Q 13: Ultra-cold atoms, ions, and BEC (joint session A/Q)

Time: Wednesday 16:30–18:30 Location: P

Q 13.1 Wed 16:30 P

Observation of a universal entropy behaviour for impurities in an ultracold bath — •Silvia Hiebel, Jens Nettersheim, Julian Fess, Sabrina Burgardt, Daniel Adam, and Artur Widera — Physics Department and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

Nonequilibrium systems usually thermalize by gradually increasing their entropy to a new equilibrium state. For systems very far from equilibrium, however, another pathway has been predicted[1], where rapidly a state of high entropy, close to the maximal entropy possible for this system, is reached. The dynamic following this so-called prethermal memory loss is predicted to be universal.

We experimentally realize such nonequilibrium dynamics in the spin manifold of single Cs impurities undergoing spin-exchange collisions with a large Rb bath. The maximum entropy of the quantum spin distribution is reached after a few spin-exchange collisions starting from a spin-polarized, low entropy state. Rescaling the following spin-distribution dynamics when maximum entropy is reached, we find the trace of each spin state identical, independent of the initially prepared spin state. We analyse and describe these mechanisms in terms of the drift and diffusion of the quantum spin distribution. Our work thus illustrates the existence of universal, prethermal dynamics in open quantum systems far from equilibrium.

[1]Ling-Na Wu and André Eckardt, PRB 101, 220302 (2020)

Q 13.2 Wed 16:30 P

Exploring p-Wave Feshbach Resonances in ultracold ^{6}Li and ^{6}Li-^{133}Cs — •Manuel Gerken[1], Kilian Welz[1], Binh Tran[1], Eleonora Lippi[1], Stephan Häfner[1], Lauriane Chomaz[1], Bing Zhu[3], Eberhard Tiemann[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, University of Heidelberg — [2]Institut für Quantenoptik, University of Hannover — [3]University of Science and Technology of China

We report on the observation of spin-rotation coupling in p-wave Feshbach resonances in ultracold mixture of fermionic ^{6}Li and bosonic ^{133}Cs. In addition to the doublet structure in the Feshbach spectrum due to spin-spin interaction, we observe a triplet structure of different m_l states by magnetic field dependent atom-loss spectroscopy. Here, the m_l states are projections of the pair-rotation angular momentum l on the external magnetic field. Through comparison with coupled-channel calculations, we attribute the observed splitting of the $m_l \pm 1$ components to electron spin-rotation coupling. We present and estimation of the spin-rotation coupling by describing the weakly bound close channel molecular state with the perturbative multipole expansion, valid in the range $R > R_{LR}$, where R is the inter nuclear distance and R_{LR} is the LeRoy radius. The underestimation of the coupling reveals a significant contribution of the molecular wave function at short inter-nuclear distances $R < R_{LR}$. We also present measurements of spin-spin coupling in p-wave Feshbach resonances in a ^{6}Li mixture and calculations of collisional cooling close to a ^{6}Li p-wave Feshabch resonance.

Q 13.3 Wed 16:30 P

Single-atom quantum otto motor driven by atomic collisions — •Jens Nettersheim[1], Sabrina Burgardt[1], Daniel Adam[1], Eric Lutz[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institute for Theoretical Physics I,University of Stuttgart, Stuttgart, Germany

Recent advances in controlling nanoscopic objects suggest the realizations of machines exploiting quantum properties. However, the increasing importance of fluctuations in quantum systems calls into question whether such devices can combine high efficiency, high output power, and small power fluctuations. Experimentally, we realize a stable quantum-Otto engine by immersing single Cs atoms into an ultracold Rb bath. Employing inelastic spin-exchange interactions, we maximize output power while minimizing power fluctuations owing to the finite quantum spin space forming the machine. We investigate the population fluctuations of the system as a function of its heat exchange and output power. For our system with seven quantum-spin levels, the initial and final states are polarized. They show no population fluctuations, in contrast to an infinite-level harmonic oscillator system at a given temperature. We analyze in which parameter range the quantum-spin engine can outperform harmonic oscillator systems in terms of output power and power fluctuations.

