A 14: Poster Session - Atomic Physics II

Time: Tuesday 16:00–18:00 Location: Empore Lichthof

A 14.1 Tue 16:00 Empore Lichthof

The attoclock and its interpretations, theoretically and experimentally — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, University of Kassel.

The measurement of the tunneling time in experiments with intense short laser pulse, termed attoclock, triggered a hot debate about the tunneling time and the separation into two regimes of ionization, the multiphoton and the tunneling. Theoretically, a crucial issue is the tunneling time, whether it is a real or an imaginary quantity. A related issue, whether time is an observable or a parameter in quantum mechanics. Another point is the statistical interpretation of the tunneling time, nevertheless we show that our real tunneling time is conform with the statistical point of view. Experimentally the issue is crucial since the result depends on the field strength calibration, and its consequence for the tunneling or multiphoton ionization regimes and hence the interpretation of the theoretical result. We give a detailed picture concerning these issues, and discuss some features for future works on both sides, experiment and theory. [1] O. Kullie, Ann. of Phys. **389**, 333 (2018), (open access) Mathematics **6**, 192 (2018).

A 14.2 Tue 16:00 Empore Lichthof

Impact of electron transport on attosecond streaking in dielectrics — •L. Seiffert[1], E. A. Herzig[1], Q. Liu[2,3], S. Zherebtsov[2,3], A. Trabattoni[4,5], P. Rupp[2,3], M. C. Castrovilli[6], M. Galli[4,6], F. Süssmann[2,3], K. Wintersperger[2], J. Stierle[2], G. Sansone[4,6], L. Poletto[6], F. Frassetto[6], I. Halfpap[7], V. Mondes[7], C. Graf[7], E. Rühl[7], F. Krausz[2,3], M. Nisoli[4,6], T. Fennel[1,8], F. Calegari[5,6,9], and M. Kling[2,3] — [1]Universität Rostock — [2]MPQ Garching — [3]LMU München — [4]Politecnico di Milano — [5]CFEL, DESY — [6]National Research Council of Italy — [7]FU Berlin — [8]MBI Berlin — [9]Universität Hamburg

Scattering of electrons in dielectrics is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of low-energy electron transport involving elastic and inelastic collisions. Here, we demonstrate real-time access to electron scattering in dielectric nanoparticles via attosecond streaking. Utilizing semiclassical transport simulations [1] we identify that the presence of the field inside the dielectric cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [2,3].

[1] F. Süßmann et al., Nat. Commun. **6**, 7944 (2015)
[2] L. Seiffert et al., Nat. Phys. **13**, 766-770 (2017)
[3] Q. Liu et al., J. Opt. **20**, 024002 (2018)

A 14.3 Tue 16:00 Empore Lichthof

Overview of a tabletop setup for the generation of ultrashort XUV laser pulses for attosecond physics — •Felix Otten, Lars Englert, Marcel Behrens, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg

Until recently, coherent X-ray sources such as free electron lasers or synchrotrons were available only for large research facilities. Due to new techniques in pulse generation, compression and amplification, ultrashort XUV light sources are now also available for small-scale laboratories. We present an overview of a tabletop setup for the generation of coherent XUV radiation in the attosecond regime based on high harmonic generation. The beamline consists of a commercial carrier-envelope-phase-stabilized IR femtosecond laser source with a hollow fiber compressor to provide few cycle driver pulses for the XUV pulse generation. We present initial results of the measured XUV spectra and give an outlook for future experiments on attosecond physics.

A 14.4 Tue 16:00 Empore Lichthof

Collisional effects in the extreme nonlinear response of dielectrics — •Benjamin Liewehr[1], Björn T. Kruse[1], Christian Peltz[1], Peter Jürgens[2], Anton Husakou[2], Tobias Witting[2], Marc J. J. Vrakking[2], Alexandre Mermillod-Blondin[2], and Thomas Fennel[1,2] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, D-18059 Rostock — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, D-12489 Berlin

The understanding of nonlinear optical phenomena in dielectric solids has been recently complemented by the physics of Bloch oscillations and interband recombination in the high frequency domain (HHG) [1,2] while low order harmonics have been linked to the strong field excitation dynamics that drive Brunel- and injection currents [3,4]. To which extent the excitation dynamics can be reconstructed from time resolved low order harmonic emission remains an open question, in particular regarding electron impact ionization and elastic collisions. Here we investigate the nonlinear electronic response using a rate-equation-based ionization-radiation model and study the effect of collisions on low-order wave-mixing. Possible routes to separate contributions from laser-driven strong-field ionization and electron-impact ionization avalanching are discussed.

