Ytterbium ion optical frequency standard for metrology and fundamental physics

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We present our latest improvements to the ytterbium ion $^{171}Yb^{+}$ optical frequency standard[1] at the National Physical Laboratory (NPL) and show results from recent measurements in both frequency metrology and fundamental physics.

A full evaluation of the uncertainty budget from systematic frequency shifts of the $^{171}Yb^{+}$ electric octupole (E3) clock transition has demonstrated a total relative standard uncertainty of 2.2×10^{-18}. This includes a first evaluation in our system of the ac Zeeman shift arising from magnetic fields oscillating at the trap-drive frequency, which were previously assumed to be zero due to the symmetric design of our trap. Our new measurements show that a small residual ac magnetic field due to asymmetries in the assembly and rf feed leads to a fractional frequency shift and uncertainty $\lesssim 1 \times 10^{-20}$.

Systematic effect	σ / ν_0 $[10^{-18}]$
Electric quadrupole	1.5
Blackbody radiation	1.2
2nd order Zeeman (dc)	0.6
Background collisions	0.6
Phase chirp	0.5
ac Stark – probe beam	0.4
2nd order Doppler	0.3
Others	< 0.1
Total	**2.2**

Table 1: Preliminary uncertainty budget for the $^{171}Yb^{+}$ (E3) clock transition, showing relative standard uncertainties.

We have made new absolute frequency measurements of the $^{171}Yb^{+}$ (E3) clock transition with total uncertainty at the low parts in 10^{16} level, with reference to our local caesium fountain NPL-CsF2 and also via a link to International Atomic Time (TAI). We have also made a new measurement of the optical frequency ratio between $^{171}Yb^{+}$ (E3) and our local strontium ^{87}Sr optical lattice clock, NPL-Sr1.

Frequency ratios between $^{171}Yb^{+}$, ^{87}Sr and ^{133}Cs standards can also be used to search for variations in the fine structure constant and the electron-to-proton mass ratio. Most recently, we have been focussing on searching for oscillations in these fundamental constants on timescales from a minute to almost a day. This has enabled us to place competitive constraints on the parameter space of models of ultralight dark matter and axion-like particles[2].

[1] A Tofful, "Advances in performance and automation of a single ytterbium ion optical clock", PhD thesis, Imperial College London, 2023.

[2] N. Sherrill *et al.*, "Analysis of atomic-clock data to constrain variations of fundamental constants", New J. Phys., vol. 25, 093012, 2023.