Testing fundamental physics with a highly charged ion-based optical clock

Lukas J. Spieß[1], Alexander Wilzewski[1], Malte Wehrheim[1], Shuying Chen[1], Steven A. King[1], Michael K. Rosner[2], Nils Rehbehn[2], Anna Viatikina[1], Jan Richter[1], Andrey Surzhykov[1,3], Vladimir Yerokhin[2], Agnese Mariotti[4], Elina Fuchs[1,4], Erik Benkler[1], Melina Filzinger[1], Nils Huntemann[1], José R. Crespo Lopez-Urrutia[2], and Piet O. Schmidt[1,5]

[1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

[2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

[3]Technische Universität Braunschweig, Braunschweig, Germany

[4]Insitut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany

[5]Insitut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

Email: lukas.spiess@quantummetrology.de

Highly charged ions (HCI) have long been sought to be used in optical clocks as frequency references. This is due to their low sensitivity to external-field perturbations and their high sensitivity to fundamental physics[1]. Additionally, their low number of electrons enables precise *ab-initio* calculations of atomic coefficients. Recent experimental progress has made it possible to extract HCI from their megakelvin production sites, and transfer them to a cryogenic linear Paul trap. There, a single HCI is recaptured and sympathetically cooled by laser-cooled Be^+ ions. This enabled quantum logic spectroscopy to resolve electronic transitions in HCI with Hz-level precision[2].

After evaluation of the systematic uncertainties to 2×10^{-17}, we demonstrated the first optical clock employing an electric-dipole forbidden transition in a HCI, namely the magnetic-dipole (M1) transition in Ar^{13+} [3]. The absolute frequency of the clock transition was determined with a fractional uncertainty of 1×10^{-16} by comparing it to the established Yb^+ electric octupole clock at PTB[4]. Measurements of the isotope shift ($^{36}Ar^{13+}$ vs $^{40}Ar^{13+}$) with a fractional uncertainty of 6×10^{-11} were compared to atomic structure calculations which resolve QED contributions to the isotope shift. The flexibility of our methods was demonstrated by applying them to Ca^{14+}, where we measured the isotope shift of all five stable, even isotopes. By combining these data with available isotope shift data for Ca^+ [5], we construct a King plot and bound new particles that would couple neutrons and electrons. Further, we measured the first- and second-order Zeeman shift coefficients and compared the result to theoretical predictions.

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