Q 4: Precision spectroscopy of atoms and ions (joint session A/Q)

Time: Monday 16:30–18:30 Location: P

Q 4.1 Mon 16:30 P

Interorbital interactions in an SU(2)⊗SU(6)-symmetric Fermi-Fermi mixture — •Koen Sponselee[1], Benjamin Abeln[1], Marcel Diem[1], Nejira Pintul[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Laser Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We characterise the *s*-wave interactions in interorbital ^{171}Yb-^{173}Yb Fermi-Fermi mixtures [1], where either ^{171}Yb is excited to the $^3P_0$ state while leaving ^{173}Yb in the ground state, or vice versa.

Using high-resolution clock spectroscopy, we measure the elastic scattering lengths and directly show the SU(2)⊗SU(6) symmetry of both interisotope interactions, which turn out to be attractive and similar. We further measure losses in these interorbital Fermi-Fermi mixtures and observe a difference of about two orders of magnitude between both interisotope interactions.

Along with other known $^1S_0$-$^3P_0$ state interactions of ytterbium, these measurements can be used as a benchmark for future ground-excited state Yb_2 molecular potential models.

This work is supported by the DFG within the SFB 925.

[1] B. Abeln, K. Sponselee, M. Diem, N. Pintul, K. Sengstock, and C. Becker, Phys. Rev. A **103**, 033315 (2021)

Q 4.2 Mon 16:30 P

Electronic structure of superheavy element ions from ab initio calculations — •Harry Ramanantoanina[1], Anastasia Borschevsky[2], Michael Block[3], and Mustapha Laatiaoui[1] — [1]Johannes Gutenberg-Universität Mainz, Deutschland — [2]University of Groningen, The Netherlands — [3]GSI Helmholtzzentrum für Schwerionenforschung Darmstadt, Deutschland

Within the framework of the recent Laser Resonance Chromatography (LRC) project, we are developing a theoretical approach to study the properties of superheavy elements ions. In this context, we use a fully relativistic model based on the 4-component Dirac Hamiltonian and multireference configuration interaction method to deal with the electronic structure and spectroscopic properties. In this presentation, we are reporting our first results of Lr+ (Z = 103), Rf+ (Z = 104) and Db+ (Z = 105). To validate the theoretical method, we have also calculated the energy spectrum of Lu+, Hf+ and Ta+, which are the lighter element homologue of the investigated superheavy ions, and we have compared the theoretical results with experimental data. Overall, the calculated energy levels and spectroscopic properties were in good agreement with the experimental data, confirming the suitability of the theoretical approach for this study and allowing us to expect good quality of the prediction for superheavy ions. The theoretical results are further discussed in terms of optical pumping schemes of metastable electronic states of the superheavy ions, very relevant for setting up future LRC experiments. This study is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

Q 4.3 Mon 16:30 P

Current status of the Al^+ ion clock at PTB — •Fabian Dawel[1,2], Johannes Kramer[1,2], Steven A. King[1,2], Ludwig Krinner[1,2], Lennart Pelzer[1,2], Stephan Hannig[1,2,3], Kai Dietze[1,2], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch Technische Bundesanstalt, 38116 Braunschweig — [2]Leibniz Universität Hannover, 30167 Hannover — [3]DLR, Institut für Satellengeodäsie und Inertialsensorik (DLR-SI)

Since 1967 time is defined via a hyperfine transition in caesium-133. Optical clocks offer advantages in terms of statistical and systematic uncertainties over microwave clocks. A particularly promising candidate is the transition $^1S_0 \rightarrow {}^3P_0$ of $^{27}Al^+$, with advantageous atomic properties resulting in small uncertainties in magnetic, electric and black-body shifts. Here we review the design and operation of the $^{27}Al^+$ clock at PTB. In our clock implementation, Al^+ is co trapped with $^{40}Ca^+$ in a linear Paul trap. The working principle of quantum logic spectroscopy and a lifetime-limited excitation rabi cycle on the Al^+ logic transition is demonstrated. We will present an evaluation of systematic frequency shifts using the more sensitive Ca^+ as a proxy. All investigated shifts have an uncertainty below 10^{-18}. First measurements on the Al^+ clock transition will be presented with a power-broadened linewidth of 48 Hz.

