A 12: Highly charged ions and their applications

Time: Tuesday 16:30–18:30 Location: P

A 12.1 Tue 16:30 P

Fundamental physics with highly charged ions — •Alexander Wilzewski[1], Lukas J. Spiess[1], Steven A. King[1], Peter Micke[1,2], Erik Benkler[1], Tobias Leopold[1], Michael K. Rosner[2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Max-Planck-Instituts für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Highly charged ions (HCIs) increase the number of optical transitions that can be probed with optical-clock-like accuracy, they are particularly interesting for isotope shift measurements and King plot analyses [1]. In our experiment, we extract HCIs from an electron-beam ion trap (EBIT) and transfer them through a beamline to a linear Paul trap where they are recaptured and sympathetically cooled by laser-cooled Be^+ ions. and We have subsequently performed quantum logic spectroscopy on a HCI-Be^+ two-ion crystal [2]. We are currently evaluating the systematic uncertainties of our $^{40}Ar^{13+}$ clock in order to determine the isotope shift between $^{40}Ar^{13+}$ and $^{36}Ar^{13+}$ with sub-Hz accuracy. Since Ca^{14+} offers many stable isotopes for a King plot analysis, we will extend the isotope shift measurements afterwards to this species, for which loading into an EBIT from a solid target was recently demonstrated, and a clock laser system is under construction.

[1] J. C. Berengut *et al.*, Phys. Rev. Research **2** (2020), [2] P. Micke *et al.*, Nature **578** (2020)

A 12.2 Tue 16:30 P

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

At heavy-ion storage rings, almost all experiments strongly benefit from cooled ion beams, i.e. beams which have a small longitudinal momentum spread and a small emittance. During the last two decades, laser cooling has proven to be a powerful tool for relativistic bunched ion beams, and its "effectiveness" is expected to increase further with the Lorentz factor (γ). The technique is based on resonant absorption (of photon momentum & energy) in the longitudinal direction and subsequent spontaneous random emission (fluorescence & ion recoil) by the ions, combined with moderate bunching of the ion beam. Laser cooling can also achieve a stronger and faster cooling than electron and stochastic cooling. We will report on recent (May 2021) preliminary results from a laser cooling test beamtime at the ESR at GSI in Darmstadt, Germany. We will also present our plans and progress for laser cooling experiments at FAIR (SIS100).

A 12.3 Tue 16:30 P

An Optical Clock based on a Highly Charged Ion — •Lukas J. Spiess[1], Steven A. King[1], Peter Micke[1,2], Alexander Wilzewski[1], Erik Benkler[1], Tobias Leopold[1], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

Highly charged ion (HCI) offer narrow transitions suitable for high-accuracy optical clocks with predicted uncertainties below 10^{-18}, since they are intrinsically less sensitive to external perturbations [1]. At the same time, the strongly relativistic character of the remaining electrons renders HCI particularly sensitive to physics beyond the Standard Model. Previously, we have demonstrated that a single HCI can be extracted from a hot plasma and injected into laser-cooled Be^+ ions. This allowed for the first demonstration of quantum logic spectroscopy using HCI and enabled high-precision spectroscopy [2].

Here, we will present optical-clock like interrogation of the 441 nm transition in Ar^{13+} and the evaluation of systematic shifts with an expected uncertainty of below 10^{-16} [3]. This is leading up to our absolute frequency measurement of Ar^{13+}, which will be the first time a transition in any HCI is measured with sub-Hz accuracy.

[1] M. G. Kozlov *et al.*, Rev. Mod. Phys. **90**, 045005 (2018)
[2] P. Micke *et al.*, Nature **578**, p. 60-65 (2020)
[3] S. A. King *et al.*, arXiv:2102.12427 (2021)

A 12.4 Tue 16:30 P

***g*-Factor Measurements of Heavy Highly Charged Ions in a Penning Trap** — •J. Morgner, C. M. König, T. Sailer, F. Heisse, B. Tu, V. A. Yerokhin, B. Sikora, Z. Harman, J. R. Crespo López-Urrutia, C. H. Keitel, S. Sturm, and K. Blaum — Max-Planck-Institute für Kernphysik, Saupfercheckweg 1, DE-69117 Heidelberg

Quantum electrodynamics (QED) has shown great success in describing microscopic systems, e.g. single ions. In low electromagnetic fields, QED has been tested with unprecedented high precision [1]. Therefore, it is especially interesting to test QED in extremely high fields by comparing theoretical and experimentally measured bound-electron g-factors of single ions. In extreme cases, e.g. $^{208}Pb^{81+}$, only a single electron is bound to the nucleus, which therefore experiences strong electric fields up to 10^{18} V/m. The Penning trap setup of ALPHATRAP is dedicated to measure these bound-electron g-factors in even the heaviest highly charged ion systems with a relative precision better than $1 \cdot 10^{-10}$ [2].
In this contribution, the status of a recent g-factor measurement of hydrogen-like and lithium-like ^{118}Sn is presented. This probes the bound-electron g-factor of heavy highly charged ions with a precision previously inaccessible. Further, progress on an electron beam ion trap is presented. In the future, this could provide ALPHATRAP with even heavier highly charged ion systems up to hydrogen-like lead.

[1] D. Hanneke *et al*, PRL **100**, 120801 (2008)
[2] S. Sturm *et al*, EPJ **227**, 1425*1491 (2019)

A 12.5 Tue 16:30 P

First DR experiments at CRYRING@ESR — •Esther Babette Menz[1,2,3], Michael Lestinsky[1], Sebastian Fuchs[4,5], Weronika Biela-Nowaczyk[6], Alexander Borovik Jr.[4], Carsten Brandau[1,4], Claude Krantz[1], Gleb Vorobyev[1], Bela Arndt[1], Alexandre Gumberidze[1], Pierre-Michel Hillenbrand[1], Tino Morgenroth[1,2,3], Ragandeep Singh Sidhu[1], Stefan Schippers[4,5], and Thomas Stöhlker[1,2,3] — [1]GSI, 64291 Darmstadt — [2]Helmholtz-Institut Jena, 07743 Jena — [3]IOQ, Friedrich-Schiller-Universität, 07743 Jena — [4]I. Phys. Institut, Justus-Liebig-Universität, 35390 Giessen — [5]Helmholtz Forschungsakademie Hessen für FAIR, Campus Giessen, 35392 Giessen — [6]Institute of Physics, Jagiellonian University, 31-007 Kraków, Poland

After its move from Stockholm to GSI, CRYRING@ESR is now back in operation with previously inaccessible ion species available from the accelerator complex as well as a smaller selection from a local injector. The first merged-beam DR measurements were performed at the CRYRING@ESR electron cooler and we will present the newly established particle detection and data acquisition setup and the results of DR measurements of astrophysically relevant neon ions in low charge states. A test run in May 2020 with Ne^{7+} from an ECR source was used to commission the setup and study electron beam temperatures. It demonstrated an undegraded resolution compared to previous measurements. It was followed up in May 2021 by a scheduled experiment on astrophysically relevant low-energy DR of Ne^{2+}.