Q 10: Precision spectroscopy of atoms and ions II (with A)

Time: Monday 14:00–16:00 Location: BEBEL E42

Q 10.1 Mon 14:00 BEBEL E42

Precision spectroscopy of atomic anions with a view to laser cooling — •Giovanni Cerchiari, Elena Jordan, and Alban Kellerbauer — MPIK, Heidelberg, Germany

We are investigating the electronic structure of negative atomic ions, looking for suitable bound-bound transitions to be used for laser cooling. Cooling of negative ions using electronic transitions has not yet been achieved and could open up the possibility to create negatively charged ensembles at fractions of Kelvin. Most atomic anions show only a single bound state. We are experimentally studying the few exceptions of this rule. Our spectroscopic studies are thus focused on the few atomic species with more than one bound state. We have completed a precise spectroscopic analysis of Os^- and are now probing La^- using similar experimental techniques. Methods of the measurements will be discussed in order to introduce the results achieved on atomic levels as well as transition rates and the energy splitting due to hyperfine and Zeeman effects.

Q 10.2 Mon 14:15 BEBEL E42

Progress towards antihydrogen hyperfine spectroscopy in a beam — •Eberhard Widmann — Stefan Meyer Institute for Subatomic Physics, Vienna, Austria, on behalf of the ASACUSA CUSP collaboration

The spectroscopy of antihydrogen promises one of the most precise tests of CPT symmetry. The ASACUSA CUSP collaboration at the Antiproton Decelerator of CERN is preparing an experiment to measure the ground-state hyperfine structure GS-HFS of antihydrogen, since this quantity is one of the most precisely determined transitions in ordinary hydrogen (relative accuracy $\sim 10^{-12}$). The experiment uses a Rabi-type atomic beam apparatus consisting of a source of spin-polarized anthihydrogen (a so-called cusp trap), a microwave cavity to induce a spin flip, a superconducting sextuple magnet for spin analysis, and an antihydrogen detector. In this configuration, a relative accuracy of better than 10^{-6} can be obtained. This precision will already allow to be sensitive to finite size effects of the antiproton, provided its magnetic moment will measured to higher precision, which is in progress by two collaborations at the AD.

The recent progress in producing a beam of antihydrogen atoms and in the development of the apparatus as well as ways to further improve the accuracy by using the Ramsey method of separated oscillatory fields will be presented.

Q 10.3 Mon 14:30 BEBEL E42

Measurement of the forbidden 2 ^{3}S$_1$ - 2 ^{1}P$_1$ transition in quantum degenerate helium — •Remy Notermans and Wim Vassen — LaserLaB, Department of Physics and Astronomy, VU University Amsterdam, The Netherlands

There is a longstanding 6.8 (3.0) MHz discrepancy between QED theory and the experimental value of the ionization energy of the 2 ^{1}P$_1$ state in helium. We present the first measurement of the forbidden 887-nm 2 ^{3}S$_1$ - 2 ^{1}P$_1$ transition in a quantum degenerate gas of ^{4}He*, using the experimental setup as used to measure the doubly forbidden 2 ^{3}S$_1$ - 2 ^{1}S$_0$ transition by van Rooij *et al.* (Science **333**, 196 (2011)). The low temperature of the gas ($\sim$1 μK) allows us to observe the transition close to its natural linewidth of 284 MHz.

From our measurements we obtain the transition frequency with a preliminary accuracy of 0.57 MHz, i.e. at 0.2% of its natural linewidth. Our result already deviates $> 3\sigma$ from the current QED theory for the 2 ^{1}P$_1$ ionization energy. Recent measurements by Luo *et al.* of the 2 ^{1}S$_0$ - 2 ^{1}P$_1$ and 2 ^{1}P$_1$ - 3 ^{1}D$_2$ transitions in a RF discharge cell (PRL **111**, 013002 (2013) and PRA **88**, 054501 (2013)) agree with our work, confirming the discrepancy with theory.

Q 10.4 Mon 14:45 BEBEL E42

Towards isotope shift and hyperfine structure measurements of the element nobelium — •Premaditya Chhetri[1], Mustapha Laatiaoui[2], Felix Lautenschläger[1], Michael Block[2,3], Werner Lauth[4], Hartmut Backe[4], Thomas Walther[1], Peter Kunz[5], and Fritz-Peter Hessberger[2,3] — [1]Institut für Angewandte Physik, TU Darmstadt, D-64289 Darmstadt — [2]Helmholtz Institut Mainz, D-55099 Mainz — [3]GSI, D-64291 Darmstadt — [4]Institut für Kernphysik, JGU Mainz, D-55122 Mainz — [5]TRIUMF, D-V6T2A3 Vancouver, Canada

Laser spectroscopy on the heaviest elements is of great interest as it allows the study of the evolution of relativistic effects on their atomic structure. In our experiment we exploit the Radiation Detected Resonance Ionization Spectroscopy technique and use excimer-laser pumped dye lasers to search for the first time the $^1P_1$ level in ^{254}No. Etalons will be used in the forthcoming experiments at GSI, Darmstadt, to narrow down the bandwidth of the dye lasers to 0.04 cm^{-1}, for the determination of the isotope shift and hyperfine splitting of ^{253,255}No. In this talk results from preparatory hyperfine structure studies in nat. ytterbium and the perspectives for future experiments of the heaviest elements will be discussed.

