A 4: Precision spectroscopy of atoms and ions I

Time: Monday 14:00–16:00 Location: BAR 205

A 4.1 Mon 14:00 BAR 205

Absolute determination of X-ray transition energies in H-like and He-like ions — •Katharina Kubicek, Hjalmar Bruhns, Johannes Braun, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We present high-precision wavelength measurements for H- and He-like ions performed with the FLASH-EBIT using a flat crystal x-ray spectrometer applying a collimation-free technique [Braun *et al.*, Rev. Sci. Instrum. 76 (2005), p. 073105] which allows to determine absolute Bragg angles without the need of reference lines. We have reduced further the already small leading experimental uncertainty [Bruhns *et al.*, Phys. Rev. Lett. 99 (2007), p. 113001] by installing the spectrometer coaxially to the electron beam, thus viewing the ion cloud as a point source. This setup reveals a minute curvature of the x-ray lines on the detector plane which hitherto had to be estimated. Results for the Lyman-α_1 and "w" ($1s2p\ ^1P_1 \rightarrow 1s^2\ ^1S_0$) transition wavelengths in H-like and He-like argon, sulfur and iron ions with experimental uncertainties of esimated $\Delta E < 4$ meV are sensitive to the far larger QED contributions of 1 eV.

A 4.2 Mon 14:15 BAR 205

Laser Spectroscopy on Highly Charged Fe^{13+} Ions — •Kirsten Schnorr, Volkhard Mäckel, José Ramón Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We report on the first successful laser spectroscopic measurements on highly charged Fe^{13+} trapped in an Electron Beam Ion Trap (EBIT) at MPIK. The forbidden M1 transition $(1s^2 2s^2 2p^6 3s^2 3p)\ ^2P_{3/2} - {}^2P_{1/2}$ has been excited resonantly with a tunable dye laser, while monitoring the fluorescence photons.

The studied line is the well-known *green coronal line* of Fe XIV, and therefore of great interest for comparison with astronomical data, since our measured wavelength is not affected by the Doppler shift.

Compared to our earlier results on Ar^{13+} ions, we have been able to enhance the resolution of the method and improve evaporative cooling. The Zeeman splitting of the transition due to the magnetic field in the EBIT has been clearly resolved. In addition we have observed optical pumping between the $\pi^{1/2}$ and $\pi^{3/2}$ Zeeman levels.

A 4.3 Mon 14:30 BAR 205

Ion trapping and laser cooling in the SPECTRAP experiment — •Zoran Andjelkovic[1,3], Shailen Bharadia[2], Radu Cazan[1,3], Richard Thompson[2], Manuel Vogel[1], and Wilfried Nörtershäuser[1,3] — [1]Gesselschaft für Schwerionenforschung, Darmstadt, Germany — [2]Imperial College, London, UK — [3]Universität Mainz, Germany

As one of the experiments associated to the HITRAP project at GSI, Darmstadt, the SPECTRAP experiment is making its first steps towards precision spectroscopy on trapped highly charged ions. As an initial test, Mg+ ions are produced externally and guided into the trap, located inside a split-coil superconducting magnet, with radial optical ports for fluorescence detection. Using a frequency-quadrupled 1118 nm fibre laser they can be laser cooled to a few mK and used for sympathetic cooling of any other ion species simultaneously trapped. This report presents the trapping technique and the methods used for detecting, cooling and manipulating the ions inside the trap, together with the first experimental results.

A 4.4 Mon 14:45 BAR 205

Commissioning of HITRAP - A Decelerator for Heavy Highly-Charged Ions — •Nicolaas P.M. Brantjes, Frank Herfurth, Ludwig Dahl, Oliver Kester, and Wolfgang Quint — GSI, Darmstadt, Germany

Heavy, highly-charged ions (HCI) with only one or few electrons are interesting systems for precision experiments as for instance tests of the theory of quantum electrodynamics (QED). To achieve high precision, kinetic energy and spatial position of the ions have to be well controlled. This is in contradiction to the production process that employs stripping of ele ctrons at high energies by sending relativistic highly-charged ions with still m any electrons through matter. In order to match the production at 400 MeV/u with the requirements of the exper iments - stored and cooled HCI at low energy - the linear decelerator facility H ITRAP has been built at the experimental storage ring (ESR) at GSI in Darmstadt. The ions are first decelerated in the ESR from 400 to 4 MeV/u, cooled and extrac ted. The ion beam phase spaces are then matched to an IH-structure, decelerated from 4 to 0.5 MeV/u before a 4-rod RFQ reduces the energy to 6 keV/u. Finally, the HCI are cooled in a Penning trap to 4 K. Here we present our progress in the commissioning of the IH-Structure and the RFQ over the past year.

