A 17: Poster III

Time: Tuesday 17:00–19:00 Location: Tent C

A 17.1 Tue 17:00 Tent C

Towards a precision measurement of the XUV-clock transition in highly charged lead — •Antonia Schaffert, Marc Botz, Dominic Hache, Moto Togawa, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Highly charged ions provide electronic transitions in all wavelengths, well suited for next-generation atomic clocks. In order to find stable clocks, metastable states at higher photon energies are needed. Recently, such a metastable electronic state has been found in highly charged, Nb-like lead using mass spectrometry in a Penning-trap [1]. Given its short wavelength, it must be examined with XUV frequency combs. Such an experiment would greatly benefit from further improvements in the precision of its known transition wavelength. We therefore present complementary measurements by measuring decay pathways of the metastable state, which is mostly deexcited to a short-lived state before relaxing to the ground state. These transitions and other adjacent transitions have been identified and accurately determined using an Electron Beam Ion Trap equipped with a high-resolution VUV Grating Spectrometer.

[1] Kathrin Kromer, et al., physics.atom-ph 2310.19365 (2023)

A 17.2 Tue 17:00 Tent C

Symmetry based gate design — •Kaloyan Zlatanov and Nikolay Vitanov — Department of Physics, St. Kliment Ohridski University of Sofia, 5 James Bourchier Boulevard, 1164 Sofia, Bulgaria

One of the main goals of contemporary quantum information is to design faster and more robust gates. We explore a Hamiltonian based approach to tackle this problem in which we design an interaction that yields a specific symmetry that allows the reduction of the system to two and three-level sub-systems in which various control techniques like adiabatic excitation, composite pulses or shaped pulses can be implemented. We illustrate this approach with examples in magnetic systems with Dzyaloshinskii-Moriya interaction as well as in ions for the improvment of the Molmer-Sorensen gate.

A 17.3 Tue 17:00 Tent C

Enhancement of Zeptonewton Force Detection with a Single-Ion Nonlinear Oscillator — •Bo Deng[1], Moritz Göb[1], Benjamin A. Stickler[2,3], Max Masuhr[1,4], Daqing Wang[1,4], and Kilian Singer[1] — [1]Institute of Physics, University of Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Institute for Complex Quantum Systems, Ulm University, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [3]Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany — [4]Institute of Applied Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Here we present an anharmonic oscillator implemented with a single atomic ion confined in a funnel-shaped potential [1]. The trapped particle experiences a coupling of radial and axial degrees of freedom that introduces nonlinearity to our system. The bifurcation and hysteresis of the resulting Duffing-type response are characterized. We further demonstrate an axial displacement force detection of $\sim$2.4 zN with a 20-fold enhancement using vibrational resonance effect [2]. The ability to conduct non-resonant low-frequency broadband sensing bears relevance for many fundamental physics studies.

[1] J. Roßnagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, and K. Singer, A single-atom heat engine, Science 352, 325 (2016).

[2] B. Deng, M. Göb, B. A. Stickler, M. Masuhr, K. Singer, and D. Wang, Amplifying a zeptonewton force with a single-ion nonlinear oscillator, PRL 131, 153601 (2023).

A 17.4 Tue 17:00 Tent C

Towards Quantum Simulations with Strontium Atoms — Thies Plassmann[1,2], Meny Menashes[1], •Leon Schäfer[1], and Guillaume Salomon[1,2] — [1]Institute for Quantum Physics, Hamburg University, Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Center for Ultrafast Imaging, Hamburg University, Luruper Chaussee 149, 22761 Hamburg

Cold atom platforms with single particle/spin detection and control offer fascinating opportunities for emerging quantum technologies. Among quantum simulators trapped atoms in programmable optical tweezer arrays and excited to Rydberg states are nearly ideal systems to study quantum spin models and opens interesting perspectives for quantum computation. Yet, simulating fermions on such systems remains a long-standing goal and the study of three-dimensional problems on arbitrary lattice structures is still to be explored. A complementary platform for quantum simulation is a quantum gas microscope where large atomic clouds are trapped in optical lattices. Whereas quantum statistics and itinerant models are natively implemented in these experiments, the current lack of programmability and long cycle time are limiting their capabilities. Our vision to overcome these challenges in quantum simulation is to combine atom manipulation using optical tweezers with quantum gas microscopy on a unique quantum simulation platform. We report here on the development of such novel quantum simulator operating with strontium with which we aim to study topological phases in three-dimensional frustrated spin systems as well as the SU(N) Fermi-Hubbard model.

