Q 10: Precision Spectroscopy of atoms and ions II (joint session A/Q)

Time: Monday 14:00–15:45 Location: S HS 2 Physik

Invited Talk Q 10.1 Mon 14:00 S HS 2 Physik

Laser spectroscopy of transferium elements — •S. Raeder[1,2], D. Ackermann[2,3], H. Backe[4], M. Block[1,2,4], B. Cheal[5], P. Chhetri[2,6], Ch. E. Düllmann[1,2,4], M. Eibach[2], J. Even[7], R. Ferrer[8], F. Giacoppo[1,2], S. Götz[1,2,4], F.P. Hessberger[2], O. Kaleja[2,4,9], J. Khuyagbaatar[1,2], P. Kunz[10], M. Laatiaoui[1,4], W. Lauth[4], L. Lens[2,4], N. Lecesne[3], A. K. Mistry[1,2], E. Minaya Ramirez[11], T. Murböck[1,2], P. van Duppen[8], Th. Walther[6], and A. Yakushev[1,2] — [1]HI Mainz — [2]GSI — [3]GANIL — [4]JGU Mainz — [5]U. of Liverpool — [6]TU Darmstadt — [7]KVI-CART, U. of Groningen — [8]KU Leuven — [9]MPIK — [10]TRIUMF — [11]IPNO

Laser spectroscopy of the heaviest elements is a versatile tool to precisely measure the energies of shell electrons, which are strongly influenced by electron-electron correlation, relativity and QED effects. The study of transfermium elements with Z>100 is hampered by low production rates and the fact that any atomic information is at best available from theoretical predictions. Using the sensitive radiation detected resonance ionization spectroscopy technique coupled to the SHIP separator at GSI, a strong optical $^1S_0 \rightarrow {}^1P_1$ ground-state transition in the element nobelium (Z=102) was identified and characterized. In further studies the isotopes ^{252,253,254}No were measured and highlying Rydberg levels were identified which enabled the extraction of the first ionization potential with unreached precision. These results will be discussed as well as the prospects for future investigations involving the study of additional nobelium isotopes and the exploration of the atomic structure of the next heavier element, lawrencium (Z=103).

Q 10.2 Mon 14:30 S HS 2 Physik

High-resolution laser resonance ionization spectroscopy of $^{143-147}$Pm — •Dominik Studer[1], Reinhard Heinke[1], Sebastian Raeder[2], Jiri Ulrich[3], Rugard Dressler[3], Dorothea Schumann[3], Nicholas van der Meulen[3], Saverio Braccini[4], Tommaso Stefano Carzaniga[4], and Klaus Wendt[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Helmholtz Institut Mainz — [3]Paul Scherrer Institut Villigen — [4]AEC-LHEP, University of Bern

Due to its exclusively radioactive nature with a maximum half-life of 17 years, the light lanthanide element promethium ($Z = 61$) is scarcely studied. In order to extract atomic and nuclear properties using the accessible miniscule sample amounts, extensive spectroscopic studies were performed at Mainz University by laser resonance ionization spectroscopy.

In the 2017 campaign we could reveal over 1000 new atomic transitions and determine the first ionization potential experimentally for the first time. Recent results focus on the extraction of isotope shifts and nuclear moments from hyperfine spectra of two different ground state transitions at 452 nm and 468 nm. For these studies the long-lived isotopes $^{143-147}$Pm were produced by irradiation of natural neodymium oxide using the external beam line of the 18 MeV medical cyclotron at the Bern University Hospital, followed by chemical separation and purification at PSI Villigen. In this talk we present our dedicated spectroscopy ion source and laser setup as well as the spectroscopic results.

Q 10.3 Mon 14:45 S HS 2 Physik

Laser spectroscopy of the fine structure of stored relativistic ions — •Sebastian Klammes[1,2], Axel Buss[3], Michael Bussmann[6], Oliver Boine-Frankenheim[1,2], Christian Egelkamp[3], Lewin Eidam[2], Daniel Kiefer[2], Volker Hannen[3], Zhongkui Huang[4], Thomas Kühl[1,5], Markus Löser[6,7], Xinwen Ma[4], Wilfried Nörtershäuser[2], Fritz Nolden[1], Rodolfo Sánchez[1], Ulrich Schramm[6,7], Mathias Siebold[6], Peter Spiller[1], Markus Steck[1], Thomas Stöhlker[1,5,8], Johannes Ullmann[2,8], Thomas Walther[2], Hanbing Wang[4], Weiqiang Wen[4], Christian Weinheimer[3], Daniel Winzen[3], and Danyal Winters[1] — [1]GSI Darmstadt — [2]TU Darmstadt — [3]Uni Münster — [4]IMP Lanzhou — [5]HI-Jena — [6]HZDR Dresden — [7]TU-Dresden — [8]Uni-Jena

High resolution laser spectroscopy is a very precise method for investigations of the atomic structure, being sensitive to the smallest effects (*e.g.* relativity, QED). In order to challenge modern theory, few-electron ions are interesting because of their strong EM fields. These ions can be studied at heavy-ion facilties, such as GSI in Darmstadt, or IMP in Lanzhou, China. In order to create high charge states, the ions must be accelerated to almost the speed of light. Laser spectroscopy of *e.g.* fine structure transitions is then possible by exploiting the huge Doppler shift (anti-collinear laser). We report on results from experiments performed at the ESR (GSI) and the CSRe (IMP) storage rings, using C^{3+} and O^{5+} ion beams, respectively. Finally, we present our preparations for laser spectroscopy of Be-like krypton.

