Q 27: Poster – Precision Spectroscopy of Atoms and Ions (joint session A/Q)

Time: Tuesday 17:00–19:00 Location: Philo 1. OG

Q 27.1 Tue 17:00 Philo 1. OG

Towards High Precision Laser Spectroscopy on a Cold Beam of Atomic Lithium — •Hannah Jost, Tim Redelbach, Gregor Schwendler, and Randolf Pohl — Institut für Physik/ QUANTUM, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Precision measurements of simple atoms and molecules are useful because comparison with equally precise theory calculations can test the theory and determine fundamental physical constants [1]. We are aiming at new precision measurements of the lithium D lines, for the first time using a cold atomic beam obtained from a 2D-MOT [2], and using an actively stabilised retroreflector [3, 4] to eliminate the first order Doppler shift. Comparison with ongoing experiments on muonic lithium [5] will in addition enable stringent tests of a variety of systematics relevant for recent and ongoing experiments in atomic hydrogen and deuterium [6], such as Quantum Interference [7], or the light-force shift [6].

[1] P. Mohr et al., arXiv 2409.03787 (2024). [2] T. Tiecke et al., Phys. Rev. A 80 1094-1622 (2009). [3] V. Wirthl et al., Optics Express 29, 7024 (2021). [4] V. Wirthl et al., Optics Express 30, 7340 (2022). [5] B. Ohayon et al., Physics 6, 206-215 (2024). [6] A. Beyer et al., Science 358, 6359 (2017). [7] T. Udem et al., Annalen der Physik 531, 1900044 (2019).

Q 27.2 Tue 17:00 Philo 1. OG

Metallic-Magnetic Calorimeters for Efficient High Resolution X-ray Spectroscopy for Energies up to 150 keV — •Daniel Kreuzberger, Andreas Abeln, Hendrik Hadenfeldt, Daniel Hengstler, Andreas Reifenberger, Daniel Unger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany

Metallic Magnetic Calorimeters are cryogenic detectors for broadband x-ray spectroscopy with high energy resolution and small, well understood non-linearity. They consist of a metallic particle absorber, typically made of gold and a paramagnetic temperature sensor made of an erbium doped noble metal host material. If a photon is absorbed, its energy is converted to heat, leading to a temperature change of the sensor material. This temperature rise changes the magnetization of the sensor material, which is read out by a sensitive SQUID magnetometer.

Experiments on highly charged ions and light muonic atoms have brought up the necessity to build densely packed arrays of MMCs with a high stopping power for photon energies up to 150 keV. This can be achieved with the presented new microfabrication-process for 120 μm thick absorbers made of electroplated gold. We also present fabrication results for the fast thermalization of the MMCs using the backside of the silicon substrate, which can be achieved by using DRIE processes, and filling these TSVs with copper. Finally we present characterization results for two different MMC arrays fabricated with those newly developed processes and results from most-recent beamtimes.

Q 27.3 Tue 17:00 Philo 1. OG

Spectroscopy and laser-cooling of zinc — •Lukas Möller, Felix Waldherr, David Röser, and Simon Stellmer — Universität Bonn, Germany

Laser-cooling and trapping of neutral atoms is a widely used technique in contemporary atomic physics and has been demonstrated for many elements of the periodic table. The element zinc, an alkaline-earth-like metal, is a promising candidate for a new optical clock. We report on the development of a DUV cw-laser source at 213.9 nm, magneto-optical trapping of zinc and our work towards narrow-line cooling and isotope shift spectroscopy on the narrow cooling transition of zinc.

Q 27.4 Tue 17:00 Philo 1. OG

Towards large-area 256-pixel MMC arrays for high resolution X-ray spectroscopy — •Andreas Abeln, Hendrik Hadenfeldt, Daniel Hengstler, Lucas Herbstritt, Daniel Kreuzberger, Andreas Reifenberger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

Metallic Magnetic Calorimeters (MMCs) are energy-dispersive cryogenic particle detectors. Operated at temperatures below 50 mK, they provide very good energy resolution, high quantum efficiency as well as high linearity over a large energy range. In many precision experiments in X-ray spectroscopy the photon flux is small, thus a large active detection area is desirable. Therefore, we develop arrays with increasing number of pixels.

In this contribution we present a detector setup featuring a novel dense-packed 16×16 pixel MMC array. The pixels provide a total active area of 4 mm × 4 mm and are equipped with 5 μm thick absorbers made of gold. This ensures a stopping power of at least 50 % for photon energies up to 20 keV. The expected energy resolution is 1.4 eV (FWHM) at an operating temperature of 20 mK. For the cost-effective read-out of the 128 detector channels we envisage the flux-ramp multiplexing technique. We present first results of the detector characterization obtained utilizing parallel 2-stage dc-SQUID read-out chains. We discuss the detector performance, focusing on the thermal behavior within the detector as well as to the thermal bath.