A 17.5 Tue 17:00 Tent C

Optimal time-dependent manipulation of Bose-Einstein condensates — •Timothé Estrampes[1,2], Alexander Herbst[1], Annie Pichery[1,2], Gabriel Müller[1], Dennis Schlippert[1], Ernst M. Rasel[1], Éric Charron[2], and Naceur Gaaloul[1] — [1]Leibniz University Hannover, Institut für Quantenoptik, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France

Quantum sensing experiments benefit from fast Bose-Einstein Condensate (BEC) generation with small expansion energies. Here, we theoretically find the optimal BEC collimation parameters with painted optical potentials to experimentally achieve 2D expansion energies of 438(77) pK taking advantage of the tunable interactions by driving Feshbach resonances and engineering the collective oscillations. Based on these findings and corresponding simulations, we propose a scenario to realize 3D expansion energies on ground below 16 pK, going beyond the experimental state of the art in microgravity [A. Herbst et al., arXiv:2310.04383 (2023)].

Furthermore, we report on current theoretical studies of the dynamics of space single- and dual-BEC experiments including applications in NASA's Cold Atom Lab aboard the International Space Station or the sounding rocket mission MAIUS-2, paving the way for next-generation quantum sensing experiments, including tests of fundamental physics such as Einstein's equivalence principle.

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A 17.6 Tue 17:00 Tent C

Spectroscopy laser setup for isotope shift measurement of highly charged xenon — •Ruben B. Henninger, Vera M. Schäfer, Elwin A. Dijck, Christian Warnecke, Stepan Kokh, Lukas F. Storz, Andrea Graf, Thomas Pfieifer, and José R. Crespo López-Urrutia — Max Planck Institut für Kernphysik, Heidelberg

Exploring the potential existence of a fifth force acting between electrons and neutrons, our research focuses on utilizing transitions in highly charged ions (HCI) as sensitive sensors for such forces. Xenon, with its numerous isotopes, emerges as a promising candidate for this investigation. To achieve the precision required to identify new physics narrow-linewidth lasers in the sub-Hertz regime are essential. This poster introduces a spectroscopy laser setup, which will be implemented in the CryPTEx-SC (Cryogenic Paul Trap Experiment - superconducting) experiment to probe these transitions using quantum logic spectroscopy. The system comprises a 1550 nm fibre laser that is locked to a 10 cm ULE reference cavity, along with two tuneable diode lasers that are locked to the fibre laser through a frequency comb. To enable probing times of order seconds, phase-noise cancellation is implemented for several optical fibres.

A 17.7 Tue 17:00 Tent C

Classifying single-shot diffraction images utilizing machine learning — •Hendrik Tackenberg, Paul Tuemmler, Christian Peltz, and Thomas Fennel — Institute for Physics, University of Rostock, Albert-Einstein-Str. 23-24, D-18059 Rostock, Germany

Single-shot coherent diffractive imaging (CDI) at X-ray free-electron lasers (FELs) has evolved into a well-established method for the structural characterization of unsupported nano-objects with targets ranging from superfluid helium droplets to large biomolecules. Expanding the corresponding experimental setup by additional excitation options, such as short pulse lasers, opens up new routes to study structural dynamics on the femtosecond time and nanometer spatial scale. However, in most scenarios, the dynamics of interest significantly depend on parameters varying on a shot-to-shot basis, such as the objects' orientations, sizes, or positions in the FEL focus. A rigorous quantitative analysis, therefore, critically depends on the evaluation of a sufficiently large data set to sample the relevant parameter space. Recording millions of scattering images in a single experiment is not unusual nowadays and calls for advanced analysis strategies like model-based forward fitting and automated data set classification.

Here, we present a machine-learning-based classification approach that we successfully applied to characterize a recent experiment studying the strong-field induced anisotropic nanoplasma expansion of laser-driven SiO_2 nanospheres at the European XFEL.