Q 4.4 Mon 16:30 P

Measurement of Magnetic Moments in Heavy, Highly Charged Ions With Laser-Microwave Double-Resonance Spectroscoypy — •Khwaish Anjum[1,2], Patrick Baus[3], Gerhard Birkl[3], Manasa Chambath[1,4], Kanika[1,5], Jeffrey Klimes[1,5,6], Wolfgang Quint[1,5], and Manuel Vogel[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung — [2]Delhi Technology University — [3]Institute for Applied Physics, TU Darmstadt — [4]Amrita Vishwa Vidyapeetham — [5]Heidelberg Graduate School for Fundamental Physics — [6]Max Planck Institute for Nuclear Physics

The ARTEMIS Penning trap will use laser-microwave double-resonance spectroscopy to measure the intrinsic magnetic moments of both electrons and nuclei in heavy, highly charged ions (HCIs). The (hyper)fine and Zeeman transitions of such HCIs in ARTEMIS are in the optical or microwave regimes respectively. A closed optical cycle probes successful induction of spin flips by microwave stimulus.

The spectroscopy trap of ARTEMIS uses a half-open design with a transparent, conductive endcap. This enables ≈ 2 sr conical access to the trap center for irradiation and detection of fluorescent light. This is more than an order of magnitude greater than conventional cylindrical designs with similar harmonicity and tunability. On the opposite side, cooled ion bunches are injected from an adjacent trap, where they are created by electron impact ionization.

Currently, ARTEMIS is working on systematics measurements with boron-like Ar^{13+} and preparing for capture of heavy HCIs such as hydrogen-like Bi^{82+} from the HITRAP facility at GSI.

Q 4.5 Mon 16:30 P

A New Experiment for the Measurements of the Nuclear Magnetic Moment of $^3He^{2+}$ and the Ground-State Hyperfine Splitting of $^3He^+$ — •Annabelle Kaiser[1,2], Antonia Schneider[1], Bastian Sikora[1], Andreas Mooser[1], Stefan Dickopf[1,2], Marius Müller[1], Alexander Rischka[1], Stefan Ulmer[3], Jochen Walz[4,5], Zoltan Harman[1], Christoph H. Keitel[1], and Klaus Blaum[1] — [1]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [2]Heidelberg University, Heidelberg, Germany — [3]RIKEN, Wako, Japan — [4]Johannes Gutenberg-University, Mainz, Germany — [5]Helmholtz-Institute Mainz, Germany

The Heidelberg ^{3}He-experiment is aiming at the first direct high-precision measurement of the nuclear magnetic moment of $^3He^{2+}$ with a relative uncertainty on the 10^{-9} level and an improved measurement of the ground-state hyperfine splitting of $^3He^+$ by at least one order of magnitude. The helion nuclear magnetic moment is an important parameter for the development of hyperpolarized ^{3}He-NMR-probes for absolute magnetometry. The HFS measurement of $^3He^+$ is sensitive to nuclear structure effects and would give information about such effects in a three-nucleon system. For the $^3He^+$ and $^3He^{2+}$ measurements, two and four Penning trap setups were designed respectively, and similar techniques as already demonstrated in proton and antiproton magnetic moment measurements [1,2] are going to be applied. The current status of the experiment is presented.

[1] Schneider et al., Science Vol 358, 1081 (2017)
[2] Smorra et al., Nature, Vol 550, 371 (2017)

Q 4.6 Mon 16:30 P

Self-injection locked laser system for quantum logic and entanglement operations — •Ludwig Krinner[1,2], Lennart Pelzer[1], Kai Dietze[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116, Braunschweig — [2]Leibniz Universität Hannover, Welfengarten 1, 30167, Hannover