Q 27.5 Tue 17:00 Philo 1. OG

Microfabricated Penning trap for quantum logic inspired CPT-tests — •Philipp Hoffmann[1], Julia Coenders[1], Nikita Poljakov[1], Jan Schaper[1], Marek Prasse[1], Juan Cornejo[2], Jacob Stupp[1], Stefan Ulmer[4,5], and Christian Ospelkaus[1,3] — [1]Leibniz Universität Hannover, Germany — [2]Universidad de Cádiz, Spain — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [4]Ulmer Fundamental Symmetries Laboratory, RIKEN, Japan — [5]Heinrich-Heine-Universität Düsseldorf, Germany

Within the framework of the BASE collaboration, we focused on testing CPT symmetry by performing high-precision measurements of the g-factor of protons [1] and antiprotons [2]. We aim to employ quantum logic spectroscopy [3] using a laser-cooled $^9Be^+$ ion to improve the sampling rate and statistical uncertainty of these measurements. Sympathetic ground-state cooling will happen through coupling. Our objective is to couple [4] the mbox(anti-)proton to the $^9Be^+$ ion, which will happen in a double-well potential. Shaping this potential is challenging, because of the different particles. Coupling is also essential for spin-state detection of the (anti-)proton. This coupling should occur within a microfabricated section of our Penning trap stack, as presented in this contribution, alongside an outline of the process for fabricating these electrodes via selective laser-induced etching (SLE) on fused silica wafers. [1] G. Schneider et. al. Science 358 (2017) [2] C. Smorra et al., Nature 550 (2017) [3] D.J.Schneider et al., Phys. Rev. A 42 (1990) [4] K. R. Brown et. al., Nature 471 (2011).

Q 27.6 Tue 17:00 Philo 1. OG

Digital Pulse Shape Analysis for Metallic Magnetic Calorimeters (MMC) — •J. H. Walch[1,2,3], D. A. Schnauss-Müller[1,2,3], M. O. Herdrich[1,2,3], Ph. Pfäfflein[1,2,3], G. Weber[1,2,3], D. Hengstler[4], A. Fleischmann[4], Ch. Enss[4], and Th. Stöhler[1,2,3] — [1]HI-Jena — [2]IOQ, FSU — [3]GSI — [4]KIP

In the recent years, MMCs have emerged as excellent single photon detectors, exhibiting a broad spectral acceptance range from a few to hundreds of keV and a high energy resolution of $E/\Delta E(FWHM) \approx 6000$ [J. Geist. PhD thesis, 2020]. Together with their fast rise time, they provide a superb opportunity for fundamental research in atomic physics. The MMC detector absorbs an incident photon. The subsequent heat up of an absorber-sensor pair leads to a change in magnetisation of the sensor generating a signal dependent on the photons energy. The shape depending on the intrinsic detector response, additional noise and artefacts from various sources. To achieve the full detector performance and accurately measure incident photon energies, it is necessary to extract the relevant pulse features while suppressing noise contributions. Several techniques to maximise statistical information involving finite impulse response filters have been explored. Additional correction techniques are needed to mitigate the effects of integral nonlinearities and temperature drift of ADCs gain behaviour. This work presents an overview of the involved steps and compare several digital filters with regard to their resolving power. In particular: a Moving Window Deconvolution based algorithm presented by M. O. Herdrich and the Optimal filter as described e.g. by A. Fleischmann.

Q 27.7 Tue 17:00 Philo 1. OG

Development of a cryogenic Paul trap setup for high-precision quantum-logic spectroscopy — •Stepan Kokh, Magdalena

Winkelvoss, Anton Sterr, Sophia Dorra, Melina Gizewski, Finja Mayer, Maili Schube, José R. Crespo López-Urrutia, Thomas Pfeifer, and Vera M. Schäfer — Max-Planck-Institut für Kernphysik, Heidelberg

Several theories for physics beyond the standard model predict a variation of the fine-structure constant α. The current upper limit on its variation is set by high-precision spectroscopy in singly charged ytterbium. Cf^{15+} and Cf^{17+} offer higher sensitivity to α and low sensitivity to external perturbations, thereby opening the potential to improve on these bounds. To achieve the required precision, care must be taken in the design of the experiment to minimise systematic errors. Here, we present a Paul trap setup designed to fulfill these requirements. Two Paul trap setups are placed on the same optical table, to perform frequency comparison between the two charge states. For improved vacuum, to suppress charge exchange with the HCIs, the Paul trap environment needs to be cooled to 4K. This is achieved through a closed-cycle cryocooler with a helium gas-exchange interface that should reduce the vibrations at the trap to below 10 nm. A superconducting niobium shield is installed around the 4K stage to suppress magnetic field noise and increase the coherence time. The system is designed for fast and easy assembly and cool-down to simplify debugging issues inside the vacuum chamber.

