A 13: Highly Charged Ions and their Applications I

Time: Wednesday 11:00–13:00 Location: F107

Invited Talk A 13.1 Wed 11:00 F107
Stability and Melting Dynamics of Mixed Species Coulomb Crystals with Highly Charged Ions — •Luca Rüffert[1], Elwin Dijck[2], Tanja Mehlstäubler[1], and José Crespo[2] — [1]Bundesallee 100, 38116 Braunschweig — [2]Saupfercheckweg 1, 69117 Heidelberg

Coulomb Crystals of various ionic species confined by a Paul trap are being used in a variety of different applications spanning from high precision spectroscopy to quantum information processing. In particular, multi-ion atomic clocks could offer increased precision and mixed crystals with highly charged ions enable the use of quantum logic operations. Pick up of electric field noise and insufficient cooling can cause those crystals to heat up and affect the systems stability in a negative way to the point of angular or radial melting. Investigating the melting dynamics of mixed species crystals aids in finding robust operating parameters to mitigate heating effects.

In collaboration between PTB Braunschweig and MPIK we are using highly charged ions implanted in Be+ ion crystals of various sizes to analyze the effects of those highly charged ions (HiCIs) on the structural stability of ion coulomb crystals (ICCs). By running Monte Carlo simulations and directly compare them to the experiment, our goal is to show how the inclusion of HiCIs inside an ICC can enhance the stability and therefore increase the melting temperature of those systems. In addition varying the charge state of the highly charged ion allows to investigate the effect of differing charge-to-mass ratios. I will present the current state of our research and discuss the different criterions for the melting of ICCs.

A 13.2 Wed 11:30 F107
Scaling relations for hydrogen-like ions in intense laser fields in the quasi-static regime — •Anvar Khujakulov and Alejandro Saenz — Newtonstraße 15, 12489 Berlin

With the availability of light sources with extreme intensities, the understanding of the behaviour of matter exposed to such light fields is of great interest. The full solution of the time-dependent Dirac equation is, however, even for the simlest system, hydrogen-like ions exposed to such light sources, prohibitively difficult. On the other hand, for highly charged ions even when exposed to intense x-rays, ionization usually occurs in the so-called quasi-static regime where the initially bound electron follows adiabatically the time variation of the electric-field component. Therefore, a systematic investigation of the ionization behaviour in the static limit was performed. Approximate scaling relations were found that allow for the prediction of the ionization rate of a highly charged ion exposed to an intense field based on the results of a lighter ion exposed to a weak field. Most importanly, a scaling relation is found that allows for obtaining results in very good agreement with the Dirac equation from the solution of a scaled Schröodinger-equation. The results should be useful for plasma simulations, the design of experiments, the isolation of relativistic effects, or the calibration of light sources with extreme peak intensities.

A 13.3 Wed 11:45 F107
Highly Efficient Dynamic Capture of Ion Bunches into a Penning Trap for high-intensity Laser Experiments — •Markus Kiffer[1], Stefan Ringleb[1], Sugam Kumar[3], Manuel Vogel[2], Gerhard Paulus[1], Wolfgang Quint[2,5], and Thomas Stöhlker[1,2,4] — [1]Friedrich-Schiller-Universität, Jena — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [3]Inter-University Accelerator Centre, New Delhi — [4]Helmholtz-Institut Jena, Jena — [5]Ruprecht Karls-Universität Heidelberg, Heidelberg

Highly-charged ions are an ideal candidate to investigate matter-light interactions. In particular, hydrogen-like systems provide a single active electron in a well-defined 1s state. For ions, such as O^{7+} or Ne^{9+}, the mean electric field intensity of the nucleus is on the order of 10^{20} W/cm^2, which is in the range of high-intensity laser systems. This presents the opportunity to measure relativistic tunnel ionisation or HHG generation in highly charged ions.

We present the status of the HILITE (High-Intensity Laser Ion-Trap Experiment) Penning trap experiment. HILTE provides a well-defined ion target for experiments at external laser facilities. The setup includes an ion source that creates bunches of various ions species. These bunches are transported by a beamline and captured dynamically into a Penning trap. We will show results of highly efficient ion bunch capture as well as ion cloud manipulation techniques to provide a high-density ion target. We will also introduce the scientific case of our next planned beamtime at the JETI200 laser facility in Jena.

A 13.4 Wed 12:00 F107
Laser cooling of bunched relativistic ion beams at the FAIR SIS100 — •Sebastian Klammes[1], Michael Bussmann[2,3], Jens Gumm[4], Volker Hannen[5], Thomas Kühl[1,6], Benedikt Langfeld[4], Ulrich Schramm[2,7], Mathias Siebold[2], Peter Spiller[1], Thomas Stöhlker[1,6,8], Ken Ueberholz[5], Thomas Walther[4,9], and Danyal Winters[1] — [1]GSI Darmstadt — [2]HZDR Dresden — [3]CASUS Görlitz — [4]TU-Darmstadt — [5]Uni Münster — [6]HI-Jena — [7]TU-Dresden — [8]Uni-Jena — [9]HFHF Frankfurt am Main

The heavy-ion synchrotron SIS100 is the core machine of the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. It is capable of accelerating a large range of ions, which will be produced by the upgraded GSI facility, up to highly relativistic velocities and extracting them for unique experiments, e.g. APPA/SPARC. In order to cool such intense beams of heavy highly charged ions, laser cooling of bunched ion beams was preferred. Therefore, laser beams from three complementary laser systems (cw and pulsed) will be superimposed in time, space and frequency to interact simultaneously with a very broad ion velocity range to maximize the cooling efficiency at the SIS100. With the construction of the synchrotron, the laser cooling pilot facility at SIS100, being also the only in-ring experiment, is currently being realized. We will present this project, give an update of its current status and also give an overview of the laser and detector systems that will be used.