Q 13.4 Wed 16:30 P

Long-distance transport of ultracold gases in an optical dipole trap utilizing focus-tunable lenses — •Maximilian Kaiser[1,2], Sian Barbosa[1], Jennifer Koch[1], Felix Lang[1], Benjamin Nagler[1], and Artur Widera[1] — [1]Physics Department, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern — [2]Physics Institute, Heidelberg University, Im Neuenheimer Feld 226, 69120 Heidelberg

In order to integrate novel optical techniques into packed quantum gas experiments, different transport approaches have been developed to bridge the gap between different sections of the experimental vacuum chamber.

We report on the realization of an optical dipole trap (ODT) transport system for ultracold gases based upon [1]. A lens system around a commercially available focus-tunable lens shifts the focus of a red-detuned ODT beam through the vacuum chamber, effectively moving trapped atoms while maintaining constant trapping conditions throughout the entire transport. We have developed a scheme for precise alignment, characterized the focal shift, and studied its spatial stability. We have verified its functionality and found spatial stability of the focus on the micrometer scale. The system is integrated into a lithium-6 quantum-gas experiment, where the transport trap is loaded with efficiencies of more than 90% for both BECs and thermal gases. Ultimately, we demonstrate the transport of an ultracold quantum gas over a distance of 507mm.

[1] Julian Léonard et al., New J. Phys. 16 093028 (2014)

Q 13.5 Wed 16:30 P

Exciton-polaron-polariton condensation — •Miguel Bastarrachea-Magnani[1,2], Aleksi Julku[2], Arturo Camacho-Guardian[3], and Georg Bruun[2] — [1]Physics Department, Universidad Autonoma Metropolitana-Iztapalapa, San Rafael Atlixco 186, C.P. 09340 CDMX, Mexico — [2]Center for Complex Quantum Systems, Department of Physics and Astronomy, Aarhus University, Ny Munkegade, DK-8000 Aarhus C, Denmark — [3]T.C.M. Group, Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge, CB3 0HE, U.K

Exciton-polaritons created in microcavity semiconductors are highly tunable quantum states that, thanks to their hybrid character, allow the transfer of features between light and matter. Polariton interactions make it possible to create quantum fluids, exhibiting macroscopic quantum states like condensation and superfluidity. Because of this they constitute a fruitful field to exchange ideas with atomic physics and to unveil novel no-linear optical effects. Recent experiments have demonstrated that, by doping the semiconductor with itinerant electrons, the exciton-polaritons get dressed in electronic excitations to create polarons, opening a new venue to explore Bose-Fermi mixtures. Here, we describe the condensation of exciton-polaritons in the presence of a two-dimensional electron gas by employing a non-perturbative many-body theory to treat exciton-electron correlations combined with a non-equilibrium theory for the condensate.

Q 13.6 Wed 16:30 P

A quantum heat engine driven by atomic collisions — •Sabrina Burgardt[1], Quentin Bouton[1], Jens Nettersheim[1], Daniel Adam[1], Eric Lutz[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany. — [2]Institute for Theoretical Physics I, University of Stuttgart, Stuttgart, Germany.

Quantum heat engines are subjected to quantum fluctuations related to their discrete energy spectra. Such fluctuations question the reliable operation of thermal machines in the quantum regime. Here, we realize an endoreversible quantum Otto cycle in the large quasi-spin states of Cesium impurities immersed in an ultracold Rubidium bath.

We employ quantum control to regulate the direction of heat transfer that occurs via inelastic spinexchange collisions. We further use full-counting statistics of individual atoms to monitor quantized heat exchange between engine and bath at the level of single quanta, and additionally evaluate average and variance of the power output. We optimize the performance as well as the stability of the quantum heat engine, achieving high efficiency, large power output and small power output fluctuations.

Q 13.7 Wed 16:30 P

Design of high-field coils for Feshbach resonances and rapid ramps in lithium-6 — •Felix Lang[1], Maximilian Kaiser[1,2], Sian Barbosa[1], Jennifer Koch[1], Benjamin Nagler[1], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universitaet Kaiserslautern, Germany — [2]Physics Institute, Heidelberg University, Im Neuenheimer Feld 226, 69120 Heidelberg

Realizing the BEC-BCS crossover in ultracold fermionic gases of lithium-6 requires high magnetic fields to address the Feshbach resonance at 832G [1]. One important tool for the control of such systems is the use of rapid magnetic-field ramps which enables, e.g., the detection of fermionic pair condensates [2].