Q 27.8 Tue 17:00 Philo 1. OG

Calcium optical clock as an absolute frequency standard for the thorium nuclear transition — •Darius Fenner[1], Valerii Andriushkov[1,2], Keerthan Subramanian[1], Ke Zhang[1], Srinivasa Pradeep Arasada[1], Florian Zacherl[1], Yumiao Wang[1,4], Christoph E. Düllmann[1,2], Dmitry Budker[1,2,3], Ferdinand Schmidt-Kaler[1], and Lars von der Wense[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Helmholtz Institut Mainz — [3]University of California, Berkeley, USA — [4]Fudan University, Shanghai, China

Nuclear clocks are expected to improve the accuracy of optical clocks due to their reduced susceptibility to external fields and higher transition frequencies. They are based on the transition of the low-lying and long-lived isomeric state of thorium-229. In our setup, thorium and calcium ions are co-trapped in a linear Paul trap for sympathetic cooling. In the future, to excite the thorium nucleus with a cw laser, the frequency of the nuclear transition must be compared to a known frequency standard. This poster presents the construction of an optical clock based on a trapped Ca^+ ion, using the 729 nm clock transition between $S_{1/2}$ and $D_{5/2}$. The clock laser is first stabilized using the Pound-Drewer-Hall technique to reach a linewidth at the Hertz level. After locking the laser to the calcium ion, its frequency will be measured using an optical frequency comb. The goal is to reach an accuracy of 10^{-15}. This project is supported by the BMFTR Quantum Futur II Grant Project NuQuant (FKZ 13N16295A) and DFG Project TACTICa (grant agreement no. 495729045).

Q 27.9 Tue 17:00 Philo 1. OG

MMC based high-precision spectroscopy on muonic atoms — •Tim Redelbach for the QUARTET-Collaboration — Institute of Physics, Mainz, Germany

The QUARTET collaboration aims for high-precision spectroscopy of muonic atoms at the Paul Scherrer Institute (PSI) to extract nuclear charge radii in simple atomic systems. A key motivation of the experiment is to reduce the relative uncertainties of nuclear charge radii for stable isotopes ranging from Lithium to Neon. The current uncertainties in this region suffer mainly from experimental uncertainties. To fill this uncertainty gap, Metallic Magnetic Calorimeters (MMC) are employed, which provide a unique combination of superb energy resolution, linearity and stability. This contribution will present the experimental concept and first results from the beam time conducted in October 2025, highlighting the performance of the MMC-based detection system and the current status of data analysis on the stable Oxygen isotopes O16, O17 and O18.

Q 27.10 Tue 17:00 Philo 1. OG

Preparation of actinide samples for applications in fundamental physics and chemical studies — •A. T. Loria Basto[1,2], C. Mokry[1,2], J. Runke[1,3], Ch .E. Düllmann[1,2,3], and D. Renisch[1,2] — [1]JGU, Mainz, Germany — [2]HIM, Mainz, Germany — [3]GSI, Darmstadt, Germany

Samples of radioisotopes serve as sources and targets in many basic chemistry and physics related research projects. Our group specializes in the production of tailor-made samples, for which a variety of parameters have to be considered. The main ones include isotopic purity, layer thickness and homogeneity as well as geometry. We present the methods available at JGU and within our collaboration network to produce, separate and characterize radionuclide samples, mainly of actinide isotopes. We also highlight the production and characterization of experiment-specific samples and give an overview of applications in Mainz as well as in national and international collaborations.

Q 27.11 Tue 17:00 Philo 1. OG

Heating rate measurements by time-resolved detection of single-phonon excitations — •Sylvain Noël[1,2], Till Rehmert[1,2], Gabriele Gatta[1,3,4], Maximilian J. Zawierucha[1,2], Piet O. Schmidt[1,2], and Fabian Wolf[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]European Laboratory for Nonlinear Spectroscopy (LENS), Via Nello Carrara 1, 50019 Sesto Fiorentino — [4]University of Florence, Department of Physics and Astronomy, Via Sansone 1, 50019 Sesto Fiorentino, Italy

Trapped ions are a well-established platform in quantum science, with applications ranging from quantum computing to high-precision spectroscopy for metrology and as a probe for new physics. These applications rely on long coherence times for coherent manipulation, making it essential to understand and quantify decoherence processes in order to mitigate them. In particular, heating of the trapped ions is one limiting effect for coherence times. Here, we present a new measurement scheme to quantify the motional heating in a Paul trap. The method relies on the time-resolved detection of single-phonon excitations, which allows us to extract the heating rate in the trap. We demonstrate that the method is consistent with the well-known technique based on comparing the red and blue sideband excitations. In addition, the presented method offers a new perspective for the investigation of different heating mechanisms by distinguishing coherent and incoherent motional excitation of the ion.