[1] H. Liu et al., Nature Phys. **13**, 262 (2017)
[2] G. Vampa, et al., Nature **522**, 462 (2015)
[3] F. Brunel, J. Opt. Soc. Am. B **4**, 521 (1990)
[4] P. Jürgens et al., arXiv:1905.05126 (2019)

A 14.5 Tue 16:00 Empore Lichthof

Electron correlation induced hole dynamics in high harmonic generation by bicircular laser fields — •Nicola Mayer, Álvaro Jiménez-Galán, Serguei Patchkovskii, and Misha Ivanov — Max Born Institute, Max-Born-Straβe 2A, 12489 Berlin, Germany

The use of bicircular laser fields to drive the high-harmonic generation (HHG) process allows for the generation of circularly polarized extreme-ultraviolet (XUV) light, hence paving the way for the study of chiral phenomena on the attosecond timescale. In the case where the frequency ratio between the two counter-rotating drivers is 2:1, the 3N+1 and 3N+2 harmonic orders are allowed, while 3N harmonics are nominally forbidden by symmetry. In Ref. [1] strong forbidden 3N lines were nonetheless observed in Helium; their appearance was attributed to the excitation of Rydberg states via the Frustrated Tunneling Ionization (FTI) mechanism [2]. In this contribution, we investigate the role of the Rydberg states in the electron-correlation-induced dynamics in the bicircular scheme of HHG. In particular, we show how the long-range Coulomb interaction between the tunneled electron and the parent ion together with the spin-orbit interaction in the core can lead to rich dynamics in the ion of a noble gas with np valence shell such as Argon or Neon. We investigate the role of the hole dynamics in the Ar and Ne ions in the high-harmonic generation process and address the possibility of observing the hole dynamics via the background-free measurement of forbidden 3N harmonic lines.

[1] A.Jiménez-Galán et al., Optics Express, Vol. 25, No. 19, (2017).
[2] T. Nubbemeyer, Phys. Rev. Lett., Vol. 101, No. 233001, (2008).

A 14.6 Tue 16:00 Empore Lichthof

Simulation of high-order harmonic generation in ZnO — •Christian Hünecke, Ivan Gonoskov, Martin Richter, and Stefanie Gräfe — Institute for Physical Chemistry, Friedrich-Schiller University Jena, Germany

Pump-probe experiments shed some light on the involvement of optical phonons in the generation of high-harmonic radiation in zinc oxide [1]. Two approaches for the theoretical description of the HHG spectra are employed. At first the time-dependent Schroedinger equation is solved numerically using a Coulomb-type potential with periodic boundary conditions. The calculated harmonic spectra are compared with the results based on the real-time real-space time-dependent density functional theory (TDDFT) obtained using the software-package "Octopus" [2]. In the TDDFT scheme the influence of a phonon is analyzed by parametrically shifting the position of the nuclei in the lattice structure of ZnO.

[1]: R. Hollinger, V. Shumakova, A. Pugžlys, S. Khujanov, A. Baltuška, C. Spielmann, D. Kartashov, "High-order harmonic generation traces ultrafast coherent phonon dynamics in ZnO", Ultrafast Phenomena 2018, to be published in Eur. Phys. J. - Web of Conferences

[2]: Xavier Andrade et al., "Real-space grids and the Octopus code as tools for the development of new simulation approaches for electronic systems", Physical Chemistry Chemical Physics 17, 31371-31396 (2015)

A 14.7 Tue 16:00 Empore Lichthof

First results of the Alphatrap *g*-factor experiment — •Fabian Heisse[1], Ioanna Arapoglou[1], Alexander Egl[1], Felix

Hahne[1,2], Martin Höcker[1], Peter Micke[1,3], Tim Sailer[1], Bingsheng Tu[1], Andreas Weigel[1], José R. Crespo López-Urrutia[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

Quantum electrodynamics (QED) is considered to be the most successful quantum field theory in the Standard Model. Its most precise test is conducted via the comparison of QED calculations with the measurement of the free electron g-factor. However, this test is restricted to low electrical field strengths. Consequently, it is of utmost importance to perform similar tests at high field strengths.

The Alphatrap experiment is a dedicated cryogenic Penning-trap setup to measure the g-factor of bound electrons in highly charged ions up to hydrogen-like lead. There, an electrical field strength on the order of 10^{16} V/cm acts on the electron, allowing to test bound-state QED with highest precision.

Our first measurement results of the g-factor of a single boron-like $^{40}Ar^{13+}$ ion as well as the laser spectroscopy of its $2p^2P_{1/2} - {}^2P_{3/2}$ fine-structure transition will be presented [1–2]. Furthermore, an outlook on upcoming studies and prospects will be given.

[1] I. Arapoglou *et al.* Phys. Rev. Lett. **122**, 253001 (2019)
[2] A. Egl *et al.* Phys. Rev. Lett. **123**, 123001 (2019)

A 14.8 Tue 16:00 Empore Lichthof

Towards Quantum Logic Spectroscopy of Molecular Oxygen Ions — •Maximilian J. Zawierucha[1], Jan C. Heip[1], Fabian Wolf[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38159 Braunschweig — [2]Institut für Quntenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Precision spectroscopy of vibrational overtones in oxygen molecular ions is a promising route for an improved upper bound on a possible variation of the proton-to-electron mass ratio. Here, we present the status of our experiment, aiming at high precision quantum logic spectroscopy of molecular oxygen ions. In the past, we have demonstrated a non-destructive internal state detection scheme for $^{24}MgH^+$ ions, that relies on the detection of state dependent forces with a co-trapped $^{25}Mg^+$ ion. We have theoretically developed a variant of this scheme for the investigation of O_2^+. Further, we will present recent experimental results on rotational state-resolved ionization from a new molecular beam setup that will be used to load single oxygen molecules into a linear Paul trap for future quantum logic spectroscopy experiments.