While diode lasers have become a prevalent tool for the cooling and coherent manipulation of atoms and ions, they typically show an inconvenient and sometimes even problematic amount of noise at Fourier frequencies of a few hundred kilohertz to a few megahertz. Especially in the case of trapped ions, this coincides with the motional frequencies of the secular motion. Excess noise can compromise coherent manipulation of sideband transitions, such as sideband cooling or entanglement operations by incoherently driving the much stronger carrier transitions. We demonstrate a self-injection locked laser system using the transmitted light of a medium-finesse linear cavity. The system can easily be adapted from an existing standard Pound-Drever-Hall laser locking scheme using a linear cavity, as opposed to Y-shaped or bow-tie cavities, which are usually employed for self-injection locking. We demonstrate the excellent suppression of high frequency noise by measuring incoherent excitation 0.3 . . . 4 MHz away from the carrier transition using a single trapped $^{40}Ca^+$ ion as a probe, finding an inferred reduction of over 30 dB in noise spectral density compared to a state-of-the art external-cavity diode laser.

Q 4.7 Mon 16:30 P

Laser photodetachment spectroscopy in an MR-ToF device — •David Leimbach for the GANDALPH and MIRACLS collaborations — Department of Physics, University of Gothenburg, Gothenburg, Sweden — CERN, Geneva, Switzerland — Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany

The electron affinity (EA) is the energy released when an additional electron is bound to a neutral atom, creating a negative ion. Due to the lack of a long-range Coulomb attraction, the EA is dominated by electron-correlation effects. A prime example for the importance of the accurate description of the electron correlation is the theoretical calculation of the specific mass shift, which is an indispensable ingredient when extracting nuclear charge radii from laser-spectroscopy work. Although the isotope shift (IS) in the EA of the stable chlorine isotopes has been determined experimentally, recent calculations improved the theoretical precision beyond the measurement precision. By using a MR-ToF device we are able to perform laser photodetachment spectroscopy while reusing the ion beam, thereby increasing the efficiency in the detection method. Additionally, we will extend this type of studies to long-lived radionuclides for the first time by determining the IS of 36Cl. This novel approach could be applied to IS measurements of short-lived isotopes as well as EA determination of sparsely produced and eventually superheavy radioelements. We will present the technique, developments and status of the experimental campaign.

Q 4.8 Mon 16:30 P

Current status of the transportable ^{87}Sr lattice clock at PTB — •Tim Lücke, Ingo Nosske, Chetan Vishwakarma, Sofia Herbers, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The prospect of direct observation and accurate determination of gravitational potential differences led to great efforts to develop transportable optical clocks within the last decade. At PTB, we are operating a ^{87}Sr lattice clock in an air-conditioned car trailer for chronometric leveling. Here we present a recent uncertainty evaluation of our clock reaching the very low 10^{-17} regime. Furthermore, we explore future measures to reduce its uncertainty into the 10^{-18} regime including a new physics package allowing the transport of the atoms into a cryogenic interrogation chamber by a moving lattice.

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 434617780 - SFB 1464 Terra Q and Project-ID 390837967 - EXC-2123 QuantumFrontiers.

Q 4.9 Mon 16:30 P

Interrogating the temporal coherence of EUV frequency combs with highly charged ions — •Chunhai Lyu, Stefano M. Cavaletto, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

An extreme-ultraviolet (EUV) frequency comb is usually generated via intra-cavity high-order harmonic generation of an infrared (IR) frequency comb. However, whether the temporal coherence of the IR frequency comb is preserved in the corresponding EUV frequency comb is still under debate. Here, we put forward a scheme to directly infer the temporal coherence of EUV frequency combs via spectroscopy of highly charged Mg-like ions. The fluctuations of the carrier-envelope phase between EUV pulses is modelled as a random walk process. Based on numerical simulations, we show that the coherence time of the EUV frequency comb can be determined from the excitation spectrum of given ionic transitions. This scheme will provide a verification of the temporal coherence of an EUV frequency comb at timescales several orders of magnitude longer than current state of the art, and at the same time will enable high-precision spectroscopy of EUV transitions down to the 15th digit.

[1]. Phys. Rev. Lett. 98, 070801 (2020).

