A 19: Precision Spectroscopy of Atoms and Ions II (joint session A/Q)

Time: Wednesday 11:00–13:00 Location: HS 1098

A 19.1 Wed 11:00 HS 1098

An ultra stable dc voltage source for ion trap experiments — •Dina-C. Rensink[1], Peter Micke[2,5], Markus Wiesinger[2], Christian Will[2], Hüseyin Yildiz[1], Christian Smorra[1,4], Jochen Walz[1,3], and Stefan Ulmer[6,4] — [1]Johannes Gutenberg-Universität Mainz — [2]Max-Planck-Institut für Kernphysik, Heidelberg — [3]Helmholtz-Institut Mainz — [4]RIKEN, Wako, Japan — [5]Helmholtz-Institut Jena — [6]Heinrich-Heine-Universität Düsseldorf

Highly stable voltages are crucial for precision ion traps. We are developing and characterizing a suitable voltage source for the BASE (Baryon-Antibaryon Symmetry Experiment) collaboration at CERN, which operates several Penning traps. These precision traps are used to perform test of the fundamental symmetry (CPT) between matter and antimatter with (anti-)protons, for instance via comparison of the g-factors. The determination of these quantities requires several frequency measurements whose precision can be limited by the stability of the voltages which bias the trap electrodes.

For this purpose, one ultra-stable LTZ1000 voltage reference and five 20 bit DACs have been combined into a programmable 5-channel voltage source. This scalable setup aims at long-term stability, low temperature drift, μV resolution over a $\pm$ 10 V range, and an output current of up to 20 mA per channel. Prior tests with a 2-channel prototype indicate a fractional stability of $< 5 \cdot 10^{-8}$ at $\tau = 10^2 ... 10^3$ s (at 7 V). The status of the project will be presented and the performance of the voltage source will be discussed.

A 19.2 Wed 11:15 HS 1098

Atomic level search in lawrencium — •Elisabeth Rickert for the Lawrencium-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — Johannes Gutenberg-Universität Mainz, 55128 Mainz,Germany — Helmholtz-Institut Mainz, 55128 Mainz, Germany

The study of the electronic shell structure of the heaviest elements is a challenging endeavour. A strong influence of relativistic effects, electron-electron correlations, and QED effects, challenge the prediction of the atomic structure. The experimental investigation of elements beyond Z=100 is further complicated by their limited availability and short half-lives as well as their experimentally unknown atomic level structure. Recent laser spectroscopy on nobelium (Z=102) in single-atom-at-a-time quantities with the RAdiation Detection Resonance Ionization Spectroscopy (RADRIS) technique opened the path towards laser spectroscopy experiments of yet heavier elements. For the heaviest actinide, lawrencium (Z=103), two ground-state transitions to the $^2S_{1/2}$ state at around 20420 cm^{-1} and to the $^2D_{3/2}$ state at around 28500 cm^{-1}, are predicted. In 2020 and 2022, over 1000 cm^{-1} around the predicted tranisition wavenumbers have been scanned to search for these transitions. In the talk, the current status of the experiment and the data analysis will be presented.

A 19.3 Wed 11:30 HS 1098

Nuclear Deformation Effects of Highly Charged Ions — •Zewen Sun, Igor A. Valuev, and Natalia S. Oreshkina — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Nuclear shape effects are theoretically investigated in terms of corrections to the electronic binding and transition energies and g factors. The corrections are numerically calculated for the widest possible range of nuclei, consisting over 1100 different samples. By solving the Dirac equation with deformed and non-deformed nuclear shapes, i.e. Fermi and deformed Fermi nuclear charge distributions, we separate the deformation effect in binding energies and wavefunctions. The model parameters for the two charge distributions are determined from experimental data. In addition, the importance of deformation effects for the process of searching for new physics is examined.

A 19.4 Wed 11:45 HS 1098

Towards a direct high-precision measurement of the nuclear magnetic moment of^{3}He^{2+} with 1ppb accuracy. — •Ankush Kaushik[1], Stefan Dickopf[1], Marius Müller[1], Annabelle Kaiser[1], Ute Beutel[1], Stefan Ulmer[2,3], Andreas Mooser[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]RIKEN, Wako, Japan — [3]HHU Düsseldorf, Germany

Accurate magnetic field measurements are of apparent importance in the field of fundamental physics [1]. However, the accuracy of the current standard in magnetometry, water NMR probes, is limited by the complex molecular structure. With a direct parts-per-billion measurement of the nuclear magnetic moment of $^3He^{2+}$ in a Penning trap, we aim to overcome this limitation and establish hyperpolarised ^{3}He probes as the new standard. To this end, spin flips of a single nucleon, indicated by miniature frequency changes, need to be detected over background of frequency fluctuations. Since the latter fluctuations are directly proportional to the motional energy, preparing particles at micro eV energies is essential [2]. To address this constraint we designed a new type of Penning trap that enables fast energy measurements while simultaneously allowing the efficient preparation of particles at the required energies. As such, the new trap will be a key element for a successful measurement. Its design and expected performance will be presented.

