Q 22: Poster II

Time: Tuesday 16:30–19:00 Location: Empore Lichthof

Q 22.1 Tue 16:30 Empore Lichthof

Conformal duality of Bose-Einstein condensates with two- and three-body interactions — •David Reinhardt[1], Matthias Meister[1], Dean Lee[2], and Wolfgang P. Schleich[3] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm, Germany — [2]Michigan State University, Department of Physics and Astronomy, East Lansing, Michigan, USA — [3]Institute of Quantum Physics, Ulm University, Ulm, Germany

It is well known that the eigenstates of nonlinear quantum systems (e.g. Bose-Einstein condensates described by the Gross-Pitaevskii equation) differ from those of the linear Schrödinger equation [1]. For instance, solitons only occur in nonlinear systems. When additionally considering three-body interactions new solution types emerge [2]. By analyzing the different solution spaces, we find that there exists a conformal duality between systems with two- and three-body interactions. This allows to predict the properties in the three-body case by means of the two-body case. For example, irregular two-body solutions can become bound solutions when including three-body interactions.

[1] L. D. Carr et al., PRA 62, 063610 (2000).
[2] H. Schürmann, PRE 54, 4312 (1996).

Q 22.2 Tue 16:30 Empore Lichthof

Matter-wave lensing of shell-shaped Bose-Einstein condensates — •Patrick Boegel[1], Alexander Wolf[2], Matthias Meister[2], and Maxim Efremov[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89081 Ulm, Germany — [2]German Aerospace Center (DLR), Institute of Quantum Technologies, D-89081 Ulm, Germany

Motivated by the recent experimental realization [1] of ultracold quantum gases in shell topology, we propose a straightforward implementation of matter-wave lensing techniques for shell-shaped Bose-Einstein condensates. This approach allows to significantly extend the observation time of the condensate shell during its free expansion and enables the study of novel quantum many-body effects on curved geometries. With both analytical and numerical methods, we derive optimal parameters for realistic lensing schemes to conserve the shell shape of the condensate for times up to hundreds of milliseconds [2].

This project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under Grants Nos. 50WM1862 and 50WM2245B.

[1] Nature 606, pages 281-286 (2022)
[2] P Boegel, et. al, arXiv:2209.04672

Q 22.3 Tue 16:30 Empore Lichthof

Understanding the dynamics of quantum mixtures for dual species atom interferometry in space — •Priyanka Guggilam.L[1], Jonas Böhm[1], Baptist Piest[1], Ernst Rasel.M[1], and the MAIUS team[1,2,3,4,5,6] — [1]Instiut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]FBH Berlin — [4]DLR Instiut für Raumfahrtsysteme, Bremen — [5]Instiut für Physik, HU Berlin — [6]Instiut für Quantenoptik, Universität Mainz

The MAIUS (Matter wave interferometry under microgravity) project aims to demonstrate atom interferometry in space as a promising tool for precision measurements, e.g., of Einstein's equivalence principle (EEP), with accuracies that couldn't be achieved with classical tests. With the launch of MAIUS-1, it was possible to create the first BECs in space using Rb-87 atoms and performing interference experiments with these macroscopic quantum objects. In the MAIUS-2/3 missions, we concentrate on the understanding of the dynamics of K-41 and Rb-87 quantum mixtures in microgravity and to utilize them as sources for dual species atom interferometry in space. This contribution focuses on the mission goals, simulation results of quantum mixture density profiles, transport of mixtures considering gravitational effects and preparation of mixtures using delta-kick cooling for further reduction of the momentum spread. These techniques are important prerequisites to perform EEP tests with BECs created on an atom chip under microgravity. 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 22.4 Tue 16:30 Empore Lichthof

Non-equilibrium steady states of driven dissipative quantum gases beyond ultraweak coupling — •Adrian Köhler, André Eckardt, and Alexander Schnell — TU Berlin, Berlin, Deutschland

The microscopic description of ideal quantum gases in presence of a finite coupling to a heat bath poses a theoretical challenge. Even though the system itself is non-interacting, the system-bath coupling is cubic in the field operators making the problem interacting. As a first step, we study the mean-field dynamics of the single-particle density matrix under the Redfield quantum master equation. We find that typical steady-state solvers converge only in a very limited parameter regime, forcing one to rely on numerically more costly time-integration. We also discuss approaches to overcome this problem using perturbation theory in the coupling strength. We apply our approach to a Bose gas coupled to two baths of different temperature, for which in the regime of ultraweak coupling Bose condensation is predicted also in cases, where both bath temperatures lie well above the equilibrium crtitical temperature [PRL 119, 140602]. In the regime of finite coupling, we find that steady-state solutions of the Redfield quantum master equation form a condensate in the ground state.

Q 22.5 Tue 16:30 Empore Lichthof

Compressibility and the equation of state of an optical quantum gas in a box — •Leon Espert Miranda, Erik Busley, Andreas Redmann, Christian Kurtscheid, Kirankumar Karkihalli Umesh, Frank Vewinger, Martin Weitz, and Julian Schmitt — Institut für Angewandte Physik, Universität Bonn, Germany

The compressibility of a medium, quantifying its response to mechanical perturbations, is a fundamental quantity determined by the equation of state. For gases of material particles, studies of the mechanical response are well established, in fields from classical thermodynamics to cold atomic quantum gases. Here we demonstrate a measurement of the equation of state as well as the compressibility of a homogeneously trapped two-dimensional quantum gas of light inside a nanostructured dye-filled optical microcavity. Upon reaching quantum degeneracy we observe signatures of Bose-Einstein condensation in the finite-size system, causing a sharp increase of the density response to an external force, hinting at the infinite compressibility of the uniform two-dimensional Bose gas.

Q 22.6 Tue 16:30 Empore Lichthof

Bath engineering in atomic quantum gas mixtures — •Lorenz Wanckel, Alexander Schnell, and André Eckardt — Technische Universität Berlin, Institut für Theoretische Physik, 10623 Berlin, Germany

Periodically driven isolated quantum systems usually heat up over time to the infinite temperature state via resonant excitation. For open driven systems, which are allowed to dissipate energy into a thermal bath, there is a non-equilibrium steady state, which is determined by the details of driving and dissipation. Appropriate engineering of the system and bath parameters can lead to interesting system states. We investigate theoretically a one-dimensional ideal Bose gas, which is locally driven and globally coupled to a three dimensional thermal bath, given by a second species of atoms. We explore the spectral densities for various baths, fermionic and bosonic, and show that the interplay of driving and dissipation can induce Bose condensation in the ground state or some excited state at bath temperatures well above the crossover temperature, at which Bose condensation would occur as a finite size effect in the system. Our analysis, which is based on a microscopic model that is solved using Floquet-Born-Markov theory, can be used to probe the results in a realistic experiment.

Q 22.7 Tue 16:30 Empore Lichthof

Vortex Motion and Annihilation in Holographic Superfluids — Paul Wittmer[1,2], Christian-Marcel Schmied[2,3], •Martin Zboron[3], Thomas Gasenzer[1,2,3], and Carlo Ewerz[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt — [3]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

Gauge-gravity duality establishes a connection between strongly correlated quantum systems and higher-dimensional gravitational theories at weak coupling. In general, finding the quantitative parameters of the quantum system thus described is challenging. We numerically simulate dynamics of generic vortex configurations in the holographic superfluid in two and in three spatial dimensions and match to these the corresponding dynamics resulting from the dissipative Gross-Pitaevskii equation. Excellent agreement between the vortex core profiles and their trajectories in both frameworks is found, both in two and three dimensions. Comparing our results to phenomenological equations for point- and line-like vortices allows us to extract friction parameters of the holographic superfluid. The parameter values suggest the applicability of two-dimensional holographic vortex dynamics to strongly coupled Bose gases or Helium at temperatures in the Kelvin range, effectively enabling experimental tests of holographic far-from-equilibrium dynamics.

Q 22.8 Tue 16:30 Empore Lichthof

Dynamical phases in an atom-cavity system: From time crystals to dark states — •Jim Skulte[1,2], Phatthamon Kongkhambut[1], Richelle J.L. Tuquero[3], Hans Kessler[1], Jayson G. Cosme[3], Andreas Hemmerich[1,2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien and Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany. — [2]The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany. — [3]National Institute of Physics, University of the Philippines, Diliman, Quezon City 1101, Philippines.

