A 22: Highly charged ions and their applications

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 22.1 Wed 16:15 S Fobau Physik

A Single Particle Scintillation Detector for Recombination Experiments at CRYRING@ESR — •Esther Babette Menz[1,3], Christoph Hahn[1,2,3], Michael Lestinsky[2], Philip Pfäfflein[1,2,3], Felix Kröger[1,3], Uwe Spillmann[2], Anton Kalinin[2,4], Jan Glorius[2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz-Institut Jena, 07743 Jena — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt — [3]Friedrich-Schiller-Universität Jena, 07743 Jena — [4]Goethe-Universität Frankfurt, 60323 Frankfurt am Main

A YAP:Ce scintillation detector for counting beamlike reaction products has been installed and tested at the CRYRING@ESR heavy ion storage ring at GSI. YAP:Ce is a durable and non-hygroscopic crystal that is bakeable to a certain degree and is thus suitable for installation directly in the ultrahigh vacuum of the storage ring. The detector system is intended for observation of electron-ion recombination in the electron cooler section of CRYRING@ESR. Electron capture by the orbiting ions causes only a minimal change to their momentum but the resulting reduced charge state means that they diverge from the closed orbit at the next downstream dipole magnet. The scintillator can be moved into the path of the respective product beam for the given initial-to-final charge-state ratio and measure with an efficiency of nearly 100% in single-particle counting mode. The setup will be used for e.g. dielectronic recombination and 1s Lamb shift measurements on slow, heavy, highly-charged ions of all species the GSI accelerator complex is able to produce and transport through ESR.

A 22.2 Wed 16:15 S Fobau Physik

The impact of dielectronic recombination on the charge state distribution at REXEBIS — •Hannes Pahl[1,2], Niels Bidault[1,3], and Fredrik Wenander[1] — [1]CERN, 1211 Geneva 23, Switzerland — [2]Universität Heidelberg, 69120 Heidelberg, Germany — [3]INFN & Sapienza University of Rome, 00185 Rome, Italy

In an electron beam ion source, charge breeding is primarily achieved through successive electron impact ionisation. During this process, it is possible to selectively increase the recombination rate for a given charge state by adjusting the electron beam energy such that it matches the resonance energy of a Dielectronic Recombination (DR) transition. This inhibits the breeding into higher charge states and causes a shift of the charge state distribution of the extracted ion beam. This study addresses the significance of DR for the operation of a charge breeder and the question whether this effect can be exploited to actively improve the charge breeding selectivity. We have performed simulations and measurements using REXEBIS at ISOLDE for the example of highly charged potassium ions (12+ to 17+). The preliminary results show a good agreement between the theoretical predictions and the measured charge state distribution and suggest that the impact of DR depends strongly on the ion species and the electron beam parameters. We conclude that DR can be of operational interest and potentially serve as a diagnostic mechanism in special cases.

A 22.3 Wed 16:15 S Fobau Physik

Status of the free-electron target for CRYRING@ESR — Carsten Brandau[1,2], Alexander Borovik Jr[1], •B. Michel Döhring[1,2], Benjamin Ebinger[1,2], Alfred Müller[1], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt (Germany)

The anti-proton and heavy-ion accelerator facility FAIR which is currently under construction in Darmstadt will provide excellent conditions for novel investigations in atomic physics. One of the first operational devices will be the storage ring CRYRING@ESR [1], where we will install a transverse free-electron target for electron-ion crossed-beams in-ring experiments. Such a crossed-beams setup has never been realised at a heavy-ion storage ring before. The transverse target is based on an earlier development in Gießen [2] and will be commissioned at a test bench there soon. A multi-electrode assembly is used that controls beam parameters such as beam size, electron density, and electron energy. The target is envisaged for electron energies up to 12.5 keV and will reach electron densities of up to 10^9 cm^{-3} electron density. The present status of the project will be presented.

[1] M. Lestinsky et al., 2016 Eur. Phys. J. ST 225 797.
[2] B. Ebinger et al., 2017 Nucl. Instrum. Meth. B 408 317.

A 22.4 Wed 16:15 S Fobau Physik

Development of a stabilized laser system for Raman sideband cooling of ^{9}Be$^+$ atoms — •Lena Haaga, Julian Stark, Sandra Bogen, Christian Warnecke, Lukas Spiess, Lisa Schmöger, and José R. Crespo López-Urrutia — Max-Planck-Institut, Heidelberg, Deutschland

Forbidden optical transitions in highly charged ions (HCIs) are less sensitive to external influences than state-of-the-art atomic transitions used for metrology [1]. Also, they are promising candidates to probe physics beyond the Standard Model, as they feature an enhanced sensitivity to variation of fundamental constants [2]. As HCIs lack suitable optical transitions they cannot be laser-cooled directly. Thus, co-trapped laser-cooled ^{9}Be$^+$ ions are used for sympathetic cooling in a cryogenic Paul trap [3]. To reach Temperatures beyond the Doppler limit, sideband cooling using a Raman transition at 313 nm is applied, transferring the HCIs and ^{9}Be$^+$ to their motional ground state [4]. We present the design of this Raman laser setup based on [5], where light at 626 nm is frequency doubled to 313 nm and then shifted to the motional sidebands of the trapped ions by passing acousto-optic modulators.