Q 10.5 Mon 15:00 BEBEL E42

On the 7.8 eV isomer transition in ^{229}Th — •Simon Stellmer[1], Matthias Schreitl[1], Georg Winkler[1], Christoph Tscherne[1], Georgy Kazakov[1], Andreas Fleischmann[2], Loredana Gastaldo[2], Andreas Pabinger[2], Christian Enss[2], and Thorsten Schumm[1] — [1]VCQ and Atominstitut / TU Wien, Vienna, Austria — [2]KIP, University of Heidelberg, Germany

The best atom clocks today employ an optical transition between two electronic states of an atom or ion. It seems tantalizing to utilize a nuclear transition instead, as such a transition would be well-isolated from collisional, electronic, and even chemical perturbations from the environment. In addition, such transitions are expected to be very sensitive probes of drifts in fundamental constants.

The only isotope known to possess an isomer transition in the optical domain is the radioactive element ^{229}Th. Various attempts have been carried out to measure or calculate the transition energy and linewidth. To date, all of these measurements have been refuted, corrected, or at least strongly debated. While a direct evidence of this transition is still pending, its commonly agreed-upon energy is 7.8(5) eV [1].

In this talk, we will present the current status of a novel measurement campaign. In a concerted effort of the Heidelberg and Vienna groups, we use a microcalorimeter to measure the spectrum of gamma photons originating from the decay of excited nuclear states. A double-peaked structure would reveal the existence of the isomer state and allow us to measure its energy with unprecedented precision.

[1] Beck *et. al*, Phys. Rev. Lett. **98**, 142501 (2007)

Q 10.6 Mon 15:15 BEBEL E42

Laser spectroscopy of the heaviest elements at SHIPTRAP — •Felix Lautenschläger[1], Mustapha Laatiaoui[2], Premaditya Chhetri[1], Michael Block[2,3], Werner Lauth[4], Hartmut Backe[4], Thomas Walther[1], Peter Kunz[5], and Fritz-Peter Hessberger[2,3] — [1]Institut für Angewandte Physik, TU Darmstadt, D-64289 Darmstadt — [2]Helmholtzinstitut Mainz, D-55128 Mainz — [3]Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt — [4]Institut für Kernphysik, JGU Mainz, D-55128 Mainz — [5]TRIUMF, Vancouver, Canada

The Radiation Detected Resonance Ionization Spectroscopy is a powerful tool for the investigation of the atomic properties of heavy and superheavy elements. For our on-line experiments, we exploit a two-step photoionization process in a buffer-gas filled stopping cell. In the first stage, the ^{1}P$_1$- level of ^{254}No, which can be produced in the complete fusion reaction ^{208}Pb(^{48}Ca,2n)^{254}No, will be sought for using 4 dye lasers delivering the first excitation step and an excimer laser providing the second non-resonant excitation step. Due to the lower ionization efficiency of the non-resonant excitation step, the impact of the excimer laser pulse energy on the ionization efficiency was studied in off-line experiments, using nat. Yb. These results and a general overview of the experimental setup will be presented.

Q 10.7 Mon 15:30 BEBEL E42

Prediction of the oscillator strengths for the electric dipole transitions in Th II — •Jerzy Dembczyński[1], Jarosław Ruczkowski[2], and Magdalena Elantkowska[2] — [1]Institute of Control and Information Engineering, Faculty of Electrical Engineering, Poznań University of Technology, Piotrowo 3A, 60-965 Poznań, Poland — [2]Laboratory of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznań University of Technology, Nieszawska 13B, 60-965 Poznań, Poland

In order to parametrize the oscillator strength, the matrix of angular coefficients of the possible transitions in multiconfiguration system were calculated. In the odd and even configuration systems, the fine structure eigenvectors for both parities were obtained, using our semiempirical method, which taken into account also the second order effects, resulting from the excitations from electronic closed shells to open shells and from open shells to empty shell.

The correctness of the fine structure wave functions was verified by the comparison of calculated and experimental hyperfine structure constants for Th II available in the literature. The least square fit to experimental values for some transitions allow to obtain the values of radial parameters and predict the oscillator strengths values for all possible transitions from the levels under consideration.

These calculations are necessary for the design of the nuclear frequency standard based on the thorium ion.

This work was supported by The National Centre for Science under the project N N519 650740

Q 10.8 Mon 15:45 BEBEL E42

First experiments with cooled clusters at the Cryogenic Trap for Fast ion beams — •Christian Meyer[1], Klaus Blaum[1], Christian Breitenfeldt[2], Sebastian George[1], Michael Lange[1], Lutz Schweikard[2], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität, 17487 Greifswald, Germany

The Cryogenic Trap for Fast ion beams (CTF) is an electrostatic ion beam trap for the investigation of charged particles in the gas phase located at the "Max-Planck-Institut für Kernphysik" in Heidelberg. It is suited to study thermionic and laser-induced electron emission of anions with complex multi-body structure such as clusters and molecules. They can be stored up to several minutes due to the low pressure of 10^{-14} mbar [1] in an ambient temperature down to 15 K. The experiments were so far hampered by the ion production in a sputter source leading to excited particles with high rovibrational states. In order to be able to investigate the ground state properties of such systems a new supersonic expansion source [2] has been implemented. A laser-induced plasma is expanded into vacuum by short pulses (50 μs) of a helium carrier gas and thereby rovibrationally cooled. First test with metal cluster will be presented and discussed.

[1] M. Lange et al., Rev. Sci. Instr., 81,055105 (2010)
[2] C. Berg et al., J. Chem. Phys. 102, 4870 (1995)