A 14.9 Tue 16:00 Empore Lichthof

Two-photon spectroscopy of Rubidium atoms in the vicinity of Silicon Nano-photonic Waveguides — •Artur Skljarow[1], Wolfram H.P. Pernice[2], Harald Kübler[1], Hadiseh Alaeian[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany — [2]Institute of Physics, University of Münster, Heisenbergstr. 11, D-48149 Münster, Germany

The marriage of photonic structures and thermal atomic vapors on a chip provides efficient atom-light coupling on a miniaturized scale well beyond the diffraction limit. We study an integrated silicon photonic chip, composed of several sub-wavelength ridge waveguides, immersed in a micro-cell with rubidium vapor. Employing two-photon excitation, including a telecom wavelength, we observe that the waveguide transmission spectrum gets modified when the photonic mode is coupled to rubidium atoms through its evanescent tail. The measured spectra corroborate pretty well with a generalized effective susceptibility model that includes the Casimir-Polder potentials, due to the silicon surface, and the transient interaction between the evanescent field and the moving atoms. This work paves the way towards a miniaturized and integrated hybrid atomic-photonic system compatible with CMOS technologies.

[1] R. Ritter et al., Appl. Phys. Lett. 107, 041101 (2015)
[2] R. Ritter et al., New Journal of Physics 18, 103031 (2016)
[3] R. Ritter et at., Phys. Rev. X 8, 021032 (2018)

A 14.10 Tue 16:00 Empore Lichthof

Resonance ionization spectroscopy on picogram amounts of $^{249-252}$Cf — •Felix Weber[1], Nina Kneip[1], Christoph E. Düllmann[2,3,4], Vadim Gadelshin[1], Christoph Mokry[2,4], Sebastian Raeder[3], Jörg Runke[2,3], Petra Thörle-Pospiech[2,4], Norbert Trautmann[2], and Klaus Wendt[1] — [1]Insitute of Physics, JGU Mainz — [2]Institute of Nuclear Chemistry, JGU Mainz — [3]GSI Helmholtzzentrum, Darmstadt — [4]Helmholtz Institute Mainz

Californium is an artificial actinide element. The isotopes $^{249-252}$Cf have half-lives $\gtrsim 1\,$a; among these, the four heaviest ones can be produced by neutron-capture in high-flux reactors. Still only few optical spectroscopic studies have been performed on californium. Resonant laser ionization spectroscopy is an efficient technique to study atomic level schemes, and can be applied on samples containing 10^9 atoms or even less, and is also a powerful technique for ultra-trace determination. A sample containing about $5 \cdot 10^9$ atoms of $^{249-252}$Cf were prepared on a zirconium backing. Widely tunable frequency doubled Ti:Sapphire lasers (350-490 nm) with an output power of up to $1\,W$ were used to identify atomic levels applying efficient two step ionization schemes. For five different first excitation steps, autoionizing states were measured. Additionally, Rydberg series of californium were identified for the first time, converging to the ground and first excited state of the ion. Also the isotopic shift for one ground state transition was determined. In a next step high resolution spectroscopy to resolve the hyperfine splitting in odd Cf-isotopes will be addressed, e.g. to determine the so far unknown nuclear moment of ^{251}Cf.

A 14.11 Tue 16:00 Empore Lichthof

Catching and trapping thorium ions from external laser-ablation ion source in a linear Paul trap and sympathetic cooling with a large calcium ion crystal — •Sebastian Wolf[1], Wenbing Li[1], Tom Kieck[1,2], Raphael Haas[1,2], Christoph E. Düllmann[1,2,3,4], Dmitry Budker[1,2,3], and Ferdinand Schmidt-Kaler[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Helmholtz-Institut Mainz — [3]PRISMA, Cluster of Excellence, Mainz — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

Isotopes of thorium, including ^{229}Th with its isomeric state provide for interesting spectroscopic tests of fundamental symmetries of nature. Trapping and sympathetically cooling thorium ions into a Paul trap is a precondition for such studies. For the production of $^{232}Th^+$ we have demonstrated laser-ablation, electron impact ionization and injection from this external source, followed by trapping and sympathetic cooling [1] and ion mass identification [2]. A new ion trap setup is now optimized to capture ^{229}Th produced from a recoil source from α-decay of ^{233}U [3]. Due to the spontaneous nature of radioactive decay, no timing information is available concerning the production of ^{229}Th. Therefore, we employ polarization gradient cooling of a large calcium ion crystal. Incoming injected thorium ions will heat the ion crystal to reveal a signature which allows for time-dependent switching of trap potentials for rapid identification of successful capture.

[1] K. Groot-Berning *et al.*, Phys. Rev. A **99**, 023420 (2019).
[2] F. Stopp *et al.*, Hyperfine Interact 240:33 (2019).
[3] R. Haas *et al.*, arXiv: 1911.11674 (2019).