Q 27.12 Tue 17:00 Philo 1. OG

A pedestrian approach to the computation of atomic structures and processes — •Stephan Fritzsche — Helmholtz-Institut Jena, Germany — Friedrich-Schiller University Jena, Germany

Electronic structure calculations of atoms and ions have a long tradition in physics with applications from basic research to precision spectroscopy, and up to astro and plasma physics. With the Jena Atomic Calculator (JAC), I here present a modern (relativistic) atomic structure code for the computation of atomic amplitudes, properties as well as a large number of excitation and decay processes. JAC [1,2] is based on Julia and provides an easy-to-use but powerful platform to extent atomic theory towards new applications. The toolbox is suitable for (most) open-shell atoms and ions across the periodic table of elements.

[1] S. Fritzsche. A fresh computational approach to atomic structures, processes and cascades. Comp. Phys. Commun., 240, 1 (2019), DOI:10.1016/j.cpc.2019.01.012.

[2] S. Fritzsche. JAC: User Guide, Compendium & Theoretical Background. https://github.com/OpenJAC/JAC.jl, unpublished (02.11.2025).

Q 27.13 Tue 17:00 Philo 1. OG

Frequency Stabilization of a 1762 nm Diode Laser for Quantum Logic Spectroscopy of Barium Ions — •Han Bap, Alexander Windt, Wei Wu, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder Straße 3, 79104 Freiburg, Germany

We report on the implementation of a frequency stabilization system for a 1762 nm diode laser, a key component for advanced experiments with trapped Barium ions 138Ba+. This laser wavelength is critical for exciting the ions from the 6S1/2 ground state to the long-lived metastable 5D5/2 state, a necessity for resolve sideband cooling and phonon number measurement. To achieve the required long-term spectral stability and narrow linewidth, we have locked the laser to a high-finesse, ultra-low expansion (ULE) glass cavity using the Pound-Drever-Hall (PDH) technique. We will show the detailed the laser system design, the characterization of the ULE reference cavity, and the implementation of the PDH locking electronics. We present a performance analysis demonstrating a locked linewidth of < 1 kHz and long-term frequency drift of < 0.1 MHz/hour. This stable 1762 nm source is a cornerstone for our ongoing work on quantum logic spectroscopy of the Barium ion's narrow optical quadrupole transition, paving the way for improved study of atom-ion collision between Barium and Rubidium.

Q 27.14 Tue 17:00 Philo 1. OG

How to overengineer an alkali vapor cell characterization system? — •Ingo Hilschenz[1,2], Marvin Kessler[2,3], Folke Dencker[3], Jens Voigt[2], Peter Krüger[2], and Ilja Gerhardt[1] — [1]light & matter group, Institute for Solid State Physics, Leibniz University Hannover, Appelstrasse 2, D-30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, D-10587 Berlin, Germany — [3]Institute of Micro Production Technology, Leibniz University Hannover, An der Universität 2, D-30823 Garbsen, Germany

Hot alkali vapor cells are very versatile in quantum sensing. Their applications cover laser locking, wavelength filters, time standards, and magnetic sensors. Therefore, micro-fabricated cells which deliver highly reproducible specifications are very sought after. As each application has its own requirements, a means of quality control is essential. For example, high vapor pressures might be ideal for a SERF magnetometer, but are less desirable for Doppler-free laser locking. We discuss the quality measures for atomic vapor cells for their specific use. A mostly automated system that combines absorption spectroscopy (Doppler and Doppler-free), longitudinal, and transversal relaxation time measurements are presented. The figures to checks the cell's suitability for magnetometers are discussed in detail. Our system can automatically record spectra around the D_1 and D_2 lines of rubidium, scan the most relevant parameters, and adapts easily to varying cell shapes.

Q 27.15 Tue 17:00 Philo 1. OG

Precision spectroscopy of highly charged ions — •Amir Khan[1], Malte Wehrheim[1], Shuying Chen[1], Lukas J. Spiess[1], Alexander Wilzewski[1], José R. C. López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Max-Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

The large binding energy of the remaining electrons in highly charged ions (HCI) makes highly charged ions ideal candidates for applications in frequency metrology and the probing of fundamental physics [1]. So far, we have realized Ar^{13+} and Ca^{14+} optical clocks with an uncertainty of 10^{-16} limited by statistics [2, 3]. In this work we demonstrate how we can overcome this limitation by using a new spectroscopy species Ni^{12+}. We report the identification of the clock [4] and logic transitions and the progress towards a clock with expected systematic and statistical uncertainties at the low 10^{-18} level. Finally, we introduce Os^{16+} as a promising contender for an optical clock. Os^{16+} features more than three clock transitions, with expected small systematic uncertainties and featuring narrow linewidths. References: [1] M. G. Kozlov, M.S. Safronova, et al., Rev. Mod. Phys. 90 (2018) [2] S. A. King, L. J. Spiess, et al., Nature 611, 43 (2022) [3] A. Wilzewski, et al., Phys. Rev. Lett. 134, 233002 (2025) [4] C. Cheung, et al., Phys. Rev. Lett. 135, 093002 (2025)