[1] V.A. Dzuba et al., Phys. Rev. A 86, 054502 (2012)
[2] J.C. Berengut et al., Phys. Rev. Lett. 106, 210802 (2011)
[3] L. Schmöger et al., Rev. Sci. Instrum. 86, 103111 (2015)
[4] D.J. Wineland et al., Phys. Rev. A 20, 1521 (1979)
[5] A.C. Wilson et al., Appl. Phys. B 105, 741 (2011)

A 22.5 Wed 16:15 S Fobau Physik

UV laser systems for sympathetic cooling of highly charged ions using ^{9}Be$^+$ — •Sandra Bogen, Julian Stark, Lukas Spiess, Lisa Schmöger, Lena Haaga, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Narrow optical transitions in highly charged ions (HCI) are promising candidates to search for physics beyond the Standard Model [1]. For the purpose of such high-precision experiments, the HCI need to be trapped and cooled. As HCI generally lack suitable optical transitions for laser cooling, sympathetic cooling with laser-cooled ^{9}Be$^+$ is employed [2]. In order to photo ionize ^{9}Be atoms, a laser at 235 nm based on [3] is used. It is generated by cavity-enhanced frequency doubling of a 940 nm diode laser twice, first using a PPKTP crystal and then a BBO crystal. This laser is resonant with the $2s^1S_0 - 2p^1P_1$ transition of the ^{9}Be atom, which is used for resonance-enhanced two-photon-ionization. The ^{9}Be$^+$ ions are Doppler-cooled via the $^2S_{1/2} -^2 P_{3/2}$ transition at 313 nm based on [4]. This laser is generated from two fiber lasers at 1051 nm and 1550 nm. By sum frequency generation inside a PPLN crystal, 626 nm light is produced, which subsequently is frequency doubled using cavity-enhanced second harmonic generation in a BBO crystal to generate the needed 313 nm light.

[1] M. G. Kozlov et al., arXiv:1803.06532 (2018)
[2] L. Schmöger et al., Science 347 (2015)
[3] H.-Y. Lo et al., Appl. Phys. B, 114:17-25 (2014)
[4] A.C. Wilson et al., Appl. Phys. B 105:741-748 (2011)

A 22.6 Wed 16:15 S Fobau Physik

CryPTEx II: A superconducting radio-frequency trap for long-time storage of highly charged ions — •Julian Stark[1], Sandra Bogen[1], Lena Haaga[1], Steffen Kühn[1], Christian Warnecke[1], Steven A. King[2], Tobias Leopold[2], Peter Micke[2], Janko Nauta[1], Jan-Hendrik Ölmann[1], Lisa Schmöger[1], Lukas Spiess[1], Thomas Pfeifer[1], Piet O. Schmidt[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundeanstalt, Braunschweig, Germany

Cold highly charged ions (HCI) are excellent candidates for the development of novel optical clocks and will serve for stringent tests of the constancy of natural constants, as they feature narrow optical transitions with an enhanced sensitivity to a possible variation of the fine-structure constant or of the proton-to-electron mass ratio [1,2]. At the cryogenic Paul trap experiment (CryPTEx), a broad range of HCI can be trapped and sympathetically cooled down to the mK range

by laser-cooled Be^+ ions, which allows for high-precision laser spectroscopy. Here, we present the commissioning of the successor experiment, CryPTEx II, which features a novel superconducting quadrupole resonator to confine ions in extremely stable radio-frequency potentials. Furthermore, in order to increase the storage times of cold HCI, a low-vibration cryogenic system was developed in collaboration with the QUEST institute at PTB in Braunschweig.

[1] J. C. Berengut et al., Phys. Rev. Lett. 106, 210802 (2011)
[2] M. G. Kozlov et al., arXiv:1803.06532 (2018)

A 22.7 Wed 16:15 S Fobau Physik

Imaging of Coulomb crystals in a cryogenic Paul trap experiment — •Christian Warnecke, Julian Stark, Sandra Bogen, Lena Haaga, Alexander Ackermann, Steffen Kühn, Janko Nauta, Jan-Hendrik Ölmann, Michael Karl Rosner, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Cold highly charged ions (HCI) are proposed to be excellent candidates for tests of Standard Model extensions as they feature low susceptibility to external influences and give access to narrow optical transitions, which are not only highly sensitive to possible variations of fundamental constants, but also to non-linearities in isotope shifts. At the Cryogenic Paul Trap Experiment CryPTEx, built at the Max-Planck-Institute for Nuclear Physics, a broad range of HCI can be trapped and sympathetically cooled by laser-cooled Be^+ Coulomb crystals, which reduces their temperature by eight orders of magnitude down to 10 mK. Its follow-up experiment CryPTEx II includes a novel, superconducting quadrupole resonator that allows for an ion confinement with extremely stable radio-frequency potentials and for higher storage times and decreased heating rates than now. We have designed an objective covering a 500 micron field of view with a solid angle of 0.379 sr at a working distance of 57 mm to image the trapped ions. Our optics is optimized to transmit wavelengths of 235, 313 and 445 nm. We discuss our design and present first commissioning results.