Here I report on the design of a low-inductance Helmholtz coil pair for high currents up to 400A which complies with these contrary conditions. Numerical calculations of the magnetic field are used to optimize the coil geometry, while complimentary electrical-circuit simulations provide insight into attainable switching times. In addition, I discuss the cooling infrastructure and temperature surveillance, as well as the elaborate manufacturing process of the coils.

[1] R. Grimm, in Proceedings of the International School of Physics "Enrico Fermi", Vol. 164, edited by C. S. M. Inguscio W. Ketterle (2007) pp. 413-462.

[2] M. W. Zwierlein, C. H. Schunck, C. A. Stan, S. M. F. Raupach, and W. Ketterle, Physical Review Letters 94, 180401 (2005).

Q 13.8 Wed 16:30 P

Towards Quantum Simulation of Light-Matter Interfaces with Strontium Atoms in Optical Lattices — •Jan Trautmann[1,2], Annie Jihyun Park[1,2], Valentin Klüsener[1,2], Dimitry Yankelev[1,2], Yilong Yang[1,2], Dimitrios Tsevas[1,2], Immanuel Bloch[1,2,3], and Sebastian Blatt[1,2] — [1]MPQ, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]MCQST, 80799 München, Germany — [3]LMU, Schellingstraße 4, 80799 München, Germany

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully emulated strongly correlated condensed matter systems. With the recent development of quantum gas microscopes, these quantum simulators can now control such systems with single site resolution. Within the same time period, atomic clocks have also started to take advantage of optical lattices by trapping alkaline-earth-metal atoms such as Sr, and interrogating them with precision and accuracy at the 2e-18 level. Here, we report on progress towards a new quantum simulator that combines quantum gas microscopy with optical lattice clock technology. We have developed in-vacuum buildup cavities with large mode volumes that will be used to overcome the limits to system sizes in quantum gas microscopes. We imaged the intensity profile of the two orthogonal cavity modes of the in-vacuum buildup cavity by loading ultracold strontium atoms in a lattice created by those modes. By using optical lattices created in this buildup cavity that are state-dependent for the clock states, we aim to emulate strongly-coupled light-matter-interfaces.

Q 13.9 Wed 16:30 P

Quantum Gas Magnifier for sub-lattice-resolved imaging of 3D systems — •Luca Asteria[1], Henrik P. Zahn[1], Marcel N. Kosch[1], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut for Laserphysics, Hamburg — [2]The Hamburg Centre for Ultrafast Imaging — [3]Zentrum für Optische Quantentechnologien, Hamburg

Imaging is central for gaining microscopic insight into physical systems, but direct imaging of ultracold atoms in optical lattices as modern quantum simulation platform suffers from the diffraction limit as well as high optical density and small depth of focus. We introduce a novel approach to imaging of quantum many-body systems using matter wave optics to magnify the density distribution prior to optical imaging, allowing sub-lattice spacing resolution in three-dimensional systems. Combining the site-resolved imaging with magnetic resonance techniques for local addressing of individual lattice sites, we demonstrate full accessibility to local information and local manipulation in three-dimensional optical lattice systems. The method opens the path for spatially resolved studies of new quantum many-body regimes including exotic lattice geometries.

Q 13.10 Wed 16:30 P

Simulation of the Quantum Rabi Model in the Deep Strong-Coupling Regime with Ultracold Rubidium Atoms — •Stefanie Moll[1], Geram Hunanyan[1], Johannes Koch[1], Martin Leder[1], Enrique Rico[2], Enrique Solano[2], and Martin Weitz[1] — [1]University of Bonn, Bonn, Germany — [2]University of the Basque Country, Bilbao, Spain

When considering light-matter interaction with a magnitude of the coupling strength that approaches the optical resonance frequency, one enters the deep strong-coupling regime, where the approximations of the Jaynes Cummings Model do not hold anymore. Theory has predicted non-intuitive dynamics in the limit of the full QRM-Hamiltonian becoming applicable.

Our experimental implementation of the quantum Rabi model uses ultracold rubidium atoms in an optical lattice potential, with the effective two-level quantum system being realized by different Bloch bands in the first Brillouin zone. The bosonic mode is represented by the oscillations of the atoms in an optical dipole trapping potential.

We observe atomic dynamics in the deep strong-coupling regime, yielding high excitation numbers of the oscillator modes being created out of the vacuum. The current status of experimental results will be presented.