Ultracold atoms placed inside a high finesse optical cavity, which are continuously pumped or periodically driven display very rich phase diagrams. We specifically discover non-equilibrium phases called time crystals emerging in this platform. Time crystals are classified as discrete or continuous depending on whether they spontaneously break discrete or continuous time translation symmetry. First, we study an emergent limit cycle phase for a blue-detuned pump and show that this state can be classified as a continuous time crystal [1]. On the other hand, phase shaking of the pump beam can be used to map the system onto a parametrically driven dissipative three-level Dicke model [2]. For weak driving this leads an incommensurate time crystal, while for strong driving this state is only metastable and relaxes into a dark state [3]. [1] P. Kongkhambut et al., Science 377, 6606 (2022)

[2] J. Skulte et al., PRA 127, 253601 (2021)

[3] J. Skulte et al., arXiv:2209.03342 (2022)

Q 22.9 Tue 16:30 Empore Lichthof

Dynamical light-matter phases in an atom-cavity platform — •Phatthamon Kongkhambut[1], Hans Kessler[1], Jim Skulte[1], Ludwig Mathey[1], Jayson G. Cosme[2], and Andreas Hemmerich[1] — [1]Institut für Laser-Physik, Universität Hamburg — [2]National Institute of Physics, University of the Philippines

We are experimentally exploring the light-matter interaction of a Bose-Einstein condensate (BEC) with a single light mode of an ultra-high finesse optical cavity. The key feature of our cavity is the very small field decay rate ($\kappa/2\pi = 3.5$ kHz), which is in the order of the recoil frequency ($\omega_{rec}/2\pi = 3.6$ kHz). This leads to a unique situation where cavity field evolves with the same time scale as the atomic density distribution. Pumping the system with a steady state light field, red detuned with respect to the atomic resonance, the Dicke model is implemented including the self-organisation phase transition. Starting in the self-ordered superradinat phase and modulating the amplitude of the pump field, we observe a dissipative discrete time crystal, whose signature is a robust subharmonic oscillation between two symmetry-broken states [1]. Modulation of the phase of the pump field give rise to an incommensurate time crystalline behaviour [2]. For a blue-detuned pump light with respect to the atomic resonance, we observe limit cycles. Since the used pump protocol is time-independent, the emergence of a limit cycle phase heralds the breaking of continuous time-translation symmetry[3]. [1] H. Keßler et al., PRL 127, 043602 (2021), [2] P. Kongkhambut et al., PRL 127, 253601 (2021), [3] P. Kongkhambut et al., Science 377, 6606 (2022).

Q 22.10 Tue 16:30 Empore Lichthof

Vortex splitting, not stirring — •Lars Arne Schäfer — Institut für angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 4A, D-64289 Darmstadt

We examine Bose-Hubbard ring systems in two dimensional configurable arrays of dipole potentials [1]. This is an example for an atomtronics device [2]. Here, an individual small ring with few sites and few particles acts like an artificial atom with a clearly resolved spectrum. We analyze the single-particle spectrum in terms of eigenfunctions of the Hamiltonian operator as well as the discrete translational symmetry of the 1-D lattice. Coupling two or more of such systems creates a quantum network.

It is experimentally feasible to create controllable time-dependent on-site optical potentials by means of electronic wavefront manipulation (DMD, SLD) and microlens arrays. In contrast to phase imprinting, we study two counter-propagating lattice potentials to create persistent currents or vortices of few bosons. This is in analogy to Bragg matter-wave splitters for linear momentum states [3]. Finally, we study the efficiency for pulsed splitting of many-body states into vortex-anti-vortex pairs.

[1] M. R. Sturm et al., Phys. Rev. A, **95**, 063625 (2017)
[2] R. Dumke et al., J. Opt., **18**, 093001 (2016)
[3] A. Neumann, M. Gebbe, and R. Walser, Phys. Rev. A, **103**, 043306 (2021)

Q 22.11 Tue 16:30 Empore Lichthof

Constructing a matter-wave microscope for lithium atoms featuring a highly tunable optical lattice — •Mathis Fischer, Nora Bidzinski, Justus Brüggenjürgen, Luca Asteria, Henrik Zahn, Marcel Kosch, Klaus Sengstock, and Christof Weitenberg — Institut für Laserphysik, Universität Hamburg, Germany

Imaging is crucial for gaining insight into physical systems. In the case of ultracold atoms in optical lattices, quantum gas microscopes have revolutionized the access to quantum many-body systems by detecting single particles. However they are limited to investigating 2D systems and are technically demanding. We have developed the novel technique of matter-wave microscopy that allows for a magnification of an atomic sample that can then be imaged using standard absorption imaging techniques. This enables sub-lattice resolution of single lattice-sites and imaging of coherence properties in 3D systems even with rather low-resolution imaging setups. In addition, we have introduced a novel lattice setup with a highly stable and dynamically controllable lattice geometry. The interference of three laser beams is suppressed by detuning their frequencies and then pairwisely reestablished by imprinting sidebands onto each beam. This setup allows us to use the same beams as a dipole trap, which we can employ as a confining potential during matter-wave optics and for creating BECs. We are currently upgrading our lithium machine to combine these developments with the precise control over the interaction strength using Feshbach resonances. In the future, we plan to implement single particle sensitive imaging to study intriguing many-body systems.

Q 22.12 Tue 16:30 Empore Lichthof

Towards a K39 Quantum gas microscope — •Ruben Erlenstedt[1], Scott Hubele[1,2], Martin Schlederer[1,2], Alexandra Mozdzen[1,2], Guillaume Salomon[1,2], and Henning Moritz[1,2] — [1]Institut für Laserphysik, Universität Hamburg, Hamburg, Deutschland — [2]Cluster of Excellence: CUI - Advanced Imaging of Matter

Ultracold atoms offer unique opportunities for studying quantum magnetism due to the tunability of the interaction strength as well as the tunneling parameters in optical lattices. In recent years, we have built a setup able to cool 39K atoms to Bose-Einstein condensation and to image them with a high resolution (NA=0.7) using an in-vacuo objective. Together with a brief overview of the machine, I will present the progress of my master's thesis towards realising the 'science' optical lattices that will be used for the realization of Hubbard models as well as near resonant 'pinning' optical lattices that will be used for single atom sensitive imaging.

Q 22.13 Tue 16:30 Empore Lichthof

A functional renormalization group approach to non-thermal fixed points in an ultracold Bose gas — •Aleksandr N. Mikheev[1,2], Jan M. Pawlowski[2,3], and Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [3]ExtreMe Matter Institute EMMI, GSI, Planckstraße 1, 64291 Darmstadt, Germany

Classification and understanding of scaling solutions in closed quantum systems far from thermal equilibrium, known as non-thermal fixed points, is one of the open problems in non-equilibrium quantum many-body theory. The usual method involves searching for possible self-similar solutions to a (non-perturbative) evolution equation, e.g., Boltzmann or Kadanoff-Baym, starting from a far-from-equilibrium initial condition. We outline an alternative approach based on the correspondence between scaling and fixed points of the renormalization group. Using an ultracold Bose gas as an example we show how possible far-from-equilibrium scaling solutions can be systematically obtained by solving fixed-point renormalization-group equations.

Q 22.14 Tue 16:30 Empore Lichthof

Non-thermal fixed points of universal sine-Gordon coarsening dynamics — Philipp Heinen[1], Aleksandr N. Mikheev[1,2], Christian-Marcel Schmied[1], and •Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

We examine coarsening of field-excitation patterns of the sine-Gordon (SG) model, in two and three spatial dimensions, identifying it as universal dynamics near non-thermal fixed points. The focus is set on the non-relativistic limit, governed by a Schrödinger-type equation with Bessel-function nonlinearity. The results of our classical statistical simulations suggest that, in contrast to wave turbulent cascades, in which the transport is local in momentum space, the coarsening is dominated by rather non-local processes corresponding to a spatial containment in position space. The scaling analysis of a kinetic equation obtained with path-integral techniques corroborates this numerical observation and suggests that the non-locality is directly related to the slowness of the scaling in space and time. Our methods, which we expect to be applicable to more general types of models, could open a long-sought path to analytically describing universality classes behind domain coarsening and phase-ordering kinetics from first principles, which are usually modelled in a near-equilibrium setting by a phenomenological diffusion-type equation in combination with conservation laws.

Q 22.15 Tue 16:30 Empore Lichthof

A sodium potassium mixture experiment for simulating polaron physics — •Jan Kilinc, Lilo Höcker, Lorenz Hahn, Joris Hoffmann, Maurus Hans, Helmut Strobel, and Markus Oberthaler — Kirchhoff Institut für Physik, Heidelberg, Deutschland

The motion of quantum impurities in a Bose-Einstein condensate (BEC) is an exemplary many-body phenomenon and a theoretical challenge especially in the regime of strong interactions between the impurities and the BEC. In the experiment such a Polaron problem can be studied using an atomic mixture, where one species realizes the impurity, while the BEC is realized with the other species. The interaction can be controlled by sizeable inter-species Feshbach resonances between sodium and potassium. In this poster, we present the current status of our sodium potassium experiment.