A 13.5 Wed 12:15 F107
Broadband laser cooling of stored relativistic bunched ion beams at the ESR — •Danyal Winters[1], Lars Bozyk[1], Michael Bussmann[2,3], Noah Eizenhöfer[4], Volker Hannen[5], Max Horst[4,9], Daniel Kiefer[4], Nils Kiefer[6], Sebastian Klammes[1], Thomas Kühl[1,7], Benedikt Langfeld[4,9], Xinwen Ma[8], Wilfried Nörtershäuser[4,9], Rodolfo Sánchez[1], Ulrich Schramm[2,10], Mathias Siebold[2], Peter Spiller[1], Markus Steck[1], Thomas Stöhlker[1,7,11], Ken Ueberholz[5], Thomas Walther[4,9], Hanbing Wang[8], Weiqiang Wen[8], and Daniel Winzen[5] — [1]GSI Darmstadt — [2]HZDR Dresden — [3]CASUS Görlitz — [4]TU Darmstadt — [5]Uni Münster — [6]Uni Kassel — [7]HI Jena — [8]IMP Lanzhou — [9]HFHF Darmstadt — [10]TU Dresden — [11]Uni-Jena

High-precision experiments at heavy-ion storage rings strongly benefit from cold ion beams, *i.e.* beams with a small longitudinal momentum spread and a small emittance. Especially for the higher ion intensities and Lorentz factors (γ) at FAIR (SIS100), laser cooling will be a powerful tool for cooling of relativistic bunched ion beams. The principle is based on resonant photon absorption (momentum & energy) in the longitudinal direction and subsequent spontaneous fluorescence (ion recoil) by the ions, combined with a moderate bunching of the ion beam. We will report on results from a 2021 laser cooling beamtime at the ESR. We could demonstrate - for the first time - broadband laser cooling of stored relativistic bunched ion beams, using a new pulsed UV laser system with a very high repetition rate (MHz), tunable pulse length, and high power.

A 13.6 Wed 12:30 F107
Towards electron cooling in the HITRAP cooling trap — •Simon Rausch[1,2], Max Horst[1,2], Zoran Andelkovic[3], Svetlana Fedotova[3], Wolfgang Geithner[3], Frank Herfurth[3], Dennis Neidherr[3], Wilfried Nörtershäuser[1,2], Nils Stallkamp[3,4], and Gleb Vorobyev[3] — [1]Institut für Kernphysik, TU Darmstadt, Schloßgartenstr. 9, Darmstadt — [2]Helmholtz Akademie Hessen für FAIR HFHF, Campus Darmstadt, Darmstadt — [3]GSI Helmholtzzentrum, Planckstr. 1, Darmstadt — [4]Institut für Kernphysik, JWGU Frankfurt, Max-von-Laue-Str. 9, Frankfurt a. M.

The HITRAP project at the GSI Helmholtzzentrum für Schwerionenforschung is designed to decelerate and cool heavy, highly charged ions. After deceleration to 6 keV/nucleon, the ion cloud can be captured within a Penning-Malmberg trap and cooled using electron cooling. For this, electrons and ions are stored simultaneously in a nested-trap configuration to enable energy transfer between them.

We present the current status of the HITRAP cooling trap and the next steps towards achieving electron cooling. We were able to capture several 10^5 highly charged Ar-ions, delivered by an EBIT at 4 keV/q. Simultaneously, about 10^9 electrons can be stored in the trap. Although the ions visibly effect the electron plasma, no cooling was observed so far. It was possible to detect ion motions, dependencies of ion properties on the storage time and to observe the space charge induced by the electron cloud. The next steps will include implementing additional detection methods in order to demonstrate electron cooling.

Funding by BMBF under contract 05P21RDFA1 is acknowledged.

A 13.7 Wed 12:45 F107

Cryogenic fast-opening valve at the ARTEMIS experiment at GSI in Darmstadt — •Bianca Reich[1,2], Khwaish Anjum[1,3], Patrick Baus[4], Gerhard Birkl[4], Manasa Chambath[1,5], Jan Hellmann[1,6], Kanika Kanika[1,2], Jeffrey Klimes[1,2], Arya Krishnan[1,4], Wolfgang Quint[1,2], Wolfgang Schott[1,7], and Manuel Vogel[1] — [1]GSI Helmholtz Center for Heavy Ion Research, Germany — [2]University of Heidelberg, Germany — [3]University of Jena, Germany — [4]Technical University of Darmstadt, Germany — [5]NITTE University, India — [6]University of Giessen, Germany — [7]Technical University of Munich, Germany

The ARTEMIS experiment at the HITRAP facility at GSI in Darmstadt aims to measure the g-factor of an electron bound to a highly charged ion by performing laser-microwave double-resonance spectroscopy. To separate the Penning trap at liquid-helium temperature to a room-temperature low-energy beamline for dynamic capture of externally produced ions a cryogenic fast-opening valve was conceived, built and implemented. The main advantage of the valve is the remote-controlled operation within sub-second times without disturbing the magnetic field of the trap. It keeps the ambient conditions inside the trap stable by effectively shielding heat radiation and separating the beamline vacuum with several 10^{-10} mbar from the cryogenic vacuum of the Penning trap with better than 10^{-16} mbar in a completely sealed state and better than 10^{-14} mbar when the valve is operated. Whereby the pressure inside the trap is estimated from the lifetime of the captures ions. The design and measurements will be presented.