Q 4.10 Mon 16:30 P

Construction and tests of image-current detection systems for the transportable antiproton trap STEP. — •Fatma Abbass[1], Christian Will[1], Daniel Popper[1], Matthew Bohman[1,7], Markus Wiesinger[1], Markus Fleck[7], Jack Devlin[2,7], Stefan Erlewein[2,7], Julia Jaeger[2,7], Barbara Latacz[7], Peter Micke[7], Klaus Blaum[3], Christian Ospelkaus[4], Wolfgang Quint[6], Yasuyuki Matsuda[5], Yasunori Yamazaki[7], Jochen Walz[1,8], Stefan Ulmer[7], and Christian Smorra[1] — [1]nstitut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, D-55128 Mainz, Germany — [2]CERN, 1211 Geneva, Switzerland — [3]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [4]Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig, Germany — [5])Graduate School of Arts and Sciences, University of Tokyo, Tokyo 153-8902, Japan — [6]GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany — [7]RIKEN, Fundamental Symmetries Laboratory, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan — [8])Helmholtz-Institut Mainz, D-55099 Mainz, Germany

We develop a Penning trap image current detection systems including a cyclotron detection system. The image current detection systems which I developed and tested are made up of superconducting toroidal coils and cryogenic amplifiers. As a result, I was able to achieve a higher Q-value with toroidal coils than we had previously achieved using solenoids.

Q 4.11 Mon 16:30 P

High-Resolution Electron-Ion Collision Spectroscopy with Slow Cooled Pb^{78+} Ions in the CRYRING@ESR Storage Ring — •Sebastian Fuchs[1,2], Carsten Brandau[1,3], Esther Menz[3,4,5], Michael Lestinsky[3], Alexander Borovik Jr[1], Yanning Zhang[6], Zoran Andelkovic[3], Frank Herfurth[2], Christophor Kozhuharov[3], Claude Krantz[3], Uwe Spillmann[3], Markus Steck[3], Gleb Vorobyev[3], Dariusz Banaś[7], Michael Fogle[8], Stephan Fritzsche[4,5], Eva Lindroth[9], Xinwen Ma[10], Alfred Müller[1], Reinhold Schuch[9], Andrey Surzhykov[11,12], Martino Trassinelli[13], Thomas Stöhlker[3,4,5], Zoltan Harman[14], and Stefan Schippers[1,2] — [1]JLU Gießen — [2]HFHF Campus Gießen — [3]GSI — [4]HI Jena — [5]FSU Jena — [6]Xi'an Jiaotong University — [7]JKU Kielce — [8]Auburn University — [9]Stockholm University — [10]IMPCAS Lanzhou — [11]TU Braunschweig — [12]PTB — [13]UPMC Paris — [14]MPIK

The experimental technique of dielectronic recombination (DR) collision spectroscopy is a very successful approach for studying the properties of ions. Due to its versatility and the high experimental precision DR spectroscopy plays an important role in the physics program of the SPARC collaboration. CRYRING@ESR is particularly attractive for DR studies, since it is equipped with an electron cooler that provides an ultra-cold electron beam promising highest experimental resolving power. Here, we report on recent results from the first DR experiment with highly charged ions in the heavy-ion storage ring CRYRING@ESR of the international FAIR facility in Darmstadt.

Q 4.12 Mon 16:30 P

Towards direct optical excitation of the nuclear clock isomer ^{229m}Th — •Johannes Thielking, Maksim V. Okhapkin, Jascha Zander, Johannes Tiedau, Gregor Zitzer, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

The transition of the ^{229}Th nucleus between its ground state and its uniquely low-lying isomer at about 8 eV has been proposed as a frequency reference for a highly precise type of optical clock [1]. Although several advances have been made in determining the transition energy and nuclear properties [2], its optical excitation is still pending. To this end, we are currently developing a vacuum ultraviolet (VUV) laser system based on resonance enhanced four-wave difference mixing in xenon. The mixing process is driven by two pulsed dye laser amplifiers with a pulse duration of 10 ns. The amplifiers are seeded with cw ring lasers to achieve a Fourier transform limited bandwidth. The laser system provides VUV pulses with photon numbers of about 10^{13} per pulse and a broad tunability that covers the current uncertainty range of the nuclear excitation energy. Here we will report on the current status of the laser development, as well as future experiments to excite the isomeric state in trapped ions and a Th-doped crystal.

[1] E. Peik, Chr. Tamm, Europhys. Lett. 61, 181 (2003).
[2] K. Beeks et al., Nature Reviews Physics 3(4), 238-248 (2021).

