A 4: Precision Spectroscopy I

Time: Monday 14:30–16:30 Location: N 3

Invited Talk A 4.1 Mon 14:30 N 3

Bound-electron g factor of highly charged ions — •Andrey Volotka — Helmholtz-Institut Jena, D-07743 Jena, Germany

In recent years, remarkable progress in experimental and theoretical investigations of the bound-electron g factor of highly charged ions has been achieved. In particular, it has led to the determination of the electron mass [1], tests of the many-electron QED [2] as well as relativistic recoil [3] effects. Here, we summarize recent results in theoretical calculations of the bound-electron g factor of H-, Li-, and B-like ions. Moreover, we discuss possibilities for investigations of nuclear and nonlinear effects as well as fine structure constant determination from g factors of heavy ions.

[1] S. Sturm et al., Nature **506**, 467 (2014)
[2] A. V. Volotka et al., Phys. Rev. Lett. **112**, 253004 (2014)
[3] F. Köhler et al., Nat. Commun. **7**, 10246 (2016)

A 4.2 Mon 15:00 N 3

A Laser Ion Source for the ALPHATRAP experiment — •Tim Sailer[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

The Penning-trap experiment ALPHATRAP, located at the Max-Planck-Institut für Kernphysik, aims to measure the g-factor of bound electrons in highly charged ions up to hydrogen-like $^{208}Pb^{81+}$. In the resulting electrical field strength of the order of 10^{16} V/cm bound-state quantum electrodynamics can be tested with highest precision in extreme conditions.

A Laser Ion Source (LIS) based on a pulsed Nd:YAG laser will be designed and built to produce $^{9}Be^{1+}$ ions, which will subsequently be laser cooled inside the trap using a 313nm laser system. Highly charged ions, which cannot be directly addressed by the laser, will be sympathetically cooled by the beryllium ions. This will enable measurements beyond the current thermal limits. The LIS will be attached to the existing beamline, allowing the external production and insertion of the $^{9}Be^{1+}$ ions into the trap as well as enabling easy adjustments such as target material switching for future uses.

A 4.3 Mon 15:15 N 3

The ALPHATRAP *g*-Factor Experiment — •Andreas Weigel[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Tim Sailer[1,2], Robert Wolf[1], José Ramon Crespo López-Urrutia[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg

The Penning-trap based experiment ALPHATRAP is currently in the commissioning phase at the Max-Planck-Institut für Kernphysik in Heidelberg. It is the follow-up to the Mainz g-factor experiment, which has performed the most sensitive test of bound-state quantum electrodynamics (BS-QED) by measuring the g-factor of the remaining electron bound in hydrogen-like $^{28}Si^{13+}$ at an uncertainty level of 10^{-11} [1]. ALPHATRAP aims for g-factor measurements on even heavier highly charged ions up to hydrogen-, lithium- and boron-like lead, with simultaneously improved accuracy. To achieve this, the ALPHATRAP experiment, consisting of an improved cryogenic double Penning-trap setup, is coupled via an ultra-high vacuum beamline to various ion-sources including the Heidelberg Electron-Beam Ion Trap. In combination with currently conducted BS-QED calculations, the measurements are expected to further contribute to the exploration of the limits of BS-QED and also aim for an independent determination of the fine-structure constant α. The current status of the project will be presented.

[1] S. Sturm et al., Phys. Rev. Lett. 107, 023002 (2011)

A 4.4 Mon 15:30 N 3

Towards Laser Cooling of Highly Charged Ions at the ALPHATRAP Experiment — •Sandro Kraemer[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

ALPHATRAP, a Penning-trap experiment currently being set up at the Max-Planck-Institut für Kernphysik, aims for a test of bound-state QED in very high field strengths by measuring the g-factor of highly charged ions (HCI) up to hydrogen-like $^{208}Pb^{81+}$. In existing systems the stored particles are cooled using resistive and electronic feedback cooling.

As a novel development, laser cooled beryllium ions will be used to sympathetically cool the HCIs stored in the same trap. A setup for laser cooling of Be^{+}-ions adressing the $^{2}S_{1/2} \leftrightarrow {}^{2}P_{3/2}$ transition at 313 nm is currently being developed. The lower achievable ion temperatures are expected to further increase the precision of the measurement. Additionally, new measurement schemes, such as simultaneous g-factor measurements on Coulomb crystallized ion pairs, become possible.

The laser system and the coupling into the trap will be discussed, and a current status of the project will be given.

