A 30: Precision spectroscopy of atoms and ions II

Time: Thursday 10:30–12:30 Location: V47.03

Invited Talk A 30.1 Thu 10:30 V47.03

X-ray laser spectroscopy at the free-electron laser LCLS — •José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

X-ray laser spectroscopy (XRLS) has been demonstrated by using an electron beam ion trap (EBIT) at the recently commissioned free-electron laser Linac Coherent Light Source (LCLS) at SLAC. Many of the limitations in accuracy and selectivity which had hitherto hampered spectroscopic investigations of highly charged ions (HCIs) are overcome by the introduction of XRLS. The present results on $Fe^{15+,16+}$ strongly challenge state-of-the-art calculations widely used for astrophysical plasma diagnostics.

The novel method has also been applied to high-energy synchrotron radiation sources (BESSY II, PETRA III) for studies of the photoionization and excitation of HCIs in charge states as high as Fe^{24+} and at photon energies in the 6 keV range.

Future improvements of these X-ray sources, e. g. through radiation seeding, will help to develop this field further. New possibilities appear for the study and diagnostics of astrophysical and terrestrial plasmas as well as for X-ray metrology. Moreover, the new data stringently benchmark and guide the development of relativistic atomic structure theory.

Invited Talk A 30.2 Thu 11:00 V47.03

Test of fundamental physics with highly charged ions — •Z. Harman[1], C. Beilmann[1], J. R. Crespo López-Urrutia[1], S. Sturm[1,2], V. Yerokhin[1,3], J. Zatorski[1], K. Blaum[1], J. Ullrich[1], and C. H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]University of Mainz, Germany — [3]St. Petersburg State Polytechnical University, Russia

In highly charged ions (HCI), the strong nuclear Coulomb force renders the electron dynamics relativistic, and effects of strong-field quantum electrodynamics (QED) are increasingly relevant at higher and higher charges. A recent study has shown that surprising electron correlation effects appear already at low charge states, e.g. in C-like Ar: it was found that a recombination process with the participation of three electrons may result in a cross section higher than that of the usual dielectronic recombination [1]. Furthermore, we propose an alternative way of determining spectral properties of HCI by employing an x-ray free electron laser and an optical laser. Bound-state QED effects can be scrutinized to high precision in Penning trap experiments: a recent measurement yielded a value for the g factor of H-like Si with a $5 \cdot 10^{-10}$ fractional uncertainty, allowing to test certain higher-order QED corrections for the first time [2]. As theoretically suggested, similar experiments may even deliver more accurate or so far unknown nuclear shape parameters [3] and magnetic moments, relevant to NMR spectroscopy [4]. – [1] C. Beilmann *et al.*, PRL **107**, 143201 (2011); [2] S. Sturm *et al.*, PRL **107**, 023002 (2011); [3] J. Zatorski *et al.*, arxiv:1110:3330; [4] V. I. Yerokhin *et al.*, PRL **107**, 043004 (2011).

A 30.3 Thu 11:30 V47.03

Accurate spectroscopic references near 488 nm — •Sebastian Albrecht[1], Heiko Jestädt[1], Sanah Altenburg[1], Tobias Murböck[1], Manuel Vogel[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

Several current experimental ventures such as the study of the hyperfine transition of highly charged $^{209}Bi^{82+}$ ions or the excitation of Rydberg states in atomic rubidium strongly profit from a spectroscopic reference at wavelengths of 480 to 490 nm. Molecular tellurium provides a map of recorded spectra in this wavelength region [1].

We operate a frequency-quadrupled laser system for the generation of light at a wavelength of 244 nm for $^{209}Bi^{82+}$ spectroscopy [2]. The blue light available after the first frequency-doubling stage allows us to record tellurium spectra with improved accuracy. Previous measurements of the 1S-2S transition of muonium, deuterium and hydrogen as well as coinciding reference lines of an Ar^+ laser have lead to calibrated tellurium resonances. Using these sub-Megahertz precise lines we can generate a continuous spectrum of tellurium with a span of 1.4 THz around 488 nm. This easily can be expanded to other wavelength regions in the blue for extended frequency calibration.