Q 22.16 Tue 16:30 Empore Lichthof

Non equilibrium dynamics of bosons populating higher bands of an optical lattice — •José Vargas[1,2], Car Hippler[1], and Andreas Hemmerich[1,2] — [1]Zentrum für Optische Quantentechnologien and Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany — [2]The hamburg center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

We experimentally and theoretically explore from single-particle to many-body dynamics of a Bose-Einstein condensate populating higher bands of an optical lattice. Topics such as Bloch-oscillations along different paths over each addressable Brillouin zone of the lattice, pair-tunneling phenomenon, and re-condensation dynamics are investigated.

Q 22.17 Tue 16:30 Empore Lichthof

Effective Model of Phase Excitations in a 1D Spin-1 BEC Far from Equilibrium — Ido Siovitz, •Hannes Köper, Aleksandr Mikheev, Philipp Heinen, Stefan Lannig, Yannick Deller, Helmut Strobel, Markus Oberthaler, and Thomas Gasenzer — Kirchhof Institut für Physik, Universität Heidelberg, Heidelberg, Deutschland

The spin-1 Bose gas quenched far from equilibrium to the easy-plane shows a plethora of interesting phenomena, of which we discuss the universal spatio-temporal self-similar scaling on account of the system's vicinity to an hypothesized non-thermal fixed point. The appearance of topological excitations, such as instantons, in the transversal spin degree of freedom during the equilibration process of the condensate leads to a varying length scale, reflecting the self-similar scaling of correlations. Due to the multitude of degrees of freedom in the spin-1 BEC, the causes of the system's behavior far from equilibrium are difficult to investigate.

We present a low-energy effective field theory to describe the dynamics of the system and find the driving mechanism behind the production of such topological objects in the system. We show that the effective model presents the same self similar scaling behavior of the full spin-1 Bose gas quenched to the easy-plane phase.

Q 22.18 Tue 16:30 Empore Lichthof

Stability analysis of a periodically driven ultra-cold Bose gas — •Larissa Schwarz, Simon B. Jäger, Dimo Claude, Imke Schneider, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, D-67663, Kaiserslautern, Germany

We theoretically study the dynamics of a Bose-Einstein condensate under periodic driving of the s-wave scattering length. In this setup, we first determine the stability of the condensate using Bogoliubov theory with time-periodic modulation. We find an exponential gain in the resonant k-modes due to a parameteric amplification which leads to a rapid condensate depletion. These findings are compared with the simulation of the Gross-Pitaevskii equation which shows the formation of a density-wave pattern with the predicted k-wavevector. We extend the Bogoliubov theory by including non-linearities which result in an effective damping of the k-modes. This enables the creation of stable density-wave pattern below a critical driving strength. Moreover, above this critical driving strength we analyze simple non-quadratic models and find macroscopic and stable occupation of the resonant k-mode.

Q 22.19 Tue 16:30 Empore Lichthof

Study of a matter wave neural network — •Moritz Sträter, Niklas Käming, Klaus Sengstock, and Christof Weitenberg — Universität Hamburg (UHH), Hamburg, Deutschland

Machine learning and neural networks have proven a powerful tool for studying quantum many-body physics. Moreover, the search for new architectures and implementations of neural networks building on optical or quantum hardware is an ongoing research topic.

In this poster, we present the progress on the evaluation of a new concept of a matter-wave neural network based on the coherent coupling of momentum modes of a BEC. We study the effects of interactions on the capacity and performance of the network for example classification tasks.

In the future, we hope to find and quantify a possible advantage of coherence, non-linearities and quantum correlations for generic classification tasks, which are offered in such cold-atom hardware.

Q 22.20 Tue 16:30 Empore Lichthof

A Rydberg Atom in a BEC — •Aileen A. T. Durst and Matthew T. Eiles — Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

A Rydberg atom immersed in a BEC has many extreme interaction features. While the interaction between one of the BEC particles and its neighbors is typically short-ranged compared to other length scales in the condensate, the range of the interaction of the enormous Rydberg impurity and the surrounding bath particles is comparable to or even larger than the mean interparticle distance in the gas. Furthermore, this interaction potential is highly oscillatory and can support multiple bound states. These properties complicate the theoretical description and analysis of the Rydberg impurity, whose interaction potential cannot be replaced in general by a contact pseudopotential. We relate the Rydberg impurity problem to other impurity problems by characterizing it by the number of bound states and, equivalently, the Rydberg-bath particle scattering length, and in this way investigate in which parameter regions the system exhibits quasiparticle character.

Q 22.21 Tue 16:30 Empore Lichthof

Pattern formation and symmetry breaking in a periodically driven 2D BEC — •Nikolas Liebster[1], Marius Sparn[1], Elinor Kath[1], Maurus Hans[1], Keisuke Fujii[2], Sarah Görlitz[2], Helmut Strobel[1], Tilman Enss[2], and Markus Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Heidelberg, Germany — [2]Institut für Theoretische Physik, Heidelberg, Germany

Dynamical pattern formation is a ubiquitous phenomenon in nature, and has relevance in many fields in physics. The emergence of these patterns, as well as how symmetries are broken, remains an open field of research in quantum physical systems. By periodically driving the scattering length in a 2D potassium-39 Bose-Einstein condensate, we use parametric resonance to non-linearly populate specific momentum modes of trapped condensates. We show the emergence of randomly oriented standing waves with D4 symmetry and investigate the effects of background density distributions on the formation of patterns on the condensate.

Q 22.22 Tue 16:30 Empore Lichthof

BKT Physics for Bose Gas in 2D Box — •Til Möhnen and Axel Pelster — Physics Department and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

For a two-dimensional Bose gas a Berezinskii-Kosterlitz-Thouless (BKT) transition from a superfluid phase of bound vortex-antivortex pairs to a normalfluid phase of unpaired vortices and antivortices occurs at a critical temperature, which is determined by the Nelson criterion. Here we analyze the finite-size effects of this phase transition by considering a Bose gas in a two-dimensional box. To this end we derive the underlying renomalization-group equations, which describe the screening of both the condensate and the superfluid density due to the presence of vortices and antivortices. Their solution for the parameters of the recent experiment [1] allows to quantify the impact of finite-size effects in terms of the condensate fraction. Furthermore, in the thermodynamic limit we obtain a vanishing condensate density in accordance with the Mermin-Wagner-Hohenberg theorem and we reproduce the universal BKT jump of the superfluid density at the critical temperature.

[1] P. Christodoulou et al., Nature **594**, 191 (2021)

Q 22.23 Tue 16:30 Empore Lichthof

Quantum many-body scars in a Bose-Hubbard quantum simulator — •Guoxian Su[1], Jean-Yves Desaules[2], Ana Hudomal[2,3], Aiden Daniel[2], Jad Halimeh[4], Zhen-Sheng Yuan[5], Jian-Wei Pan[5], and Zlatko Papic[2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, UK — [3]Institute of Physics Belgrade, University of Belgrade, 11080 Belgrade, Serbia — [4]Munich Center for Quantum Science and Technology (MCQST), Schellingstraße 4, D-80799 München, Germany — [5]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Quantum many-body scarring is a phenomenon where a chaotic system prepared in special initial conditions exhibits long-lived oscillations. It presents a novel mechanism for delaying the onset of thermalization. We realize many-body scars in a Bose-Hubbard quantum simulator, which hosts an abundance of scar states. We show the slowed growth of entanglement entropy in scarred dynamics. And we investigate the ubiquity of scarring and its interaction with quantum criticality. Our work makes the resource of scarring accessible to a broad class of ultracold-atom experiments and enables the study of such phenomena in fundamental physics such as lattice gauge theories.

Q 22.24 Tue 16:30 Empore Lichthof

Entropy extraction in spinor Bose gases — •Yannick Deller[1], Moritz Reh[1], Stefan Lannig[1], Alexander Schmutz[1], David Feiz[1], Helmut Strobel[1], Martin Gärttner[1,2,3], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]Physikalisches Institut, Universität Heidelberg — [3]Institut für Theoretische Physik, Universität Heidelberg

The concept of entropy plays an important role for quantum informational properties of many-body systems. However, experimental extraction of entropies is in general a challenging task due to the rapid increase of the Hilbert space dimension with system size.

As our testbed we use a spin-1 Bose-Einstein condensate of rubidium in a tight optical trap, where we routinely generate non-classical spin states by quantum dynamics after a parameter quench. With a generalized POVM protocol [1], we are able to simultaneously measure two non-commuting spin observables. We extract an entropy using distributions of experimental repetitions with a statistical estimator, that avoids binning and coarse-graining of the data. We discuss how to extend these techniques to multiwell-systems with tunnel-coupling between the wells.