A 14.12 Tue 16:00 Empore Lichthof

Lineare Paulfalle mit transparenten Elektroden — •Alexander Wilzewski[1,2], Sebastian Wolf[1,2], Kai Krimmel[1,2], Johannes Heinrich[3], Mark Keil[4], Ron Folman[4], Dmitry Budker[1,2,5] und Ferdinand Schmidt-Kaler[1,2] — [1]Helmholtz-Institut Mainz, Mainz 55218, Germany — [2]QUANTUM, Institut für Physik, JGU Mainz, Mainz 55128, Germany — [3]Laboratoire Kastler Brossel, UPMC-Sorbonne Universites, CNRS, ENS-PSL Research University, College de France — [4]Department of Physics, Ben-Gurion University of the Negev, Be'er Sheva 84105 Israel — [5]Department of Physics, University of California at Berkeley, Berkeley, CA 94720, USA

Wir stellen erste Messungen zur Charakterisierung einer linearen segmentierten Ionenfalle aus transparenten Chips vor. Diese sind aus Quartzglas-Substrat hergestellt und mit leitendem ITO sowie Goldelektroden beschichtet, was es erlaubt das Fluoreszenzlicht großer Be^+ Wolken und Kristalle durch die Falle selbst zu beobachten. Die Kristalle aus Be^+ sollen zum sympathetischen Kühlen anderer Ionenspezies genutzt werden und Anwendung beim Kühlen von Antiwasserstoffionen [1] oder der Speicherung und Kühlung von geladenen Teilchen sehr unterschiedlicher Ladungs-zu-Masse-Verhältnissen [2] finden.

[1] P. Pérez et al., “The GBAR antimatter gravity experiment”, Hyperfine Interactions 233, 21-27 (2015)
[2] N. Leefer et al., “Investigation of two-frequency Paul traps for antihydrogen production”, Hyperfine Interactions 238:12 (2017)

A 14.13 Tue 16:00 Empore Lichthof

Towards a planar, single-beam MOT for strontium atoms — •Saskia Bondza[1,2], Tobias Leopold[1,2], Stefanie Kroker[1,3], and Christian Lisdat[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]DLR-Institut für Satellitengeodäsie und Inertialsensoren, c/o Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]TU Braunschweig, LENA Laboratory for Emerging Nanometrology Universitätsplatz 2, 38106 Braunschweig

With recent advances of lab-scale optical atomic clocks, a demand for the development of transportable and miniaturized quantum-optical technology has emerged. For neutral-atom-based optical clocks, atoms from the alkaline-earth group, e.g. strontium, feature a particularly useful level structure with a strong and a narrow cooling transition and an ultra-narrow clock transition, all in the visible wavelength regime. We aim to extend the successful approach of miniaturization for alkali atom magneto-optical traps (MOT), where single-beam trapping geometries are routinely employed, to the case of strontium. Here, the challenge is to build a planar beam-shaping geometry with achromatic properties with respect to the two cooling wavelengths. Different approaches to solve this problem are presented and evaluated alongside accompanying work on laser-controlled strontium atom sources.

A 14.14 Tue 16:00 Empore Lichthof

Towards sympathetic cooling of single (anti-)protons — •Teresa Meiners[1], Johannes Mielke[1], Matthias Borchert[1,3], Frederik Jacobs[1], Julian Pick[1], Amado Bautista-Salvador[2], Juan Manuel Cornejo[1], Ralf Lehnert[1,4], Malte Niemann[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Ulmer Fundamental Symmetries Laboratiory, RIKEN, Wako, Saitama 351-0198, Japan — [4]Indiana University Center for Spacetime Symmetries, Bloomington, IN 47405, USA

The aim of the BASE collaboration is to test fundamental physics by performing precision measurements on single (anti-)protons, such as g-factor comparisons, for a stringent test of CPT invariance with baryons. The state-of-the-art measurements are performed in cylindrical Penning traps using resistive cooling and image current detection. Sympathetically cooling the (anti-)proton using a co-trapped atomic ion would significantly decrease preparation times and therefore considerably increase the sampling rate of the experiment (which would allow measurements at considerably improved precision).

We develop concepts for sympathetic cooling of single protons using a laser cooled $^{9}Be^{+}$ ion within the BASE collaboration. We present our recently upgraded apparatus including Penning traps for production, cooling, transport, and detection of $^{9}Be^{+}$ ions and protons as well as a trap for motional coupling of these two ion species.

A 14.15 Tue 16:00 Empore Lichthof

Search for electronic bridge excitation of the nuclear clock isomer ^{229m}Th — •David-Marcel Meier, Johannes Thielking, Gregor Zitzer, Maxim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

The transition between the nuclear ground state and the low-energy isomer of ^{229}Th has been proposed as a frequency reference for an optical clock of high accuracy, but its optical excitation is still pending.

We are investigating the excitation of the nucleus via electronic bridge/NEET processes, using two-photon laser excitation to access high-lying electronic levels in Th^{+} and in Th^{2+} [1]. About 100 excited electronic states of Th^{+} with energies ranging from 7.4 to 9.6 eV have been investigated for their fluorescence decay signals, without observing an indication of nuclear excitation. Experiments with selected levels of Th^{2+} have been performed using resolved hyperfine spectra [2] for a detection of the isomer. It is planned to revisit with improved statistics the narrower range of excitation energy 8.28(17) eV that has recently been obtained at LMU [3].