A 4.5 Mon 15:00 BAR 205

Spectroscopic reference for the measurement of the transition frequency of highly charged bismuth ions — Sanah Altenburg[1], •Sebastian Albrecht[1], Gerhard Birkl[1], and the SPECTRAP collaboration[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt — [2]GSI, Planckstraße 1, 64291 Darmstadt

The investigation of the ground state hyperfine splitting of highly charged ions is one of the objectives of the experiments planned to be carried out within the SPECTRAP collaboration within the HITRAP facility at GSI. For $^{209}Bi^{82+}$ ions, transitions between hyperfine ground states can be exited using light at 243.9 nm. This light is produced in a laser system and two frequency-doubling stages resulting in 15 mW in the UV.

The expected wavelength of the transition between the hyperfine ground states is located near previously measured resonances of the 1S-2S transitions of muonium, deuterium and hydrogen. For those earlier measurements some molecular resonances of tellurium vapour have been calibrated with sub-Megahertz precision. These references can be used to create new references in the regime of the expected bismuth transition.

The spectrum between these calibrated resonances has been measured with an accuracy corresponding to the one of our laser system. In our presentation we describe the technique used and the performance reached.

A 4.6 Mon 15:15 BAR 205

Nuclear corrections to the g-factor of a bound electron — •Jacek Zatorski[1], Zoltan Harman[1,2], Christoph H. Keitel[1], Birgit Schabinger[3], Sven Sturm[3], Anke Wagner[3], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, 64291 Darmstadt, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany

The g-factor of a bound electron has recently gained a lot of experimental as well as theoretical interest. Comparison between theoretical and experimental results for $^{12}C^{5+}$ and $^{16}O^{7+}$ led to the determination of the most accurate value of the electron mass [1]. Upcoming experiments [2] with the somewhat heavier ions Si^{13+} and Ca^{19+} and beyond are expected to achieve an even greater accuracy, which in turn will call for accordingly more accurate theoretical predictions. We present theoretical results for medium-Z hydrogen-like ions with an emphasis on effects arising due to the nuclear structure.

[1] P. J. Mohr *et al.*, Rev. Mod. Phys. **80**, 633 (2008).
[2] S. Sturm *et al.*, J. Phys. B: At. Mol. Opt. Phys. **43**, 074016 (2010).

A 4.7 Mon 15:30 BAR 205

QED in strong fields: hyperfine structure and g factor in heavy ions — •Andrey Volotka[1,2], Dmitry Glazov[2], Vladimir Shabaev[2], Ilya Tupitsyn[2], and Günter Plunien[1] — [1]Institut für Theoretische Physik, TU Dresden, Germany — [2]St. Petersburg State University, Russia

Investigations of the hyperfine splitting and g factor in highly charged ions provide access to a test of bound-state QED in strongest electromagnetic field available for experimental study. To date, accurate measurements of the ground-state hyperfine structure and of the g factor were performed in several H-like heavy ions and in H-like carbon and oxygen ions, respectively. An extension of such kind of experiments to highly charged Li-like ions will provide the possibility to investigate a specific difference between the corresponding values for H- and Li-like ions, where the uncertainty due to the nuclear effects can be substantially reduced. In this talk we present ab initio QED calculations of the hyperfine splitting and g factor of heavy high-Z ions. Special attention is focused on recent results of our rigorous evaluation of the complete gauge-invariant set of the screened one-loop QED corrections to the hyperfine structure and g factor in highly charged Li-like ions. The current status of the evaluations of the two-photon exchange corrections is also reported. As a result, the specific difference between the ground-state hyperfine splitting values of H- and Li-like Bi ions and for the g factor of the Li-like Pb ion are presented.

A 4.8 Mon 15:45 BAR 205

Bound electron g-Factor Measurement by Double-Resonance Spectroscopy on a Fine-Structure Transition — •David von Lindenfels[1,2,3], Wolfgang Quint[1,2], Manuel Vogel[1], and Gerhard Birkl[4] — [1]GSI Darmstadt, Germany — [2]Universität Heidelberg, Germany — [3]MPIK Heidelberg, Germany — [4]TU Darmstadt, Germany

Precise determination of bound-electron g-factors in highly-charged ions (e.g. boron-like argon Ar^{13+} and calcium Ca^{15+}) provides a stringent test of bound-state QED in extreme fields and contributes to the determination of fundamental constants. We have designed a cryogenic trap assembly with a creation trap and a spectroscopy trap. Argon ions are produced by electron impact ionization and transferred to the spectroscopy trap. We will excite the fine-structure transition $2^2P_{1/2}$ – $2^2P_{3/2}$ with laser radiation and probe microwave transitions between Zeeman sub-levels (laser-microwave double-resonance technique). From this the electronic g-factor g_J can be determined on a ppb level. We have developed and tested a field emission electron source, a novel cryogenic gas valve and an optical setup to detect the low fluorescence signal of the magnetic dipole transition. In future, the trap will be connected to the HITRAP beamline at GSI, and the method will be applied to hyperfine-structure transitions of hydrogen-like heavy ions in order to measure electronic and nuclear magnetic moments. The contribution presents techniques and the current status of the experiment.