Optical Clock Comparisons searching for Physics beyond the Standard Model

Nils Huntemann, Moustafa Abdel Hafiz, Ali Al-Masoudi, Erik Benkler, Sören Dörscher, Richard Lange, Thomas Legero, Burghard Lipphardt, Christian Lisdat, Ekkehard Peik, Johannes Rahm, Christian Sanner, Roman Schwarz, Hu Shao, Uwe Sterr, Christian Tamm, Stefan Weyers

Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany.

We report on direct frequency comparisons of optical clocks based on different reference transitions. At PTB, we realize the $^2S_{1/2} - ^2D_{3/2}$ electric quadrupole (E2) and $^2S_{1/2} - ^2F_{7/2}$ electric octupole (E3) transition frequency using a single $^{171}Yb^+$ ion. For the E3 transition frequency systematic uncertainties as low as 3×10^{-18} have been achieved [1]. These ion-based clocks have been compared to Sr lattice clocks that use the $^1S_0 - ^3P_0$ transition of ^{87}Sr atoms confined in an optical lattice near the magic wavelength as the reference [2]. Besides the comparison between optical clocks, their frequencies were also measured using caesium fountain clocks [3].

Data acquired over the last years permit not only a validation of clock uncertainties, but also allow for searches for so-called "new physics", because of the very different sensitivity of the reference transitions on the fine structure constant α. Furthermore, the optical to microwave comparison enables tests for possible temporal variations in the proton-to-electron mass ratio μ.

We will give an overview of the acquired data and show how they can be used to improve existing limits on a potential temporal linear drift in α and μ. Focusing on a possible oscillatory behavior in the data, we can substantially improve previous work on a possible α mediated coupling to dark matter.

[1] C. Sanner, *et al.*, *Optical clock comparison for Lorentz symmetry testing,* Nature **567**, 204 (2019).
[2] C. Grebing, *et al.*, *Realization of a timescale with an accurate optical lattice clock,* Optica **3**, 563 (2016).
[3] S. Weyers, *et al.*, *Advances in the accuracy, stability, and reliability of the PTB primary fountain clocks,* Metrologia **55**, 789 (2018).