Q 32: Precision Spectroscopy IV - highly charged ions (joint session A/Q)

Time: Tuesday 14:00–15:45 Location: K 1.016

Invited Talk Q 32.1 Tue 14:00 K 1.016

High precision hyperfine measurements in bismuth challenge bound-state strong field QED — •Rodolfo Sánchez — GSI, Darmstadt, Germany

High-resolution laser spectroscopy on the ground-state hyperfine splitting of hydrogen-like and lithium-like bismuth ions ($Bi^{82+,80+}$) has been carried out at the "Experimentier Speicherring" (ESR) at the GSI Helmholtz-Center for Heavy Ion Research in Darmstadt. The accuracy of the hyperfine splitting determination was improved by more than an order of magnitude compared to previous measurements and sufficient to test bound-state strong-field QED in the so-called specific difference between the two hyperfine splitting energies for the first time. We found a surprising discrepancy from the atomic theory predictions by more than 7σ. I will report on these measurements, possible explanations for this "hyperfine puzzle" of strong-field QED and on further activities that have been started to resolve this issue.

Q 32.2 Tue 14:30 K 1.016

X-Ray Spectroscopy of the KLL-Dielectronic Recombination Resonances with a Heidelberg Compact EBIT — •Peter Micke[1,2], Steffen Kühn[1], Jannik Dierks[2], Thomas Pfeifer[1], Piet O. Schmidt[2,3], Sven Bernitt[1,4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Leibniz Universität Hannover, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

The study of highly charged ions is of great interest for atomic, plasma and astrophysics, as well as fusion research. Moreover, their electronic levels include strongly enhanced contributions of special relativity and quantum electrodynamics. We have carried out high-resolution x-ray spectroscopy of the KLL dielectronic recombination resonances of highly charged argon and iron in one of the novel 0.86 T Heidelberg Compact Electron Beam Ion Traps (HC-EBIT). In this resonant process a free electron out of the EBIT's mono-energetic electron beam is captured into the L-shell of a trapped ion, promoting a second, bound K-shell electron into the L-shell. The excited intermediate state releases a K_α photon during decay, recorded by a high-purity Ge detector. We achieved an excellent electron-energy resolving power of more than 860 together with high relative accuracy for the resonance positions on the order of 50 to 100 meV by using a PTB calibrated high-precision voltage divider. By comparing our results with theoretical values, accurate absolute resonance energies can be deduced and atomic structure theory benchmarked.

Q 32.3 Tue 14:45 K 1.016

Identifications of optical transitions in highly charged ions for metrology and searches of variation of the fine-structure constant — •Hendrik Bekker[1], Julian Berengut[2], Anastasia Borschevsky[3], Nicky Potters[1], Julian Rauch[1], Alexander Windberger[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Insitüt für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]School of Physics, The University of New South Wales, Sydney NSW 2052 — [3]Van Swinderen Institute, Universiteit Groningen, Nijenborgh 4, 9747 AG Groningen

Compared to the neutral and singly charged ions that are used in current optical clocks, level-shifts due to external perturbations are greatly suppressed in highly charged ions (HCI). Furthermore, increased relativistic effects in HCI lead to a strong sensitivity to variation of the fine-structure constant α. Many HCI are predicted to have optical transitions suitable for laser spectroscopy due to level crossings. However, for these HCI, theory is not capable of predicting the energy level structures to the required precision. To address this issue, we investigated several of the proposed HCI, which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap (HD-EBIT). The wavelengths of subsequent fluorescence light were determined at the ppm-level using a grating spectrometer. We present our latest results for $Ir^{16+,17+,18+}$ and $Pr^{9+,10+}$ which are used to benchmark state-of-the-art atomic theory calculations and to provide a deeper insight into the suitability of the proposed HCI for metrology purposes. This is a necessary step towards future laser spectroscopy.

Q 32.4 Tue 15:00 K 1.016

Electron-gun development for electron-ion crossed-beams experiments — •B. Michel Döhring[1], Alexander Borovik Jr.[1], Benjamin Ebinger[1], Kurt Huber[1], Tobias Molkentin[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

Reliable atomic data for electron impact ionisation of atoms are of crucial importance for the modelling of ionised-matter environments and other plasma related applications. To achieve a greater range of accessible electron energies and densities a new electron gun [1,2,3] that delivers a ribbon-shaped beam has been integrated into the experimental crossed-beams setup in Giessen. This gun is designed for electron energies from 10 to 3500 eV with high electron currents at all energies. Ten different electrodes provide a high degree of flexibility for choosing a number of operation modes. Here, we present the latest developments and the commissioning status of the high-power electron gun. In particular, we focus on the challenges associated with fast energy scan measurements.

[1] W. Shi et al., NIMB 205 (2003) 201-206.
[2] A. Borovik Jr. et al., J. Phys.: Conf. Ser. 488 (2014) 142007.
[3] B. Ebinger et al., NIMB 408 (2017) 317-322.

Q 32.5 Tue 15:15 K 1.016

Two-loop corrections to the bound-electron *g*-factor — •Bastian Sikora[1], Natalia S. Oreshkina[1], Halil Cakir[1], Vladimir A. Yerokhin[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

The g-factor of electrons bound in H-like ions can be measured and calculated with high accuracy. Comparisons between the theoretical and experimental values of the g-factor allow precision tests of QED and the determination of fundamental constants such as the electron mass or the fine-structure constant α [1].

In order to achieve high accuracy in theoretical predictions in heavy ions, the interaction with the nuclear potential needs to be taken into account to all orders in $Z\alpha$. Currently, the largest theoretical uncertainty arises from the two-loop self-energy corrections. We present all-order evaluations of the loop-after-loop self-energy contributions, and partial results for other diagrams, in which we treat the Coulomb interaction in intermediate states to zero and first order. – [1] V. A. Yerokhin, E. Berseneva, Z. Harman *et al.*, Phys. Rev. Lett. **116** 100801 (2016).

Q 32.6 Tue 15:30 K 1.016

Precision theory of the *g* factor of highly charged ions — •Zoltán Harman[1], Bastian Sikora[1], Halil Cakir[1], Vladimir A. Yerokhin[1,2], Natalia S. Oreshkina[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

Quantum electrodynamic (QED) contributions to the electron g factor in strong binding fields have been tested to high precision in Penning trap measurements: an experiment with $^{28}Si^{13+}$ allowed to benchmark certain higher-order QED corrections for the first time [1]. Recently, the uncertainty of the electron mass has been largely decreased via measurements on the $^{12}C^{5+}$ ion [2], and by using the theoretical value of the g factor. In order to reduce theoretical uncertainties, we calculate further higher-order corrections.

An independent and improved determination of the fine-structure constant α may also be possible in near future employing a weighted difference of the g factors of the H- and Li-like ions of the same element. This weighted difference in chosen to maximize the cancellation of detrimental nuclear effects between the two charge states. It is shown that this method can be used to extract a value for α from bound-electron g-factor experiments with an accuracy competitive with or better than the present literature value [3]. – [1] S. Sturm *et al.*, Phys. Rev. Lett. **107** 023002 (2011); [2] S. Sturm *et al.*, Nature **506** 467 (2014); [3] V. A. Yerokhin *et al.*, Phys. Rev. Lett. **116** 100801 (2016).