The PTB Sr lattice clock: status and frequency measurement

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The progress of optical frequency standards depends strongly on improved evaluations of their uncertainty budgets[2,3] and the comparison with other frequency standards, among which caesium primary clocks naturally have a special status.

We have measured the frequency of our strontium lattice clock with the two PTB caesium fountain clocks.[4] During this measurement campaign, also the Yb^+ single ion standard based on the octupole transition[5] was operated providing a reduced phase noise microwave signal to the CSF2 fountain. The combination of Sr–Yb^+ and Cs–Yb^+ frequency ratio data yielded an effective averaging time of 350 000 s against the fountain clocks reducing the statistical uncertainty to about 2×10^{-16}. Adding all systematic uncertainty contributions, we were able to determine the frequency of our lattice clock with an uncertainty of 170 mHz or 4×10^{-16}. The frequency is in very good agreement with a long series of other measurements of several groups (Fig. 1). In particular we are in excellent agreement with the recent measurement at SYRTE that has an uncertainty of only 132 mHz.[6]

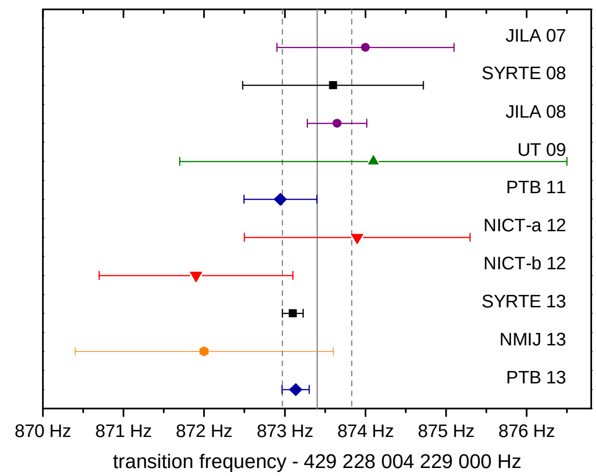

Fig. 1: Comparison of measured absolute frequencies of the $5s^2\ {}^1S_0 - 5s5p\ {}^3P_0$ transition in ^{87}Sr (references in [4]). The vertical line indicates the 2013 recommendation by the BIPM[1] with the dashed lines showing the assigned frequency uncertainty of 1×10^{-15}.

In addition to the presentation of these results, we will summarize our recent evaluation of stray electric fields that potentially cause large dc-Stark frequency shifts, the reduction of temperature gradients and the implementation of a new ultrastable clock laser, which now allow us to operate our lattice clock with a fractional uncertainty of 3×10^{-17}.

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[1] Report of the 101th meeting of the Comité International des Poids et Mesures (CIPM). Bureau International des Poids et Mesures (BIPM), Sevres, Paris Cedex, 2013.

[2] C. Chou *et al.*, “Frequency comparison of two high-accuracy Al^+ optical clocks”, Phys. Rev. Lett. **104**, 070802, (2010).

[3] B. Bloom *et al.*, “An optical lattice clock with accuracy and stability at the 10^{-18} Level”, Nature **506**, 71 (2014).

[4] S. Falke *et al.*, “A strontium lattice clock with 3×10^{-17} inaccuracy and its frequency, arxiv:1312.3419, (2013).

[5] N. Huntemann *et al*. “High-accuracy optical clock based on the octupole transition in $^{171}Yb^+$”, Phys. Rev. Lett. **108**, 090801 (2012)

[6] R. Le Targat *et al.*, “Experimental realization of an optical second with strontium lattice clocks”, Nature Com. **4**, 2109, 2013