Q 35: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

Time: Wednesday 11:00–13:00 Location: HS PC

Invited Talk Q 35.1 Wed 11:00 HS PC

A planar rotor in an ion crystal — •Monika Leibscher[1], Ferdinand Schmidt-Kaler[2], and Christiane P. Koch[1] — [1]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, Germany — [2]QUANTUM, Institut für Physik, Universität Mainz, Germany

Charged molecules and nanoparticles are a promising platform for quantum sensing, quantum information or for tests of fundamental physics. Their rotational structure is amenable to sideband quantum logic spectroscopy if it can be coupled to the collective vibrations of a mixed crystal, composed of atomic ions and one molecular ion, or one charged nanoparticle. We model the dipole coupling by a planar rotor in the center of a linear ion Coulomb crystal. Calculating the dipole interaction for particles with mass ranging from diatomic molecular ions to that of charged silicon nanoclusters we identify its strength. We identify ranges, where the resulting energy splitting is sufficiently large to be detected by state-of-the-art sideband laser spectroscopy.

Q 35.2 Wed 11:30 HS PC

Upper-level spectroscopy of cold trapped 174Yb atoms for their preparation in the metastable $^3P_0$ state — •Ke Li, Gabriel Dick, Saran Shaju, and Jürgen Eschner — Universität des Saarlandes, Saarbrücken,Germany

We trap and cool 174 Yb atoms in a magneto-optical trap (MOT) inside a high-finesse cavity for exploring atom-cavity interaction on the $^1S_0$ - $^3P_0$ clock transition at 578 nm[1,2]. For populating the metastable $^3P_0$ level, we employ repumping lasers resonantly driving the $^3P_1$ - $^3S_1$ and $^3P_2$- $^3S_1$ transitions, thereby transferring all atoms from $^3P_1$, $^3P_2$ states to $^3P_0$ state via $^3S_1$.In order to characterize how effective the repumping process is, the time-resolved measurements including repumping rate, population dynamics are studied, which also facilitating detailed investigations of the clock transition.

[1]D. Meiser, Jun Ye, D. R. Carlson, and M. J. Holland Phys. Rev. Lett. 102, 163601, 2009
[2]H. Gothe, D. Sholokhov, A. Breunig, M. Steinel, and J. Eschner. Phys. Rev. A, 99, 0134 15, 2019.

Q 35.3 Wed 11:45 HS PC

Shelving spectroscopy of narrow UV transitions in dysprosium — •Kevin Ng[1], Paul Uerlings[1], Fiona Hellstern[1], Luis Weiss[1], Alexandra Köpf[1], Michael Wischert[1], Tanishi Verma[1], Stephan Welte[1,2], Ralf Klemt[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]CZS Center QPhoton

Current efforts in analogue quantum simulation aim to increase the interaction strengths between trapped particles in order to probe long-range interactions and correlations on the microscopic scale. By reducing the separation between dysprosium atoms trapped in optical lattices made from UV (˜360nm) light, a large enhancement of the magnetic dipole-dipole interaction can be achieved, albeit with a higher required imaging resolution for quantum gas microscopy.

To implement imaging techniques that overcome the diffraction limit to resolve particles only 180nm apart, we plan to use long lived excited states trapped at magic wavelengths. Such knowledge of the ground and excited state atomic polarizabilities depend on the strength and positions of transitions in the vicinity of the trapping wavelength. Here, we present a characterization of multiple weak UV transitions in dysprosium on a thermal atomic beam. We measure isotope shifts, hyperfine splittings and lifetimes of such transitions by using the known strong 421nm transition as a probe, amplifying signal detection by a factor of ˜600 compared to detection via standard absorption or fluorescence spectroscopy.

Q 35.4 Wed 12:00 HS PC

Dirac-Fock Rechnungen von Manganese Kα and Kβ Energien — •Khalid Rashid — Dept of Mathematics, QAU, Islamabad, Pakistan

Die 3d K Energien und Intensitäten von Mn I bis Mn VIII und deren Satallien Linien in Anwesenheit von eimem Loch in der 2p und 3p Schallen werder in multikonfiguration Dirac-Hartree- Fock Nährng berechnet.(MCDF). Diese Methode erlaubt die Behandlung von Drehimpuls Kopplung von äusseren und inneren Elektronen. Dudurch entstehen recht komplexex K Spektrum. Untersucht wurde die Fälle, Mn 3d54s2 gibt es durch die Kopplung von 1s1 mit 3d5 zwei Anfangszustände 5S2 (j=2) und 7S3 (J=3). Durch die Kopplung von 2p1 mid 3d5 gibt es zu J=1, 17 Zustände; zu J=2,12 Zustände; zu J=3, 5 Zustände, zu J=4, 1 Zustand. Dies eegibt zu J=1, 17 Übergänge; zu J=2, 24 Übergänge; zu J, 8 Übergänge, zu J=1, 1 Ubergang. Ähnliche Analysen haben wir ausgeführt für Mn I bis Mn VIII in Anwesenheit von einem Loch in der 2p Schale. und für ein Loch in der 3p Schale. Aus diesen gerechneten Daten werden durch Lorentz fits Spektren um die gemessenen Spektren zu interpretieren

