A 7: Precision spectroscopy of atoms and ions I

Time: Monday 14:00–16:00 Location: f107

Invited Talk A 7.1 Mon 14:00 f107

Laser spectroscopy of the heaviest actinides — •Premaditya Chhetri[1,2], Dieter Ackermann[3], Hartmut Backe[4], Michael Block[1,2,4], Bradley Cheal[5], Christoph Emanuel Düllmann[1,2,4], Julia Even[6], Rafael Ferrer[7], Francesca Giacoppo[1,2], Stefan Götz[1,2,4], Fritz Peter Hessberger[1,2], Mark Huyse[7], Oliver Kaleja[1,4], Jadambaa Khuyagbaatar[1,2], Peter Kunz[8], Mustapha Laatiaoui[1,2,4], Werner Lauth[4], Lotte Lens[1], Enrique Minaya Ramirez[9], Andrew Mistry[1,2], Tobias Murböck[1], Sebastian Raeder[1,2], Fabian Schnieder[2], Piet Van Duppen[7], Thomas Walther[10], and Alexander Yakushev[1,2] — [1]GSI, Darmstadt, Germany — [2]HI Mainz, Mainz, Germany — [3]GANIL, Cean, France — [4]JGU, Mainz, Germany — [5]Liverpool University, Liverpool, UK — [6]University of Groningen, KVI-CART, Groningen, Netherlands — [7]KU Leuven, Leuven, Belgium — [8]TRIUMF, Vancouver, Canada — [9]IPN, Orsay, France — [10]TU Darmstadt, Darmstadt, Germany

Precision measurements of optical transitions of the heaviest elements are a versatile tool to probe the electronic shell structure which is strongly influenced by electron-electron correlations, relativity and QED effects. Optical studies of transfermium elements with Z>100 is hampered by low production rates and the fact that any atomic information is initially available only from theoretical predictions. Using the sensitive RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) 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 [1]. The isotopes of ^{252,253,254}No were measured [2]. Production of ^{255}No via the electron capture of ^{255}Lr, at very low rate, made the measurements of hyperfine structure of ^{255}No possible. From these measurements, nuclear information on the shapes and sizes were inferred. In addition, several high-lying Rydberg levels were observed, which enabled the extraction of the first ionization potential with high precision [3].

These results as well as the prospects for future exploration of the atomic structure of the next heavier element, lawrencium (Z=103) will be discussed.

[1] M. Laatiaoui et al., Nature **538**, 495 (2016).
[2] S. Raeder et al., PRL **120**, 232503 (2018).
[3] P. Chhetri et al., PRL **120**, 263003 (2018).

A 7.2 Mon 14:30 f107

Resonance ionization mass spectrometry on $^{243-248}$Cm — •Nina Kneip[1], Christoph E. Düllmann[2,3,4], Christian M. Marquardt[5], Christoph Mokry[2,4], Petra J. Panak[5,6], Sebastian Raeder[3], Jörg Runke[2,3], Petra Thörle-Pospiech[2,4], Felix Weber[1], Klaus Wendt[1], and Norbert Trautmann[2] — [1]Institute of Physics, Johannes Gutenberg University Mainz — [2]Institute of Nuclear Chemistry, Johannes Gutenberg University Mainz — [3]GSI Helmholtz Centre for Heavy Ion Research mbH, Darmstadt — [4]Helmholtz Institute Mainz — [5]Institute for Nuclear Waste Disposal, Karlsruhe Institute of Technology, Karlsruhe — [6]Institute of Physical Chemistry, Heidelberg University

In numerous applications resonance ionization mass spectroscopy has demonstrated its versatility as a highly efficient and selective method for the ultra-trace determination of actinides. The RISIKO facility involves a 30 kV magnetic sector field mass separator in combination with a laser ion source and a high repetition rate pulsed Ti:sapphire laser system. Optical spectroscopy on a number of curium isotopes was performed using sample sizes of typically 10^9 atoms. The individual tunable lasers involve automated grating-tuning and Intra-Cavity Second Harmonic Generation. Efficient two-step ionization schemes for Cm were identified and scans across Rydberg series were performed using two different first excitation steps. With a Cm sample containing the isotopes 243 to 248 isotope shifts were measured for the first time of all these isotopes and the ionization potential was deduced with significantly enhanced precision using the Rydberg Ritz formula.