A 4.5 Mon 15:45 N 3

Development of a Modified-Cyclotron Detection System for Resistively Cooling a Single Trapped Antiproton — •James Harrington[1,2], Mustafa Besirli[2], Matthias Borchert[2,4], Takashi Higuchi[2,5], Hiroki Nagahama[2,5], Stefan Sellner[2], Christian Smorra[2,3], Toya Tanaka[2,5], Matthew Bohman[1,2], Andreas Mooser[2], Georg Schneider[6,2], Natalie Schön[6], Klaus Blaum[1], Yasuyuki Matsuda[5], Christian Ospelkaus[4,7], Wolfgang Quint[8], Jochen Walz[6,9], Yasunori Yamazaki[10], and Stefan Ulmer[2] — [1]Max-Planck-Institut für Kernphysik, Germany — [2]Ulmer Initiative Research Unit RIKEN, Wako, Japan — [3]CERN, Geneva, Switzerland — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [5]Graduate School of Arts and Sciences, University of Tokyo, Japan — [6]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [7]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [8]GSI-Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [9]Helmholtz-Institut Mainz, Germany — [10]Atomic Physics Laboratory RIKEN, Wako, Japan

The development of an improved tuned circuit, for resistively cooling the modified-cyclotron mode of a single trapped antiproton, is described. Efficient cooling of the radial modified-cyclotron mode is of the utmost importance when performing single particle spin quantum-transition spectroscopy in Penning traps. This is because at low modified-cyclotron quantum states the radial heating rates are small, which improves axial frequency stability. This is necessary to improve the spin-flip identification fidelity, which is crucial for our planned high-precision measurement of the antiproton g-factor. This system has been developed as an upgrade for the BASE experiment, located at CERN's antiproton decelerator facility.

The instrument consists of a helical superconducting coil inside of a cylindrical copper shield which produces an unloaded Q-value on the order of 15000 at 29.774 MHz. When connected to the trap and active-amplifier electronics, a cooling time constant of $\tau \approx 18$ s is achieved – a 17-fold improvement compared to the resistive damping system currently used in the experiment.

A 4.6 Mon 16:00 N 3

Proof of concept of Precise High Voltage measurements by collinear laser spectroscopy — •Tim Ratajczyk[1], Kristian König[1], Christopher Geppert[2], Phillip Imgram[1], Bernhard Maass[1], Ernst Otten[3], Johannes Ullmann[1], Jörg Krämer[1], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [3]Institut für Physik, Johannes Gutenberg Universität Mainz

The ALIVE experiment at the TU Darmstadt is a new collinear laser spectroscopy setup. The goal of the experiment is the measurement of high voltages in the range of 10 to 100 kV using precise laser spectroscopy of ions with a well-known transition frequency as it has been suggested in [1]. The aim is to achieve an accuracy of 1 ppm, which is of interest for many applications.

First measurements have been performed to test collinear laser spectroscopy with a new two chamber approach as a high voltage standard. To show the feasibility of this concept the well-known 4s1/2 -> 4p3/2 transition of 40Ca+ was used to mark a velocity class with a narrow bandwidth laser, as the multiply excited ions decay into the meta stable 3d5/2 state. The marked ions are accelerated by the unknown static high voltage and can be probed by re-exciting them from the 3d5/2 state. The shift of the resonance frequency introduced by the Doppler effect is then used to refer the high-voltage measurement to a high accuracy frequency measurement. First results will be presented.

[1] O. Poulsen, Nuclear Instruments & Methods in Physics Research 202 (1982) 503.

A 4.7 Mon 16:15 N 3

Determination of ground-state hyperfine splitting energies in $Bi^{80+,82+}$ ions to test QED — •Johannes Ullmann[1,2], Zoran Andelkovic[3], Carsten Brandau[3,11], Andreas Dax[8], Wolfgang Geithner[3], Christopher Geppert[2], Christian Gorges[2], Michael Hammen[5,7], Volker Hannen[4], Kristian König[3], Simon Kaufmann[2], Yuri Litvinov[3], Matthias Lochmann[2], Bernhard Maass[2,3], Johann Meisner[6], Tobias Murböck[10], Rodolfo Sánchez[3], Stefan Schmidt[2,7], Matthias Schmidt[6], Markus Steck[3], Thomas Stöhlker[1,3], Richard C. Thompson[9], Christian Trageser[11], Jonas Vollbrecht[4], Christian Weinheimer[4], and Wilfried Nörtershäuser[2] — [1]Helmholtz Inst. Jena — [2]Inst. f. Kernphysik, TU Darmstadt — [3]GSI Darmstadt — [4]Inst. f. Kernphysik, Uni Münster — [5]Helmholtz Inst. Mainz — [6]PTB Braunschweig — [7]Inst. f. Kernchemie, Uni Mainz — [8]PSI, Villigen, Switzerland — [9]Imperial College London, UK — [10]Inst. f. Angew. Physik, TU Darmstadt — [11]I. Phys. Institut, Uni Gießen

The measurement of the ground state hyperfine splittings in Bi^{82+} and Bi^{80+} ions tests the theory of bound-state quantum electrodynamics (QED) in the strong field of the nucleus. Precise theoretical predictions use a specific difference of both splitting energies to cancel the large uncertainty of nuclear contributions. In the recent laser spectroscopy beamtime at the storage ring ESR at GSI Darmstadt, we reduced the largest experimental uncertainty by an order of magnitude. Systematic effects will be discussed and we will present the first high precision value of the specific difference, which deviates significantly from theory.