Q 13.11 Wed 16:30 P

A high-resolution Ion Microscope to Probe Quantum Gases — •Moritz Berngruber, Nicolas Zuber, Viraatt Anasuri, Yiquan Zou, Florian Meinert, Robert Löw, and Tilman Pfau — Universität Stuttgart, Germany

On our poster, we present a high-resolution ion microscope, which is designed as a versatile tool to study cold quantum gases, ground-state ensembles, Rydberg excitations, and ionic impurities. The ion microscope consists of three electrostatic lenses that allow to image charged particles on a delay-line detector.

The microscope provides a highly tunable magnification, ranging from 200 to over 1500, a spatial resolution better than 200 nm and a depth of field of more than 70 μm. These properties enable the study of bulk quantum gases and phenomena ranging from microscopic few body processes to extended many-body systems. By additionally evaluating the time-of-flight to the detector, it is possible to obtain 3D-images of the cold atomic cloud.

Excellent electric field compensation allows us to study highly excited Rydberg systems and cold ion-atom hybrid systems. We will present recent results in the field of ion-atom hybrid systems, where the interaction between ions and Rydberg atoms results in a novel long-range atom-ion Rydberg molecule.

Q 13.12 Wed 16:30 P

All-optical production of K-39 BECs utilizing tunable interactions — •Alexander Herbst, Henning Albers, Sebastian Bode, Knut Stolzenberg, Ernst Rasel, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover

The all-optical production of potassium-39 BECs is of large interest for the field of guided atom interferometry and its application for quantum inertial sensors. Contrary to other setups and atomic species this combination allows for the use of small external magnetic fields to control atomic interactions for the suppression of dephasing effects. However, the negative background scattering length and the narrow hyperfine splitting of potassium-39 pose a major experimental challenge.

We report on the loading of a crossed optical dipole trap at 2 um wavelength and the subsequent generation of a BEC. By using a gray molasses technique on the D1 line we are able to directly load the trap without the need for magnetic trapping as an intermediate step.

For evaporation we utilize time-averaged optical potentials to control the trap frequencies in combination with Feshbach resonances to change the atomic scattering length to positive values. We realize BECs of up to $2 \cdot 10^5$ atoms after a 4 second long evaporation ramp and more than $5 \cdot 10^4$ atoms after less than 1 second. We discuss our experimental sequence, the current limitations of our setup and the perspectives for producing BECs of higher atom number with the fast ramp.

Q 13.13 Wed 16:30 P

Trapping Ion Coulomb Crystals in Optical Lattices — •Daniel Hönig[1], Fabian Thielemann[1], Joachim Welz[1], Wei Wu[1], Leon Karpa[2], Amir Mohammadi[1], and Tobias Schätz[1] — [1]Albert-Ludwigs Universität Freiburg — [2]Leibniz Universität Hannover

Optically trapped ion Coulomb crystals are an interesting platform for quantum simulations due to the long range of the Coulomb interaction as well as the state dependence of the optical potential. Optical lattices expand the possible application of this platform by trapping the ions in seperate potential wells as well as giving optical confinement along the axis of the beam. In the past we presented the succesfull trapping of a single ion in a one dimensional optical lattice as well as of ion coulomb crystals in a single beam optical dipole trap.

In this Poster, we present recent advancements in trapping of Ba138+ ions in a one dimensional optical lattice at a wavelength of 532nm and report the first successfull trapping of small ion coulomb crystals ($N \leq 3$) in this lattice. We compare trapping results between the lattice and a single beam optical dipole trap and investigate the effect of an axial electric field on the trapping probability of a single ion to demonstrate the axial confinement of the ion in the optical lattice.

Q 13.14 Wed 16:30 P

Quantum droplet phases in extended Bose-Hubbard models with cavity-mediated interactions — •Peter Karpov[1,2] and Francesco Piazza[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]National University of Science and Technology "MISiS", Moscow, Russia

Extended Bose-Hubbard (eBH) models have been studied for more than 30 years. We numerically found a set of new phases present in generic eBH models with competing long-range attractive and local repulsive interactions [1]. These are different phases of self-bound quantum droplets. We observe a complex sequence of transitions between droplets of different sizes, and of compressible (superfluid or supersolid) as well as incompressible (Mott or density-wave insulating) nature, governed by the competition between the local repulsion and the finite-range attraction.

