Q 52: Precision Spectroscopy of Atoms and Ions III (with A)

Time: Thursday 11:00–13:00 Location: M/HS1

Q 52.1 Thu 11:00 M/HS1

Untersuchung von Lanthanoiden mittels Laserresonanzionisation an der Mainzer Atomic Beam Unit — •Patrick Dyrauf, Michael Franzmann, Tina Gottwald, Tom Kieck, Tobias Kron, Pascal Naubereit, Fabian Schneider, Dominik Studer und Klaus Wendt — Institut für Physik, Universität Mainz

Die Spektren einiger Lanthanoiden sind bis heute im Bereich hochliegender Resonanzen in der Nähe des ersten Ionisationspotentials noch wenig bzw. gar nicht erforscht. Dies liegt primär an ihrer komplexen atomaren Struktur, die sowohl Messungen als auch besonders deren Auswertung und Interpretation erschwert. Die Anwendung des Verfahrens der mehrstufigen Resonanzionisations-Massenspektrometrie zur elementselektiven Ionisation an Isotopenproduktionsanlagen bzw. zur Isobarenabtrennung wird dadurch behindert. Gleichzeitig bietet dies aber auch gute Möglichkeiten um hier nützliches atomphysikalisches Datenmaterial zu generieren und damit Ionisationsprozesse und deren Effizienz zu optimieren bzw. ein tieferes Verständnis der reichen Niveauschemata zu erlangen. Hierzu wird an der Universität Mainz ein hoch-repetierendes Titan-Saphir-Lasersystem an der Atomstrahlapparatur MABU verwendet, die ein kompaktes Quadrupol-Massenspektrometer zur Isotopenselektion enthält. Erste Untersuchungen betrafen Anregungsschemata im Spektrum des Dysprosiums, zusätzlich sind Messungen an Holmium und Erbium vorgesehen. Der Einsatz eines weit abstimmbaren Lasers mit reduzierter Linienbreite ist vorgesehen, um die Signifikanz bereits erzielter Daten zu erhöhen und einen möglichst großen Energiebereich abzudecken.

Q 52.2 Thu 11:15 M/HS1

Ba^+ Atomic Properties from Single Ion Experiments — •Elwin A. Dijck, Amita Mohanty, Mayerlin Nunez-Portela, Nivedya Valappol, Andrew T. Grier, Oliver Boell, Steven Hoekstra, Lorenz Willmann, and Klaus Jungmann — Van Swinderen Institute, University of Groningen, The Netherlands

Single trapped, laser cooled Ba^+ and Ra^+ ions are ideally suited for high precision measurements of the weak mixing angle at low energy; in addition, the same experimental setup can be used to build an atomic clock with a fractional frequency uncertainty of 10^{-18}. Both applications require powerful diagnostics of trap dynamics and percent level accuracy in atomic theory. Here the lifetime of the metastable $5d^2D_{5/2}$ level of Ba^+ provides a sensitive diagnostic for perturbations of the ion. Using quantum jump spectroscopy of a single trapped ion, a lifetime of 26(2) s was determined, correcting for collisions with residual gas. Furthermore, we have determined the $6s^2S_{1/2}$–$6d^2P_{1/2}$ and $6s^2P_{1/2}$–$5d^2D_{3/2}$ transition frequencies to MHz accuracy using Raman spectroscopy referenced to an optical frequency comb. This constitutes an improvement in the absolute accuracy of some 2 orders of magnitude.