Q 27.16 Tue 17:00 Philo 1. OG

Towards a Quantum Logic Clock for Precision Spectroscopy of Highly Charged Heavy Ions — •Nadine Homburg[1,2,3], Lukas Kau[1,2,3], Hiroshi Hayakawa[1,2,3], Zoran Andelkovic[2], Thomas Stöhlker[1,2,3,4], and Peter Micke[1,2,3,4] — [1]Helmholtz Institute Jena — [2]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt — [3]Friedrich Schiller University Jena — [4]Abbe Center of Photonics, Jena

Quantum logic spectroscopy (QLS) has driven significant advances in optical frequency metrology by enabling optical clocks based on ions that lack direct laser cooling and state detection transitions. Heavy highly charged ions (HCIs) offer optical transitions with strongly suppressed systematic shifts and enhanced sensitivity to fundamental physics. Substantial progress on medium-mass HCIs has been demonstrated, but extending QLS to the heaviest HCIs remains an open challenge. In this contribution, we present our experimental setup for QLS on heavy HCIs, specifically targeting the optical hyperfine-structure transition in $^{207}Pb^{81+}$ at 1019.7 nm. The experiment, located at GSI in Darmstadt, will provide suitable cryogenic trapping conditions for such extreme charge states. A monolithic linear Paul trap is under development for reduced excess micromotion and trap-related systematic effects. Additionally, the setup includes laser systems for in-situ production of the logic ion Be^+, laser cooling to the motional ground state, and coherent manipulation of qubit and HCI clock transitions.

Q 27.17 Tue 17:00 Philo 1. OG

Development of a cryogenic XUV-comb spectroscopy setup for the ^{229}Th nuclear isomer — •anant agarwal[1], lennart guth[1], tobias heldt[1], florian zacherl[2], thorsten schumm[3], lars von der wense[2], thomas pfeifer[1], and josé r. crespo lópez-urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Johannes Gutenberg University Mainz, Germany — [3]Vienna University of Technology, Austria

The laser-accessible (148 nm) nuclear transition in ^{229}Th offers intriguing pathways for fundamental physics research and development of novel frequency standards. We aim to investigate the temperature dependence of the transition frequency and variations in the decay time at cryogenic temperatures. In this work, we describe a setup designed to excite the nuclei of Th^{4+} ions embedded in a $Th{:}CaF_2$ crystal cooled in a helium cryogenic environment, using an extreme-ultraviolet (XUV) frequency comb. The XUV comb is generated as the 7^{th} harmonic of a near-infrared frequency comb through intra-cavity high harmonic generation.

Q 27.18 Tue 17:00 Philo 1. OG

Development of a YBCO-based step-up resonator for cryogenic Paul traps — •Hiroshi Hayakawa[1,2,3], Nadine Homburg[1,2,3], Elena Jordan[5], Lukas Kau[1,2,3], and Peter Micke[1,2,3,4] — [1]Helmholtz Institute Jena — [2]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt — [3]Friedrich Schiller University Jena — [4]Abbe Center of Photonics, Jena — [5]Physikalisch-Technische Bundesanstalt, Braunschweig

Step-up resonators are used to drive Paul traps at enhanced radio-frequency voltages; they additonally filter electrical noise and can reduce ion heating. Cryogenic setups typically offer improved passive temperature stability and thus result in inherently more stable trap drives. Despite these advantages, the permissible thermal load is limited and must be minimised. For these reasons, a high Q-factor becomes of paramount importance.

Exploiting the cryogenic environment, we are developing a step-up resonator based on the high-temperature superconductor YBCO. We aim at a high trap-drive frequency of up to 50 MHz for quantum logic spectroscopy with Be^+ ions in the Lamb-Dicke regime. This demands an exceptionally high Q-factor to compensate for the high trap-drive frequency with a sufficiently large trap voltage for a given trap parameter q.

Q 27.19 Tue 17:00 Philo 1. OG

Buffer-Gas Positron Source for Loading a Dual-Frequency Paul Trap — •Mohammadreza Nematollahi[1,2,3], Vladimir Mikhailovskii[1,2,3], Natalija Sheth[1,2,3], Zhiheng Xue[5], K. T Satyajith[6], Christian Smorra[2,7], Gunther Werth[3], Hartmut Haffner[4], Ferdinand Schmidt-Kaler[3], Hendrik Bekker[1,2,3], and Dmitry Budker[1,2,3,4] — [1]Helmholtz-Institut Mainz, 55128 Mainz, Germany — [2]GSI Helmholtzzentrum fur Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]QUANTUM, Institut fur Physik, Johannes Gutenberg-Universitat, 55128, Mainz, Germany — [4]Department of Physics, University of California, 94720-7300, Berkeley, USA — [5]University of Science and Technology of China, Heifie, China — [6]Delta Q, IMJ Institute of Research & Department of Physics — [7]Heinrich Heine University Dusseldorf, 40225 Dusseldorf, Germany

A dual-frequency trap has been proposed for confining antimatter to enable high-precision measurements [1]. This system is intended to co-trap positrons and antiprotons to form antihydrogen. In this work, we present an approach for generating low-energy bunches of positrons and delivering them into the trap. We simulated positron deceleration and bunching in a buffer-gas trap under various conditions. Our presented trap design and performance are informed by these simulations. We furthermore discuss several prospective methods to inject the positrons into the Paul trap.