[1] J. Cariou and P. Luc, Atlas du spectre d'absorption de la molecule de tellure (Laboratoire Aime-Cotton, Paris, 1980)

[2] S. Albrecht, S. Altenburg, C. Siegel, N. Herschbach, G. Birkl, Appl. Phys. B, DOI: 10.1007/s00340-011-4732-8 (2011)

A 30.4 Thu 11:45 V47.03

Laserspektroskopie an relativistischen 209-Bi82+ und 209-Bi80+ Ionen am Speicherring ESR der GSI — •Christopher Geppert[1,2], Matthias Lochmann[1], Rodolfo M. Sanchez[1,2], Michael Hammen[1], Nadja Frömmgen[1], Elisa Will[1], Benjamin Botermann[1], Zoran Andjelkovic[1], Raphael Jöhren[3], Jonas Mader[3], Volker Hannen[3], Christian Weinheimer[3], Danyal Winters[2,4], Thomas Kühl[2], Yuri Litvinov[2], Thomas Stöhlker[2,4], Andreas Dax[5], Michael Bussmann[6], Weiqiang Wen[7], Richard Thompson[8] und Wilfried Nörtershäuser[1,2] — [1]Institut für Kernchemie, Universität Mainz — [2]GSI Helmholtzzentrum, Darmstadt — [3]Institut für Kernphysik, Universität Münster — [4]Physikalisches Institut, Universität Heidelberg — [5]Department of Physics, University Tokyo — [6]Helmholtz-Zentrum Dresden-Rossendorf — [7]IMP Lanzhou — [8]Imperial College, London

Die genaue Bestimmung der Hyperfeinstrukturaufspaltung (HFS) von hochgeladenen Ionen erlaubt im Abgleich mit theoretischen Berechnungen einen Test der QED. Die Messung an schweren und hochgeladenen Ionen erlaubt einen Test der QED in starken Feldern.

Im Rahmen der LIBELLE (E083)-Kollaboration am Helmholtzzentrum für Schwerionenforschung (GSI) wurden hierzu wasserstoff- und lithium-ähnliches Bismut bei Geschwindigkeiten von β=0.7 im Speicherring ESR gespeichert und mittels Laserspektroskopie untersucht. Nach 12-jähriger Suche wurde nun erstmals der verbotene HFS-Übergang im lithium-ähnlichen Bismut gefunden.

A 30.5 Thu 12:00 V47.03

Test of many-electron QED effects in the presence of magnetic fields — •Andrey Volotka[1], Dmitry Glazov[2], Oleg Andreev[2], Vladimir Shabaev[2], Ilya Tupitsyn[2], and Günter Plunien[1] — [1]Institut für Theoretische Physik, TU Dresden — [2]St. Petersburg State University, Russia

Recent progress in rigorous QED calculations of the hyperfine splitting and g factor of highly charged Li-like ions will be reported. A special attention will be paid to the evaluation of the two-photon exchange corrections in the presence of a magnetic field. Together with the screening radiative corrections they represent the most difficult many-electron QED diagrams, which have been so far rigorously evaluated. As a result, the accuracy for the specific difference between the hyperfine splitting values of H- and Li-like ions as well as for the g factor of Li-like ions has been significantly increased, thus providing the theoretical prerequisite for a test of many-electron QED effects at strong electromagnetic fields.

A 30.6 Thu 12:15 V47.03

Production of Be^+ crystals in a cryogenic Paul trap for the sympathetic cooling of highly charged ions — •Alexander Windberger[1], Maria Schwarz[1], Oscar O. Versolato[1], José R. Crespo López-Urrutia[1], Alexander D. Gingell[2], Anders K. Hansen[2], Magnus A. Sørensen[2], Michael Drewsen[2], Piet O. Schmidt[3], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]University of Aarhus, Denmark — [3]Physikalisch-Technische Bundesanstalt, Braunschweig und Leibniz Universität, Hannover, Germany

Due to the deep core potential of highly charged ions (HCIs), optically active electrons involved in forbidden transitions are strongly bound. This type of electronic configuration offers various possibilities for high precision spectroscopy with applications to metrology and fundamental quantum dynamics. An efficient way of producing and trapping HCIs is the electron beam ion trap (EBIT). However, ion temperatures in the order of MK limit spectral resolution. With a new cryogenic Paul trap (CryPTEx) HCIs can be stored and laser cooled in a 4 K environment in which the rate of collisions with residual gas is strongly reduced. HCIs in CryPTEx will be sympathetically cooled with Be^+ ions. To address the 313 nm cooling transition, a cw laser system has been developed. It comprises sum frequency and second harmonic generation stages of 1050 nm and 1550 nm fiber lasers. An output power at

313 nm of up to 750 mW can be reached. Furthermore, a source is under development for providing sufficient amounts of Be^+ ions without disturbing the excellent cryogenic conditions inside the trap.