[1] Kunkel et. al., PRL 123, 063603 (2019)

Q 22.25 Tue 16:30 Empore Lichthof

Observation of edge states in topological Floquet systems — •Johannes Arceri[1,2], Christoph Braun[1,2,3], Alexander Hesse[1,2], Raphaël Saint-Jalm[1,2], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, München — [2]Munich Center for Quantum Science and Technology (MCQST), München — [3]Max-Planck-Institut für Quantenoptik, Garching

Floquet engineering, i.e., periodic modulation of a system's parameters, has proven as a powerful tool for the realization of quantum systems with exotic properties that have no static analog. In particular, the so-called anomalous Floquet phase displays topological properties even if the Chern number of the bulk band vanishes. [1]

Our experimental system consists of bosonic atoms in a periodically driven honeycomb lattice. Depending on the driving parameters, several out-of-equilibrium topological phases can be realized, including an anomalous phase. [2]

As the bulk-boundary correspondence relates the properties of the bulk bands to the number of topologically protected edge modes, special interest lies in studying the behavior of them. We are investigating the real-space evolution of a wavepacket close to the edge after the release from a tightly-focused optical tweezer. This way, we observe the chiral nature of the edge state, even in the anomalous Floquet phase, thereby directly revealing the topological nature of this phase.

[1] Rudner et al., Phys. Rev. X 3, 031005 (2013)
[2] Wintersperger et al., Nat. Phys. 16, 1058-1063 (2020)

Q 22.26 Tue 16:30 Empore Lichthof

Self-oscillating pump in a topological dissipative atom-cavity system — •Justyna Stefaniak, Davide Dreon, Alexander Baumgaertner, Simon Hertlein, Xiangliang Li, Tobias Donner, and Tilman Esslinger — ETH Zurich

Pumps are transport mechanisms in which direct currents result from a cyclic evolution of the potential. As Thouless showed, the pumping process can have topological origins, when considering the motion of quantum particles in spatially and temporally periodic potentials. However, the periodic evolution that drives these pumps has always been assumed to be imparted from outside, as has been the case in the experimental systems studied so far. Here we report on an emergent mechanism for pumping in a quantum gas coupled to an optical resonator, where we observe a particle current without applying a periodic drive. The pumping potential experienced by the atoms is formed by the self-consistent cavity field interfering with the static laser field driving the atoms. Owing to dissipation, the cavity field evolves between its two quadratures, each corresponding to a different centrosymmetric crystal configuration. This self-oscillation results in a time-periodic potential analogous to that describing the transport of electrons in topological tight-binding models, such as the paradigmatic Rice*Mele pump. In the experiment, we directly follow the evolution by measuring the phase winding of the cavity field with respect to the driving field and observing the atomic motion in situ. The observed mechanism combines the dynamics of topological and open systems, and features characteristics of continuous dissipative time crystals.

Q 22.27 Tue 16:30 Empore Lichthof

Stability and vulnerability of quantum gases along the BEC-BCS crossover with quenched disorder — •Felix Lang, Jennifer Koch, Sian Barbosa, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

Quantum fluids in the so-called BEC-BCS crossover show very different microscopic pairs underlying the superfluid. This changing pairing might also change the response to perturbations of the system. We investigate the response of a molecular BEC and of a resonantly interacting Fermi gas to quenches into and out of an optical disorder potential. We monitor the response of the in-situ density distribution as well as the ability for hydrodynamic expansion, which we interpret as a measure of long-range phase coherence. Concerning the latter, we find that the BEC recovers hydrodynamic expansion after disorder quenches on time scales which can be related to energy scales in the system, whereas the unitary Fermi gas permanently loses its ability for hydrodynamics. We attribute this observation to an efficient breaking of Fermi pairs in the BEC-BCS crossover. Our work sheds light on the mechanisms underlying the superfluid pairing in interacting Fermi gases.

Q 22.28 Tue 16:30 Empore Lichthof

Report on an Erbium-Lithium machine — Florian Kiesel and •Alexandre De Martino — Eberhard Karls Universität Tübingen, Physikalisches Institut AG Groß, Auf der Morgenstelle 14, 72076 Tübingen

Ultracold Fermions cannot be cooled below about 10% of the Fermi temperature with conventional methods. Sympathetic cooling with a classical gas as an entropy reservoir may provide a new direction to overcome the current limit. Here we report on the construction and implementation of first cooling stages of a two species apparatus for the optimized symp. cooling of fermionic Li with bosonic Er. This mixture has several promising features, that have not yet been utilized for symp. cooling in any other mixture. Pushing the temperature limit is essential for the quantum simulation of strongly correlated phenomena, in particular in optical lattice.

Q 22.29 Tue 16:30 Empore Lichthof

Towards quantum simulation with strontium atoms — •Thies Plassmann[1,2], Meny Menashes[1], Leon Schaefer[1], and Guillaume Salomon[1,2] — [1]Institute of Laserphysics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg, Germany

Individually controlled ultracold atoms in programmable potential landscapes have emerged as powerful systems to explore exotic states of matter in highly-correlated quantum many-body systems.

We are currently building a new quantum simulation platform based on strontium atoms. We will report on the building of our experimental apparatus designed for short cycle times and quantum gas microscopy with single particle as well as single spin resolution. By combining optical lattices with programmable optical tweezers, we aim to study the Fermi-Hubbard model and frustrated quantum magnetism with atoms trapped in tunable 3D potentials and excited to Rydberg states.

Q 22.30 Tue 16:30 Empore Lichthof

Pair correlations in a strongly interacting two-component Fermi gas — •Manuel Jäger and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Deutschland

We study pair correlations in a two-component fermionic system. In particular we investigate the crossover from a Bardeen-Cooper-Schrieffer (BCS) superfluid of loosely bound Cooper pairs to a Bose-Einstein condensate (BEC) of tightly bound dimers.

For studying this system experimentally, we use a spin-balanced mixture of the two lowest ^{6}Li Zeeman states and set their interaction strength by means of the Feshbach resonance at 832 G. We then perform photoexcitation of the pairs at various temperatures and interaction strengths. The photoexcitation induces a two-body loss in our system. From analyzing the loss rate we obtain Tan's contact.

Our measurements of the two-body contact extend previously reported measurements and calculations carried out at low temperatures and at unitarity. Moreover, we find that our results above 0.5 T_F can be well described by the second order quantum virial expansion in the whole BCS-BEC crossover.

Q 22.31 Tue 16:30 Empore Lichthof

Solving the Floquet matrix for driven optical lattices — •Anna Lena Hauschild, Niklas Köming, Corinna Menz, Christof Weitenberg, and Klaus Sengstock — Institute for Laser Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Ultra cold atoms in optical lattices are a highly-tunable system for quantum emulation of many body physics in solid state systems. By changing the setup of a driven lattice system, different band structure can be studied. In our project we want to build a numerical simulation of driven lattice systems.

Here we implement the Floquet matrix method, which gives a time independent matrix working with modified copies of the base Hamiltonian. In comparison to other relevant methods such as direct time evolution of tight-binding models, the computational effort of this method is higher, but due to less approximation it is in certain cases more accurate.

For the Floquet matrix method the resulting bands will not be ordered correctly:
For intersecting bands we investigate the eigenstates and their properties around the point of intersection for the correct assignment. With this project we want so be able to find topological properties of the system and a preparation for experimental implementation.

Q 22.32 Tue 16:30 Empore Lichthof

Observation of Chiral Edge Current Suppression for Strongly Interacting Fermions in Hall Ladder Systems — •Marcel Diem[1], Tobias Petersen[1], Nejira Pintul[1], Benjamin Abeln[1], Koen Sponselee[1], Oscar Murzewitz[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Laserphysics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

Ultracold quantum gases of neutral atoms are an excellent platform for quantum simulation of Hall physics due to their ability to implement artificial gauge fields and, thus, to mimic the physics of charged particles in strong magnetic fields.

Here, we present the experimental realization of 2D Hall ladder systems in one real and one synthetic dimension and study edge currents for two ultracold fermionic ytterbium isotopes to access the role of interactions in topologically non-trivial systems. One isotope, ^{171}Yb, is non-interacting, whereas the isotope ^{173}Yb interacts repulsively. We use Raman beams to couple states with different m_F quantum number and momentum. This coupling gives rise to a strong artificial magnetic field, which is essential for the quantum Hall effect.

We observe a significant suppression of chiral edge currents for strongly interacting fermions in direct comparison to non-interacting fermions. Our work paves the way towards a better understanding of interaction effects in Hall systems.

Q 22.33 Tue 16:30 Empore Lichthof

Heidelberg Quantum Architecture: Fast and modular quantum simulation — •Tobias Hammel, Maximilian Kaiser, Vivienne Leidel, Micha Bunjes, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

More is always better. This is especially true when talking about the amount of data a Quantum Simulator can produce in a given time. The reason why is multi-layered, ranging from the achievable signal-to-noise ratios in data demanding experiments, over the requirements on stability during an experimental run, to aspects of ease of use and debuggability.