1. N. Leefer, et al. Hyperfine Interact 238, 12 (2017)

Q 27.20 Tue 17:00 Philo 1. OG

The superconducting resonator Paul trap: status and developments — •Ruben B. Henninger, Elwin A. Dijck, Vera M. Schäfer, Devanarayanan Rajeeb Kumar, Sebastian Davidson, K Shreya Rao, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Quantum logic spectroscopy of highly charged ions (HCIs) offers sensitivity to variations of fundamental constants and tests of bound state QED in extreme fields, while offering intrinsically low polarizability and therefore suppressed resonance shifts. This makes HCIs prime candidates for next generation clocks and precision tests. In order to accomplish this, a cryogenic trap setup that integrates a linear Paul trap into a superconducting RF resonator was developed. The first generation system provides intrinsic RF filtering, magnetic self shielding, and a stable quantization field with observed Ramsey coherence times above 200ms on a B field sensitive transition. In addressing residual AC field systematics, potential control limits and retrapping robustness, a redesigned trap and resonator employ optimized electrode geometry and upgraded cryogenics and optics. We present benchmark results from the working setup and initial data from the new platform, outlining a path to increased secular frequencies and lower magnetic systematics for HCI QLS.

Q 27.21 Tue 17:00 Philo 1. OG

Mechanical structure for alignment of a microfabricated cylindrical Penning trap — •Marek Prasse[1], Jan Schaper[1], Nikita Poljakov[1], Philipp Hoffmann[1], Julia Coenders[1], Juan Manuel Cornejo[2], Stefan Ulmer[3,4], and Christian Ospelkaus[1,5] — [1]Leibniz Universität Hannover — [2]Universidad de Cádiz, Spain — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN, Japan — [4]Heinrich-Heine-Universität Düsseldorf, Germany — [5]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

As part of the BASE collaboration, we aim to contribute to CPT symmetry tests by high-precision (anti-)proton g-factor measurements[1,2]. We use a cryogenic multi-Penning trap and want to implement quantum logic spectroscopy techniques with ^{9}Be$^+$ as cooling and logic ion. While optical sideband spectroscopy[3], ground-state cooling[4], and fast adiabatic transport[5] of single ^{9}Be$^+$ ions has been achieved, a microfabricated cylindrical Penning trap ($d = 800\,\mu$m) will be added for ground-state cooling and spin-state detection of (anti-)protons by Coulomb coupling to ^{9}Be$^+$. Particle confinement during ion-transport then requires a precise alignment with the magnetic field. We present a custom-made two-axis mechanical feedthrough suitable for the ≈ 40 kg weight of the experimental structure and with low heat flow to the cryogenic stages that has been designed and is in commissioning. [1]C. Smorra et al., Eur. Phys. J. Special Topics 224, 3055-3108 (2015) [2]J.M. Cornejo et al., New J. Phys. 23 (2021) [3]J.M. Cornejo et al., Phys. Rev. Res. 5 (2023) [4]J.M. Cornejo et al., Phys. Rev. Res. 6 (2024) [5]M. v. Boehn et al., Comms. Phys. 8 (2025)

Q 27.22 Tue 17:00 Philo 1. OG

Ground-state cooling of mixed-ion crystals in the intermediate Lamb-Dicke regime — •Sebastian Davidson, Elwin A. Dijck, Vera M. Schäfer, Ruben Henninger, Devanarayanan Rajeeb Kumar, Shreya K. Rao, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Ground-state cooling of motional modes in mixed-species ion crystals is a key requirement for implementing quantum logic spectroscopy of highly charged ions (HCIs). Building on our demonstrated ground-state cooling of both single Be$^+$ ions and two-ion Be$^+$ crystals using a combination of continuous sideband cooling on higher-order sidebands and pulsed sideband cooling, we extend these techniques to a Be$^+$-Ar^{13+} two-ion crystal. Since our current trap operates in an intermediate Lamb-Dicke regime with η up to 0.7 for the mixed species crystal, we explore adapted cooling strategies that remain effective outside the Lamb-Dicke limit. We report our progress toward achieving ground-state cooling of axial modes of a Be$^+$-Ar^{13+} crystal under these conditions, including characterization and optimization of cooling sequences. These advances represent an essential step toward full quantum logic spectroscopy of HCIs and the high-precision tests of fundamental physics that they enable.