A 17.8 Tue 17:00 Tent C

Emulating Rydberg Quantum Computers — •Santiago Higuera-Quintero[1], Sebastian Weber[1], Katharina Brechtelsbauer[1], Nicolai Lang[1], Tilman Pfau[2], Florian Meinert[2], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III and IQST, University of Stuttgart, 70550 Stuttgart, Germany — [2]5th Institute of Physics and IQST, University of Stuttgart, 70550 Stuttgart, Germany

Modelling noise processes in noisy intermediate-scale quantum (NISQ) devices plays an important role in designing hardware and algorithms in the journey for scalable quantum computers. In this era, classical emulators of quantum systems can help to better understand typical errors in quantum information processing which arise from coupling to the environment and experimental limitations. Furthermore, it can be used to test error correction schemes towards fault-tolerant quantum computation. In this poster, we present the current state of our gate-based emulator of the Rydberg quantum computer of the QRydDemo project. We provide an overview of our online platform that provides users the opportunity to try out the emulator and get familiar with QRydDemo's native gate operations.

A 17.9 Tue 17:00 Tent C

Laser spectroscopy on sympathetically cooled Th^{3+} alpha-recoil ions — •Gregor Zitzer[1], Johannes Tiedau[1], Maksim Okhapkin[1], Ke Zhang[1], Christoph Mokry[2,3], Jörg Runke[2,4], and Christoph E. Düllmann[2,3,4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Johannes Gutenberg University Mainz, Mainz — [3]Helmholtz Institute Mainz, Mainz — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

The isotope thorium-229 has a first excited state at only about 8 eV which enables excitation by coherent laser radiation. This unique property promises advantages for future versions of optical clocks. The presented setup is dedicated for high-resolution hyperfine spectroscopy of electronic transitions of nuclear ground and isomeric states in $^{229}Th^{3+}$. Here, the actual status and results of sympathetically cooled Th^{3+} ions are demonstrated in an experiment where ^{229}Th and ^{230}Th are extracted from uranium recoil ion sources and cotrapped with laser-cooled $^{88}Sr^{+}$ ions. The absolute frequencies and isotope shifts of the $5F_{5/2} \rightarrow 6D_{5/2}$ transition at 690 nm and the $5F_{7/2} \rightarrow 6D_{5/2}$ transition at 984 nm of $^{230}Th^{3+}$ are investigated.

A 17.10 Tue 17:00 Tent C

Modeling controlled sub-wavelength plasma formation in dielectrics — •Jonas Apportin, Christian Peltz, Björn Kruse, Benjamin Liewehr, and Thomas Fennel — Institute for Physics, Rostock, Germany

Laser induced damage in dielectrics due to short pulse excitation plays a major role in a variety of scientific and industrial applications, such as the preparation of 3D structured evanescently coupled wave-guides [1] or nano-gratings [2]. The corresponding irreversible material modifications predominantly originate from higher order nonlinearities like strong field ionization and plasma formation, which makes their consistent description imperative for any kind of theoretical modelling aiming at improving user control over these modifications. In particular the associated feedback effects on the field propagation can have drastic implications.

We developed and utilized a numerical model, that combines a local description of the plasma dynamics in terms of corresponding rate equations for ionization, collisions and heating with a fully electromagnetic field propagation via the Finite-Difference-Time-Domain method, adding self-consistent feedback effects like the sudden buildup of plasma mirrors. Here we present recent numerical results regarding the creation and control of sub-wavelength gratings formed at the rear side of pure and gold-coated fused silica films.

[1] L. Englert et al, Opt. Express 15, 17855-17862 (2007)
[2] M. Alameer et al, Opt. Lett. 43, 5757-5760 (2018)

A 17.11 Tue 17:00 Tent C

Towards laser spectroscopy of molecular hydrogen ions in Alphatrap — •K. Singh[1], A. Kulangara Thottungal George[1], C. M. König[1], I. V. Kortunov[2], J. Morgner[1], T. Sailer[1], V. Vogt[2], M. Bohman[1], F. Heisse[1], B. Tu[1], K. Blaum[1], S. Schiller[2], and S. Sturm[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Institut für Experimentalphysik, Universität Düsseldorf, 40225 Düsseldorf

Optical spectroscopy on trapped molecular hydrogen ions (MHI), e.g. HD^{+} and H_2^{+}, is one of the most sensitive techniques to probe fundamental physics and to extract fundamental constant such as m_p/m_e, perform tests on Quantum Electrodynamics and look for beyond standard model physics [1].