A 7.3 Mon 14:45 f107

Two-Photon Shelving spectroscopy on a UV-transition in atomic Dysprosium — •Jan-Niklas Schmidt, Viraatt Anasuri, Fabian Böttcher, Kevin Ng, Mingyang Guo, Tim Langen, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Dysprosium features one of the largest magnetic moment in the periodic table. The non-negligible dipole-dipole interaction has therefore a strong influence on the properties of an ultracold atomic cloud and can even yield to new phases of matter [1]. To further increase the dipolar interaction between individual atoms in a lattice the lattice spacing has to be reduced, e.g. by means of a lattice in the UV region.

In order to find a magic wavelength we perform precise measurements on a UV transition at 359 nm with an expected linewidth of 52 kHz in an atomic beam of dysprosium. We use a electron shelving technique to amplify the spectroscopic signal on the weak transition. This enables us to map out the isotope shifts for the most abundant isotopes. In the case of fermionic Dysprosium we determine the hyperfine structure splitting and calculate the values for the hyperfine coefficients. In addition to this we give an upper bound to the lifetime of the excited state.

[1] M. Guo et al., Nature **574**, 386-289 (2019)

A 7.4 Mon 15:00 f107

Prospects for laser spectroscopy beyond nobelium (Z>102) — •Mustapha Laatiaoui[1,2,3], Alexei Buchachenko[4,5], and Larry Viehland[6] — [1]Johannes Gutenberg-Universität, Fritz-Strassmann Weg 2, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, Staudingerweg 18, 55128 Mainz, Germany — [3]KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium — [4]Skolkovo Institute of Science and Technology, Skolkovo Innovation Center, Nobel str. 3, Moscow 121205, Russia — [5]Institute of Problems of Chemical Physics RAS, Chernogolovka, Moscow District 142432, Russia — [6]Chatham University, Pittsburgh, Pennsylvania 15232, USA

Optical spectroscopy constitutes the historical path to accumulate basic knowledge on the atom and its structure. Former work based on fluorescence and resonance ionization spectroscopy enabled identifying optical spectral lines up to element 102, nobelium [Nature (2016) 538:495]. The new challenges faced in this research field are the refractory nature of the heavier elements and the decreasing production yields. In this contribution, a new concept of ion mobility-assisted laser spectroscopy will be presented, which will enable to overcome the sensitivity limits of atomic structure investigations persisting in the region of the superheavy elements. The concept offers capabilities of both broadband level searches and high-resolution hyperfine spectroscopy of synthetic elements beyond nobelium.

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A 7.5 Mon 15:15 f107

hyperfine splitting in Li- and B-like multi-charged ions — •Valeriia Kosheleva[1,2,3], Andrey Volotka[1,2], Dmitry Glazov[3], and Stephan Fritzsche[1,2] — [1]Helmholtz Institute Jena, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]Department of Physics, St. Petersburg State University, 199034 St. Petersburg, Russia

We report a complete evaluation of the two-photon exchange corrections to the hyperfine structure (hfs) in Li-like ions for a wide range of nuclear charge Z within the framework of rigorous QED approach [1]. In comparison to the previous theoretical calculations, we substantially improved the accuracy of the interelectronic-interaction corrections to the ground-state hfs in Li-like ions by applying the extended Furry picture framework.Furthermore, we perform comprehensive relativistic calculations of the interelectronic- interaction and QED contributions to the ground-state hfs for selected B-like ions in the range Z = 49-83 [2]. As the result, we tabulated the most accurate theoretical hfs values in B-like ions. It is worth noting that the uncertainty of final values almost equally originates from the Bohr-Weisskopf correction and from the higher-order interelectronic-interaction contribution. The Bohr-Weisskopf uncertainty, however, can be canceled in specific differences of the hfs values. While the second uncertainty strongly motivates the rigorous evaluation of the two-photon exchange diagrams, which has been performed so far only for lithiumlike ions.