Q 27.23 Tue 17:00 Philo 1. OG

Monolithic frequency doubling cavities for Beryllium photoionization — •Anton J. Sterr, Magdalena Winkelvoss, Stepan Kokh, Sophia Dorra, Melina Gizewski, Finja Mayer, Maili Schube, José R. Crespo López-Urrutia, Thomas Pfeifer, and Vera M. Schäfer — Max-Planck-Institut für Kernphysik, Heidelberg

High-precision spectroscopy of optical transitions in Cf^{15+} and Cf^{17+} is a promising tool to search for variations of the fine structure constant [1]. To extract information from the californium ions, they are co-trapped with a singly charged beryllium logic ion.

Beryllium is ionized via two-photon absorption that requires a continuous wave laser source at 235 nm. Building on an existing approach [2], two monolithic cavities are designed to quadruple the frequency of an infrared source at 940 nm using periodically poled KTP and BBO crystals. We target at least 50 mW of UV power for a source of 1 W. To achieve optimum conversion efficiency, simulations for different cavity geometries are performed, taking thermal lensing effects into account. We present power measurements and locking performance of the first doubling stage.

[1] Kozlov, et al., Rev. Mod. Phys. 90, 045005 (2018)
[2] Hannig, et al., Rev. Sci. Instrum. 89, 013106 (2018)

Q 27.24 Tue 17:00 Philo 1. OG

Laser stabilization for high-precision spectroscopy of highly charged ions using an ultra-stable optical reference cavity — •Devanarayanan Rajeeb Kumar, Ruben B. Henninger, Elwin A. Dijck, Shreya Rao Kodancha, Sebastian Davidson, Vera M. Schäfer, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Frequency metrology of clock transitions requires lasers of sub-hertz linewidth and exceptional frequency stability. For our work with highly charged ions, an ultra-stable, high finesse optical reference cavity was developed and is operated near room temperature to stabilize our lasers. Our ultra-low-expansion glass Fabry-Pérot etalon achieves a projected noise floor of 3.6×10^{-16} relative frequency uncertainty at 1 second - approaching that of state-of-the-art cryogenic silicon cavities. Additional stabilization techniques are implemented to suppress residual technical noise: Fiber-induced phase noise is actively canceled, laser power is stabilized to improve the fidelity of the cavity lock, and residual amplitude modulation is minimized through active control of the electro-optical modulator operating point. A frequency comb is then phase-locked to the cavity stabilized laser which enables low-noise frequency transfer to a spectroscopy laser. The resulting stabilized laser system should provide the stringent frequency stability and linewidth requirements needed for highly charged ion spectroscopy.

Q 27.25 Tue 17:00 Philo 1. OG

Characterising Atomic Hydrogen beam for precision spectroscopic experiment — •Surabhi Deshpande[1,2], Derya Taray[1], Vincent Weis[1], Patrick Schaile[1], Alexander Wilzewski[1], Omer Amit[1], Vitaly Wirthl[1], Theodor W. Hänsch[1,2], and Thomas Udem[1,2] — [1]Max Planck Institute for Quantum Optics (MPQ), Garching, Germany — [2]Department of Physics, Ludwig-Maximilians-Universität, Munich, Germany

Precision Spectroscopy of atomic hydrogen is a promising approach for measuring fundamental constants and testing QED due to the very simple structure of the atom. One of the most vital demands for such experiments is a stable source of atomic hydrogen and a method of precisely quantifying the atomic hydrogen population. In this poster, I will give an overview of the methods I attempted to characterise our atomic hydrogen beam in the 1S-3S Direct Frequency Comb Spectroscopy Experiment at MPQ. This includes Optical Emission Spectroscopy of the hydrogen plasma used to dissociate molecular hydrogen to atomic hydrogen, to compare optical emissions of atomic and molecular hydrogen, i.e., Balmer lines and Fulcher bands. In addition, a Calorimetric Wire Detector is being developed for in situ detection of atomic hydrogen. It is based on the resistance change of a very thin wire due to the heat released from the recombination of atomic hydrogen on its surface. I will present preliminary results from the Calorimetric Wire Detector for qualitative detection of atomic hydrogen.

Q 27.26 Tue 17:00 Philo 1. OG

High-resolution spectroscopy of ^{173}Yb$^+$ ions — Jian Jiang[1], •Anna Viatkina[1,2], Saaswath JK[1], Martin Steinel[1], Melina Filzinger[1], Ekkehard Peik[1], Sergey Porsev[3], Marianna Safronova[3], Andrey Surzhykov[1,2], and Nils Huntemann[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Technische Universität Braunschweig, 38106 Braunschweig, Germany — [3]University of Delaware, Newark, Delaware 19716, USA

^{173}Yb$^+$ is a promising candidate for optical clocks, new physics searches, and quantum computing. However, to date, the electronic spectrum of ^{173}Yb$^+$ remains poorly characterized due to its complexity.