We propose a concrete experimental implementation scheme based on the multimode optical cavities. The analogous infinite-range model was experimentally realized by the Zürich group [2] using single-mode optical cavities. The recent progress with multimode optical cavities by the Stanford group [3] makes it possible to realize the eBH model with tunable finite-range sign-changing interactions.

[1] P. Karpov, F. Piazza, arXiv:2106.13226 (2021).
[2] R. Landig et al, Nature **532**, 476 (2016).
[3] V. Vaidya et al, Phys. Rev. X **8**, 011002 (2018).

Q 13.15 Wed 16:30 P

Density Fluctuations across the Superfluid-Supersolid Phase Transition in a Dipolar Quantum Gas — •Jan-Niklas Schmidt[1], Jens Hertkorn[1], Mingyang Guo[1], Kevin Ng[1], Sean Graham[1], Paul Uerlings[1], Tim Langen[1], Martin Zwierlein[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]MIT-Harvard center for Ultracold Atoms, Research Laboratory of Electronics, and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Supersolidity is a counter-intuitive state of matter that simultaneously shows superfluid flow and crystalline order. Dipolar quantum gases confined in elongated trapping geometries feature an interaction induced modulational instability driven by the softening of a roton excitation that eventually get stabilized by quantum fluctuations. By directly measuring density fluctuation in situ we extract the static structure factor across the transition, identify the roton modes as the dominant cause of the crystallization, and simultaneously observe BEC and crystal phonons on the supersolid side of the transition as a hallmark of supersolidity. An advanced study in circularly symmetric trapping geometries reveals the role of angular roton excitations in the crystallization process to two-dimensional droplet arrays. This understanding forms an important step toward the realization of a two-dimensional dipolar supersolid marking just the starting point to a rich phase diagram of structured patterns including novel exotic phases such as supersolid honeycomb and amorphous labyrinthine phases.

Q 13.16 Wed 16:30 P

Formation of spontaneous density-wave patterns in DC driven lattices — •Henrik Zahn, Vijay Singh, Luca Asteria, Marcel Kosch, Lukas Freystatzky, Klaus Sengstock, Ludwig Mathey, and Christof Weitenberg — Universität Hamburg, Hamburg, Deutschland

Driving a many-body system out of equilibrium induces phenomena such as the emergence and decay of transient states. This can manifest itself as pattern and domain formation. The understanding of these phenomena expands the scope of established thermodynamics into the out-of-equilibrium domain. Here, we study the out-of-equilibrium dynamics of a bosonic lattice model subjected to a strong DC field, realized as ultracold atoms in a strongly tilted triangular optical lattice. We observe the emergence of pronounced density wave patterns – which spontaneously break the underlying lattice symmetry – as well as their domains using a novel single-shot imaging technique with single-site resolution in three-dimensional systems. We explain the dynamics as arising from center-of-mass-conserving pair tunneling processes, which appear in an effective description of the tilted Hubbard model. More broadly, we establish the far out-of-equilibrium regime of lattice models subjected to a strong DC field, as an exemplary and paradigmatic scenario for transient pattern formation.

Q 13.17 Wed 16:30 P

Quantum gas microscopy of Kardar-Parisi-Zhang superdiffusion — •David Wei[1,2], Antonio Rubio-Abadal[1,2], Bingtian Ye[3], Francisco Machado[3,4], Jack Kemp[3], Kritsana Srakaew[1,2], Simon Hollerith[1,2], Jun Rui[1,2], Sarang Gopalakrishnan[5,6], Norman Y. Yao[3,4], Immanuel Bloch[1,2,7], and Johannes Zeiher[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Germany — [3]University of California, Berkeley, USA — [4]Lawrence Berkeley National Laboratory, California, USA — [5]The Pennsylvania State University, Pennsylvania, USA — [6]College of Staten Island, New York, USA — [7]Ludwig-Maximilians-Universität, Munich, Germany

The Kardar-Parisi-Zhang universality class describes the coarse-grained dynamics of numerous classical stochastic models. Surprisingly, the emergent hydrodynamics of spin transport in the one-dimensional (1D) quantum Heisenberg model was recently conjectured to fall into this class. We test this conjecture experimentally in a cold-atom quantum simulator in spin chains of up to 50 spins by studying the relaxation of domain walls. We find that domain-wall relaxation indeed scales with the superdiffusive KPZ dynamical exponent z=3/2. By probing dynamics in 2D and by adding a net magnetization, we verify that superdiffusion requires both integrability and a non-abelian SU(2) symmetry. Finally, we leverage the single-spin-sensitive detection enabled by our quantum-gas microscope to measure spin-transport statistics, which yields a clear signature of the non-linearity that is a hallmark of KPZ universality.