Q 35.5 Wed 12:15 HS PC

Buffer Gas Stopping Cell for Extraction of ^{229}Th Ions for Nuclear Clock Development — •Srinivasa Arasada[1], Florian Zacherl[1], Keerthan Subramanian[1], Jonas Stricker[2,3], Valerii Andriushkov[2,4], Yumiao Wang[1], Nutan Kumari Sah[1], Ke Zhang[1], Ferdinand Schmidt-Kaler[1], Dmitry Budker[1,2,4], Christoph Düllman[2,3,4], and Lars von der Wense[1] — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz, Germany — [2]Helmholtz Institute Mainz, Germany — [3]Department of Chemie, Johannes Gutenberg-Universität Mainz, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The isomeric state of ^{229}Th offers a unique opportunity for precision spectroscopy due to its exceptionally low excitation energy, making it most suitable for developing nuclear clocks with unprecedented accuracy. The isomeric state in ^{229}Th can be populated via a 2% decay branch during α decay of ^{233}U. Here we outline our plans for extracting thorium ions from a ^{233}U recoil-ion source using a buffer gas stopping cell. The system utilizes ultra-pure helium gas to minimize substantial losses caused by charge exchange or molecular formation. The extracted Th^{3+}ions are subsequently loaded into a Paul trap together with laser-cooled $^{40}Ca^+$ ions for spectroscopic interrogation.

This project is being supported by the BMBF Quantum Futur II Grant Project 'NuQuant'(FKZ 13N16295A).

Q 35.6 Wed 12:30 HS PC

Towards a Precision Measurement of the ^{229m}Th Isomeric Lifetime via Hyperfine Structure Laser Spectroscopy — •Kevin Scharl, Markus Wiesinger, Georg Holthoff, Tamila Teschler, Mahmood I. Hussain, and Peter G. Thirolf — Ludwig-Maximilians-Universität München

The development of a nuclear clock based on the unusually low-lying isomeric transition in ^{229}Th at 8.355733554021(8) eV [Zhang et al., *Nature* **633**, 63-70 (2024)] is of high interest for several research fields from precision metrology over geodesy to dark matter research.

In the recent past, several milestones towards the nuclear clock were reached via VUV spectroscopic measurements of ^{229}Th in a solid state environment. In contrast to that, the LMU thorium nuclear clock setup uses $^{229(m)}$Th ions confined in a cryogenic Paul trap and sympathetically Doppler cooled with co-trapped $^{88}Sr^+$ ions. This approach allows for an alternative and more precise measurement of the vacuum ionic half-life of the isomeric state which so far is reported to be 1400^{+600}_{-400}s [Yamaguchi et al., *Nature* **629**, 26-66 (2024)].

In this talk on the LMU experimental setup, we focus on the electronic hyperfine structure spectroscopy of $^{229(m)}Th^{3+}$ ions as an efficient way to distinguish between the two nuclear states. Moreover, the scheme for the isomeric state readout necessary for the realization of a nuclear clock and the measurement of the isomeric lifetime is presented.

This work was supported by the European Research Council (ERC) (Grant agreement No. 856415) and BaCaTec (7-2019-2).

Q 35.7 Wed 12:45 HS PC

Collinear laser spectroscopy of helium-like $^{12-14}C^{4+}$ — •Emily Burbach[1], Kristian König[1], Aaron Bondy[2], Gordon Drake[2], Phillip Imgram[3], Patrick Müller[4], Wilfried Nörtershäuser[1], Xiao-Qiu Qi[5], and Julien Spahn[1] — [1]TU Darmstadt, Germany — [2]University of Windsor, Canada — [3]KU Leuven, Belgium — [4]University of California, USA — [5]Zhejiang Sci-Tech University, China

Light helium-like systems are ideal test cases for nuclear and atomic structure calculations as they exhibit a greatly varying nuclear struc-

ture and are accessible for high-precision ab-initio calculations. In an ongoing effort, it is planned to determine absolute and differential nuclear charge radii, R_C and $\delta\langle r^2\rangle$, of the light elements Be to N by purely using collinear laser spectroscopy and non-relativistic quantum electrodynamics calculations in the helium-like ions. As a first step, the $1s2s\,^3\mathrm{S}_1 \rightarrow 1s2s\,^3\mathrm{P}_J$ transitions in $^{12-14}\mathrm{C}^{4+}$ were determined using the Collinear Apparatus for Laser Spectroscopy and Applied Science (COALA) at the Technical University of Darmstadt. In those measurements a significant splitting isotope shift (SIS) was observed. It is defined as the difference in fine-structure splittings between different isotopes of the same atom after averaging over the hyperfine structure. It is compared to the theoretical SIS, which is determined by the relativistic finite nuclear mass and recoil contributions to the energy [1], which provides a clear test of the experimental accuracy. This project is supported by DFG (Project-ID 279384907 - SFB 1245).

[1] L.-M. Wang et al. Phys. Rev. A 95, 032504 (2017).