A 7: Highly charged ions and their applications

Time: Monday 14:30–16:30 Location: f107

Invited Talk A 7.1 Mon 14:30 f107

Probing QED in strong fields via the magnetic moment of highly charged ions — •Sven Sturm — Max-Planck-Institut für Kernphysik Heidelberg

The validity of the Standard Model, particularly Quantum Electrodynamics (QED), has been exquisitely tested by precision experiments in the low-field regime. However, in the presence of strong fields higher-order contributions beyond the Standard Model might become significant. The ultra-precise measurement of the g-factor of highly-charged ions provides a unique possibility to probe the validity of the Standard Model in extreme electric fields up to 10^{16} V/cm. By measuring the Larmor- and cyclotron frequencies of single highly charged ions in a cryogenic Penning trap with previously unprecedented precision, we have been able to perform the most stringent test of QED in strong fields. Recently, we were able to explicitly probe the effect of the nucleus on the g-factor of the electron and thus open a novel access to nuclear structure information. Currently, a new setup, ALPHATRAP, is being commissioned at the Max-PIanck-Institut für Kernphysik in Heidelberg, which will push these experiments towards the heaviest elements up to hydrogenlike $^{208}Pb^{81+}$. This will not only enable the most sensitive tests of QED, but also open a unique access to fundamental constants as the atomic mass of the electron and the finestructure constant α.

A 7.2 Mon 15:00 f107

The g-factor of light hydrogen- and lithiumlike ions for an improved extraction of the fine-structure constant — •Zoltán Harman[1], Vladimir A. Yerokhin[1,2], Ekaterina Berseneva[1,3], Ilya I. Tupitsyn[3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia — [3]St. Petersburg State University, 198504 St. Petersburg, Russia

A specific weighted difference of the g-factors of the H- and Li-like ions of the same element is studied and optimized in order to maximize the cancelation of finite nuclear size effects between the two charge states [1]. It is shown that this weighted difference, or its combination for two different elements, can be used to extract the fine-structure constant from future bound-electron g-factor experiments with an accuracy improvement compared to its present value.

[1] V. A. Yerokhin, E. Berseneva, Z. Harman, I. I. Tupitsyn, C. H. Keitel, submitted (2015); arXiv:1509.08260

A 7.3 Mon 15:15 f107

A compact 0.74 T room-temperature electron beam ion trap — •Peter Micke[1,2], Sven Bernitt[1,3], James Harries[4], Ioanna Arapoglou[1,5], Klaus Blaum[1], Lisa F. Buchauer[1], Thore M. Bücking[1], Alexander Egl[1,5], Sandro Kraemer[1,5], Steffen Kühn[1,5], Thomas Pfeifer[1], Thomas Stöhlker[3], Sven Sturm[1], Robert Wolf[1], Piet O. Schmidt[2,6], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, QUEST, Braunschweig — [3]Friedrich-Schiller-Universität Jena — [4]SPring-8, Hyogo, Japan — [5]Ruprecht-Karls-Universität Heidelberg — [6]Leibniz Universität Hannover

Research on highly charged ions (HCI) is of great interest for atomic physics, and electron beam ion traps (EBIT) have proven to be indispensable tools for their production and study. In an EBIT, an electron beam, compressed by a strong, inhomogeneous magnetic field, is used to breed and trap HCIs. We have built a room-temperature EBIT based on permanent magnets, allowing low-maintenance operation. It can provide a continuous beam of Xe ions up to charge state 29+, and a total ion current of 100 pA, with a 4 mA 2 keV electron beam. Pulsed extraction of Ar ions up to charge state 16+ was demonstrated. The protoype currently serves as a HCI source for ALPHATRAP, a device dedicated to high-precision g-factor determinations. Three more EBITs are under construction to provide HCIs for quantum logic spectroscopy, XUV spectroscopy as well as X-ray laser spectroscopy at synchrotrons.