This experiment aims at cycle rates of up to 10 cycles per second, possibly bridging the gap to programmable, on-demand quantum simulation. The key bottlenecks that are addressed in this newly build Lithium-6 machine are a reduction of MOT loading times and a high speed thermalization into an optical dipole trap.

Modularly exchangeable optical setups including an accordion lattice, a DMD and a dark ODT paired with various characterization modules enable the simulation of a variety of physical systems. Initially, the main focus will be on the fast preparation of few-fermion systems with high fidelities.

Q 22.34 Tue 16:30 Empore Lichthof

Ultracold Fermi Gases in Box Potentials — •Rene Henke, Hauke Biss, Cesar Cabrera, Lennart Sobirey, Niclas Luick, and Henning Moritz — Institute of Laserphysics, University of Hamburg, Hamburg, Germany

In the past years, our group has managed to create homogeneous ultracold Fermi gases of ^{6}Li atoms, both in 2D and 3D trap geometries. Using Bragg spectroscopy, we measured the excitation spectrum in a momentum resolved fashion. This allowed us to observe superfluidity in the BEC-BCS crossover, to extract the superfluid gap and to compare 2D and 3D systems directly.

This poster will review some of these results and present our progress towards creating spin imbalanced mixtures in two dimensions. For these, many questions still remain unanswered, especially concerning the nature of a potential spin-polarized superfluid. One of the key questions in these systems is, whether the theoretically predicted but elusive FFLO phase exists. In this phase, fermions are theorized to form Cooper pairs with finite total momentum, due to the different Fermi momenta of spin majority and minority. More accessible open questions are whether a partially polarized superfluid can be observed in general, how stable it is and whether the transition between fully paired superfluid and partially polarized Fermi gas is of first or higher order.

Q 22.35 Tue 16:30 Empore Lichthof

Engineering of lattice models with local control in fermionic quantum gas microscopes — •Si Wang[1,2], Sarah Hirthe[1,2], Dominik Bourgund[1,2], Petar Bojovic[1,2], Thomas Chalopin[1,2], Immanuel Bloch[1,2,3], and Timon Hilker[1,2] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Ludwig Maximilian University of Munich, Munich, Germany

Quantum simulation of ultracold atoms is a powerful tool for investigating long-standing problems in condensed matter physics. Our quantum gas microscope allows us to study the exotic phases of the Fermi-Hubbard model with single-site density and spin resolution. Furthermore, our recently implemented bichromatic superlattices, together with digital micromirror devices (DMDs) in real and Fourier space, open the possibility for the realization of collisional gates with individual site control.

Q 22.36 Tue 16:30 Empore Lichthof

Towards fast, deterministic preparation of few-fermion states — •Vivienne Leidel, Tobias Hammel, Maximilian Kaiser, Micha Bunjes, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg (Germany)

Heidelberg Quantum Architecture is a new experiment using ultracold Lithium-6 atoms aiming to achieve rapid cycle times of under one second. Among others, our approach is to speed up the MOT loading with more available laser power enabling the use of a high flux 2D MOT as well as a modular design with micrometer reproducibility.

In particular I will present setting up a laser lock to the Lithium-6 D2 transition using a modulation transfer scheme to ensure minimal drifts in frequency. An AOM Doublepass module enabling high stability and quick setup times is presented.

Physics in lower dimension often exhibits peculiar properties. Hence, we want to fine tune the dimentionality of the system using a miniaturized accordion lattice setup. It consists of two laser beams intersecting at a tunable angle. In this way controlling the spacing between the interference fringes, and therefore the strength of the confinement of our atoms.

Q 22.37 Tue 16:30 Empore Lichthof

Emergence of collective excitations in few Fermion systems — •Johannes Reiter, Philipp Lunt, Paul Hill, Philipp Preiss, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Deutschland

The emergence of collective behaviour in strongly-interacting mesoscopic systems has been a long-standing question in nuclear and cold atom physics [1,2]. Our previously established technique to deterministically prepare few Fermion systems [3] in combination with the tunability of interactions in ultracold gases allows us to address this question. However, to observe clear signatures of elementary excitations in a strongly interacting few Fermion system precise control of the optical potential is required.

We present a refined version of phase shift interferometry [5] to detect wavefront aberrations on the atoms and compensate for them using a spatial light modulator.

Building on this, we study the quadrupole mode across the BEC-BCS crossover by means of spectroscopic probes. Tuning of the interparticle interactions via a broad Feshbach resonance allows us to observe the transition from single-particle to collective excitations and varying the atom number enables us to observe the emergence of collective behaviour atom by atom.

[1] B. Mottelson *Science* 193 (4250), 287-294 (1976) [2] S. Giorgini et al. *Rev.Mod.Phys.* 80, 125 (2008) [3] F. Serwane et al. *Science* 332 (6027), 336-338 (2011) [4] L. Bayha et al. *Nature* 587.7835, 583-587 (2020) [5] P. Zupancic et al. *Optics express* 24.13, 13881-13893 (2016)

Q 22.38 Tue 16:30 Empore Lichthof

High-Resolution Optics for Modular Quantum Simulation — •Micha Bunjes[1], Tobias Hammel[1], Maximilian Kaiser[1], Philipp Preiss[2], Matthias Weidemüller[1], and Selim Jochim[1] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg (Germany) — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Heidelberg Quantum Architecture (HQA) is a new modular quantum simulator built to study the emergence of quantum phenomena in few to many-body systems.

At the heart of the custom-designed mounting structure lies a high-resolution objective acting as a fixed optical reference. To verify the performance enabled by the high numerical aperture, a modular test bench and a sub-resolution nanopore device are used to scan the point spread function of this objective across the entire field of view. In addition, the angle between the mechanical and optical axis is measured. Characterizing this system in detail enables an improved performance and counteract aberrations.

A crucial goal of HQA is an increased cycle rate, up to 10 cycles per second. To this end, a new proposal aims to accelerate the preparation of few-particle systems using a blue-detuned ring trap to increase local density and thermal scattering rate. After evaporation in this trap, the thermalization of atoms into a tight optical tweezer could be optimized. Two experimental solutions using axicons and Moiré lenses are explored.

Q 22.39 Tue 16:30 Empore Lichthof

Feshbach molecules in an orbital optical lattice — •Max Hachmann, Yann Kiefer, and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg

We experimentally study strongly interacting degenerate Fermi gases exposed to an optical lattice. As a first benchmark, Kapitza-Dirac scattering at a 1D-optical standing wave is used to probe coherence properties of different atomic samples, including a strongly interacting Fermi gas spanning the whole BEC-BCS crossover regime. Adjusting the magnetic field in the vicinity of a Feshbach resonance allowed to create bosonic dimers formed by two fermionic 40K atoms, which are also studied in the optical lattice. Using a bipartite optical square lattice ultimately resulted in the successful selective population of higher Bloch bands, which are then analysed by means of a method resembling mass spectrometry. Binding energies and lifetimes in the second (first) Bloch band were extensively studied, where the longest lifetimes are observed at the onset of unitarity with values around 100ms(300ms). Our work prepares the stage for orbital BEC-BCS crossover physics.

Q 22.40 Tue 16:30 Empore Lichthof

Cavity-based Quantum Processor: Engineering Entanglement with Programmable Connectivity — •Marvin Holten, Stephan Roschinski, Johannes Schabbauer, Davide Natale, Giacomo Hvaring, Iris Haubold, Nicole Heider, Alexander Heiss, and Julian Leonard — Atominstiut, TU Wien, Austria

Entanglement is the fundamental resource for applications like quantum computation and communication beyond the possibilities of classical machines. Many current devices are limited to a small number of qubits if full connectivity between any two qubits independent of their spatial separation is required. Our goal is to investigate an alternative platform for quantum simulation and information processing with qubit full connectivity. The idea is to trap an array of individually addressable atoms inside an optical cavity. The photon-mediated interactions of the atoms in the cavity will enable us to introduce non-local couplings and entangling operations between any two atoms or qbits in the system. We will implement a non-destructive readout scheme that relies on injecting a few-photon field into the cavity. We plan to investigate in what ways the all-to-all connectivity of our quantum processor enables us to efficiently create highly entangled many-body ensembles, like GHZ states. Finally, we want to use the quantum processor to address longstanding questions about the thermalisation of closed quantum systems and information scrambling. With its scalability and fully programmable connectivity, our architecture has the potential to open up new pathways for a wide range of fields like quantum optimization, communication and simulation.