Q 13.18 Wed 16:30 P

Bosonic Continuum Theory of One-Dimensional Lattice Anyons — •Martin Bonkhoff[1], Kevin Jägering[1], Sebastian Eggert[1], Axel Pelster[1], Michael Thorwart[2,3], and Thore Posske[2,3] — [1]Physics Department and Research Center Optimas,Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee149, 22761 Hamburg, Germany

Anyons with arbitrary exchange phases exist on 1D lattices in ultracold gases. Yet, known continuumt heories in 1D do not match. We derive the continuum limit of 1D lattice anyons via interacting bosons. The theory maintains the exchange phase periodicity fully analogous to 2D anyons [1]. This provides a mapping between experiments, lattice anyons, and continuum theories, including Kundu anyons with a natural regularization as a special case. We numerically estimate the Luttinger parameter as a function of the exchange angle to characterize long-range signatures of the theory and predict different velocities for left-and right-moving collective excitations.

[1] M. Bonkhoff, K. Jägering, S. Eggert, A. Pelster, M. Thorwart, and T. Posske, Bosonic continuum theory of one-dimensional lattice anyons, Phys. Rev. Lett. 126, 163201, (2021).

Q 13.19 Wed 16:30 P

Dual-species BEC for atom interferometry in space — •Jonas Böhm[1], Baptist Piest[1], Maike D. Lachmann[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], and the MAIUS Team[1,2,3,4,5,6,7] — [1]Institute of Quantum Optics, LU Hanover — [2]Department of Physics, HU Berlin — [3]ZARM, U Bremen — [4]DLR Institute of Space Systems, Bremen — [5]Institute of Physics, JGU Mainz — [6]DLR Simulation and Software Technology, Brunswick — [7]FBH, Berlin

Atom interferometry is a promising tool for measurements of the gravitational constant, universality of free fall and gravitational waves. As the sensitivity scales with the squared interrogation time, conducting atom interferometry in microgravity is of great interest.

The sounding rocket mission MAIUS-1 demonstrated the first BEC and matter wave interferences of it in space. With the follow-up missions MAIUS-2 and -3, we extend the apparatus by another species to perform atom interferometry with Rb-87 and K-41, paving the way for dual-species interferometers on bord of space stations or satellites.

In this contribution, the current status of the scientific payload MAIUS-B is discussed, fulfilling the requirements of generating Rb-87 and K-41 BECs with a high repetition rate in a compact, robust, and autonomously operating setup. The atomic state preparation and the manipulation using Raman double-diffraction processes are highlighted as well.

The MAIUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number: 50WP1431.

Q 13.20 Wed 16:30 P

Feshbach resonances in a hybrid atom-ion system — •Wei Wu[1], Fabian Thielemann[1], Joachim Welz[1], Thomas Walker[1], Pascal Weckesser[1,2], Daniel Hönig[1], Amir Mohammadi[1], and Tobias Schätz[1] — [1]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

We present the first observation of Feshbach resonances between neutral atoms and ions. [1,2] While Feshbach resonances are commonly utilized in neutral atom experiments, however, reaching the ultracold regime in hybrid traps is challenging, as the driven motion of the ion by the rf trap limits the achievable collision energy. [3] We report three-body collisions between neutral 6Li and 138Ba+, where we are able to resolve individual resonances. We demonstrate the enhancement of two-body interactions through an increase in the sympathetic cooling rate of the ion by the atomic cloud, determined through optical trapping of the ion. and molecule formation evidenced by subsequent three-body losses. This paves the way to new applications such as the coherent formation of molecular ions and simulations of quantum chemistry. [4]

[1] Weckesser P, et al. arXiv preprint arXiv:2105.09382, 2021.
[2] Schmidt J, et al. Physical review letters, 2020, 124(5): 053402.
[3] Cetina M, et al. Physical review letters, 2012, 109(25): 253201.
[4] Bissbort U, et al.Physical review letters, 2013, 111(8): 080501.

