A 1: Precision spectroscopy of atoms and ions I (with Q)

Time: Monday 11:30–13:15 Location: C/HSW

A 1.1 Mon 11:30 C/HSW

The Detection System of the ALPHATRAP Experiment — •Andreas Weigel, Robert Wolf, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The Penning-trap experiment ALPHATRAP is currently being set up at the Max-Planck-Institut für Kernphysik in Heidelberg. It is the follow-up to the Mainz g-factor experiment, which has recently succeeded in the most stringent test of quantum electrodynamics in the regime of strong fields on hydrogen-like $^{28}Si^{13+}$ at the level of 10^{-11}. ALPHATRAP aims for g-factor measurements on even heavier highly charged ions up to $^{208}Pb^{81+}$, with simultaneously improved accuracy. This shall further contribute to the exploration of the limits of bound-state quantum electrodynamics.

The determination of the g-factor is based on the non-destructive determination of the electron spin state inside a magnetic bottle via the continuous Stern-Gerlach effect. For this purpose the ion eigenfrequencies have to be measured via the detection of image currents, which the ion induces into the trap electrodes. These currents are typically on the order of a few femto-Ampère. Therefore, special highly sensitive detection electronics consisting of superconducting tank circuits with extremely high Q-factors followed by ultra-low noise cryogenic amplifiers will be used. This shall allow for a higher signal-to-noise ratio resulting in an increased measurement precision. The ALPHATRAP detection system and electronics design will be presented.

A 1.2 Mon 11:45 C/HSW

Isotope shifts of $^{40,42,44,48}Ca^+$ in the $4s_{1/2} \rightarrow 4p_{3/2}$ transition measured at TRIGA-LASER — •Christian Gorges for the TRIGA-SPEC-Collaboration — Institut für Kernphysik, TU Darmstadt

The TRIGA-LASER experiment at the TRIGA research reactor in Mainz is a collinear laser spectroscopy setup [1]. It is a prototype for the LaSpec-Experiment at FAIR [2] and will first be used to investigate short-lived radioactive isotopes which are produced by neutron induced fission of ^{235}U, ^{239}Pu or ^{249}Cf in the TRIGA reactor. For commissioning, we have measured the isotope shifts of the stable calcium isotopes $^{40,42,44,48}Ca$ in the $4s_{1/2} \rightarrow 4p_{1/2,3/2}$ transitions. This was motivated by the relatively large uncertainty of the isotope shifts in the $4s_{1/2} \rightarrow 4p_{3/2}$ transition, which are needed as reference for recent measurements of exotic short-lived $^{49-52}Ca$ at COLLAPS (collinear laser spectroscopy at Isolde-CERN). Using precise isotope shifts in the $4s_{1/2} \rightarrow 4p_{1/2}$ transition from trap measurements for voltage calibration, we were able to reduce the uncertainties in this transition considerably.

[1] J. Ketelaer et al., Nucl. Instr. Meth. A 594, 162 (2008)

[2] D. Rodriguez et al., Eur. Phys. J. Special Topics 183, 1-123 (2010)

A 1.3 Mon 12:00 C/HSW

Determination of ground-state hyperfine splitting energies in highly charged bismuth ions — •Johannes Ullmann für die LIBELLE-Kollaboration — Institut für Kernphysik, Technische Universität Darmstadt, Germany — Helmholtz Institut Jena, Germany

While quantum electrodynamics (QED) is usually referred to as the most accurately tested theory, its consistency for bound electrons in strong fields is still to be tested more rigourosly. The strongest static magnetic fields available in the laboratory are experienced by ground-state electrons of highly charged, heavy ions which can be probed by hyperfine transition spectroscopy.

The transition in Li-like Bismuth was directly observed for the first time in 2011 at the experimental storage ring ESR located at GSI Darmstadt, the major improvement being an optimized detection system collecting the Doppler-shifted photons. Yet the accuracy of the result was limited by the calibration of the electron cooler voltage, determining the ion velocity which is required to transform the measured transition wavelength to the rest frame of the ion. We were able to reduce the uncertainties in nearly all experimental parameters in a second beamtime at the ESR in 2014. The continuous in-situ measurement of the electron cooler voltage using a precise high voltage divider provided by the Physikalisch-Technische Bundesanstalt minimized the main uncertainty of 2011. We will present results of the transition wavelength in H-like and Li-like ions and discuss the relevance for a test of strong-field bound-state QED.

A 1.4 Mon 12:15 C/HSW

ALIVE - Measuring High Voltage with ppm Accuracy using Collinear Laser Spectroscopy — •Jörg Krämer[1], Kristian König[1], Wilfried Nörtershäuser[1], Christopher Geppert[2], Ernst W. Otten[3], and Johannes Ullmann[1] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]Institut für Kernchemie, Universität Mainz — [3]Institut für Physik, Universität Mainz

Collinear laser spectroscopy has widely been used for the determination of nuclear properties like spins, moments and charge radii in radioactive beam facilities world wide. To extract these properties from the hyperfine structure of atoms, knowledge of the acceleration voltage is essential which is measured using classical voltage dividers.