[1] D.-M. Meier et al., Phys. Rev. A 99, 052514 (2019).
[2] J. Thielking et al., Nature 556, 321-325 (2018).
[3] B. Seiferle et al., Nature 573, 243-246 (2019).

A 14.16 Tue 16:00 Empore Lichthof

Ion trap system for sympathetic cooling of $^{229}Th^{3+}$ ions — •Gregor Zitzer, Johannes Thielking, David-Marcel Meier, Maksim Okhapkin, and Ekkehard Peik — Physikalisch-Technsiche Bundesanstalt, 38116 Braunschweig, Germany

The energy determination of the low-energy ^{229}Th nuclear isomer is progressing and the latest results indicate an energy value of 8.3 eV [1]. The corresponding VUV transition wavelength is accessible for direct laser excitation of the nucleus. This is of special interest for a novel type of optical clocks, providing an elevated accuracy and a unique sensitivity for tests of fundamental physics in the hadron sector.

The charge state 3+ for ^{229}Th is preferred for a potential clock system with laser-cooled ions where one can benefit from the relatively simple and convenient electronic level structure.

We have set up an ion trap system for Th^{3+} ions sympathetically cooled with $^{88}Sr^{+}$ for experiments with large Coulomb crystals, precision hyperfine spectroscopy and future clock operation. The trap system consists of a multi-segmented linear radiofrequency ion trap in which we are able to load, cool and store the Sr^{+} crystals. In these crystals, $^{229}Th^{3+}$ will be localized close to the trap axis, inside a tubular shell of Sr^{+} ions. The $^{229}Th^{3+}$ ions will be generated by a ^{233}U source via α-decay [2] and guided towards the Paul trap. The current status of the Th loading and trapping system will be presented.

[1] B. Seiferle et al., Nature, 573, 243-246 (2019) [2] L. v. d. Wense et al., Nature, 533, 47-51 (2016)

A 14.17 Tue 16:00 Empore Lichthof

Current status of the Al^{+} ion clock at PTB — •Fabian Dawel[1,2], Johannes Kramer[1,2], Nils Scharnhorst[1,2], Ludwig Krinner[1,2], Lennart Pelzer[1,2], Stephan Hannig[1,2], Kai Dietze[1,2], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, D — [2]Leibnitz-Universtität-Hannover, 30167 Hannover, D

Here we present the status of the $^{27}Al^{+}$ clock at PTB. The Al^{+} ion optical clock has one of the lowest systematic uncertainties [1]. This is due to its very low sensitivity to external fields. Al^{+} exhibits only nuclear linear Zeeman shifts and a very small black body radiation shift which is estimated to be less than 10^{-19} in our trap setup. The Al^{+} is co-trapped with $^{40}Ca^{+}$ in a linear Paul trap. The Ca^{+} ion is used for cooling and quantum logic spectroscopy (QLS) of the Al. For QLS groundstate cooling is needed and achived by DEIT which results in a fractional second order Doppler shift from residual motion of the Al^{+}/Ca^{+} crystal of well below 10^{-18} [2]. We present coherent excitation of the $^{1}S_{0}$ to $^{3}P_{1}$ transition of Al^{+} with a contrast of around 90%. We also present a scheme for phase-stabilising the clock laser light paths from the IR-laser to the ion to achieve long probe times on the clock transition $^{1}S_{0}$ to $^{3}P_{0}$ at 267 nm.

[1]*Brewer et al. Phys. Rev. Lett. **123**, 033201 (2019)
[2]*Scharnhorst et al., Phys. Rev. A **98**, 023424 (2018)

A 14.18 Tue 16:00 Empore Lichthof

Towards high-precision spectroscopy of the 1S–2S transition in He^{+} — •Fabian Schmid[1], Akira Ozawa[1], Johannes Weitenberg[1,2], Theodor W. Hänsch[1,3], and Thomas Udem[1,3] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fraunhofer-Institut für Lasertechnik ILT, Aachen — [3]Ludwig-Maximilians-Universität München

Accurate tests of a physical theory require a system whose properties can be both measured and calculated with very high precision. One famous example is the hydrogen atom which can be precisely described by bound-state quantum electrodynamics (QED) and whose transition energies can be accurately measured by laser spectroscopy.

We are currently setting up an experiment to perform spectroscopy on the narrow 1S–2S transition in hydrogen-like He^{+} ions. Due to their charge, He^{+} ions can be held near-motionless in the field-free environment of a Paul trap, providing ideal conditions for a high precision measurement. Furthermore, interesting higher-order QED corrections scale with large exponents of the nuclear charge, making this measurement much more sensitive to these corrections compared to the hydrogen case.

Driving the transition requires narrow-band extreme-ultraviolet (XUV) radiation at 61 nm. Our approach is to apply direct frequency comb spectroscopy with an XUV frequency comb which is generated from an infrared source using intracavity high harmonic generation. The target He^{+} ions will be trapped in a linear Paul trap and sympathetically cooled by co-trapped Be^{+} ions.