Invited Talk A 7.4 Mon 15:30 f107

X–ray emission from highly charged ions — •Andrey Surzhykov[1], Stephan Fritzsche[1,2], Andrey Volotka[1], Vladimir Yerokhin[3], and Thomas Stöhlker[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Universität Jena, Germany — [3]St. Petersburg Polytechnical University, Russia

With the recent advents of coherent light sources and ion traps, new possibilities arise to study the electronic structure of simple atomic systems in strong nuclear fields. The information about this electronic structure is usually obtained from the analysis of photon emission from highly charged ions. During the last decade, a large number of experiments have been performed to observe x–rays emitted in the course of characteristic bound–state transitions and elastic light scattering. To understand the outcome of these measurements, detailed theoretical investigations of the structure of highly charged ions and of their coupling to the electromagnetic field are needed. In our contribution, therefore, we present an overview of recent theoretical advances in the treatment of interaction of few–electron ions with light. We will pay special attention to the second–order QED processes such as two–photon transitions and elastic (Rayleigh) x–ray scattering. The analysis of these processes requires the knowledge about the complete Dirac spectrum of many–electron ions as represented either by Green's function or by B–spline basis sets. After a short discussion of both theoretical approaches, we will present and discuss calculations for the two–photon decay of beryllium–like ions as well as of elastic x–ray scattering by closed–shell medium– and high–Z systems.

A 7.5 Mon 16:00 f107

Performance and readout of state-of-the-art MMC detector arrays — •D. Hengstler, M. Wegner, J. Geist, M. Keller, M. Krantz, C. Schötz, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University

Metallic magnetic calorimeters (MMCs) are energy dispersive X-ray detectors which have a very good energy resolution, a large dynamic range as well as an excellent linearity. An MMC operates at millikelvin temperatures and converts the energy of an incoming particle into a rise of temperature of an absorber and an attached paramagnetic temperature sensor. The resulting change of sensor magnetization is read out by a SQUID and serves as a measure for the energy input.

One of our goals is the development of large detector arrays to provide a large detection area for low-rate applications, to cope with a significantly increased count rate or to provide imaging capabilities. For this, we have developed several medium-scale detector arrays which are optimized for x-rays up to 20, 30 and 200 keV, respectively. They have a resolving power $E/\Delta E$ above 1500 and are read out using individual dc-SQUIDs. To account for the readout of very large arrays with up to 1000 detectors, we develop a cryogenic frequency domain multiplexer which enables the readout of such large arrays using only one HEMT amplifier and two coaxial cables.

In this contribution we present our micro fabricated detector arrays and discuss their performance in the field of high resolution X-ray spectroscopy. In addition we show for the very first time a simultaneous readout of MMCs using our cryogenic multiplexer.

A 7.6 Mon 16:15 f107

Laser cooling of relativistic highly charged ions — •Danyal Winters[1], Tobias Beck[2], Gerhard Birkl[2], Oliver Boine-Frankenheim[1,2], Christina Dimopoulou[1], Lewin Eidam[1,2], Volker Hannen[3], Thomas Kühl[1,4,5], Matthias Lochmann[1,4], Markus Löser[6,7], Xinwen Ma[8], Fritz Nolden[1], Wilfried Nörtershäuser[1,2,4], Benjamin Rein[2], Rodolfo Sanchez[1], Ulrich Schramm[6,7], Mathias Siebold[6], Peter Spiller[1], Markus Steck[1], Thomas Stöhlker[1,5,9], Johannes Ullmann[2,5], Thomas Walther[2], Weiqiang Wen[6,8], Jie Yang[8], Dacheng Zhang[8], and Michael Bussmann[6] — [1]GSI Helmholtzzentrum Darmstadt — [2]Technische Universität Darmstadt — [3]Universität Münster — [4]Universität Mainz — [5]Helmholtz Institut Jena — [6]Helmholtz-Zentrum Dresden-Rossendorf — [7]Technische Universität Dresden — [8]Institute of Modern Physics, Lanzhou, China — [9]Universität Jena

An overview of recent laser cooling activities with relativistic heavy ion beams at the ESR (GSI, Darmstadt, Germany) and the CSRe (IMP, Lanzhou, China) storage rings will be presented. Some of the latest results will be shown and new developments concerning xuv-detector systems and cw and pulsed laser systems will be addressed. Finally, plans for laser cooling at the future facility FAIR in Darmstadt will be described.