A 15: Precision spectroscopy of atoms and ions / Highly charge ions (joint session A/Q)

Time: Wednesday 14:00–16:00 Location: H1

Invited Talk A 15.1 Wed 14:00 H1

Laser spectroscopy of the heaviest actinides — •Premaditya Chhetri[1,2,3], Dieter Ackermann[4], Hartmut Backe[5], Michael Block[1,2,5], Bradley Cheal[6], Christoph Emanuel Düllmann[1,2,5], Julia Even[7], Rafael Ferrer[3], Francesca Giacoppo[1,2], Stefan Götz[1,2,5], Fritz Peter Hessberger[1,2], Mark Huyse[3], Oliver Kaleja[1,5], Jadambaa Khuyagbaatar[1,2], Peter Kunz[8], Mustapha Laatiaoui[1,2,5], Werner Lauth[5], Lotte Lens[1], Enrique Minaya Ramirez[9], Andrew Mistry[1,2], Tobias Murböck[1], Sebastian Raeder[1,2], Fabian Schnieder[2], Piet Van Duppen[3], Thomas Walther[10], and Alexander Yakushev[1,2] — [1]GSI, Darmstadt, Germany — [2]HI Mainz, Mainz, Germany — [3]KU Leuven, Leuven, Belgium — [4]GANIL, Cean, France — [5]JGU, Mainz, Germany — [6]Liverpool University, Liverpool, UK — [7]University of Groningen, KVI-CART, Groningen, Netherlands — [8]TRIUMF, Vancouver, Canada — [9]IPN, Orsay, France — [10]TU Darmstadt, Darmstadt, Germany

Precision measurements of optical transitions of the heaviest elements are a versatile tool to probe the electronic shell structure which is strongly influenced by electron-electron correlations, relativity and QED effects. Optical studies of transfermium elements with Z>100 is hampered by low production rates and the fact that any atomic information is initially available only from theoretical predictions. Using the sensitive RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique coupled to the SHIP separator at GSI, a strong optical $^1S_0 \rightarrow ^1P_1$ ground-state transition in the element nobelium (Z=102) was identified and characterized [1]. The isotopes of ^{252,253,254}No were measured [2]. From these measurements, nuclear information on the shapes and sizes were inferred. In addition, several high-lying Rydberg levels were observed, which enabled the extraction of the first ionization potential with high precision [3]. Using an indirect production mechanism, laser spectroscopy was performed on some Fermium isotopes. These results as well as the prospects for future exploration of the atomic structure of the next heavier element, lawrencium (Z=103) will be discussed.

[1] M. Laatiaoui et al., Nature **538**, 495 (2016).
[2] S. Raeder et al., PRL **120**, 232503 (2018).
[3] P. Chhetri et al., PRL **120**, 263003 (2018).

Invited Talk A 15.2 Wed 14:30 H1

Status update of the muonic hydrogen ground-state hyperfine splitting experiment — •A. Ouf and R. Pohl on behalf of the CREMA collaboration — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Exzellenzcluster PRISMA +, Mainz, Germany

The ground state hyperfine splitting (1S-HFS) in ordinary hydrogen (the famous 21 cm line) has been measured with 12 digits accuracy almost 50 years ago [1], but its comparison with QED calculations is limited to 6 digits by the uncertainty of the Zemach radius determined from elastic electron-proton scattering. The Zemach radius encodes the magnetic properties of the proton and it is the main nuclear structure contribution to the hyperfine splitting (HFS) in hydrogen. The ongoing experiment of the CREMA Collaboration at PSI aims at the first measurement of the 1S-HFS in muonic hydrogen (μp) with the potential for a hundredfold improved determination of the proton structure effects (Zemach radius and polarizability), which will eventually improve the QED test using the 21 cm line by a factor of 100. The experiment introduces several novel developments toward the (μp) 1s-HFS spectroscopy. We will present the current efforts of the various developments from the pulsed 6.8 μm laser, to the novel multi pass cavity, and the scintillator detection system.

[1] L. Essen *et al*, Nature **229**, 110 (1971)
[2] R. Pohl *et al.*, Nature **466**, 213 (2010)
[3] A. Antognini *et al.*, Science **339**, 417 (2013)

Invited Talk A 15.3 Wed 15:00 H1

Coupled ions in a Penning trap for ultra-precise *g*-factor differences — •Tim Sailer[1], Vincent Debierre[1], Zoltán Harman[1], Fabian Heisse[1], Charlotte König[1], Jonathan Morgner[1], Bingsheng Tu[1], Andrey Volotka[2], Christoph H. Keitel[1], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Department of Physics and Engineering, ITMO University, St. Petersburg, Russia

Measurements of the electronic magnetic moment (or g factor) of highly charged ions (HCI) in Penning traps have been shown to provide a stringent probe for quantum electrodynamics (QED) in the strongest electromagnetic fields. The isotope shift additionally allows the study of nuclear parameters since many of the common contributions and their uncertainties to the g factor are identical and do not have to be considered. Such measurements become however quickly limited by other factors, for example inherent magnetic field fluctuations. Here, we report on a novel measurement technique based on coupling two ions on a common magnetron orbit to exploit the near-perfect correlation of such magnetic field fluctuations. This has enabled us to directly measure the difference for the isotopes of $^{20}Ne^{9+}$ and $^{22}Ne^{9+}$ to 0.25 parts-per-trillion precision relative to the g factors, which corresponds to an improvement of more than two orders of magnitude compared to conventional techniques. This resolves and verifies a QED contribution to the nuclear recoil for the very first time, while the observed agreement with theory also allows to strengthen the constraints for a potential fifth-force of Higgs-portal-type dark matter interaction.

Invited Talk A 15.4 Wed 15:30 H1

Unraveling the mechanisms of single- and multiple-electron removal in energetic electron-ion collisions: from few-electron ions to extreme atomic systems. — •Alexander Borovik Jr — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany

For over a half century, electron-impact ionization of ions remains an open topic in atomic physics [1]. While single-electron removal processes in light few-electron systems are currently understood and can be reliably described by theoretical approaches, ionization of many-electron ions, especially multiple ionization, are still not understood completely. In this situation, experiment, where available, is the only reliable source of information [2]. However, as we move to ions in high charge states, requirements on the experimental conditions rise, making new approaches and instrumentation necessary. In the present overview, we describe the current status in the field and report on recent activities that aim at expanding the experimental capabilities by the development of electron guns beyond the state-of-the-art and by employing large heavy-ion accelerator facilities such as FAIR [3].

[1] A. Müller, Adv. At. Mol. Phys. 55, 293 (2008). [2] D. Schury et al. J. Phys. B 53, 015201 (2019). [3] M. Lestinsky et al., Eur. Phys. J. ST 225, 797882 (2016).