A 27: Precision spectroscopy of atoms and ions I (with Q)

Time: Wednesday 14:30–16:30 Location: f428

Invited Talk A 27.1 Wed 14:30 f428

Atomic level scheme of neutral actinium — •Sebastian Raeder[1], Randolf Beerwerth[2], Rafael Ferrer[3], Camilo Granados[3], Amin Hakimi[4], Mustapha Laataoui[1], Volker Sonnenschein[5], Norbert Trautmann[6], and Klaus Wendt[4] — [1]Helmholtz Institut Mainz — [2]Helmholtz Institut Jena — [3]KU Leuven — [4]Institut für Physik, Universität Mainz — [5]University of Jyväskylä — [6]Institut für Kernchemie, Universität Mainz

The atomic structure of actinium was investigated as preparation for laser spectroscopy on short lived radio isotopes. Albeit it is the name-giving element of the actinide series the available information on the atomic level scheme of neutral actinium is insufficient for laser spectroscopic applications. Using wide range tunable Ti:sa lasers allowed for the identification of new atomic energy levels, resulting in a precise determination of the first ionization potential and provided the information on auto-ionizing states for further resonance ionization spectroscopy. Additionally, the hyperfine structure of several levels was investigated using an injection-locked narrow bandwidth pulsed Ti:sa laser. Besides the identification of a suitable optical transition with high sensitivity to nuclear properties some errors in the available literature on the atomic levels were identified. The measured level properties are compared to theoretical multi configuration Dirac-Fock (MCDF) calculations resulting in a revised level scheme for low lying atomic levels in actinium.

A 27.2 Wed 15:00 f428

MCDF Isotope-Shift Calculations for Medium and Heavy Elements — •Randolf Beerwerth[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Universit{\"a}t Jena, 07743 Jena, Germany

The isotope shift is described in terms of the mass and field-shift parameters. The former arises due to the nuclear recoil, while the latter links the electronic response to changes in the nuclear radius. This allows to use optical spectroscopy to obtain information about the nucleus, when the isotope-shift parameters are known. When it is infeasible to determine the isotope-shift parameters purely experimentally, atomic calculations can instead be utilized to provide estimates.

We apply the Multi-Configuration Dirac-Fock (MCDF) method to calculate the isotope-shift parameters for medium to heavy elements. After computation of the wave function, we utilize the configuration-interaction method to calculate the isotope-shift parameters for a chain of isotopes.

Since the isotope shift of heavy elements is dominated by the field shift, we put special emphasis on its computation. Very often it is estimated from the electronic charge density inside the nucleus, however this estimate is only precise for light elements. For light to medium elements, our method agrees very well with this estimate. However, for heavy elements we obtain significantly lower values.

We present results for Actinium and Nobelium, where several experiments were recently performed. The extracted nuclear parameters compare well with results for other elements.

A 27.3 Wed 15:15 f428

Design and commissioning of the ALPHATRAP ion transfer beamline — •Alexander Egl[1,2], Ioanna Arapoglou[1,2], J.R. Crespo Lopez-Urrutia[1], Henrik Hirzler[1,2], Sandro Kraemer[1,2], Peter Micke[1,3], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik, Universität Heidelberg — [3]Physikalisch-Technische Bundesanstalt, QUEST, 38116 Braunschweig

The Penning-trap experiment ALPHATRAP at the Max-Planck-Institut für Kernphysik aims to test bound-state quantum electrodynamics by determining the g-factor of the bound electron in the electric field of highly charged ions (HCI) with ultra-high precision. HCI up to hydrogen-like $^{208}Pb^{81+}$ will be provided by the Heidelberg Electron Beam Ion Trap (Heidelberg-EBIT). Therefore, an ultra-high vacuum room temperature ion transfer beamline will be used to guide HCI to the ALPHATRAP setup, consisting of a custom-made cryostat and a superconducting magnet containing the precision Penning-trap system. Superior vacuum conditions are essential to reduce recombination reactions of the HCI to negligible levels. In addition to the Heidelberg-EBIT, a compact room temperature EBIT is available, which allows flexible creation of HCI from injected gas, e.g. $^{40}Ar^{15+}$ or $^{129}Xe^{25+}$. These ions in turn will be used during the commissioning phase of ALPHATRAP. The design and commissioning of the ion transfer beamline as well as results from the compact room temperature EBIT will be presented.