[1] Mooser *et al.*, J. Phys.: Conf. Ser. 1138 012004 (2018)
[2] Ulmer *et al.*, Physical Review Letters, 106(25) 253001 (2011)

A 19.5 Wed 12:00 HS 1098

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

We aim to exploit ultra-narrow transitions in highly charged ions (HCIs) for novel frequency standards and fundamental physics studies. Due to the strong binding of electrons to the nucleus, these transitions are in the extreme ultraviolet (XUV), where narrow-bandwidth laser sources are not commercially available. Therefore, we have built an XUV frequency comb that transfers the coherence of a near-infrared (NIR) comb to the XUV by high harmonic generation (HHG) [1]. To achieve the required intensity ($I_{peak} > 10^{13}$ W/cm^2) for HHG, we amplify an NIR comb to 80 W in a chirped pulse fiber amplifier and resonantly overlap them in a passive femtosecond enhancement cavity. Our system generates harmonics up to 40 eV and with μW of power each.

We will give an overview of the current status of our experiment and discuss our plans for resonance-enhanced two-photon ionization to resolve the XUX-comb structure. In our spectroscopy approach, we excite argon with one photon from a referenced comb tooth of the 13th harmonic, followed by ionization with a narrow-bandwidth NIR cw-laser. We record the momentum of the released electrons using the velocity map imaging technique to ensure the correct Rydberg state.

[1]J. Nauta et al., Opt. Lett. 45, 2156-2159 (2020)

A 19.6 Wed 12:15 HS 1098

A Cryogenic Paul Trap Experiment for Laser Spectroscopy of the ^{229m}Th Nuclear Clock Isomer — •Kevin Scharl[1], Georg Holthoff[1], Mahmood I. Hussain[1], Markus Wiesinger[1], Daniel Moritz[1], Lilli Löbell[1], Tamila Rozibakieva[1], Sandro Kraemer[1,2], Benedict Seiferle[1], Shiqian Ding[3], Florian Zacherl[1], and Peter G. Thirolf[1] — [1]LMU Munich — [2]KU Leuven, Belgium — [3]Tsinghua University, Beijing, China

^{229}Th plays a unique role in the nuclear landscape because of its low-lying isomeric first excited state at 8.338 ± 0.024 eV, thus accessible via modern VUV-laser systems. A nuclear clock based on the thorium isomer holds promise not only to push the limits of high-precision time keeping, but also to contribute to dark matter and other fundamental physics research as a novel type of quantum sensor.

The cryogenic Paul trap experiment currently operated at the LMU Munich is primarily designed for long ion storage times, which allows to measure the still unknown ionic lifetime of the isomer. This quantity is expected to be several thousands of seconds and is essential for the realization of a nuclear frequency standard. In a second step, the setup will be a platform for VUV spectroscopy of the isomer, paving the way towards a first nuclear clock prototype.

In this talk, the building blocks of the experimental setup for trapping and sympathetic laser cooling of $^{229}Th^{3+}$ by $^{88}Sr^{+}$ are presented and the status of first preparatory measurements is discussed.

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A 19.7 Wed 12:30 HS 1098

Tests of QED with hydrogenlike helium and tin ions and high-precision theory of the bound-electron g-factor — •Bastian Sikora, Vladimir A. Yerokhin, Zoltan Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The g-factor of electrons bound in hydrogenlike ions can be measured and calculated with high accuracy. In recent collaborations, the experimental and theoretical g-factors of the bound electron in hydrogenlike $^3He^+$ and $^{118}Sn^{49+}$ ions were found to be in excellent agreement [1,2]. We present the theory of the bound-electron g-factor of hydrogenlike ions, as well as the status of two-loop QED calculations aimed to improve the uncertainty of theoretical bound-electron g-factors in the high-Z regime [3]. Such calculations will enable improved tests of QED in planned experiments in the near future and are relevant for the determination of fundamental constants such as the electron mass or the fine-structure constant α as well as searches for physics beyond the standard model.

[1] A. Schneider, B. Sikora, S. Dickopf, et al., Nature **606**, 878 (2022)
[2] J. Morgner, B. Tu, C. M. König, et al., Nature **622**, 53 (2023)
[3] B. Sikora, V. A. Yerokhin, N. S. Oreshkina, et al., Phys. Rev. Research **2**, 012002(R) (2020)

A 19.8 Wed 12:45 HS 1098

Ionization potential evaluation by Rydberg analysis in iron with resonance ionization spectroscopy — •Thorben Niemeyer[1], Sebastian Berndt[1], Christoph E. Düllmann[1,2,3], Tom Kieck[2,3], Jung-Bog Kim[4], Nina Kneip[5], Dominik Studer[1], and Klaus Wendt[1] — [1]Johannes-Gutenberg-Universität, Mainz — [2]GSI Zentrum für Schwerionenforschung, Darmstadt — [3]Helmholtz-Institut, Mainz — [4]Korea National University of Education, Cheongju — [5]Leibniz Universität, Hannover

The energetic position of high-lying Rydberg levels and their convergence limit, defining the ionization potential (IP), are characteristic properties for every element and give insights into its specific atomic structure. As a well suited technique, Resonance Ionisation Mass Spectrometry was applied to develop a new two-step ionization scheme in the atomic spectrum of iron using ti:sa lasers, involving frequency doubling and trippling. Literature data is complemented by numerous newly found even parity Rydberg levels. The IP, obtained through the Rydberg-Ritz formalism, is in perfect agreement with the literature value, which was obtained by three-step resonance ionization with similar precision. This confirms the independence of the IP from parity. A number of Rydberg series above the IP converging to higher-lying continua of the Fe ion were measured and analysed.

The set of data provides the basis for applying RIMS to the EU PrimA-LTD project, for which radioactive Fe-55 ions are implanted into metallic magnetic microcalorimeters for precision studies on the electron-capture decay of this isotope.