A 24: Precision spectroscopy of atoms and ions III (joint session A/Q)

Time: Thursday 10:30–12:15 Location: A-H3

Invited Talk A 24.1 Thu 10:30 A-H3

Spectroscopy of a Highly Charged Ion Clock with Sub-Hz Uncertainty — •Lukas J. Spiess[1], Steven A. King[1], Peter Micke[1,2], Alexander Wilzewski[1], Tobias Leopold[1], Erik Benkler[1], Nils Huntemann[1], Richard Lange[1], Andrey Surzhykov[1], Robert Müller[1], Lisa Schmöger[2], Maria Schwarz[2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Modern optical clocks are the most accurate metrological devices ever built. So far, such systems were only based on neutral and singly charged atoms. Potential further candidates are highly charged ions (HCI) which are intrinsically less sensitive to several types of external perturbations [1]. In previous work, we have demonstrated quantum logic spectroscopy of a HCI [2], enabling the first ever clock-like spectroscopy of these species.

We will present the first sub-Hz accuracy measurement of an optical transition in a HCI. The transition frequency of the 441 nm line in Ar^{13+} is compared to the electric octupole transition frequency in $^{171}Yb^{+}$. Measurements were performed for the two isotopes ^{40}Ar and ^{36}Ar which yields the isotope shift at sub-Hz accuracy and provides input for theoretical studies.

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

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

A 24.2 Thu 11:00 A-H3

Tailored Optical Clock Transition in $^{40}Ca^{+}$ — •Lennart Pelzer[1], Kai Dietze[1], Johannes Kramer[1], Fabian Dawel[1], Ludwig Krinner[1], Nicolas Spethman[1], Victor Martinez[2], Nati Aharon[3], Alex Retzker[3], Klemens Hammerer[2], and Piet Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Theoretische Physik, Appelstraße 2, 30167 Hannover 30167 Hannover, Germany — [3]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Optical clocks based on single trapped ions are often impeded by long averaging times due to the quantum projection noise limit. Longer probe time would improve the statistical uncertainty, but currently, phase coherence of clock laser systems is limiting probe times for most clock candidates. We propose pre-stabilization of the laser to a larger $^{40}Ca^{+}$ ion crystal, offering a higher signal-to-noise ratio. We engineer an artificial optical clock transition with a two stage continuous dynamical decoupling scheme, by applying near-resonant rf dressing fields. The scheme suppresses inhomogeneous tensor shifts as well as the linear Zeeman shift, making it suitable for multi-ion operation. This tailored transition has drastically reduced magnetic-field sensitivity. Even without any active or passive magnet-field stabilization, it can be probed close to the second-long natural lifetime limit of the $D_{5/2}$ level. This ensures low statistical uncertainty. In addition, we show a significant suppression of the quadrupole shift on a linear five-ion crystal by applying magic angle detuning on the rf-drives.

A 24.3 Thu 11:15 A-H3

Towards continuous superradiance driven by a thermal beam of Sr atoms for an active optical clock — •Francesca Famà, Camila Beli Silva, Sheng Zhou, Stefan Alaric Schäffer, Shayne Bennetts, and Florian Schreck — Institute of Physics, University of Amsterdam

Continuous superradiant lasers have been proposed as next generation optical atomic clocks for precision measurement, metrology, quantum sensing and the exploration of new physics [1]. A superradiant laser consists of phase-synchronized atoms showing an enhanced single atom emission rate, allowing direct lasing on narrow clock transitions [2]. Despite pulsed superradiance having been demonstrated [3-4], steady-state operation remains an open challenge. Here we describe our machine aimed at validating a proposal [5] for a rugged superradiant laser operating on the 1S0-3P1 transition of 88Sr using a thermal collimated continuous atomic beam. The elegance of this approach is that a single cooling stage and a low finesse cavity appear sufficient to fulfill the requirements for continuous superradiance. Expected performances are up to 1 μW output power with a reduced output linewidth of 2π x 8 Hz and a sensitivity to frequency drift due to cavity-mirrors fluctuations suppressed by two orders of magnitude. Such a device promises a compact, robust and simple optical frequency reference, ideal for a wide range of industrial and scientific applications. [1] Chen, Chi.Sci.Bull. 54, 3,(2009). [2] Dicke, Phys.Rev. 93, 99 (1954). [3] Norcia et al., Sci.Adv. 2, e1601231(2016). [4] Schaffer et al., Phys.Rev.A 101, 013819(2020). [5] Liu et al., Phys.Rev.Lett. 125, 253602(2020).