Q 52.3 Thu 11:30 M/HS1

Light Shifts: Measuring Atomic Parity Violation in Single Trapped Ions — •Amita Mohanty, Elwin A. Dijck, Mayerlin Nunez Portela, Nivedya Valappol, Andrew T. Grier, Steven Hoekstra, Klaus Jungmann, and Lorenz Willmann — Van Swinderen Institute, University of Groningen, The Netherlands

Light shifts permit the mapping of weak interaction effects onto the energy splitting of the magnetic sub-levels in Ra^+. A precise measurement of atomic parity violation (APV) provides for the determination of the weak mixing angle ($\sin^2 \Theta_W$), the Standard Model parameter which describes the connection between the electromagnetic and weak interactions. APV is also sensitive to light dark matter bosons, e.g dark Z bosons with masses below a few 100 MeV. For the experiment, localization of a single ion within a fraction of an optical wavelength in two orthogonal light fields of known polarization is required in order to disentangle the electromagnetic and weak contributions to the light shift. The heavy alkaline earth ion Ra^+ is very well suited for such experiments because the APV signal scales significantly stronger than with Z^3. Ba^+ serves as a precursor and the precise determination of the light shift in the $5d^2D_{3/2}$–$6s^2S_{1/2}$ transition is the next step towards the Ra^+ ion APV experiment.

Q 52.4 Thu 11:45 M/HS1

Search for optical excitation of the low-energy nuclear isomer of ^{229}Th — •David-Marcel Meier, Maksim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Direct optical excitation of the nuclear transition between ground state and the 7.8 eV isomer in ^{229}Th is the missing link towards a study of this system as a precise nuclear clock. We plan to use two-photon laser excitation via electronic bridge processes in Th^+ [1]. The high density of states within the energy range from 7.3 to 8.3 eV [2,3] in Th^+ promises a strongly enhanced nuclear excitation rate. Using laser ablation loading of the ion trap and photodissociation of molecular ions that are formed in reactions of Th^+ with impurities in the buffer gas, we efficiently load and stably store ions of the radioactive ^{229}Th isotope. We have measured the hyperfine structure and isotope shifts of two resonance lines where one of these lines shows an untypical negative isotope shift compared to all previously known lines in ^{229}Th which show a positive shift. Both lines are suitable as first excitation stages of the electronic bridge.

[1] S. G. Porsev et al., Phys. Rev. Lett. 105, 182501 (2010)
[2] O. A. Herrera-Sancho et al., Phys. Rev. A 85, 033402 (2012)
[3] O. A. Herrera-Sancho et al., Phys. Rev. A 88, 012512 (2013)

Q 52.5 Thu 12:00 M/HS1

Astrophysical line diagnosis requires non-linear dynamical atomic modeling — •Natalia S. Oreshkina, Stefano M. Cavaletto, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Line intensities and oscillator strengths for the controversial 3C and 3D astrophysically relevant lines in neonlike Fe^{16+} ions are calculated [1]. First, a large-scale configuration-interaction calculation of oscillator strengths is performed with the inclusion of higher-order electron-correlation effects. Also, QED effects to the transition energies are calculated. Further considered dynamical effects give a possible resolution of the discrepancy of theory and experiment found by recent x-ray free electron laser measurements [2]. We find that, for strong x-ray sources, the modeling of the spectral lines by a peak with an area proportional to the oscillator strength is not sufficient and non-linear dynamical effects have to be taken into account. Thus we advocate the use of light-matter interaction models also valid for strong light fields in the analysis and interpretation of astrophysical and laboratory x-ray spectra.

[1] N. S. Oreshkina, S. M. Cavaletto, C. H. Keitel and Z. Harman, Phys. Rev. Lett. **113**, 143001 (2014).
[2] S. Bernitt, G. V. Brown, J. K. Rudolph, R. Steinbrügge *et al.*, Nature **492**, 225 (2012).

