A 11: Precision Spectroscopy of Atoms and Ions II (joint session A/Q)

Time: Tuesday 11:00–12:45 Location: F303

A 11.1 Tue 11:00 F303

Highly-sensitive photodetachment spectroscopy in an MR-ToF device — •Franziska Maria Maier[1,2] and Erich Leistenschneider[1] — [1]ISOLDE/CERN — [2]Universität Greifswald

For the MIRACLS and GANDALPH collaboration.

The electron affinity (EA) reflects the energy released when an electron is attached to a neutral atom. An experimental determination of this quantity serves as an important benchmark for atomic models describing electron-correlation effects [1]. However, the EA of several radioactive elements is still unknown and detailed information about isotope shifts or hyperfine splittings of EAs are only available for a handful of cases, mainly with modest precision.

Exploiting the low-energy version of the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS) [2], we have initiated a high-precision measurement of the isotope shift in the electron affinity. By trapping ion bunches between the two electrostatic mirrors of MIRACLS multi-reflection time-of-flight (MR-ToF) device, the same ion bunch is probed by the spectroscopy laser repeatedly. Thus, the signal sensitivity is 3-4 orders of magnitude higher compared to conventional single-pass photodetachment experiments, see e.g. [1].

I will introduce the novel technique, present the first experimental results on Chlorine and discuss future possibilities of an MR-ToF device for highly sensitive and high-precision measurements of EAs for various radioactive samples.

[1] D. Leimbach et al., Nat Commun 11, 3824 (2020).
[2] S. Sels et al., Nucl. Instr. Meth. Phys. Res. B 463, 310 (2020).

A 11.2 Tue 11:15 F303

Nuclear polarization effects in atoms and ions — Victor V. Flambaum[1,2,3], Igor B. Samsonov[1], Hoang Bao Tran Tan[1,4], and •Anna V. Viatkina[2,3,5,6] — [1]School of Physics, University of New South Wales, Sydney 2052, Australia — [2]Helmholtz Institute Mainz, GSI Helmholtzzentrum für Schwerionenforschung, 55099 Mainz, Germany — [3]Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [4]Department of Physics, University of Nevada, Reno, Nevada 89557, USA — [5]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [6]Institute of Mathematical Physics, Technical University Braunschweig, 38106 Braunschweig, Germany

Precision isotope shift spectroscopy offers an opportunity to search for new physics by means of measuring King plot (KP) nonlinearities. However, KP nonlinearities might arise from standard-model effects as well, thus obscuring possible new-physics signal. One of such effects is the variation of nuclear polarizabilities between isotopes. Even though this effect is estimated to be relatively small and not the leading contribution to KP nonlinearity, it should not be overlooked in the interpretation of the data. In our work, we calculated energy-level shifts due to electric-dipole and -quadrupole nuclear polarization for 1s, 2s, $2p_{1/2}$ states in hydrogenlike ions, and for high-ns valence states in neutral atoms with $Z \geq 20$. We fit the results with elementary functions of nuclear parameters and derive a set of effective potentials which may be used to calculate polarization energy-level shifts in many-electron atoms and ions.

A 11.3 Tue 11:30 F303

Enhancing Atom-Photon Interaction with Novel Integrated Nano-photonic Resonators — •Benyamin Shnirman — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany

The marriage of thermal atomic vapor with nanophotonics provides a unique testbed for the manipulation of atom-atom and atom-photon interactions. While benefitting from strong miniaturisation, integration and scalability, this platform struggles with short atom-light interaction due to the thermal motion.

In order to overcome this dephasing mechanism, we need atom-light interaction to reach the strong coupling regime. A suitable candidate is a photonic crystal cavity (PhC), which combines a tight mode confinement with a high quality factor. In order to create an interface for atom-light interaction, we have developed a novel fabrication technique to suspend PhC's. This allows us to investigate cavity QED effects that are sensitive to single photons and single atoms. We present first characterization data of the fabricated PhC's and compare it to the simulation results.

Our other lines of research on nanophotonics and thermal atoms include the use of the Rydberg blockade effect on chip to generate single photons. In order to couple to the Rydberg states efficiently, the light field is locally enhanced by ultralow-loss micro-ring resonators.We also study topological edge states in arrays of ring resonators and how thermal atoms can be used to study the effect of optical nonlinearity on the bulk and edge modes.

A 11.4 Tue 11:45 F303

Minimizing entanglement of sources of P,T-violation with complementary low-energy experiments — •Konstantin Gaul and Robert Berger — Fachbereich Chemie, Philipps-Universität Marburg,Hans-Meerwein-Straße 4, 35032 Marburg, Germany

The detection of an atomic or molecular P,T-odd electric dipole moment (EDM) would be a direct evidence of physics beyond the Standard Model. Internal enhancement effects render atoms and molecules very promising candidates for a first direct detection of P,T-violation. The EDM of an atom or molecule stems from various fundamental sources of P,T-violation, such as P,T-odd currents or EDMs of elementary particles [1]. Therefore, interpretations and predictions of EDMs are difficult and several experiments are required for a global model-independent analysis of the results [2]. In this contribution all sources of the P,T-odd EDMs of atoms and molecules are studied within a simple qualitative electronic-structure model in terms of electronic and nuclear angular momenta and the nuclear charge number. For comparison accurate calculations of the electronic structure parameters [3] of most experimentally relevant atoms and molecules are performed and selection of good candidates for future experiments is discussed in the light of minimizing the coverage region in the global P,T-odd parameter space.