A 14.19 Tue 16:00 Empore Lichthof

The ARTEMIS Experiment For Precision Measurements Of The Electron g-Factor In Highly Charged Ions — Patrick Baus[1], Gerhard Birkl[1], Zhexi Guo[2,3,4], •Kanika Kanika[2,3], Jeffrey Klimes[2,3,4], Wolfgang Quint[2,3], and Manuel Vogel[3] — [1]Institute of Applied Physics, Technical University Darmstadt, 64289

Darmstadt, Germany — [2]Department of Physics and Astronomy, University of Heidelberg, 69120 Heidelberg, Germany — [3]GSI Helmholtz Centre for Heavy Ion Research, 64291 Darmstadt, Germany — [4]Max Planck Institute for Nuclear Physics, 69120 Heidelberg, Germany

The ARTEMIS experiment at the HITRAP facility at GSI, Darmstadt aims at high precision g-factor measurements of electrons bound to highly charged ions (HCIs) using the Laser-Microwave double-resonance spectroscopy. The highly charged ions are stored in a small volume in a half-open Penning trap in a homogeneous magnetic field of 7 T and can be resistively cooled through their image currents. The long storage times of weeks indicate a residual gas pressure inside the trap chamber of less than 10^{-15} mbar. The Creation Trap allows for the in-situ production of ions, acting as a mini-EBIT and also to have the in-flight capture of the ions from the HITRAP beamline. The Spectroscopy Trap has an Indium Tin Oxide (ITO) window, which also acts as an endcap electrode and provides for large optical access for the Laser-Microwave spectroscopy technique. After connection to the HITRAP beamline, the method will be applied to H-like heavy ions such as Bi^{82+}, U^{91+} to probe the hyperfine structure transitions and measure the nuclear and electron magnetic moments.

A 14.20 Tue 16:00 Empore Lichthof

A new value for the isomer energy of ^{229}Th, determined by high-resolution γ-spectroscopy with metallic magnetic micro-calorimeters — •D. Hengstler[1], J. Geist[1], S. Allgeier[1], M. Arndt[1], M. Friedrich[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], S. Stellmer[2], T. Schumm[3], and C. Düllmann[4] — [1]Heidelberg University — [2]University of Bonn — [3]Vienna University of Technology — [4]Mainz University

The isotope ^{229}Th has the nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physics with a potential application in a nuclear clock. However, in order to excite this very narrow transition from the ground state to the isomer state with a laser a precise knowledge of the transition energy is needed. A detector with good energy resolution allows to deduce this transition energy from a high-statistic γ-spectrum of ^{229}Th originating from the α-decay of ^{233}U.

To improve the accuracy of the currently most accepted value of (7.8 ± 0.5) eV, we developed and fabricated the detector array maXs-30 consisting of 8×8 metallic magnetic calorimeters. The detector features a large active detection area of 4 mm × 4 mm to face the low rate of the relevant γ-transitions, a world-record energy resolution $\Delta E_{\mathrm{FWHM}} < 10$ eV up to 60 keV as well as a very small non-linearity and reliable energy calibration.

We present our latest ^{229}Th spectrum measured with a purified ^{233}U source and derive a trustful value for the isomer energy on different ways, leading to a result of $E_{\mathrm{iso}} = (8.09 \pm 0.13(\mathrm{stat})^{+0.05}_{-0.14}(\mathrm{syst}))$ eV.

A 14.21 Tue 16:00 Empore Lichthof

Metallic Magnetic Calorimeters for High Precision X-Ray Spectroscopy on Highly Charged Ions — •M. Friedrich[1], S. Allgeier[1], M. Arndt[1], J. Geist[1], D. Hengstler[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], Ph. Pfäfflein[2], S. Trotsenko[2,3], T. Morgenroth[3], M.O. Herdrich[2], G. Weber[2], R. Märtin[2], and Th. Stöhlker[2,3,4] — [1]KIP, Heidelberg University — [2]HI Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

Heavy Highly Charged Ions (HCIs) are promising candidates to test QED in extreme electromagnetic fields. Due to the high nuclear charge of such ions the electronic transitions are shifted to the X-ray regime, while the Lamb-Shift amounts to more than 0.1 % of the transition energies. Metallic magnetic calorimeters are energy dispersive X-ray detectors, which provide an extremely high energy resolution over a wide energy range as well as an excellent energy calibration. Thus, they are perfectly suited for high precision X-ray spectroscopy on HCIs in ion storage rings where photon flux is small and beam time is limited.

For an upcoming measurement on H-like U^{91+} at CRYRING@ESR we report on our newly developed, fabricated and characterised two-dimensional detector array maXs100 consisting of 64 pixels with a total detection area of 10x10 mm^2. An absorber thickness of 100 μm (50 μm) results in an expected energy resolution of $\Delta E_{\mathrm{FWHM}} \sim 38$ eV(27 eV). This detector is mounted on a side arm of a dilution refrigerator and will enable the determination of the 1s Lamb-Shift with sub-eV precision.