Q 22.41 Tue 16:30 Empore Lichthof

Preparation for the Integration of the BECCAL Laser System — •Marc Kitzmann[1], Victoria Henderson[1,2], Tim Kroh[1,2], Jakob Pohl[1,2], Matthias Schoch[1], Christoph Weise[1], Hrudya Thaivalappil Sunilkumar[1], Hamish Beck[1], Bastian Leykauf[1], Evgeny Kovalchuk[1], Achim Peters[1,2], and the BECCAL Collaboration[1,2,3,4,5,6,7,8,9,10] — [1]HUB, Berlin — [2]FBH, Berlin — [3]JGU, Mainz — [4]LUH, Hannover — [5]DLR-SI, Hannover — [6]DLR-QT, Ulm — [7]UULM, Ulm — [8]ZARM, Bremen — [9]DLR, Bremen — [10]DLR, Braunschweig

BECCAL (Bose-Einstein Condensate and Cold Atom Laboratory) is a cold atom experiment designed for operation on the ISS. It is a DLR and NASA collaboration, built on a heritage of sounding rocket and drop tower experiments, and NASA's CAL. This multi-user facility enables the exploration of fundamental physics with Rb and K BECs and ultra-cold atoms in microgravity, facilitating prolonged timescales and ultra-low energy scales. In contrast to lab-based cold atom experiments, BECCAL must be operable without interference for three years on the ISS. To reach that goal and match the complexity of this space-based system to the stringent size, weight, and power limitations, we have to fulfill strict product assurance requirements for the laser system including higher cleanliness facilities and ESD protection. In this context, the planning and implementation of the specific lab setup and the first essential integration tests, using mock-ups, will be presented. This work is supported by the DLR with funds provided by the BMWK under grant numbers DLR 50WP1702, and 50WP2102.

Q 22.42 Tue 16:30 Empore Lichthof

A narrow linewidth and high power lasersystem for dual-species atom interferometry — •Wei Liu, Alexander Herbst, Henning Albers, Ashwin Rajagopalan, Knut Stolzenberg, Sebastian Bode, Ernst.M. Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

The universality of free fall is one of the foundations of general relativity, which can be tested by observing the free falling of different test masses. The development of atom optics has allowed performing of quantum tests with dual-species atom interferometers. However trapping and cooling of different atomic species require lasers with different wavelengths, resulting in large and complex laser systems.

We present a new laser system capable of trapping and cooling ^{39}K, ^{41}K and ^{87}Rb. The system features high power and low maintenance by using frequency doubled C-band fiber lasers. We replace 11 external-cavity diode lasers and 8 tapered amplifiers with only 6 fiber lasers, remove all optical active components except acousto- and electro- optic modulators, and therefore simplify the laser system. On this poster we will describe the optical set up, characterisation measurements and the scheme of frequency stabilisation.

Q 22.43 Tue 16:30 Empore Lichthof

Rapid generation and number-resolved detection of spinor Rubidium Bose-Einstein condensates — Cebrail Pür[1], Mareike Hetzel[1], •Martin Quensen[1], Andreas Hüper[1,4], Jiao Geng[2,3], Wolfgang Ertmer[1,4], and Carsten Klempt[1,4] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany — [2]Key Laboratory of 3D Micro/Nano Fabrication and Characterization, School of Engineering, Westlake University, Zhejiang Province, China — [3]Institute of Advanced Technology, Westlake Institute for Advanced Study, Zhejiang Province, China — [4]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Satellitengeodäsie und Inertialsensorik (DLR-SI), Callinstraße 30b, D-30167 Hannover, Germany

High data acquisition rates and low-noise detection of ultracold neutral atoms present important challenges for high-precision atom interferometers that exploit the excellent mode quality of Bose-Einstein condensates. Here, we present a high-flux source of Rb-87 Bose-Einstein condensates combined with a number-resolving detection.

For the high-fidelity tomography of many-body quantum states in the spin degree of freedom, it is desirable to select a single mode for a number-resolving detection. We demonstrate the low-noise selection of subsamples with average atom numbers of up to 35 and their subsequent detection via accurate atom counting. The presented techniques offer an exciting path towards the creation and analysis of mesoscopic quantum states with unprecedented fidelities, and their exploitation for fundamental and metrological applications.

Q 22.44 Tue 16:30 Empore Lichthof

Light-induced correlations in ultracold dipolar atoms — •Ishan Varma, Marvin Proske, Dimitra Cristea, Nivedith Anil, and Patrick Windpassinger — Institute of Physics, JGU Mainz

Dysprosium is a fascinating candidate for studying cooperative and collective effects in dense ultra-cold media. With the largest ground-state magnetic moment of all elements in the periodic table (10 Bohr-magnetons), it offers a platform to study the effect on scattering of light due to competition between magnetic dipole-dipole interactions (DDI) and light induced correlations. In a sufficiently dense regime, the strong magnetic DDI significantly influence the propagation of light within the atomic sample. In particular, we want to look at signatures of collective light scattering phenomena like Super-radiance and Sub-radiance.

This poster reports on the progress made in generating dense samples of ultracold dysprosium atoms. We plan to optically transport atoms into a home-built science cell with high optical access. A high NA custom objective, designed and assembled in-house, will then be used to create dense atomic samples inside this cell. We evaluate the performance and discuss the installation of the custom objective in our experimental system. Further, an outlook is given on future measurements exploring collective and cooperative effects in the generated sample.

Q 22.45 Tue 16:30 Empore Lichthof

Two-dimensional grating magneto-optical trap — •Aaditya Mishra[1], Hendrik Heine[1], Joseph Muchovo[1], Julian Lemburg[1], Kai Bruns[1], Waldemar Herr[1,2], Christian Schubert[1,2], and Ernst M. Rasel[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Satellitengeodäsie und Inertialsensorik, Callinstr. 30b, D-30167 Hannover, Germany

Ultracold atoms provide exciting opportunities for precision measurements and testing fundamental physics. Two-dimensional(2D) magneto-optical traps(MOT) are advantageous in faster loading to 3D-MOTs and cooling more atoms. However, compact and power-efficient setups are essential in performing transportable experiments. In this poster, we will present a design of a two-dimensional grating magneto-optical trap (2D gMOT) requiring only a single input cooling beam. The cold atomic beam from the 2D gMOT will load atoms in a 3D gMOT implemented on an atom chip for efficient generation of BECs. This will lead to a robust, compact and efficient source of ultracold atoms that can be used in ground and space experiments.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate protection (BMWK) due to the enactment of the German Bundestag under grant number DLR 50WM1947 (KACTUS-II), DLR 50RK1978 (QCHIP) and by the German Science Foundation (DFG) under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

Q 22.46 Tue 16:30 Empore Lichthof

Chip-Scale Quantum Gravimeter — •Julian Lemburg[1], Hendrik Heine[1], Joseph Muchovo[1], Aaditya Mishra[1], Kai Bruns[1], Ernst M. Rasel[1], Waldemar Herr[1,2], and Christian Schubert[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Institut für Satellitengeodäsie und Intertialsensorik, DLR-SI

Interferometers with Bose-Einstein condensates (BECs) enable a very precise measurement of inertial forces like gravity. Potential applications can be in ground and space-borne geodesy. A lower size, weight, and power consumption of these sensors can be realized by using atom chips. The latter enables the creation of a high flux of delta-kick collimated BECs bringing in reach an unprecendented, low measurement uncertainty.

In this poster, we will present a concept to further reduce the sensor head to about shoe-box size. With a novel atom chip combined with the implementation of a relaunch scheme, an innovative single-beam quantum gravimeter is envisaged. The further miniaturization and reduction of complexity of the sensor head are the key features to improve the transportability and ease the in-field operation of the quantum gravimeter.

This work is funded by the German Research Foundation (DFG) in the CRC 1464 "TerraQ" (Project A03) and under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

Q 22.47 Tue 16:30 Empore Lichthof

Realization of an optical accordion for ultracold atoms — •Carole Peiffer, Felix Lang, Sian Barbosa, Jennifer Koch, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

Optical lattices, created by the interference of two or more coherent and often far-detuned laser beams, are among the most established tools used to manipulate quantum gases. One special realization, the so-called optical 'accordion', promises enhanced flexibility: when changing the angle of the two interfering beams, the lattice constant changes, allowing control over the lattice spacings over a large range of values. We aim at realizing such an accordion setup using a beamsplitter, consisting of two custom Dove-prisms, glued together by a special UV-curing epoxy, in combination with a large focusing lens. When a single beam passes through the prism pair, it is split into two parallel rays, and their distance depends on the incidental beam's. After focussing by the lens onto the atom's position , interference creates the lattice potential. I will report the planning, construction and ex-situ characterization of an optical accordion which will be used to access lower dimensions in our setup with ultracold lithium-6 atoms.