[1] Khriplovich, Lamoreaux, CP Violation without Strangeness (1997).
[2] Jung, JHEP 2013, 168 (2013); Engel *et al.*, PPNP 71, 21 (2013); Chupp, Ramsey-Musolf, PRC 91, 035502 (2015).
[3] Gaul *et al.*, PRA 99, 032509 (2019); JCP 152, 044101 (2020).

A 11.5 Tue 12:00 F303

Path integral formalism for radiative corrections in bound-state QED — •Sreya Banerjee and Zoltán Harman — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

A step-by-step theory of radiative corrections in bound-state quantum electrodynamics is developed using Feynman's path integral formalism. As a first step, we derive the free Dirac propagator in spherical coordinates. This is followed by the derivation of the Dirac-Coulomb Green's function (DCGF) in the Furry picture by reducing it in a basis such that the effective action becomes similar to that of the non-relativistic hydrogen atom. As such, the DCGF is obtained in closed form along with the energy spectrum of the bound states. In the final step, the lowest-order vacuum polarization correction and one-loop self-energy correction to the energy levels of bound electrons are calculated using perturbative path integral formalism. Starting from an interparticle classical action, we arrive directly at the propagators of quantum electrodynamics. The energy level shifts are then calculated from the perturbative shift of poles of the Green's functions obtained.

A 11.6 Tue 12:15 F303

Trapping and cooling Th ions with Ca ion crystal for quantum logic spectroscopy — •Azer Trimeche[1], Jonas Stricker[2,3], Can Patric Leichtweiss[1], Valerii Andriushkov[2], Dennis Renisch[2,3], Dmitry Budker[1,2], Christoph E. Düllmann[2,3,4], and Ferdinand Schmidt-Kaler[1] — [1]QUATUM, Institute of Physics, Johannes Gutenberg-Universität Mainz — [2]Helmholtz-Institut Mainz — [3]Department of Chemistry, Johannes Gutenberg-Universität Mainz — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Thorium isotopes became of high interest in the search for new physics, and fundamental physics tests, because of their unique nuclear and atomic properties. The Trapping And Cooling of Thorium Ions in Calcium crystals (*TACTICa*) project develops ion trapping and spectroscopic techniques for a precise determination of the nuclear moments, hyperfine intervals, and isotope shifts with different Th isotopes. For the production, we dispose of two different sources: an ion recoil source [1] and a laser ablation source [2]. Th ions are trapped in a Ca^{+} crystal [3], tagged by fluorescence calorimetry technique [4], cooled down sympathetically by polarization gradient cooling of Ca^+ crystal [5], and investigated by quantum logic spectroscopy technique.

[1] R. Haas et al., Hyperfine interactions 241 (2020) 25.
[2] K. Groot-Berning et al., *PRA* 99 (2019) 023420.
[3] K. Groot-Berning et al., *PRL* 123 (2019) 106802.
[4] M. Gajewski et al. *PRA* 106 (2022) 033108.
[5] W. Li et al., *NJP* 24(4) (2022) 043028.

A 11.7 Tue 12:30 F303

Metallic magnetic calorimeters: Novel detectors for high-resolution X-ray spectroscopy — •D. Hengstler[1], A. Abeln[1], S. Allgeier[1], A. Brunold[1], L. Eisenmann[1], M. Friedrich[1], A. Gumberidze[2], M.-O. Herdrich[2,3,4], F. Kröger[2,3,4], P. Kuntz[1], A. Fleischmann[1], M. Lestinsky[2], E. Menz[2,3,4], A. Orlow[1], Ph. Pfäfflein[2,3,4], U. Spillmann[2], B. Zhu[4], G. Weber[2,3,4], Th. Stöhlker[2,3,4], and C. Enss[1] — [1]KIP, Heidelberg University — [2]GSI, Darmstadt — [3]IOQ, Jena University — [4]HI Jena

Metallic magnetic calorimeters (MMCs) are energy-dispersive X-ray detectors which provide an excellent energy resolution over a large dynamic range combined with a very good linearity. They are operated at mK temperatures and convert the energy of each incident photon into a temperature rise which is monitored by a paramagnetic sensor.

To probe QED, we developed the 2-dimensional detector array maXs-100. The detector features 8x8 pixels with an active detection area of $1\,\mathrm{cm}^2$ and a stopping power of 40 % at 100 keV. An absolute energy calibration on eV-level as well as an energy resolution of 40 eV (FWHM) at 60 keV were demonstrated. We discuss the detector performance during the recent beam time at the ion storage ring CRYRING@FAIR (Darmstadt), where electron transitions within highly charged, He-like U^{90+} ions were studied and present ongoing detector improvements and possible future applications.

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