Q 10.4 Mon 15:00 S HS 2 Physik

Spectroscopy of an electric-dipole-forbidden fine structure transition with a single $^{40}Ar^{13+}$ ion at ALPHATRAP — •Alexander Egl[1], Ioanna Arapoglou[1], Martin Höcker[1], Kristian König[2], Tim Ratajczyk[2], Tim Sailer[1], Bingsheng Tu[1], Andreas Weigel[1], Robert Wolf[1], Wilfried Nörtershäuser[2], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Kernphysik,Technische Universität Darmstadt, Germany

Highly charged ions are excellent candidates to test fundamental theories such as bound-state quantum electrodynamics (BS-QED). The strong electromagnetic fields which can be found in those systems can shift the energies of fine structure or even hyperfine structure transitions into the optical regime. Measuring such transitions constitutes a stringent test on BS-QED including relativistic many electron calculations and nuclear contributions.

We present a novel method that does not rely on any fluorescence signal which allows to find straight forward a transition by using the continuous Stern Gerlach effect. Using this method we have recently performed laser spectroscopy of the magnetic dipole (M1) $2p\,^2P_{1/2} - {}^2P_{3/2}$ fine structure transition in $^{40}Ar^{13+}$ stored in a cryogenic Penning-trap system of the ALPHATRAP g-factor experiment at the Max-Planck-Institut für Kernphysik. Results of this will be presented.

Q 10.5 Mon 15:15 S HS 2 Physik

Determination of the electron affinity of astatine for IS615 — •David Leimbach — CERN, Geneva, Switzerland — Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — Department of Physics, University of Gothenburg, Gothenburg, Sweden

Astatine is a purely radioactive and the rarest naturally occurring element on earth, exhibiting a number of short lived alpha emitting isotopes. E.g. one of the longer lived isotopes, 211At, is of special interest as an agent for targeted alpha therapy (TAT), a method of treating cancer directly at the location of a tumor with alpha emitting particles. On the other hand, the fundamental quantity of the electron affinity (EA) of astatine is not known. Together with the just recently measured first ionization potential (IP) this value is of importance to determine the unknown electronegativity of this element which could give valuable benchmarks for quantum chemical calculations predicting the chemical properties of this element and its compounds. In order determine the EA of radioisotopes via laser photodetachment, the Gothenburg Anion Detector for Affinity measurements by Laser PHotodetachment (GANDALPH) was built. Following the first ever measurement of the EA of a radiogenic isotope in 2016 [4], GANDALPH has recently received multiple upgrades to facilitate beam tuning and detection of low intensity (<1pA) ion beams. During an experimental campaign at CERN-ISOLDE in 2018, the GANDALPH beamline was used to successfully measure the EA of astatine. Experiment and results of these measurements will be presented and compared to expectations and recent theoretical calculations.

Q 10.6 Mon 15:30 S HS 2 Physik

Laser Spectroscopy of Boron Isotopes — •Bernhard Maass[1], Jason Clark[2], Phillip Imgram[1], Simon Kaufmann[1], Kristian König[1], Jörg Krämer[1], Jan Krause[1], Alessandro Lovato[2], Peter Müller[2], Krzysztof Pachucki[3], Mariusz Puchalski[3], Maria Piarulli[4], Robert Roth[1], Rodolfo Sánchez[5], Guy Savard[2], Felix Sommer[1], Robert Wiringa[2], and Wilfried Nörtershäuser[1] — [1]IKP, TU Darmstadt, DE — [2]ANL, Lemont, IL, USA — [3]University of Warsaw, PL — [4]Washington University, St. Louis, MO, USA — [5]GSI Darmstadt, DE

We report on the first determination of the nuclear charge radius of stable boron isotopes by resonance ionization mass spectrometry (RIMS). By combining high-resolution measurements of the isotope

shift in an atomic ground state transition and high-accuracy *ab initio* mass-shift calculations of the five-electron system, the difference in the mean-square charge radius between the stable isotopes ^{10,11}B can be extracted. The result is then used to benchmark new *ab initio* nuclear structure calculations using the no-core shell model and Greens-Function Monte Carlo approaches. In near future, collinear laser spectroscopy will be performed in the same transition on the short-lived (770 ms) proton halo candidate ^{8}B at Argonne National Laboratory. The difference in mean-square charge radius will deliver a model-independent test of its proton halo character.

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