Q 13.21 Wed 16:30 P

A dipolar quantum gas microscope — •Paul Uerlings, Kevin Ng, Jens Hertkorn, Jan-Niklas Schmidt, Sean Graham, Mingyang Guo, Tim Langen, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We present the progress towards constructing a dipolar quantum gas microscope using dysprosium atoms. This new apparatus combines the long-range interactions found in dipolar quantum gases with the single-site resolution found in quantum gas microscopes. Ultracold dipolar quantum gases are a powerful and versatile platform to study quantum phenomena in and out of equilibrium. The large magnetic moment of dysprosium atoms allows for long-range and anisotropic interactions that give rise to exotic states of matter. By implementing a quantum gas microscope, microscopic details such as site occupation and site correlations will be observable. We plan to do this using magnetic atoms trapped in an ultraviolet optical lattice with a lattice spacing of a $\approx$ 180 nm. Combined with the long-range dipole interaction ($\propto 1/r^3$), the short lattice spacing will significantly increase the nearest-neighbour interaction strength to be on the order of 200 Hz (10 nK). This will allow us to study the regime of strongly interacting dipolar Bose-/and Fermi-Hubbard physics where even next-nearest-neighbour interactions could be visible. Our upcoming dipolar quantum gas microscope will enable further studies relating to quantum simulations and quantum magnetism.

Q 13.22 Wed 16:30 P

Imaging the interface of a qubit and its quantum-many-body environment — •Sidharth Rammohan[1], S.K. Tiwari[1], A. Mishra[1], A. Pendse[1], A.K. Chauhan[1,2], R. Nath[3], A. Eisfeld[4], and S. Wüster[1] — [1]Department of Physics, Indian Institute of Science Education and Research, Bhopal, MP, India — [2]Department of Optics, Faculty of Science, Palacky University, 17.listopadu, Czech Republic — [3]Department of Physics, Indian Institute of Science Education and Research, Pune, India — [4]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We show that two major facets of the decoherence paradigm are experimentally accessible for a single impurity atom embedded in a Bose-Einstein condensate when the impurity is brought into an electronic superposition of two Rydberg states. Not only can the electronic decoherence of the Rydberg atom be read out by microwave interferometry, the platform also provides unique access to the accompanying entangled state of the environment. We theoretically demonstrate signatures of the latter in total atom densities during the transient time in which the impurity is becoming entangled with the medium but the resultant decoherence is not complete yet. The Rydberg impurity thus provides a handle to initiate and read-out mesoscopically entangled superposition states of Bose atom clouds affecting about 500 condensate atoms. We find that the timescale for its creation and decoherence can be tuned from the order of nanoseconds to microseconds by choice of the excited Rydberg principal quantum number ν and that Rydberg decoherence dynamics is typically non-Markovian.

Q 13.23 Wed 16:30 P

dynamics of atoms within atoms — •Shiva kant Tiwari[1], F. Engel[2], M. Wagner[3], R. Schmidt[3], F. Meinert[2], and S. Wüster[1] — [1]Department of Physics, Indian Institute of Science Education and Research, Bhopal, Madhya Pradesh 462 066, India — [2]Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Recent experiments with Bose-Einstein condensates have entered a regime in which, after the excitation of a single atom into a highly excited Rydberg state, thousands of ground-state condensate atoms fill the Rydberg-electron orbit. Scattering off the electron then sets these into motion, such that one can study the quantum-many-body dynamics of atoms moving within the Rydberg atom. It has been suggested to use these features for tracking the motion, detecting the position and inferring or decohering the the quantum state of isolated Rydberg impurities. Here we numerically model this scenario using Gross-Pitaevskii and truncated Wigner theory. Our focus is on the cumulative effect of multiple sequential Rydberg excitations on the same condensate and the local heating dynamics. We also investigate the impact of details in the electron-atom interaction potential, such as the rapid radial modulation, which is important for the condensate response within the Rydberg orbit but is less relevant for subsequent density waves outside the Rydberg excitation region.