A 27.4 Wed 15:30 f428

Investigation of Ir^{17+} as a sensitive detector of variation of the fine-structure constant — •Hendrik Bekker[1], Alexander Windberger[1,2], Oscar O. Versolato[2], Anastasia Borchevsky[3], Natalia S. Oreshkina[1], Julian C. Berengut[4], Zoltán Harman[1], Christoph H. Keitel[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Advanced Research Center for Nanolithography, Amsterdam — [3]Van Swinderen Institute for Particle Physics and Gravity, Groningen — [4]University of New South Wales, Sydney

Many highly charged ions have been proposed for use in next generation optical clocks for metrology purposes. We aim at implementing one of the original proposals, to use Ir^{17+} to investigate variation of the fine-structure constant [1]. But as with all the proposed systems, theory is not capable of predicting the energy level structure to the precision required for laser spectroscopy. Therefore we investigated Ir^{17+} which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap. The wavelengths of subsequent optical fluorescence light were determined at the ppm-level using a grating spectrometer. Direct identification of the 30 observed lines was not possible due to their dense spacing and uncertainties on the predictions. But by employing several other techniques we identified transitions important for future high-precision laser spectroscopy experiments. The identification techniques and additional new results will be presented.

[1] J. C. Berengut *et al.*, Phys. Rev. Lett. **106**, 210803 (2011)
[2] A. Windberger *et al.*, Phys. Rev. Lett. **114**, 150801 (2015)

A 27.5 Wed 15:45 f428

Influence of ion movement in a particle trap on the bound-electron g-factor — •Niklas Michel, Jacek Zatorski, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

The bound-electron g-factor is defined via the energy difference of a spin-up and spin-down state of the electron in an external magnetic field and its measurement provides one of the most stringent tests of QED in strong external fields. When measured in a Penning trap, the electron spin also couples to the external electric trapping potential and the total momentum of the ion. Therefore, the motional state of an ion in a particle trap influences measurements of internal observables such as energy levels or the g-factor [1]. We calculated the resulting relativistic shift of the Larmor frequency and the corresponding g-factor correction for a bound electron in a hydrogenlike ion in the 1S state due to the ion moving in a Penning trap.

[1] N. Michel, J. Zatorski, C. H. Keitel, Phys. Rev. A **92**, 052509 (2015).

A 27.6 Wed 16:00 f428

A highly sensitive single particle detector at 75 MHz — •Matthias Borchert[1], Klaus Blaum[2], Takashi Higuchi[3,4], Yasuyuki Matsuda[4], Teresa Meiners[1], Andreas Mooser[3], Hiroki Nagahama[3,4], Malte Niemann[1], Christian Ospelkaus[1], Wolfgang Quint[6], Georg Schneider[7], Stefan Sellner[3], Christian Smorra[3,8], Jochen Walz[5,7], Yasunori Yamazaki[9], and Stefan Ulmer[3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Ulmer Initiative Research Unit, RIKEN, Wako, Japan — [4]Graduate School of Arts and Sciences, University of Tokyo, Tokyo, Japan — [5]Helmholtz-Institut Mainz, Mainz, Germany — [6]GSI-Helmholzzentrum für Schwerionenforschung, Darmstadt, Germany — [7]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [8]CERN, Geneva, Switzerland — [9]Atomic Physics Laboratory, RIKEN, Wako, Japan

The BASE collaboration aims at a stringent test of the CPT symmetry by comparing the magnetic moments of the proton and the antipro-

ton with high precision. The magnetic moment in units of the nuclear magneton is determined by measuring the ratio of the spin-precession frequency to the cyclotron frequency, respectively, in an advanced cryogenic Penning trap system.

One limitation in current state of the art experiments is given by noise induced quantum transitions in the modified cyclotron mode of the trapped particles. Higher magnetic field strengths reduce the heating rate of the cyclotron mode, which inspires the development of a non-destructive image-current detector for the modified cyclotron frequency at 75 MHz. For a proton this corresponds to a magnetic field strength of about 5 Tesla.

In this talk I will present the development of such a detector based on a superconducting resonator.

A 27.7 Wed 16:15 f428

Comparison of the Lγ(2,3) line shape for Ba2+ compounds and metal — •Malkhaz Jabua, Detlev Gotta, and Thomas Strauch — Institüt für Kernphysik, Forschungszentrum Jülich, D-52425 Jülich, Deutschland

The Lγ(2,3) line from Ba2+ compounds shows a complex structure. Nevertheless, both peak energy and shape of the complex are apparently unaffected by the nature of the anion. Therefore, a comparison measurement was performed using metallic barium. For the measurement was used the Johann spectrometer at the institute of nuclear physics (IKP) at Forschungszentrum Jülich (FZJ). The set-up allows to record simultaneously an energy interval covering the complete structure Ba Lγ(2,3) structure. As Bragg crystal a spherically bent quartz crystal was used. The diffracted X-rays were recorded with a 24 mm x 24 mm charge-coupled device having a pixel size of 40 micrometer x 40 micrometer. The spectra of metallic Ba complete a series of measurements including the spectra from the salts BaCl2, BaCO3, Ba(OH)2, and BaSO4. The X-ray energies were determined to an accuracy of about 40 meV. The talk aims to describe the experimental setup, measurement techniques, and to present the data analysis methodology and some recent results.