Q 4.13 Mon 16:30 P

High-Precision Spectroscopy of Single Molecular Hydrogen Ions in a Penning Trap at Alphatrap — •Charlotte M. König, Fabian Heisse, Jonathan Morgner, Tim Sailer, Bingsheng Tu, Klaus Blaum, and Sven Sturm — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

As the simplest molecules, molecular hydrogen ions (MHI) are an excellent system for testing QED. In collaboration with the group of Stephan Schiller (Heinrich-Heine-University Düsseldorf), we plan to perform high-precision spectroscopy on single MHI in the Penning-trap setup of Alphatrap [1]. The first measurements, in the microwave and MHz regime, will investigate the hyperfine structure of HD^+. This will allow extracting the bound g-factors of the constituent particles and coefficients of the hyperfine hamiltonian, from which rovibrational laser spectroscopy performed on this ion species can benefit [2].
In the future, we aim to extend our methods to single ion rovibrational laser spectroscopy of H_2^+ at IR wavelengths enabling the ultra precise determination of fundamental constants, such as $m_\mathrm{p}/m_\mathrm{e}$ [3]. The development of the required techniques for this measurement will be an important step towards spectroscopy of an antimatter $\overline{H}_2^-$ ion for tests of matter-antimatter symmetry [4]. In this contribution, I will present an overview of the experimental setup and the measurement schemes.

[1] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425-1491 (2019)
[2] I. V. Kortunov, *et al.*, Nature Physics **17**, 569 573 (2021)
[3] J.-Ph. Karr, *et al.*, Phys. Rev. **A94**, 050501(R) (2016)
[4] E. Myers, Phys. Rev. **A98**, 010101(R) (2018)

Q 4.14 Mon 16:30 P

A cryogenic Penning trap system for sympathetic laser cooling of atomic ions and protons — •Julia-Aileen Coenders[1], Johannes Mielke[1], Teresa Meiners[1], Malte Niemann[1], Amado Bautista-Salvador[2], Ralf Lehnert[3], Juan Manuel Cornejo[1], Stefan Ulmer[4], 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]Indiana University Center for Spacetime Symmetries, Bloomington, IN 47405, USA — [4]Ulmer Fundamental Symmetries Laboratiory, RIKEN, Wako, Saitama 351-0198, Japan

High precision measurements of the fundamental properties of protons and antiprotons carried out within the BASE collaboration serve as tests of CPT invariance in the baryon sector. However, present experiments fight against systematic uncertainties depending on the motional amplitude of the particle. To this end, experimental schemes based on sympathetic cooling of single (anti-)protons through co-trapped laser cooled atomic ions can contribute to the ongoing strive for improved precision through fast preparation times and low particle temperatures.

Here we present a cryogenic Penning trap system for free space coupling of two particles via Coulomb interaction in an engineered double-well potential. We report on recent results of thermometry measurements with $^9Be^+$ ions and sideband cooling of the same. Prospects for sympathetic cooling of protons in a micro-coupling trap will be discussed.

Q 4.15 Mon 16:30 P

Towards high precision quantum logic spectroscopy of single molecular ions — •Maximilian J. Zawierucha[1], Till Rehmert[1], Fabian Wolf[1], and Piet O. Schmidt[1,2] — [1]Physikalisch- Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

High precision spectroscopy of trapped molecular ions constitutes a promising tool for the study of fundamental physics. Possible applications include the search for a variation of fundamental constants and measurement of the electric dipole moment of the electron.

Compared to atoms, molecules offer a rich level structure, permanent dipole moment and large internal electric fields which make them exceptionally well suited for those applications.

However, the additional rotational and vibrational degrees of freedom result in a dense level structure and absence of closed cycling transitions. Therefore, standard techniques for cooling, optical pumping and state detection cannot be applied. This challenge can be overcome by quantum logic spectroscopy.

In addition to the molecular ion, a well-controllable atomic ion is co-trapped, coupling strongly to the molecule via the Coulomb interaction. The shared motional state can be used as a bus to transfer information about the internal state of the molecular ion to the atomic ion, where it can be read out using fluorescence detection.

