A 14: Highly Charged Ions

Time: Tuesday 14:30–16:15 Location: HS 20

A 14.1 Tue 14:30 HS 20

Investigations of highly charged ions with applications for optical frequency standards and metrology — •Hendrik Bekker[1], Alexander Windberger[1,2], Nicky Potters[1], Julian Rauch[1], Julian Berengut[3], Anastasia Borchevsky[4], and Jose R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Advanced Research Center for Nanolithography, Amsterdam — [3]University of New South Wales, Sydney — [4]Van Swinderen Institute for Particle Physics and Gravity, Groningen

Many highly charged ions (HCI) have been proposed for use in next generation optical clocks for metrology purposes. But for these HCI, theory is not capable of predicting the energy level structures to the precision required for laser spectroscopy [1,2]. Therefore, we investigated several of the proposed HCI, which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap. The wavelengths of subsequent fluorescence light were determined at the ppm-level using a grating spectrometer. We present our latest results for Ir^{17+}, which features transitions with extremely high sensitivity to variation of the fine-structure constant [2,3]. Furthermore, our latest results for Pr^{9+} and Pr^{10+} are discussed. All results are used to benchmark state-of-the-art atomic theory calculations. Our investigations aim to provide a deeper insight into the suitability for metrology of the proposed HCI, and to pave the way for future laser spectroscopy.

[1] J. C. Berengut *et al.*, Phys. Rev. Lett. 106, 210803 (2011)
[2] M. S. Safronova *et al.*, Phys. Rev. Lett. 113, 030801 (2014)
[3] A. Windberger *et al.*, Phys. Rev. Lett. 114, 150801 (2015)

A 14.2 Tue 14:45 HS 20

Status of the Penning-trap mass spectrometer PENTATRAP — •Alexander Rischka[1], José Ramón Crespo López-Urrutia[1], Sergey Eliseev[1], Pavel Filianin[1], Yuri Novikov[2], Rima Schüssler[1], Christoph Schweiger[1], Sven Sturm[1], Stefan Ulmer[3], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Petersburg Nuclear Physics Institute,188300 Gatchina, Russia — [3]RIKEN, Ulmer Initiative Research Unit, Japan

The Penning-trap mass spectrometer PENTATRAP is currently in the commissioning phase at the Max-Planck-Institute for Nuclear Physics in Heidelberg. We are aiming at measurements of mass ratios using highly charged ions with a relative uncertainty of better than 10^{-11}. This allows, among others, contributions to neutrino physics research by a sub-eV measurement of the Q-value of the electron capture in ^{163}Ho. Furthermore, for a precession test of the energy-mass equivalence $E = mc^2$ and thus of special relativity, the mass difference of ^{35}Cl and ^{36}Cl and the sum of energies of the gamma-rays emitted after the neutron capture in ^{35}Cl are needed. The former will be measured at PENTATRAP and the latter - at ILL. To reach trapping times of weeks for highly charged ions and to perform a full characterization of the Penning-trap system in order to start first precision measurements, a major revision of the cryogenic setup and the ion transfer beamline is presently prepared and will be commissioned soon.

A 14.3 Tue 15:00 HS 20

Dielectronic-recombination processes in highly-charged heavy ions — •Alexander Borovik[1,2,3], Joan Dreiling[2], Roshani Silwal[2,4], Dipti Dipti[2], Endre Takács[2,4], John Gillaspy[2,5], Ramaz Lomsadze[3,6], Vladimir Ovsyannikov[3], Kurt Huber[3], and Alfred Müller[3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Quantum Measurement Division, National Institute of Standards and Technology, Gaithersburg MD, USA — [3]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen — [4]Department of Physics and Astronomy, Clemson University, Clemson SC, USA — [5]Division of Physics, National Science Foundation, Arlington VA, USA — [6]Department of Physics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia

Dielectronic-recombination (DR) spectra of highly-charged W^{q+} and Ir^{q+} ions have been measured by employing the Electron-Beam Ion Trap (EBIT) at National Institute of standards and Technology [1] and the Main Magnetic Focus Ion Trap (MaMFIT) [2] at Justus-Liebig Universität Gießen, respectively, over wide ranges of electron-beam energies. A series of DR resonances involving transitions between $2l \to 3l'$ and $2l \to 4l'$ subshells in Na-like through Ar-like tungsten have been revealed in the NIST EBIT spectra, while in the MaMFIT, DR resonances involving transitions between $2l \to 3l'$ subshells in K-like through Ni-like iridium were seen. Detailed modeling of the observed spectra has been performed. [1] J. D. Gillaspy, AIP Conf. Proc. 1438 (2012) 97. [2] V. P. Ovsyannikov, arXiv:1403.2168 (2014)

A 14.4 Tue 15:15 HS 20

A superconducting resonator-driven linear radio-frequency trap for long-time storage of highly charged ions — •Julian Stark[1], Lisa Schmöger[1,2], Andrii Borodin[1], Janko Nauta[1], Dieter Liebert[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Cold, strongly localized highly charged ions (HCIs) are particularly interesting candidates for novel frequency standards at a potential 10^{-19} level of relative accuracy and the search for possible variations of fundamental constants. Motional cooling of HCIs down to the mK range can be achieved by sympathetic cooling with directly laser-cooled Be^+ ions inside a cryogenic linear radio-frequency (RF) Paul trap [1,2]. For a stable localization of the trapped ions a high voltage RF field with low noise is required. Here, a novel superconducting RF resonator design with integrated Paul trap electrodes is presented. The high quality factor Q of the resonator will drastically reduce Paul trap heating rates as well as improve the overall stability of the trapping conditions. A normal-conducting prototype is currently being commissioned. First measurements yield a quality factor of 5816(23) at a resonance frequency of 29.772(4) MHz. In the superconducting version a much higher Q value will render electrodynamical losses of trapped ions negligible. This will enable precise localization of HCIs which is needed for high precision laser spectroscopy.