Q 22.48 Tue 16:30 Empore Lichthof

A compact and robust fiber-based laser system for cold atom experiments in microgravity — •Janina Hamann[1], Jan Simon Haase[1], Jens Kruse[2], and Carsten Klempt[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]DLR Institut für Satellitengeodäsie und Inertialsensorik, Callinstr. 30b, 30167 Hannover

Operating atom interferometers in space opens up the possibility of a further improved phase sensitivity due to prolonged interrogation times. Especially Bose-Einstein condensates (BEC) are suitable for zero-gravity interferometry due to their well-controlled spatial mode and slow expansion rate. To prepare cold atom experiments for space operation, microgravity facilities such as the Einstein-Elevator are used for ground testing. The generation and detection of a ^{87}Rb BEC in the Einstein-Elevator requires a laser system with a high frequency stability and robustness to 5 g accelerations and vibrations. We design a fiber-based laser system with a tuneable offset frequency stabilization that uses telecom components to ensure robustness. The rugged fiber-based setup is housed in a 19" crate, where fiber-based modulators generate an adjustable offset for the 780 nm laser and additional sidebands at several GHz. An atomic reference module is used for modulation transfer spectroscopy (MTS) on ^{85}Rb. We achieve a tuneable frequency stabilization with a frequency stability of 90 kHz that can perform frequency ramps of 300 MHz in milliseconds.

Q 22.49 Tue 16:30 Empore Lichthof

Laser systems for photoassociation spectroscopy of cold Hg-atoms — •Rudolf Homm and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstraße 7, 64289 Darmstadt

Cold Hg-atoms in a magneto-optical trap offer opportunities for various experiments. The two stable fermionic isotopes are interesting with regard to a new time standard based on an optical lattice clock employing the $^1S_0$ - $^3P_0$ transition at 265.6 nm. All stable isotopes can be used to form ultra-cold Hg-dimers through photoassociation in connection with vibrational cooling by applying a specific excitation scheme.

We will present our laser systems for photoassociation spectroscopy of cold Hg-atoms. The Hg-isotopes are preselected via a 2D-MOT and cooled in a 3D-MOT, while both are driven by the cooling laser system. It consists of a MOFA-Setup at 1014.8 nm followed by two consecutive frequency-doubling stages. The output power is over 900 mW at 253.7 nm without a sign of degradation in the BBO-crystal used in the second frequency-doubling stage, due to a cavity with elliptical focus in the crystal [1].

The setting of the spectroscopy laser system is quite similar to the cooling laser, while the aims are different. The output power needs to be only several dozen mW at the target wavelength of 254.1 nm, but the frequency tuning range of the system has to be much higher. We will report on the status of the experiments.

[1] Preißler, D., *et al.*, *Applied Physics B* **125** (2019): 220

Q 22.50 Tue 16:30 Empore Lichthof

Ultracold Bose gases in temporally and spatially modulated Potentials — •Marco Decker, Erik Bernhart, Marvin Röhrle, and Herwig Ott — Department of Physics and Research center OPTIMAS, RPTU Kaiserslautern-Landau

We investigate Bose-Einstein condensates in spatially and temporally modulated potentials. This allows us to study quantum transport phenomena and quantum scattering problems.

To extend discrete models to continuum physics, we shift from lattice potentials to localized potentials in an optical trap. The potentials are projected onto the atoms with an objective inside the vacuum chamber, which is also used for absorption imaging. The atomic cloud can additionally be imaged via an electron column with high spatial resolution. Additionally, implementing two blue-detuned light sheets, we can furthermore change the trap geometry from 3D to quasi 2D.

Future studies will include time-dependent barriers and local dissipation via the electron column.

Q 22.51 Tue 16:30 Empore Lichthof

Sideband Thermometry on Ion Crystals — •Ivan Vybornyi[1], Laura Dreissen[2], Daniel Vadlejch[2], Tanja Mehlstäubler[2], and Klemens Hammerer[1] — [1]Institut für theoretische Physik, Leibniz Universität Hannover, Appelstraße 2,30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100,308116 Braunschweig, Germany

Crystals of ultracold trapped ions reach sizes of hundreds of individual particles and require high level of control over their motional temperature to account for the second-order Doppler shift in clocks and implement high-fidelity quantum gates in quantum computers. The existing thermometry tools fail to provide an accurate temperature estimation for large ground-state cooled crystals, either focusing only on the symmetric c.o.m. mode of motion or neglecting the involved spin-spin correlations between the ions.

To resolve the thermometry large-N bottleneck, we consider crystal many-body dynamics arising when motional sideband transitions are driven in a near ground-state regime, which is a widely used approach in thermometry of a single ion. To gain some valuable insights on the sideband thermometry method, we also address the single ion case and study it from the Fisher Information prospective.

Extending the approach further, we account for entanglement created between the ions in a crystal to derive a new reliable temperature estimator, insensitive to the number of ions, and field-test in experiments with 4- and 19-ion crystals done by colleagues from PTB and Innsbruck.

Q 22.52 Tue 16:30 Empore Lichthof

Invisible flat bands on a topological chiral edge — •Youjiang Xu, Irakli Titvinidze, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany

We prove that invisible bands associated with zeros of the single-particle Green*s function exist ubiquitously at topological interfaces of 2D Chern insulators, dual to the chiral edge/domain-wall modes. We verify this statement in a repulsive Hubbard model with a topological flat band, using real-space dynamical mean-field theory to study the domain walls of its ferromagnetic ground state. Moreover, our numerical results show that the chiral modes are split into branches due to the interaction, and that the branches are connected by invisible flat bands. Our work provides deeper insight into interacting topological systems. (preprint: arXiv:2204.11946)

Q 22.53 Tue 16:30 Empore Lichthof

Optical simulations for highly sensitive atom interferometry — •Gabriel Müller, Stefan Seckmeyer, and Naceur Gaaloul — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Using atom interferometers as highly sensitive quantum sensors requires both precise understanding and control of their main building block: atom light interactions. To properly describe the atom light interactions we need an accurate description of the laser-driven light fields. Distortions of ideal Gaussian beams on their path to the atoms can cause several disturbing effects. For example, the occurrence of asymmetric optical dipole forces acting on the atoms can cause a loss of contrast. Here, we build an optical simulation tool using Fast-Fourier-transform beam propagation methods to take into account arbitrarily shaped obstacles. We compare these results, on small scales, to solutions of Maxwell's equations finding good agreement. Finally, we apply our optical simulations to guide the design of the next unit of NASA's Earth-orbiting Cold Atom Lab and DESIRE, a microgravity experiment searching for Dark Energy.

This work is supported by DLR funds from the BMWi (50WM2245A-CAL-II and 50WM2253A-(AI)^2).

Q 22.54 Tue 16:30 Empore Lichthof

Green's functions formulation of Floquet topological invariants — •Marcus Meschede, Helena Drüeke, and Dieter Bauer — University of Rostock

Floquet topological insulators (FTIs) allow for topological protection through their time evolution as opposed to static topological insulators, which are only protected by their band topology. FTIs have become ubiquitous in the pursuit of realizing new phases of matter. In general, the momentum-dependent quasi-energy spectrum of single-particle time evolution operators or, equivalently, Floquet Hamiltonians is used to classify the band topology. In the presence of many-particle interactions, this single-particle picture breaks down. In order to overcome this issue, topological invariants of static systems have been formulated through their single-particle Green's functions. [1,2] We expand on this work by calculating Floquet topological invariants through their Floquet Green's function. As there is much experimental work on realizing FTIs, we hope to provide another tool to determine the topological properties of these systems through their bulk spectral function.

[1] Gurarie, V. "Single-Particle Green*s Functions and Interacting Topological Insulators." Physical Review B 83, 085426 (2011).

[2] He, Yuan-Yao, Han-Qing Wu, Zi Yang Meng, and Zhong-Yi Lu. "Topological Invariants for Interacting Topological Insulators. I. Efficient Numerical Evaluation Scheme and Implementations." Physical Review B 93, 195163 (2016)

Q 22.55 Tue 16:30 Empore Lichthof

Light-induced correlations in cold dysprosium atoms — •Nivedith Anil, Marvin Proske, Ishan Varma, Dimitra Cristea, and Patrick Windpassinger — Institut für Physik, JGU Mainz

We intend to study light-matter interactions to explore the effect of magnet dipole-dipole interactions in highly dense samples of atoms exhibiting large permanent magnetic dipole moments. When the average interatomic distances are smaller than the wavelength of the scattering light, strong electric and magnetic dipole-dipole interactions give rise to collective light-scattering phenomena in the spectral and temporal domains. With the largest ground-state magnetic moment in the periodic table (10 Bohr-magneton), dysprosium is the perfect candidate for these experiments.