At Alphatrap [2], we can trap single ions for months in our cryogenic Penning trap. Using sensitive image current detection method and the continuous Stern-Gerlach effect [3], we have recently performed millimeter-wave spectroscopy on the molecular hyperfine structure of HD^{+} and we plan to perform optical spectroscopy of the rovibrational structure in HD^{+} and H_2^{+}. The techniques developed here are suitable to be directly applied to the antihydrogen molecular ion $\bar{H}_2^{-}$ in the future for stringent CPT tests [4]. We will present an overview of the trap and future plans for the laser spectroscopy of MHI at Alphatrap.

[1] S. Schiller, Contemporary Physics **63** (4), 247-279 (2022)
[2] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425-1491 (2019)
[3] H. Dehmelt, Proc. Natl. Acad. Sci. USA **83**, 2291 (1986)
[4] E. Myers, Phys. Rev. A **98**, 010101(R) (2018)

A 17.12 Tue 17:00 Tent C

Emergence of Synchronisation in a Driven-Dissipative Hot Rydberg Vapour — •Karen Wadenpfuhl[1,2] and C. Stuart Adams[1] — [1]Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, Durham, DH1 3LE, United Kingdom — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Continuously driven, non-linear systems show interesting behaviours such as bistability and self-oscillations. An interesting question regards the interplay of many self-oscillating entities with coupled dynamics due to an interaction between the individual oscillators. A collective response of a self-oscillating ensemble has been observed in e.g. the applause of audiences, and is theoretically understood within the framework of synchronisation.

Recently, we have observed the emergence of synchronisation in a driven-dissipative hot Rydberg vapour [1]. Synchronisation occurs in a strongly-driven three-level ladder scheme in Rb where we couple the intermediate $5P_{3/2}$ state to a Rydberg state. The synchronised state manifests as oscillations of the transmission of the probe beam through the atomic vapour. The wide tunability of the system parameters as well as fast oscillation frequencies on the order of 10 kHz allow for an exploration of the synchonisation transition over a large parameter space and with many cioupled oscillators.

[1] K. Wadenpfuhl and C. S. Adams, Emergence of Synchronization in a Driven-Dissipative Hot Rydberg Vapor, PRL 131, 143002 (2023)

A 17.13 Tue 17:00 Tent C

Ab initio MCDHF calculations of transition rates and energy levels of Lr I — •Joseph Andrews[1], Jon Grumer[2], Per Jönsson[3], Jacek Bieroń[4], and Stephan Fritzsche[1,5,6] — [1]Friedrich-Schiller-Universität, Jena, Germany — [2]Uppsala universitet, Uppsala, Sweden — [3]Malmö universitet, Malmö, Sweden — [4]Uniwersytet Jagielloński, Krakow, Poland — [5]Helmholtz-Institut, Jena, Germany — [6]GSI, Darmstadt, Germany

Lawrencium (Z=103), is the heaviest actinide and heaviest element prior to the superheavy region, residing at the forefront of atomic and nuclear physics research. However few experimental results exist for it and theoretical results differ from each other [Phys. Rev. A 104, 052810 (2021), Eur. Phys. J. D 45, 107 (2007)]. To assist their search, experimentalists require precise calculations of transitions with a high Einstein coefficient A. Calculations were initially performed on its lighter homologue Lutetium where experimental results exist to determine the predictive accuracy of our model. Energy levels, transition rates and Landé g-factors of Lr I and Lu I are investigated using the multiconfigurational Dirac-Hartree-Fock (MCDHF) method. Results of both neutral atoms are presented and compared to previous calculations and experiments. Previous calculations of Lr with MCDHF may be considered unreliable due to the small number of correlation orbitals being used, thus it is unclear whether convergence was reached. We report more reliable values than previous MCDHF calculations of the energy levels and Landé g-factors of the $7s^28s\ ^1S_0$, $7s^27p\ ^2P_{1/2,3/2}$, $7s^27d\ ^2D_{3/2,5/2}$ levels and the corresponding transition rates.