A 14: Precision Spectrosocopy III - trapped ions (joint session A/Q)

Time: Monday 16:15–17:45 Location: K 1.016

Invited Talk A 14.1 Mon 16:15 K 1.016

Collinear Laser Spectroscopy for High Voltage Metrology at the 1 ppm accuracy level — •Jörg Krämer[1], Kristian König[1], Christopher Geppert[2], Phillip Imgram[1], Bernhard Maass[1], Johann Meisner[3], Ernst W. Otten[4], Stephan Passon[3], Tim Ratajczyk[1], Johannes Ullmann[5], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [3]Physikalisch-Technische Bundesanstalt, Braunschweig — [4]Institut für Physik, Johannes Gutenberg Universität Mainz — [5]Institut für Kernphysik, Westfälische Wilhelms-Universität Münster

Voltages of the order of a few Volts can be traced back to a Josephson standard that converts a microwave frequency to a voltage by inducing a current between two superconductors. However, high voltages cannot be traced back directly, but have to be divided down by precision high voltage dividers that reach a relative accuracy of 1 ppm at best.

Similar to the Josephson effect, collinear laser spectroscopy connects the laser frequency in the laboratory frame to the high voltage used to accelerate the ions via the Doppler shift. Since this frequency can be measured with 1 Hz precision using an optical frequency comb, this technique has the potential to reach an accuracy of <1 ppm.

We will present results of laser spectroscopic high voltage measurements using a pump and probe scheme on Ca ions at the 5 ppm level, and we will elaborate on how we plan to further decrease our uncertainties by using indium ions from a liquid metal ion source and an alternative pump and probe approach.

A 14.2 Mon 16:45 K 1.016

Measuring the temperature and heating rate of a trapped single ion by imaging — •Bharath Srivathsan[1,2], Martin Fischer[1,2], Lucas Alber[1,2], Markus Weber[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2,3] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen - Nürnberg (FAU), Department of Physics, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada

We present a technique to measure the temperature and the heating rate of a Doppler-cooled, single ion confined in a harmonic trap. In our experiment, we use a single $^{174}Yb^{+}$ ion trapped at the focus of a parabolic mirror covering almost 4π solid angle. The fluorescence light scattered by the ion from the cooling laser is imaged onto an EMCCD camera. We measure the size of this image while varying the power of the cooling laser. From this measurement data, we determine the heating rate by a fit to a well-known theoretical model for cooling in a trap [1]. Our method enables one to measure the heating rate directly at the Doppler limit, i.e. in a regime which is generally inaccessible to other common techniques.

[1] Stig Stenholm, Rev. Mod. Phys. 58, 699 (1986).

A 14.3 Mon 17:00 K 1.016

Optical ion traps for investigation of atom-ion interactions — •Markus Debatin, Pascal Weckesser, Fabian Thielemann, Yannick Minet, Julian Schmidt, Leon Karpa, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Germany

We demonstrate optical trapping of $^{138}Ba^{+}$ ions in absence of any rf-confinement for durations of up to 3 seconds [1] as well as optical trapping of Coulomb crystals. With the trapping probability approaching unity for durations of 100 ms and with low heating, and electronic decoherence rates, our results establish optical ion trapping as a novel and robust tool for the manipulation of cold trapped ions, e.g. in atom-ion interaction experiments [2,3]. We give an update of our experiments, which combine the Ba^{+} ion with bosonic ^{87}Rb and fermionic ^{6}Li atoms in order to explore ultracold interactions.

[1] A. Lambrecht et al., Nature Photonics **11.11** 704 (2017)
[2] see e.g.: A. Grier et al., PRL **102**, 223201 (2009)
[3] M. Tomza et al. *arXiv:1708.07832 (2017)

A 14.4 Mon 17:15 K 1.016

Fock state interferometry: The single ion quantum pendulum — •Fabian Wolf[1], Chunyan Shi[1], Jan C. Heip[1], Manuel Gessner[2], Luca Pezzè[2], Augusto Smerzi[2], Marius Schulte[3], Klemens Hammerer[3], and Piet O. Schmidt[1,4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]QSTAR, INO-CNR and LENS, Firenze, Italy — [3]Institute for Theoretical Physics, Institute for Gravitational Physics (Albert Einstein Institute), Leibniz Universität, Hannover, Germany — [4]Institut für Quantenoptik, Leibniz Universität, Hannover, Germany

The motion of a single trapped ion constitutes a physical implementation of the quantum mechanical harmonic oscillator that is controllable on the single quantum level.

We demonstrate frequency and amplitude measurements of this "quantum pendulum" with sensitivities below what is achievable with its classical counterpart.

For this purpose we prepare the ion in motional Fock states. The non-classical features of these states provide metrological gain independent of the relative phase of the ion's oscillation with respect to the local oscillator, which is a major advantage over non-classical probing schemes based on squeezing or Schrödinger cat states and allows quantum-enhanced probing of two conjugate variables with the same state. We present a metrological analysis of our probing scheme based on the Fisher information and via an Allan-deviation analysis for both a trapping frequency and an oscillation amplitude measurement.

A 14.5 Mon 17:30 K 1.016

Test of the isotropy of space with a high-precision long-term comparison of two single-ion optical clocks — •Richard Lange, Christian Sanner, Nils Huntemann, Burghard Lipphardt, Christian Tamm, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We employ two $^{171}Yb^{+}$ single-ion optical frequency standards that differ significantly with respect to trap geometry, control software and interrogation sequence. The clock frequency is determined by the $^{2}S_{1/2} \rightarrow {}^{2}F_{7/2}$ electric octupole (E3) transition. The relative systematic uncertainty of the clocks has been evaluated to less than 4×10^{-18} [PRL **108**, 090801 (2016)]. In a long-term comparison of the two clocks for a period of seven month with a duty cycle of up to 95 % per day, we found an agreement of the clock frequencies within the systematic uncertainty. Due to the electronic structure of the $^{2}F_{7/2}$ state, the E3 transition frequency is very sensitive to violations of Local Lorentz Invariance (LLI) [Nature Physics **12**, 465 (2016)]. In our experiment, this violation would manifest itself in a modulation of the clocks' frequency difference caused by the rotation of the earth in space. Analyzing our long-term data with millihertz resolution, we improve the current limits of violations of LLI in the electron sector by a factor of 100.