



Contribution ID: 2

Type: **Talk**

Clocks based on highly charged ions for tests of fundamental physics

Tuesday, 19 July 2022 12:00 (25 minutes)

Highly charged ions (HCI) have many favorable properties. They offer a high sensitivity to test fundamental physics and for the search of new physics, a simplified atomic structure due to a small number of bound electrons, and a low susceptibility to external perturbing fields [1]. Therefore, HCI are also well-suited for next-generation optical atomic clocks, which can in principle operate at record fractional uncertainties of better than 10^{-18} . However, up to recently HCI were not accessible for such type of instruments.

In this talk, I will briefly review how we overcame all previous obstacles by demonstrating Coulomb crystallization of HCI [2], the implementation of quantum logic spectroscopy [3], and ground-state cooling of weakly-coupled motional modes [4]. With these prerequisites we realized the first optical atomic clock based on an HCI by stabilizing an ultrastable clock laser to the ground-state fine-structure transition in Ar^{13+} at 441 nm. By comparing this optical frequency to the one of the electric-octupole transition in $^{171}\text{Yb}^{+}$, we realized a frequency ratio measurement with a fractional uncertainty of about 1×10^{-16} , limited by statistics. We thereby improved the uncertainty of the absolute transition frequency of Ar^{13+} by about eight orders of magnitude. The systematic uncertainty was 2.2×10^{-17} , dominated by the time dilation shift uncertainty from excess micromotion. Importantly, this level of excess micromotion can be considerably reduced with a new, carefully manufactured ion trap. All other systematic uncertainties are at or below 10^{-18} , demonstrating the potential of HCI as highly accurate atomic references for time keeping and unprecedented tests of fundamental physics. Furthermore, we compared the transition frequencies of the two isotopes $^{40}\text{Ar}^{13+}$ and $^{36}\text{Ar}^{13+}$ in order to determine the isotope shift with an improvement of nine orders of magnitude – resolving the QED nuclear recoil contribution.

The experimental approach is universal and thereby generally unlocks HCI for such precision experiments.

[1] M. G. Kozlov et al., Rev. Mod. Phys. 90 (2018)

[2] L. Schmöger et al., Science 347 (2015)

[3] P. Micke et al., Nature 578 (2020)

[4] S. A. King et al., Phys. Rev. X 11 (2021)

Primary authors: MICKE, Peter (CERN and University of Mainz); Dr KING, S. A. (Physikalisch-Technische Bundesanstalt); SPIß, L. J. (Physikalisch-Technische Bundesanstalt); WILZEWSKI, A. (Physikalisch-Technische Bundesanstalt); Dr LEOPOLD, T. (Physikalisch-Technische Bundesanstalt); Dr BENKLER, E. (Physikalisch-Technische Bundesanstalt); Dr LANGE, R. (Physikalisch-Technische Bundesanstalt); Dr HUNTEMANN, N. (Physikalisch-Technische Bundesanstalt); Prof. SURZHYKOV, A. (Physikalisch-Technische Bundesanstalt and Technische Universität Braunschweig); Dr YEROKHIN, V. A. (Physikalisch-Technische Bundesanstalt); Prof. CRESPO LÓPEZ-URUTIA, J. R. (Max Planck Institute for Nuclear Physics); Prof. SCHMIDT, P. O. (Physikalisch-Technische Bundesanstalt)

Presenter: MICKE, Peter (CERN and University of Mainz)

Session Classification: Session 6