[1] M. Schwarz et al., Rev. Sci. Instrum. 83, 083115 (2012)
[2] L. Schmöger et al., Science 347, 6227 (2015)

A 14.5 Tue 15:30 HS 20

A novel off-axis gun for electron beam ion traps — •Steffen Kühn[1], Sven Bernitt[1,2], Thore M. Bücking[1], André Cieluch[1], Peter Micke[1,3], Thomas Stöhlker[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität Jena, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

In an electron beam ion trap (EBIT) highly charged ions (HCIs) are produced using an electron beam compressed to very high densities, which sequentially ionizes atoms. EBITs usually employ on-axis electron guns blocking the view along the trap axis. This can constitute a limitation for certain applications like laser spectroscopy where the photon beam is lost hitting the gun. A novel off-axis gun (OAG) was built with the cathode displaced from the central axis, which is therefore free of any obstacles and the photon beam is available for further experiments downstream. One of the envisaged applications is using HCIs as a new in situ calibration standard for high energy photon beams as provided e.g. by synchrotrons. First performance checks in a compact 0.86 T permanent magnet EBIT have shown stable operation with a 20 mA electron beam and up to 10 keV beam energy.

A 14.6 Tue 15:45 HS 20

Compact 0.86 T room-temperature electron beam ion traps — •Peter Micke[1,2], Sven Bernitt[1,3], Klaus Blaum[1], Lisa F. Buchauer[1], Thore M. Bücking[1], André Cieluch[1], Alexander Egl[1], James Harries[4], Steven A. King[2], Sandro Kraemer[1], Steffen Kühn[1], Tobias Leopold[2], Janko Nauta[1], Thomas Pfeifer[1], Lisa Schmöger[1,2], Rima X. Schüssler[1], Christoph Schweiger[1], Julian Stark[1], Thomas Stöhlker[3], Sven Sturm[1], Joachim Ullrich[2], Robert Wolf[1], Piet O. Schmidt[2,5], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Friedrich-Schiller-Universität Jena — [4]SPring-8, Hyogo, Japan — [5]Leibniz Universität Hannover

To facilitate accessibility to highly charged ions (HCI) for a wider physics community we have developed a novel type of high-performance room-temperature electron beam ion trap (EBIT). It is based on permanent magnets featuring low-maintenance operation. HCIs are bred and trapped by an electron beam, compressed by the strong, inhomogeneous magnetic field. A protoype proved successful operation and provided a 100 pA continuous beam of Xe ions and charge states of up to 36+ with a 4.6 mA 3 keV electron beam. A second generation of three more EBITs is under commissioning to supply HCIs for precision measurements in Paul and Penning traps as well as X-ray spectroscopy using synchrotron radiation and free-electron lasers. With a magnetic field of 0.86 T, stable operation of a 50 mA electron beam at 1.7 keV was demonstrated.

A 14.7 Tue 16:00 HS 20

Recent laser cooling and laser spectroscopy experiments at the ESR — •Danyal Winters[1], Oliver Boine-Frankenheim[1,2], Axel Buss[3], Christian Egelkamp[3], Lewin Eidam[2], Volker Hannen[3], Zhongkui Huang[4], Daniel Kiefer[2], Sebastian Klammes[2], Thomas Kühl[1,5], Markus Löser[6,7], Xinwen Ma[4], Fritz Nolden[1], Wilfried Nörtershäuser[2], Rodolfo Sanchez Alarcon[1], Ulrich Schramm[6,7], Mathias Siebold[6], Markus Steck[1], Thomas Stöhlker[1,5,8], Johannes Ullmann[2,8], Thomas Walther[2], Hanbing Wang[4], Weiqiang Wen[4], Christian Weinheimer[3], Daniel Winzen[3], and Michael Bussmann[6] — [1]GSI Darmstadt — [2]TU-Darmstadt — [3]Uni Münster — [4]IMP Lanzhou — [5]HI-Jena — [6]HZDR Dresden — [7]TU-Dresden — [8]Uni-Jena

Laser cooling is one of the most promising techniques for ion beam cooling at high energies. The fluorescence emitted during the cooling process can be used for both optical beam diagnostics and precision spectroscopy. We present results on experiments with $^{12}C^{3+}$ beams (122 MeV/u) stored in the experimental storage ring (ESR) in Darmstadt, Germany. To excite the cooling transition, a pulsed laser system with a high repetition rate, and a wide-scanning cw laser system have been used. To detect the fluorescence, a novel XUV detector system, installed inside the vacuum of the ESR, was used. We will present the experimental setup and preliminary data on the interaction of the lasers with the ion beam, and discuss it in the light of future experiments at the high-energy storage rings of FAIR in Germany and HIAF in China.