A 14.22 Tue 16:00 Empore Lichthof

Active Control of a Femtosecond Enhancement Cavity for XUV Spectroscopy — •Patrick Knauer, Janko Nauta, Jan-Hendrik Oelmann, Alexander Ackermann, Ronja Pappenberger, Nick Lackmann, Steffen Kühn, Julian Stark, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Driving narrow transitions of highly charged ions in the extreme ultraviolet (XUV) regime requires a coherent XUV source. A femtosecond enhancement cavity can provide this by transferring an infrared frequency comb with a peak intensity of up to $\approx 3 \cdot 10^{14}$ W/cm^2 at a repetition rate of 100 MHz to the XUV through high-harmonic generation [1,2]. The enhancement cavity is mounted on a rigid titanium structure for stable long-term operation, and vibrations from the vacuum pumps are isolated from the optical setup by air-lifted feet [3]. To achieve a high enhancement of the driving infrared frequency comb, the cavity has to be precisely stabilised at high intra-cavity powers of several kW. Noise caused by thermal expansion, residual vibrations or other sources has to be cancelled. For this, we present an active stabilisation control consisting of a short and long term feedback loop, which is implemented using a field programmable gate array equipped micro controller.

[1] C. Gohle et al., Nature 436, 234-237 (2005).
[2] G. Porat et al., Nat. Photon, 12, 387 - 391 (2018).
[3] J. Nauta et al., Nucl. Instrum. Meth. B 408, 285 (2017).

A 14.23 Tue 16:00 Empore Lichthof

Designed quantum states for ^{40}Ca$^+$ clock interrogation — •Lennart Pelzer[1], Kai Dietze[1], Ludwig Krinner[1,2], Stephan Hannig[1,3], Nicolas Spethmann[1], Nati Aharon[4], Alex Retzker[4], Tanja E. Mehlstäubler[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany — [3]DLR-Si, 30167 Hannover, Germany — [4]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Single ion optical clocks are limited in their statistical uncertainty by quantum projection noise. Stabilizing the interrogation laser to a transition in a multi-ion crystal would allow longer probe times and thus improve statistical uncertainty, but increasing the number of ions while maintaining low systematic uncertainties is demanding.

Using engineered quantum states by employing a continuous dynamical decoupling scheme, all relevant frequency shifts in a ^{40}Ca$^+$ ion-crystal get suppressed. Furthermore, entangling atoms on an optical transition can improve the statistical uncertainty as well as the systematic uncertainty by engineering entangled states that are e.g. free of the linear Zeeman shift.

We present progress on tailoring a robust clock transition by dressing both Zeeman manifolds of the $S_{1/2}$ to $D_{5/2}$ transition with four driving RF-fields as well as first results on entangling two Ca$^+$ ions using a Mølmer-Sørensen gate.

A 14.24 Tue 16:00 Empore Lichthof

A recoil ion source providing slow $^{229\mathrm{(m)}}$Th ions in a broad charge state distribution — •Tom Kieck[1,2], Dmitry Budker[1,2,3,4], Christoph E. Düllmann[1,2,4,5], Raphael Haas[1,2], Dennis Renisch[1,2], and Ferdinand Schmidt-Kaler[1] — [1]Johannes Gutenberg-Universität Mainz, Germany — [2]Helmholtz-Institut Mainz, Germany — [3]University of California, Berkeley, CA, USA — [4]PRISMA Cluster of Excellence, Mainz, Germany — [5]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

$^{229\mathrm{m}}$Th is a nuclide of high interest in fundamental and applied physics. Currently, $^{229\mathrm{m}}$Th is best obtained from the alpha decay of ^{233}U. The TACTICa (Trapping And Cooling of Thorium Ions with Calcium) collaboration aims at capturing Th ions inside a ^{40}Ca$^+$ Coulomb crystal. They will be sympathetically cooled in a Paul trap and available for precision spectroscopy. For ^{229}Th, the alpha decay imparts 84 keV kinetic energy. The recoil ions are electrostatically decelerated to facilitate trapping. This mechanism retains the original charge state distribution up to high charge states. Complementary, a laser-ablation ion source is installed, providing Th^{1+} ions of isotopes available in macroscopic quantities. This combination of ion sources allows the investigation of a large number of Th isotopes in different charge states. Simulation results of the ion beam, alpha spectra of the ^{233}U source and a first design of the setup will be presented.

R. Haas et al., arXiv:1911.11674

A 14.25 Tue 16:00 Empore Lichthof

A free-electron target for the ion-storage rings at FAIR: current status — Carsten Brandau[1,2], Alexander Borovik Jr[1], •B. Michel Döhring[1,2], Benjamin Ebinger[1,2], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt (Germany)

The Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany, is presently under construction and will provide worldwide unique possibilities for heavy-ion research. For the investigation of electron-ion collisions, a free-electron target is presently built [1]. It will be installed initially at the low-energy ring CRYRING@ESR but can also easily be adapted to the other heavy-ion storage rings of FAIR. The electron target will operate in 90 degrees geometry between ion and a ribbon-shaped electron beam. The electrode geometry has been designed such that a large part of the well localized electron-ion interaction region can be easily accessed by x-ray and electron spectrometers under large solid angles. We will summarize the physics, the concept and the present status of the project.

[1] M. Lestinsky et al., 2016 Eur. Phys. J. ST 225 797.