Here, we present the status of our experiment, aiming at high precision quantum logic spectroscopy of molecular oxygen ions.

Q 4.16 Mon 16:30 P

Experimental and simulation progress of the Laser Resonance Chromatography technique — •EunKang Kim[1,2], Michael Block[1,2,3], Mustapha Laatiaoui[1,2], Harry Ramanantoanina[1,2], Elisabeth Rickert[1,2,3], Elisa Romero Romero[1,2,3], Philipp Sikora[1], and Jonas Schneider[1] — [1]Department Chemie, Johannes Gutenberg-Universität, Fritz-Strassmann Weg 2, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, Staudingerweg 18, 55128 Mainz, Germany — [3]GSI, Planckstraße 1, 64291 Darmstadt, Germany

The superheavy elements present an experimental challenge as they exhibit low production yields and very short half-lives, and their atomic structure is barely known. Traditional techniques like monitoring fluorescence are no longer suitable as they lack the sensitivity required for superheavy element research. To overcome this challenge, a new technique called *Laser Resonance Chromatography* (LRC) is proposed for probing the heaviest product ions in situ. In this contribution, I will explain the principle, configuration, simulation and progress of the LRC experiment. This work is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

Q 4.17 Mon 16:30 P

Two-loop QED corrections to the bound-electron g-factor: M-term — •Bastian Sikora[1], Vladimir A. Yerokhin[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

The theoretical uncertainty of the bound-electron g-factor in high-Z hydrogenlike ions is dominated by uncalculated Feynman diagrams with two self-energy loops. In our previous study, we have obtained full results for the loop-after-loop diagrams, and partial results for the nested and overlapping loop diagrams by taking into acount the Coulomb interaction in intermediate states to zero and first order [1].

In this work, we present our results for the so-called M-term contribution. This corresponds to the ultraviolet finite part of nested and overlapping loop diagrams in which the Coulomb interaction in intermediate states is taken into account to all orders.

Our results will be highly relevant for planned near future tests of QED in high-Z ions as well as for an independent determination of the fine-structure constant α from the bound-electron g-factor.

[1] B. Sikora, V. A. Yerokhin, N. S. Oreshkina et al., Phys. Rev. Research 2, 012002(R) (2020).

Q 4.18 Mon 16:30 P

Theory of the Zeeman and hyperfine splitting of the $^3He^+$ ion — •Bastian Sikora, Zoltán Harman, Natalia S. Oreshkina, Igor Valuev, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

When exposed to an external magnetic field, the combined hyperfine and Zeeman effect leads to a splitting of the ground state of the $^3He^+$ ion into four sublevels. Measurements of transition frequencies [1] between these sublevels allow the determination of the bound electron's g-factor, the ground-state hyperfine splitting in the absence of an external magnetic field as well as the magnetic moment of the nucleus, shielded by the presence of the bound electron.

We present the theoretical calculation of the shielding constant which is required to extract the magnetic moment of the bare nucleus. Furthermore, we present the theory of the ground-state hyperfine splitting and the bound-electron g-factor. The theoretical accuracy of the bound-electron g-factor is limited by the accuracy of the fine-structure constant α. Furthermore, assuming the correctness of theory of hyperfine splitting, one can extract the nuclear Zemach radius from the experimental hyperfine splitting value.

[1] A. Mooser, A. Rischka, A. Schneider, et al., J. Phys.: Conf. Ser. 1138, 012004 (2018)

Q 4.19 Mon 16:30 P

Engineering Atom-Photon and Atom-Atom Interactions with Nano-photonics — •Artur Skljarow[1], Benyamin Shnirman[1], Harald Kübler[1], Hadiseh Alaeian[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany — [2]Departments of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana, USA

We study an integrated silicon photonic chip, composed of several sub-wavelength ridge and slot waveguides, immersed in a micro-cell with rubidium vapor. With the help of a two-photon excitation, we observe that the guided mode transmission spectrum gets modified when the photonic mode is coupled to rubidium atoms through its evanescent tail. We also investigate the coupling of atomic vapor to slot waveguides. The slot mode constrains the probed atomic density to an effective one-dimensional system. This is interesting to study the collective atom-atom interactions in 1D. We developed a Monte-Carlo simulation method to predict and interpret the measured data. In addition to the silicon plattform we are also fabricating and investigating Nano-devices made of silicon nitride. In order to reach the interesting quantum regime with thermal vapors we plan to create a non-linearity by enhancing the light field with a photonic crystal cavity. We have fabricated these devices with a novel underetching technique where specified regions with the Si3N4 PhCs are suspended in air. This technique allows direct coupling into the cavity via the waveguide and enables a more versatile design of the chip.