[1] V. P. Koshelva, A. V. Volotka, D. A. Glazov, S. Fritzsche, to be published. [2] D. A. Glazov, et al., Phys. Rev. A 99, 062503 (2019).

A 7.6 Mon 15:30 f107

maXs: micro-calorimeter arrays for high-resolution X-ray spectroscopy — •S. Allgeier[1], M. Arndt[1], M. Friedrich[1], J. Geist[1], C. Schötz[1], D. Hengstler[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], R. Märtin[2], G. Weber[2], S. Trotsenko[3], T. Morgenroth[3], M.O. Herdrich[2], P. Pfäfflein[2], Th. Stöhlker[2,3,4], T. Schumm[5], and S.P. Stellmer[6] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]IOQ, Jena University — [5]Vienna University of Technology — [6]PI, Bonn University

Metallic magnetic calorimeters (MMCs) are energy dispersive particle detectors which provide an excelent energy resolution over a large energy range combined with a very good linearity. MMCs are operated at millikelvin temperatures and convert the energy of an incoming X-ray photon into a temperature pulse which is measured by a paramagnetic temperature sensor. The resulting change of sensor magnetization is read out by a highly sensitive SQUID magnetometer. We developed several two-dimensional detector arrays optimized for X-ray energies up to 20, 30, 100 and 200 keV respectivly. The micro-fabricated detectors are operated in a mobile dilution refrigerator. We discuss the performance of our detectors including a record breaking energy resolution of 9.8 eV @ 60 keV. With their performance MMCs have been used in various applications, including the measurement of the ^{229}Th isomer energy and are an ideal tool for upcoming precision QED tests at CRYRING@GSI/FAIR.

A 7.7 Mon 15:45 f107

In Search for the Unobserved Low Lying Atomic Energy Levels of Actinium — •Ke Zhang[1,2], Dominik Studer[2], Vadim Gadelshin[2], Felix Weber[2], Nina Kneip[2], Tom Kieck[1,2], Sebastian Raeder[1,2], Dmitry Budker[1,2], and Klaus Wendt[2] — [1]Helmholtz Institute Mainz, 55099 Mainz, Germany — [2]Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

Actinium (Z = 89) is the name giver and the first member of the series of actinides. Based upon its ground state configuration $7s^2 6d\ ^2D_{3/2}$, the element exhibits a highly complex atomic structure. Recently 86 energy levels in the energy range between 0 cm^{-1} and 36 218 cm^{-1} have been predicted by theory, from which so far only 28 level energies have been confirmed experimentally. In particular the lowest lying missing odd levels $7s^2 7p\ ^2P^o_{1/2}$ and $7s^2 7p\ ^2P^o_{3/2}$, predicted at 7565 cm^{-1} and 12 345 cm^{-1}, which are accessible by direct laser excitation from the atomic ground state, are of high relevance to test the theoretical description of the Ac spectrum. We utilize two-step resonance ionization spectroscopy with high repetition rate pulsed Titanium: sapphire lasers operating on about 10^{10} atoms in a hot cavity ion source at the Mainz university atomic beam apparatus MABU. The study of these optical transitions involves direct non-resonant ionization into the continuum beyond 43 394.45 cm^{-1}. For the first infrared transition to excite the $^2P^o_{1/2}$ level, predicted at 1321.8 nm, difference frequency generation is needed, while the ionization step employs 279 nm light generated by frequency tripling.