trap of the endcap type, see Fig. 1, designed for low radio-frequency heating. A compact aluminum vacuum chamber enables a low vacuum pressure, which is beneficial for both the collisional shift and the ion lifetime, and small temperature gradients, which simplifies the evaluation of the blackbody radiation (BBR) shift. The electric fields and field gradients created by the applied voltages have been studied in detail by a combination of measurements and simulations, which allows precise control of the electric quadrupole shift[1].

Recent experimental improvements include a new cooling laser and the implementation of state preparation by optical pumping, which increases the excitation probability of the clock transition by a factor of two. Following theoretical work on noise-induced servo errors[2], we have implemented a moving-mean normalized servo discriminator and, in addition, alternate the order of probing the two sides of the clock transitions, which reduces these servo errors to a negligible level. The AC magnetic field caused by the 14.4 MHz trap drive has recently been measured to be only 30 nT (RMS) due to the symmetric trap design. The uncertainty evaluation is being finalized, and we expect a total fractional systematic uncertainty at the low 10^{-18} level.

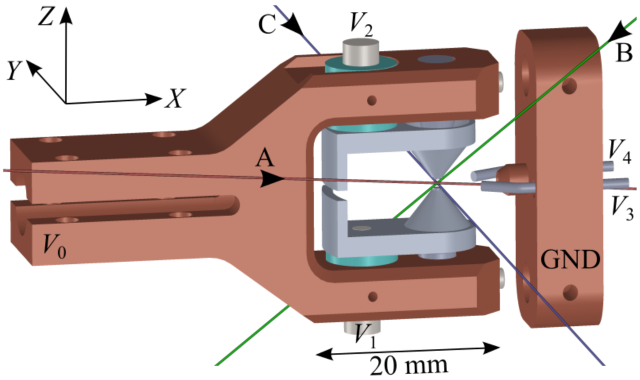

Fig. 1: Endcap trap. V_0 is the trap rf voltage, V_1-V_4 are dc bias voltages. The three laser beam directions are indicated by arrows labelled A-C.

In March 2022, the clock participated in its first international comparison campaign via a GPS IPPP link within the EMPIR ROCIT project. At the same time, the absolute frequency was measured against International Atomic Time (TAI) and was found to be in good agreement with recent values from NRC[3] and PTB[4]. Automated unattended clock operation for extended periods is being developed, including e.g. periodic micromotion minimization, and recooling the ion after collisions that cause loss of fluorescence. An optical-optical clock comparison against PTB's transportable Yb^+ clock is planned for 2024Q3 within the EPM TOCK project.

[1] T. Lindvall *et al.*, "High-accuracy determination of Paul-trap stability parameters for electric-quadrupole-shift prediction", J. Appl. Phys. **132**, 124401 (2022).

[2] T. Lindvall *et al.*, "Noise-induced servo errors in optical clocks utilizing Rabi interrogation", Metrologia **60**, 045008 (2023).

[3] B. Jian *et al.*, "Improved absolute frequency measurement of the strontium ion clock using a GPS link to the SI second", Metrologia **60**, 015007 (2023).

[4] M. Steinel *et al.*, "Evaluation of a $^{88}Sr^+$ Optical Clock with a Direct Measurement of the Blackbody Radiation Shift and Determination of the Clock Frequency", Phys. Rev. Lett. **131**, 083002 (2023).