A 14.26 Tue 16:00 Empore Lichthof

Study of astrophysical plasmas in a compact EBIT — •Moto Togawa, Steffen Kühn, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik

The Heidelberg compact electron beam ion traps (HC-EBIT) use permanent magnets instead of superconducting coils, operate at room temperature, and are easily transportable. They reliably produce highly charged ions (HCI) at electron-beam energies up to 10 keV. Combining them with a high brilliance synchrotron-radiation source enables resonant fluorescence spectroscopy in the X-ray region, and precision measurements stringently benchmarking atomic structure calculations and models of astrophysical plasmas. We show how, using narrow bandwidth X-ray sources and a HC-EBIT with an off-axis electron gun (Polar-X-EBIT) specific electronic processes present in astrophysical plasmas can be separately studied.

A 14.27 Tue 16:00 Empore Lichthof

ECR ion source for the local injector of CRYRING at GSI/FAIR — •Sebastian Fuchs[1,2], Paul Willamowski[1], Alexander Borovik Jr[1], Svetlana Fedotova[2], Gleb Vorobjev[2], Frank Herfurth[2], Michael Lestinsky[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany

We report on the adaptation of an all-permanent-magnet 10-GHz electron-cyclotron-resonance (ECR) ion source for the local injector of the low-energy heavy-ion storage ring CRYRING at the international Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. CRYRING which is currently being commissioned offers world-unique possibilities for atomic physics experiments [1]. The here featured activity aims at providing a reliable and powerful ECR ion source of the 'multi-mode' type [2] for the local injector, that can be used without the GSI accelerator chain for first in-ring experiments. The ion source was optimized at the Giessen ion-source test bench, e. g. for intense C^+ ion beam production using different source gases reaching a C^+ current of up to 15.5 μA. The employment of the present ion source at CRYRING required several adjustments, among others, an adaptation of the ion-beam forming optics onto the acceleration voltage of 40 kV.

[1] M. Lestinsky *et al.*, Eur. Phys. J. ST **225**, 797 (2016).
[2] F. Broetz *et al.*, Phys. Scr. **T92**, 278 (2001).

A 14.28 Tue 16:00 Empore Lichthof

BMBF-Verbundforschung im Rahmen von APPA@FAIR — •Stefan Schippers[1] und Thomas Stöhlker[2,3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Helmholtzinstitut Jena, 07743 Jena

APPA (Atomic and Plasma Physics and Applications) ist eine der vier Forschungssäulen von FAIR. Die unter dem gemeinsamen Dach von APPA agierenden internationalen Forschungskollaborationen BIOMAT (Biophysik und Materialwissenschaften), HED@FAIR (Plasmaphysik) und SPARC (Atomphysik), konzentrieren sich auf die Erforschung der Bausteine und Phänomene der Materie unter extremen Bedingungen (hohe Felder, Dichten, Drücke und Temperaturen). Gegenstand der APPA-Verbundforschung sind thematisch abgestimmte Forschungsprojekte im Bereich beschleunigergestützter Experimente mit schweren Ionen an der zukünftigen FAIR-Anlage. Zentrale Punkte dabei sind: 1) Fortentwicklung der Großgeräteinfrastruktur, vor allem Forschung und Entwicklung zur Steigerung der wissenschaftlichen Leistungsfähigkeit vorhandener Anlagen sowie zukünftiger Beschleuniger- und Detektorsysteme einschließlich der entsprechenden Basistechnologien, 2) Aufbau der APPA-Experimente bei FAIR und 3) Durchführung des Forschungsprogramms der derzeit laufenden FAIR-Phase 0.

A 14.29 Tue 16:00 Empore Lichthof

Towards the Development of the Compact Setup for Ion-Production and Spectroscopy — •Alexander Borovik Jr. — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany

A compact setup based on the MaMFIS [1] technology, capable of production and trapping of highly charged ions under room temperatures is under operation in Giessen since several years. It constantly undergoes uprades aimed at its development into a versatile setup for spectroscopy of highly charged ions with a possibility of their extraction for further utilization. In the present contribution, we report on the development of a new compact electron gun, which, under high spatial constraints, is capable of delivering electron beams with energies at least up to 15keV and can be moved along the X,Y and Z axes during operation. The latter feature allows for the optimization of the electron-beam transmission, which, as a result, can now be as high as 99,999%. The progress in the development of the compact power-efficient electron collector will also be addressed. [1] V.P. Ovsyannikov A.V. Nefiodov 2016 *Nucl. Instrum. Meth. B* **370** 32-41

A 14.30 Tue 16:00 Empore Lichthof

Relativistic calculation of one Photoionization of neutral atom — •Jiahao Fan[1], Jiri Hofbrucker[1,2], Andrey Volotka[2,3], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller-Universität Jena,Gemany — [2]Helmholtz-Institut Jenam, Gemany — [3]St. Petersburg State University, Russia

Photoionzation is one of the most fundamental atomic process which occurs in the light-matter interaction, and the most extensively studied. The neutral atom obtains the energy carried by a photon, and then the electron can be excited which has the corresponded Binding energy, and the electron is excited into continuum state and leaves a ion. Only photons that posses an energy corresponding to an ionization the electron transition of the system are absorbed, with a certain probability. This makes Photoionization very wavelength sensitive. My work is to verify and simulate the total cross section of this process within the framework of relativistic second-order Pertubation theory and independent particle approximation on Mathmatica, compare the different results in F, Ne and Na elements. Indeed I checked the different differential cross section distribution with different incoming photon energy.