In our experiment we will use the inverse approach: We will probe ions with well-known properties and by calculating the actual Doppler shift of the transition frequency, we can determine the high voltage that was used to accelerate the ions. With our two-chamber approach we envisage to reach an accuracy of <1 ppm which would exceed the performance of state-of-the-art high accuracy high voltage dividers.

We will present the basic outline of the experiment with the two-chamber pump/probe scheme and give a status update.

A 1.5 Mon 12:30 C/HSW

Cold highly charged ions for novel optical clocks and the search for α variation — •Lisa Schmöger[1,2], Oscar O. Versolato[1,2], Maria Schwarz[1,2], Matthias Kohnen[2], Tobias Leopold[2], Stefanie Feuchtenbeiner[1], Baptist Piest[1], Alexander Windberger[1], Joachim Ullrich[2], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Physikalisch-Technische Bundesanstalt — [3]Institut für Quantenoptik, Leibniz Universität Hannover

Optical forbidden transitions in highly charged ions (HCIs) are both insensitive to external perturbations and extremely sensitive to possible drifts of the fine structure constant α. Thus, cold, strongly localized HCIs are of particular interest for the development of novel optical clocks and the search for a possible α variation. We have recently succeeded in the first preparation of Coulomb crystallized ultra-cold HCIs through sympathetic cooling in a cryogenic linear Paul trap. The ions (Ar^{13+}) produced in and extracted from an electron beam ion trap (EBIT) are decelerated and pre-cooled by means of two serrated and interlaced pulsed drift tubes before they are injected into the Paul trap. Subsequently, they are forced to interact multiple times with a Coulomb crystal of laser-cooled Be+ ions before they lose enough energy to become implanted in it and thermalize close to the Be+ crystal temperature. We investigated various cooling configurations of large mixed-species crystals and fluids, over strings of few ions down to a single HCI cooled by a single Be+ ion - a prerequisite for future quantum logic spectroscopy at a potential 10^{-19} level accuracy.

A 1.6 Mon 12:45 C/HSW

Spectroscopy of the hyperfine structure splitting and isotopic shift on $^{97-99}$Technetium — •Tobias Kron[1], Michael Franzmann[1], Jose-Luis Henares[2], Sebastian Raeder[3], Tobias Reich[4], Pascal Schönberg[4], and Klaus Wendt[1] — [1]Institute of Physics, Mainz University — [2]GANIL, Caen, France — [3]KU Leuven, Belgium — [4]Institute for Nuclear Chemistry, Mainz University

The radioactive trace element technetium is one of the dominant fission fragments and therefore might cause radio-toxic threat or, on the other hand, could serve as a long-term indicator of nuclear debris. Nuclear reactors and atomic bombs primarily create the isotope ^{99}Tc with a half-life time of $2.1 \cdot 10^5$ years. Measurements on dissemination in the environment correspondingly require highest significance and selectivity on samples containing only about 10^{10} atoms or less. Resonant laser ionization is the most suitable approach for this purpose, as it combines high elemental selectivity and highest ionization efficiency widely independent of chemical sample composition.

Successive optical excitation and subsequent ionization following strong unique dipole transitions serves as fingerprint for every element. For this purpose, the detailed knowledge of the hyperfine structure and isotopic shift in the different transitions along the excitation ladders is

mandatory, in particular as ^{97}Tc serves as tracer for quantification of analytical results. We examined these parameters for the ground state and energetically higher lying levels in the spectrum of Tc I using a high repetition rate tunable narrow bandwidth titanium:sapphire laser system, to evaluate possible effects on the determined isotopic ratios.

A 1.7 Mon 13:00 C/HSW

ARTEMIS: Bound-Electron *g*-Factor Measurements by Double-Resonance Spectroscopy — •Marco Wiesel[1,2,4], David von Lindenfels[1,2,3], Sadegh Ebrahimi[1,2], Wolfgang Quint[1,2], Manuel Vogel[1,4], Alexander Martin[4], and Gerhard Birkl[4] — [1]GSI Darmstadt — [2]Universität Heidelberg — [3]MPI-K Heidelberg — [4]TU Darmstadt

Magnetic moments of electrons bound in highly charged ions provide access to effects of quantum electrodynamics (QED) in the extreme fields close to the ionic nucleus. The cryogenic Penning trap setup ARTEMIS is dedicated to determine the electronic *g*-factors of highly charged ions such as boron-like argon (Ar^{13+}) via the method of double-resonance spectroscopy. A closed cycle between the fine-structure levels $2^2P_{1/2}$ - $2^2P_{3/2}$ is driven by a laser whereas microwaves are tuned to excite transitions between Zeeman sublevels. With this Larmor frequency and the measurement of the ion cyclotron frequency the *g*-factor can be determined with an expected accuracy of 10^{-9} or better. Such measurements are also able to resolve higher-order contributions to the Zeeman effect. We report the commissioning of the novel half-open double trap with in-trap ion creation, characterization of the trap and first measurements performed at ARTEMIS which is part of the experimental program of the HITRAP facility. The double-resonance method can also be applied to *g*-factor measurements of the hyperfine structures of heavy hydrogen-like ions.