Q 13.24 Wed 16:30 P

Collisions of solitary waves in condensates beyond mean-field theory — •Aparna Sreedharan[1], S Choudhury[1], R Mukherjee[1,2], A Streltsov[3,4], and S Wüster[1] — [1]Department of Physics, IISER Bhopal, Madhya Pradesh 462066, India — [2]Department of Physics, Imperial College, SW7 2AZ, London, UK — [3]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Germany — [4]SAP Deep Learning Center of Excellence and Machine Learning Research SAP SE, Germany

A soliton is a self-reinforcing wave packet that maintains its shape despite dispersion, and appears in a large number of natural nonlinear systems including BEC. Solitons with a density maximum are referred to as bright solitons and those in BEC are composed of hundreds or thousands of identical atoms held together by their weak contact interactions. They behave very much like a compound object, with behaviour dictated by the nonlinear wave equation describing the mean field of their many body wave function. Soliton interactions in BEC are strongly affected by condensate fragmentation dynamics which we study using the TWA and MCTDHB. We also show that separate solitary waves decohere due to phase diffusion that depends on their effective ambient temperature, after which their initial mean-field relative phases are no longer well defined or relevant for collisions. In this situation, collisions are predominantly repulsive and can no longer be described within mean-field theory. Using different quantum many body techniques, we present a unified view on soliton fragmentation, phase diffusion and entanglement in their collision dynamics.

Q 13.25 Wed 16:30 P

All-Optical Matter-Wave Lens for Atom Interferometry — •Henning Albers[1], Alexander Herbst[1], Ersnt M. Rasel[1], Dennis Schlippert[1], and The Primus-Team[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen

The instability of quantum based inertial sensors highly depends on the center-of-mass motion and the expansion rate of the atomic ensemble. Precise control of these degrees of freedom is essential to perform accurate measurements of inertial effects, such as rotations or accelerations. Using time-averaged potentials in a 2μm crossed dipole trap we realize an all optical matter-wave lens which can be applied at all stages of the evaporative cooling process. By rapid decompression of the trap confinement we induce size oscillations of the trapped ensemble. Turning off the trap at a turning point of this oscillation results in a reduced velocity spread of the atomic cloud and thus a lowered expansion rate. We are able to reduce the transverse expansion temperature of ensembles containing 4×10^5 atoms from 40nK down to 3nK. The current limitations as well as the perspective to lens in transversal and longitudinal direction will be discussed.

Q 13.26 Wed 16:30 P

Quantum gas microscopy of Rydberg macrodimers — •Kritsana Srakaew[1], Simon Hollerith[1], David Wei[1], Daniel Adler[1], Antoni Rubio-Abadal[2], Andreas Kruckenhauser[3], Valentin Walther[4], Christian Gross[5], Immanuel Bloch[1,6], and Johannes Zeiher[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]The Institute of Photonic Sciences Mediterranean Technology, Castelldefels, Spain — [3]Institute for Quantum Optics and Quantum Information, Innsbruck, Austria — [4]ITAMP, Harvard-Smithsonian Center of Astrophysics, Campridge, USA — [5]Physikalisches Institut, Eberhard Karls Universität, Tübingen, Germany — [6]Ludwig-Maximilians-Universität, Fakultät für Physik, München, Germany

A precise study of molecules is difficult due to a large number of motional degrees of freedom and the presence of an internal quantization axis, the interatomic axis. In the field of quantum simulation, Rydberg atoms recently gained attention due to their large interactions. These interactions also give rise to molecules with bond lengths reaching the micron scale, so-called macrodimers. Their large size allows one to pin atom pairs at a fixed orientation and distance matching the molecular bond length before photoassociation, which gives direct access to the molecular axis. Precise control and exploiting Quantum gas microscopy enables access to study different molecular symmetries and electronic structure tomography of the molecular state.

Q 13.27 Wed 16:30 P

Atomic MOT from a buffergas beam source — •Simon Hofsäss[1], Sid Wright[1], Sebastian Kray[1], Maximilian Doppelbauer[1], Eduardo Padilla[1], Boris Sartakov[2], Jesús Pérez Ríos[1], Gerard Meijer[1], and Stefan Truppe[1] — [1]Fritz Haber Institute of the Max Planck Society, Berlin, Germany — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

A sample of cold atoms is the starting point of many applications in atomic and molecular physics. When trapping atoms from a hot background gas or oven source into a magneto optical trap (MOT), the loading time is usually on the order of seconds and limits the repetition rate of such experiments. Using our pulsed buffer gas beam source - originally designed for the production of diatomic molecules such as Aluminium monofluoride - we can load the MOT with 10^8 Cadmium atoms in less than 10ms. We trap the atoms using the ${}^1P_1 \leftarrow {}^1S_0$ transition at 229nm using light from a frequency-quadrupled Ti:sapphire laser.