Here, we report on efficient laser cooling, state preparation, and detection of a single trapped ^{173}Yb$^+$ ion. The previously unobserved

$^2S_{1/2} \to {}^2D_{3/2}$ electric quadrupole transition at 436 nm is coherently excited, and the isotope shift between ^{171}Yb$^+$ and ^{173}Yb$^+$ on this transition is determined with an uncertainty of 1.4 Hz. Using microwave spectroscopy, we resolve the hyperfine structure (HFS) of the $^2D_{3/2}$ state with a relative uncertainty below 10^{-8}.

Combining the HFS measurement data and our atomic structure calculations, we infer for ^{173}Yb a nuclear magnetic octupole moment $\Omega = -0.062(8)$ (b$\times\mu_N$) with uncertainty reduced by more than two orders of magnitude compared to previous studies and determine hyperfine anomalies for the $^2S_{1/2}$ and $^2D_{3/2}$ states. These findings provide further information on the nuclear deformation and nuclear magnetization distribution of ytterbium.

Q 27.27 Tue 17:00 Philo 1. OG

Spectroscopy of the $^3[11/2]_{11/2}$ state in Yb$^+$ — •Mohamed Elshorbagy, Melina Filzinger, Martin Steinel, Jian Jiang, William Eckner, and Nils Huntemann — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

The $^2S_{1/2} \to {}^2F_{7/2}$ electric octopole (E3) transition in Yb$^+$, with its exceptionally long excited-state lifetime and strong sensitivity to the fine-structure constant α, has been used to set the most stringent limits on its variations [PRL 130, 253001 (2023)]. These limits were derived from frequency comparisons against the $^2S_{1/2} \to {}^2D_{3/2}$ transition of the same ion. The precision achieved in the comparisons was limited by the large quantum projection noise resulting from the 53 ms lifetime of the $^2D_{3/2}$ state. A larger lifetime of several seconds is expected for the $^3[11/2]_{11/2}$ state that can be excited with laser radiation at 1094 nm from the $^2F_{7/2}$ state. We present the current status of our investigation and details of the corresponding probe laser system and interrogation sequence.

Q 27.28 Tue 17:00 Philo 1. OG

Characterization of an XUV Frequency Comb by Spectroscopy of Rydberg States — •Lennart Guth, Tobias Heldt, Anant Agarwal, Lukas Matt, Jan-Hendrik Oelmann, Nick Lackmann, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We aim to use ultra-narrow transitions in highly charged ions (HCI) for novel frequency standards and fundamental physics studies. These transitions occur in the extreme ultraviolet (XUV), where narrow-bandwidth laser sources are unavailable. To address this, we built an XUV frequency comb that transfers coherence from a near-infrared (NIR) comb to the XUV via high harmonic generation (HHG) [1,2]. Using intra-cavity HHG, our system generates harmonics up to 40 eV with μW power in each order. We propose resonance-enhanced two-photon spectroscopy as a preliminary test towards spectroscopy of HCI, aiming to resolve individual teeth of our XUV comb and characterize its properties. In this approach, we excite neutral argon with one photon from a referenced 13th harmonic comb tooth to a Rydberg state, followed by ionization with a narrow-bandwidth continuous wave NIR laser. We then use velocity-map imaging to record the momentum of the released electrons, allowing us to identify the resonant Rydberg state. [1]Opt. Express 29, Issue 2, pp. 2624-2636 (2021) [2]Rev. Sci. Instrum. 95, 035115 (2024)

Q 27.29 Tue 17:00 Philo 1. OG

Internal conversion of Thorium-229 upon laser photoexcitation — •Marc Seitz[1], Daniel Moritz[2], Shengfeng Zeng[3], Francesca Calegari[1], Hannes Hübener[4], Umberto de Giovannini[4], Peter G. Thirolf[2], and Andrea Trabattoni[1] — [1]Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]LMU München, Fakultät für Physik, 85748 Garching bei München, Germany — [3]Shenzhen Geim Graphene Center, Institue of Materials Research, Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen 518055, China — [4]Max Planck Institute for the Structure and Dynamics of Matter and Center for Free-Electron Laser Science, 22761 Hamburg, Germany

The low-energy isomeric transition of Thorium-229 and its dominant internal-conversion (IC) decay channel provide a unique platform for studying electron-nucleus interactions. Prior work indicates that the IC decay can be strongly influenced by the electronic environment. Here, we investigate the IC decay of Th-229 in the presence of an ultraviolet (UV) laser field. Thorium atoms are deposited on a high-bandgap surface to minimize hybridization with surface states. A UV laser resonantly promotes an electron to the lowest excited atomic state prior to nuclear decay. The resulting IC electrons are detected via time-of-flight spectroscopy. By comparing laser-on and laser-off measurements, we identify changes in the IC decay dynamics induced by photo-excitation. This constitutes, to our knowledge, the first experimental study of laser-perturbed Th-229m IC nuclear decay.