A 24.4 Thu 11:30 A-H3

Investigation of frequency shifts induced by thermal radiation for an $^{88}Sr^{+}$ optical clock — •Martin Steinel[1], Hu Shao[1], Thomas Lindvall[2], Melina Filzinger[1], Richard Lange[1], Burghard Lipphardt[1], Tanja Mehlstäubler[1,3], Ekkehard Peik[1], and Nils Huntemann[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]VTT Technical Research Centre of Finland, National Metrology Institute VTT MIKES, P.O. Box 1000, 02044 VTT, Finland — [3]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

To realize transition frequencies in optical clocks with high accuracy, a careful investigation of all frequency shifts is required. For most systems operated at room temperature, the AC Stark shift induced by thermal radiation is important. It shows a T^4-dependence, and is proportional to the differential polarizability of the states. For an ion in a radiofrequency (rf) trap, it is challenging to determine the effective temperature T of blackbody radiation, if the trap assembly is heated by rf-losses. Temperature sensors and infrared cameras can be employed to determine T from FEM simulations. Because of the low thermal conductivity of our trap assembly, we expect large uncertainties from such investigations. Thus, we determine the frequency shift from thermal radiation by measuring the clock transition frequency of a single $^{88}Sr^{+}$ ion at three different trap drive powers using our $^{171}Yb^{+}$ clock as the reference. Using the known polarizability of $^{88}Sr^{+}$, we find a temperature uncertainty of only 4 K and determine the ratio of the unperturbed transition frequencies with 6×10^{-17} fractional uncertainty.

A 24.5 Thu 11:45 A-H3

Two-color grating magneto-optical trap for narrow-line laser cooling — •Saskia Anna Bondza[1,2], Christian Lisdat[1], Stefanie Kroker[3,4,1], and Tobias Leopold[2] — [1]1Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]2DLR-Institute for Satellite Geodesy and Inertial Sensing c/o Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]Technische Universität Braunschweig, Institut für Halbleitertechnik, Hans-Sommer-Str. 66, 38106 Braunschweig — [4]LENA Laboratory for Emerging Nanometrology, Langer Kamp 6, 38106 Braunschweig, Germany

We present for the first time design and operation of a two-color grating magneto-optical trap (gMOT) optimized for cooling and trapping of ^{88}Sr atoms on the first and second cooling transition. We trap 10^6 ^{88}Sr atoms on the $^1S_0 \rightarrow {}^1P_1$ transition at 461 nm with a linewidth of 30.2 MHz that are initially cooled to few mK and subsequently transferred to the second cooling stage on the narrow line $^1S_0 \rightarrow {}^3P_1$ transition at 689 nm with a linewidth of 7.48 kHz where they are further cooled to a temperature of 5 μK. We reach a transfer efficiency of 25%. We outline general design considerations for two-colour cooling with a gMOT transferable to other atom species. These results present an important step in further miniaturization of quantum sensors based on cold alkaline-earth atoms.

A 24.6 Thu 12:00 A-H3

ARTEMIS - HITRAP: Status of the beamline — •Khwaish Kumar Anjum[1,2], Patrick Baus[3], Gerhard Birkl[3], Manasa Chambath[1,4], Kanika Kanika[1,5], Jeffrey Klimes[1,5,6], Wolfgang Quint[1,5], and Manuel Vogel[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [2]Dept. of Applied Physics, Delhi Technological University, New Delhi, India — [3]Institut für Angewandte Physik, TU Darmstadt, Darmstadt, Germany — [4]Amrita Vishwa Vidyapeetham, Kollam, India — [5]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany — [6]International Max Planck Research School for Quantum Dynamics in Physics, Chemistry and Biology, Heidelberg, Germany

In ARTEMIS (AsymmetRic Trap for measurement of Electron Magnetic moment in IonS), at HITRAP, we aim to perform the g-factor measurements of medium to heavy highly charged ions. It serves as a test of QED in strong fields and we do this using laser-microwave double-resonance spectroscopy. Currently, we are in the process of attaching the cold valve to ARTEMIS which will mark the completion of the beamline. This connects the experiment to the HITRAP facility and the EBIT, an offline ion source, and is on schedule for the planned beamtime of May 2022. Alongside this, in-situ production and analysis of Ar13+ ions are being successfully carried out (up to a few weeks). As of 2021, we have completed the individual assembly of the parts of the beamline connecting ARTEMIS to the HITRAP facility and have received ions in the final Faraday cup of the vertical beamline.