Q 4.20 Mon 16:30 P

High-Resolution Microcalorimeter Measurement of X-Ray Transitions in He-like Uranium at CRYRING@ESR — •Felix Martin Kröger[1,2,3], Steffen Allgeier[4], Andreas Fleischmann[4], Marvin Friedrich[4], Alexandre Gumberidze[3], Marc Oliver Herdrich[1,2,3], Daniel Hengstler[4], Patricia Kuntz[4], Michael Lestinsky[3], Bastian Löher[3], Esther Babette Menz[1,2,3], Philip Pfäfflein[1,2,3], Uwe Spillmann[3], Günter Weber[1,2,3], Christian Enss[4], and Thomas Stöhlker[1,2,3] — [1]HI Jena, Fröbelstieg 3, Jena, Germany — [2]IOQ Jena, FSU Jena, Max-Wien-Platz 1, Jena, Germany — [3]GSI, Planckstraße 1, Darmstadt, Germany — [4]KIP, RKU Heidelberg, Im Neuenheimer Feld 227, Heidelberg, Germany

We present the first application of metallic magnetic calorimeter detectors for high resolution X-ray spectroscopy at the electron cooler of CRYRING@ESR, the low energy storage ring of GSI, Darmstadt. Within the experiment, X-ray radiation emitted as a result of recombination events between the cooler electrons and a stored beam of U^{91+} ions was studied. For this purpose, two maXs detectors were positioned under observation angles of 0° and 180° with respect to the ion beam axis. This report will focus on details of the experimental setup, its performance and its integration into the storage ring environment.

This research has been conducted in the framework of the SPARC collaboration, experiment E138 of FAIR Phase-0 supported by GSI. We acknowledge substantial support by ErUM-FSP APPA (BMBF n° 05P19SJFAA).

Q 4.21 Mon 16:30 P

maXs100: A 64-pixel Metallic Magnetic Calorimeter Array for the Spectroscopy of Highly-Charged Heavy Ions — •S. Allgeier[1], M. Friedrich[1], A. Gumberidze[2], M.-O. Herdrich[2,3,4], D. Hengstler[1], F. M. Kröger[2,3,4], P. Kuntz[1], A. Fleischmann[1], M. Lestinsky[2], E. B. Menz[2,3,4], Ph. Pfäfflein[2,3,4], U. Spillmann[2], B. Zhu[4], G. Weber[2,3,4], Th. Stöhlker[2,3,4], and Ch. Enss[1] — [1]KIP, Heidelberg University — [2]GSI, Darmstadt — [3]IOQ, Jena University — [4]HI Jena

Metallic magnetic calorimeters (MMCs) are energy-dispersive X-ray detectors which provide an excellent energy resolution over a large dynamic range combined with a very good linearity. MMCs are operated at millikelvin temperatures and convert the energy of each incident photon into a temperature pulse which is measured by a paramagnetic temperature sensor. The resulting change of magnetisation is read out by a SQUID magnetometer. For the investigation of electron transitions in $U^{\mathbf{90}+}$ at CRYRING@FAIR we developed the 2-dimensional maXs-100 detector array within the framework of the SPARC collaboration. It features 8x8 pixels with a detection area of 1 cm^2 and 50 μm thick absorbers made of gold, resulting in a stopping power of 40 % at 100 keV. An energy resolution of 40 eV at 60 keV was demonstrated in co-added spectra. The non-linearity of the detector system including the read-out chain was shown to be in the range of 0.2 % @ 136 keV. We will discuss the cryogenic setup of the two detector systems used during the beam time in April 2021, as well as the properties of the maXs-100 detector array including a sub-eV absolute energy calibration.