An ytterbium ion optical clock with 2.2 × 10^{-18} fractional systematic uncertainty

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The impending redefinition of the SI second based on an optical frequency is motivated by the high accuracy of optical atomic clocks, which have been demonstrated to outperform caesium primary frequency standards by two orders of magnitude [1]. Optical clocks based on singly-charged trapped ions present an advantage in terms of achievable accuracy thanks to their typically low sensitivity of the clock transition to external perturbations. In particular, the $^{171}Yb^+$ ion is a promising candidate for a primary optical frequency standard (OFS), with the availability of two optical clock transitions including a strongly forbidden electric octupole (E3) transition with a natural linewidth of the order of nHz [2].

The $^{171}Yb^+$ ion optical clock at the National Physical Laboratory (NPL) has recently undergone a full re-evaluation of its systematic uncertainty budget [3], leading to a relative standard uncertainty of 2.2 × 10^{-18}. This result aligns well with the Consultative Committee for Time and Frequency (CCTF) target of $\lesssim 2 \times 10^{-18}$ evaluated uncertainty ahead of the redefinition of the second [1].

This ytterbium ion optical clock has participated in several measurement campaigns, which involved measuring both optical frequency ratios and absolute frequency. In addition to the local ratio with the ^{87}Sr optical lattice clock at NPL, several measurements of remote frequency ratios below the 10^{-16} level of uncertainty were performed via the European optical fibre link network connecting NPL to LNE-SYRTE, PTB and INRIM.

Absolute frequency measurements of the E3 transition were performed against the local caesium fountain and also via International Atomic Time (TAI). Figure 1 represents a summary of the absolute frequency results from the last three campaigns compared with recent results in the literature, showing a consistent picture over the years. These measurements are necessary to show reproducibility and ensure continuity with the future definition of the second.

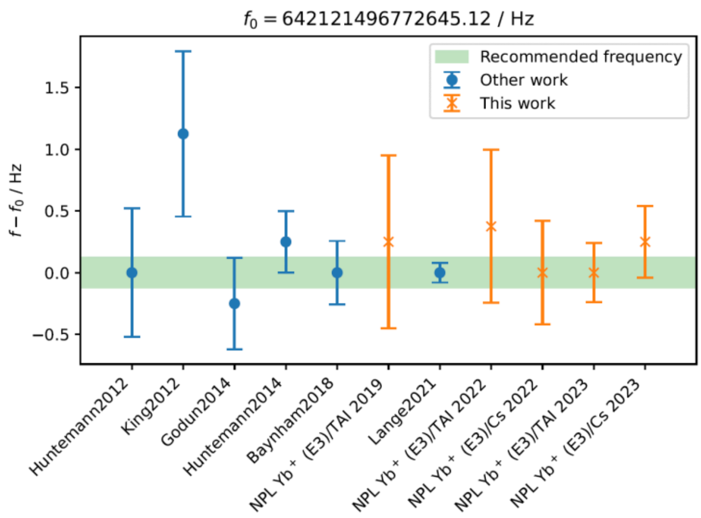

Figure 1: Measurements of the E3 transition of $^{171}Yb^+$ at NPL during measurement campaigns in 2019, 2022 and 2023 compared to previously published work. Figure from Ref. [3].

References

[1] N. Dimarcq et al.: Roadmap towards the redefinition of the second, Metrologia, Vol. 61, 012001, 2024.
[2] R. Lange et al.: Lifetime of the $^2F_{7/2}$ level in Yb^+ for spontaneous emission of electric octupole radiation, Phys. Rev. Lett., Vol. 127, 213001, 2021.
[3] A. Tofful et al.: $^{171}Yb^+$ optical clock with 2.2 × 10^{-18} systematic uncertainty and absolute frequency measurements, Metrologia, Vol. 61, 045001, 2024.