Q 52.6 Thu 12:15 M/HS1

Life times of the HFS transitions in H-like and Li-like bismuth — •Jonas Vollbrecht for the LIBELLE-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, Germany

In 2011 the LIBELLE collaboration succeeded to measure the hyperfine splitting in highly charged $^{209}Bi^{82+}$ and for the first time in a laser spectroscopy experiment, in $^{209}Bi^{80+}$. For this purpose the ions were accelerated to 400 MeV/u by the GSI accelerator infrastructure and stored in the experimental storage ring (ESR) in the form of two bunches at a velocity of $\beta \approx 0.71$. One of the bunches was excited by a laser and the emitted fluorescence photons were detected by specialized detector systems. Besides the transition wavelengths some data for the life time of the lithium like bismuth were recorded. The precision of the measurement was limited by the calibration of the electron cooler voltage that determines the ion velocity which is needed to transform the results from co-moving coordinates to the rest frame. Therefore a second beam time was scheduled for march 2014 with an improved voltage calibration via a high precision voltage divider provided by Physikalisch-Technische Bundesanstalt Braunschweig (PTB) and an updated DAQ system. Besides a much higher accuracy of the transition energies, the new setup also allowed to gather high statistics data on the life times of both HFS transitions in $^{209}Bi^{82+}$ an $^{209}Bi^{80+}$. The analysis of the life times will be presented in this talk.

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Q 52.7 Thu 12:30 M/HS1

Search for the $^{1}P_1$ level in ^{254}No in a buffer-gas cell — •Felix Lautenschläger[1], Hartmut Backe[2], Michael Block[3,4], Bradley Cheal[5], Premaditya Chhetri[1], Peter Kunz[6], Fritz-Peter Hessberger[3,4], Mustapha Laatiaoui[3,4], Werner Lauth[2], Sebastian Raeder[7], Thomas Walther[1], and Calvin Wraith[5] — [1]Technische Universität Darmstadt, Deutschland — [2]Johannes Gutenberg-Universität Mainz, Deutschland — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Deutschland — [4]Helmholtzinstitut Mainz, Deutschland — [5]University of Liverpool, Großbritannien — [6]TRIUMF, Kanada — [7]Katholieke Universiteit Leuven, Belgien

The atomic structure of the heaviest elements (Z>100) is strongly affected by relativistic effects. Their description in modern Relativistic-Coupled-Clusters and Multi-Configuration-Dirac-Fock theories can be benchmarked by laser spectroscopy of the atomic levels in ^{254}No, which has a simple atomic structure allowing precise predictions of the atomic transitions. At present, no experimental information is available for the atomic levels of ^{254}No. It can be produced using the nuclear fusion reaction ^{208}Pb(^{48}Ca,2n)^{254}No. In our experiment, we employ the Radioation Detected Resonance Ionization Spectroscopy in a buffer-gas cell behind the velocity-filter SHIP at GSI. In a recent experiment the search for the predicted $5f^{14}7s7p\ ^{1}P_1$ level in ^{254}No has been continued. First results of this measurement campaign will be presented.

Q 52.8 Thu 12:45 M/HS1

The ALPHATRAP Experiment — •Robert Wolf[1], Stefan Erlewein[1,2], Henrik Hirzler[1,2], Sandro Kraemer[1,2], Tim Sailer[1,2], Andreas Weigel[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik, Universität Heidelberg

The ALPHATRAP experiment aims for the ultra-high precision determination of the *g*-factor of the bound electron in highly charged hydrogen-, lithium- and boron-like heavy ions as $^{208}Pb^{81+}$, $^{208}Pb^{79+}$ and $^{208}Pb^{77+}$. In these systems the electron is exposed to extremely strong fields of up to 10^{16} V/cm. Simultaneously, bound-state quantum electrodynamic (BS-QED) effects scale with the nuclear charge number, making these measurements a very stringent test of the underlying theory under extreme conditions. In combination with currently conducted BS-QED calculations, the measurement will provide an independent determination of the fine-structure constant α with high precision. To achieve this, the prospective ALPHATRAP experiment, consisting of a cryogenic double Penning-trap setup, is coupled via an ultra-high vacuum beamline to the Electron-Beam Ion Trap at the Max-Planck Institut für Kernphysik, which provides the highly charged ions. The status of the project as well as the measurement program will be presented.