This poster reports on our progress in generating extremely dense ultracold atomic dysprosium clouds. We present our method to optically transport the atoms into a home-built science cell using a high-precision air-bearing translation stage. A custom-built high NA objective will re-trap the transported atoms in a tightly focussed microscopic optical dipole trap. Further, we discuss the design of a magnetic field system, which allows for highly precise magnetic field control and the ability to tune the contact interactions between the dysprosium atoms.

Q 22.56 Tue 16:30 Empore Lichthof

Borromean states in a one-dimensional three-body system — •Tobias Schnurrenberger[1], Lucas Happ[2], and Maxim Efremov[1] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany — [2]RIKEN Nishina Center, Strangeness Nuclear Physics Laboratory, Wako 351-0198, Japan

We explore the Borromean states of a one-dimensional quantum three-body system composed of two identical heavy particles and a different particle of smaller mass. There is no heavy-heavy interaction potential and no bound state supported by the heavy-light one. To determine the parameters of the heavy-light potential for which the Borromean states may exist, we apply and compare two approaches: (i) the Born-Oppenheimer approximation, being usually valid for a large mass ratio between heavy and light particles, and (ii) the Faddeev equations, being exact for any mass ratio.

Q 22.57 Tue 16:30 Empore Lichthof

Snapshot-based detection of hidden off-diagonal long-range order on lattices — Fabian Pauw[1], •Felix A. Palm[1], Annabelle Bohrdt[2], Sebastian Paeckel[1], and Fabian Grusdt[1] — [1]LMU Munich & MCQST, Munich, Germany — [2]Harvard University & ITAMP, Cambridge (MA), USA

Revealing the existence of hidden off-diagonal long range order is believed to be a promising avenue towards identifying and characterizing topological order. In continuum fractional quantum Hall systems this can be accomplished by attaching gauge flux tubes onto the particles. Following the recent advances of cold atom experiments in optical lattices, probing this hidden, non-local order parameter with Fock-basis snapshots for lattice analogs is now within reach. Here, we demonstrate the existence of hidden off-diagonal long range order in quasi two-dimensional lattices in the $\nu = 1/2$-groundstate of the experimentally realistic isotropic Hofstadter-Bose-Hubbard model. To this end, we provide a MPS-driven, hybrid one and two-site snapshot procedure to sample the one-particle reduced density matrix and all particle positions simultaneously, emulating an experimentally feasible protocol. We present strong numerical indications for the emergence of an algebraic decay and discuss the resolution achievable using only few snapshots.

Q 22.58 Tue 16:30 Empore Lichthof

Few fermions in an arbitrary potential — •Jonas Herkel, Sandra Brandstetter, Carl Heintze, Keerthan Subramanian, and Selim Jochim — Physikalisches Institut, University Heidelberg, Germany

Fermionic quantum systems with a tuneable atom number have proven to be a viable platform for exploring the emergence of many-body phenomena. In our experiment we are able to prepare a fermionic few-body system of 6Li atoms by spilling a two dimensional trap.

We use two different matter wave optic techniques to achieve single atom resolution. Combined with our spin resolved imaging technique, this allows for the examination of correlations between atoms in different spin states. A non interacting expansion maps the initial momenta to real space. For real space imaging we use a technique similar to (1), which combines the evolution in two harmonic potentials with different trapping frequencies, to magnify the spatial distribution. These imaging techniques allows us to explore hydrodynamic behavior of the few body limit.

We plan to setup a digital-micro-mirror-device (DMD) in a compact and modular way. The DMD will allow us to form nearly arbitrary uniform potentials, with a blue detuned laser. One possible application is a double box to explore the transport physics of a small number of atoms. The fast dynamics of the DMD additionaly allows for dynamic potentials, which could be utilized to explore collectivity of few atoms.
(1) Asteria et al. Nature 599, 571*575 (2021).
https://doi.org/10.1038/s41586-021-04011-2

Q 22.59 Tue 16:30 Empore Lichthof

Commercial Off-The-Shelf Replicate of the BECCAL Laser System for Cold Atom Experiments on the ISS — •Hamish Beck[1], Victoria Henderson[1,2], Tim Kroh[1,2], Jakob Pohl[1,2], Matthias Schoch[1], Christoph Weise[1], Hrudya Thaivalappil Sunilkumar[1], Marc Kitzmann[1], Bastian Leykauf[1], Evgeny Kovalchuk[1], Achim Peters[1,2], and the BECCAL Collaboration[1,2,3,4,5,6,7,8,9,10] — [1]HUB, Berlin — [2]FBH, Berlin — [3]JGU, Mainz — [4]LUH, Hannover — [5]DLR-SI, Hannover — [6]DLR-QT, Ulm — [7]UULM, Ulm — [8]ZARM, Bremen — [9]DLR, Bremen — [10]DLR, Braunschweig

BECCAL (Bose-Einstein Condensate–Cold Atom Laboratory) is a cold atom experiment designed for operation on-board the ISS. This DLR and NASA collaboration builds upon the heritage of sounding rocket and drop tower experiments as well as NASA's CAL. Fundamental physics with Rb and K BECs and ultra-cold atoms will be explored in this multi-user facility in microgravity, providing prolonged timescales and ultra-low energy scales compared to those achievable on earth. A ground-based replicate of the apparatus must also be built to support the operation of the flying experiment. The size, weight, and power constraints of such a Ground-based Test Bed (GTB) are relaxed, and so the laser system may be made from Commercial Off-The-Shelf (COTS) components. The design of this GTB laser system will be presented alongside the design of the flight hardware for a direct comparison.

This work is supported by the DLR with funds provided by the BMWK under grant numbers DLR 50WP1702, and 50WP2102.

Q 22.60 Tue 16:30 Empore Lichthof

Cryogenic system for Rydberg quantum optics — •Cedric Wind, Julia Gamper, Valerie Mauth, Florian Pausewang, Tore Homeyer, Hannes Busche, and Sebastian Hofferberth — Institute of Applied Physics, Bonn, Germany

Thanks to their strong interactions, Rydberg atoms are a key to neutral atom quantum simulation and computing or to implement nonlinear single photon devices such as single photon sources, optical transistors or photon-photon gates based on Rydberg quantum optics. Rydberg atoms also offer electric transitions over a wide range of the electromagnetic spectrum ranging from optical transitions close to the ground state to strong microwave transitions between Rydberg states. These properties make them an attractive ingredient to implement hybrid quantum systems interfacing optical and microwave frequencies.

Here, we present our design and construction of a cryogenic setup producing ultracold atoms in a 4K-environment to implement hybrid systems including Rydberg atoms. The system combines a closed-cycle cryostat with vibration isolation and an ultracold-atom production setup starting with a room-temperature magneto-optical trap and a magnetic transport into the cryo-region. In particular, the whole system is designed to enable fast exchange and cooling of samples in the experiment region to 4 K which can include electromechanical oscillators, superconducting circuits, or integrated photonic circuits. The cryostat promises a strong suppression of black-body induced Rydberg decay and improved vacuum conditions thanks to cryo-pumping that eliminates the need to bake the system when changing samples.

Q 22.61 Tue 16:30 Empore Lichthof

Rydberg superatoms for waveguide QED — •Nina Stiesdal[1], Lukas Ahlheit[1], Anna Spier[1], Jan de Haan[1], Kevin Kleinbeck[2], Jan Kumlin[3], Hans-Peter Büchler[2], and Sebastian Hofferbert[1] — [1]IAP, University of Bonn — [2]ITP3, University of Stuttgart — [3]CCQ, Aarhus University

Waveguide-systems where quantum emitters are strongly coupled to a single propagating light mode offer an interesting platform for quantum nonlinear optics. We work towards realizing a cascaded system in free space by using Rydberg superatoms - single Rydberg excitations in individual atomic ensembles smaller than the Rydberg blockade-volume - as directional effective two-level systems.

On this poster we show our setup implementing a one-dimensional chain of Rydberg superatoms with low internal dephasing. We employ a double magic-wavelength optical lattice to pin atoms during optical experiments using Rydberg states and thus reduce motional dephasing of the collective excitation. We further show our interferometer setup for obtaining phase information about the photons to perform full state tomography of outgoing multi-photon pulses to characterize the effective photon-photon interaction mediated by the superatom chain.

Q 22.62 Tue 16:30 Empore Lichthof

Rydberg quantum optics in ultracold Ytterbium gases — •Thilina Muthu-arachchige[1], Xin Wang[1], Jonas Ceislick[1], Katherina Gillen[2], and Sebastian Hofferberth[1] — [1]Institute for Applied Physics, University of Bonn, Germany — [2]California Polytechnic State University, San Luis Obispo, USA

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons paves the way to realize and control high optical nonlinearities at the level of single photons. Demonstrations of photon-photon gates or multi-photon bound states based on this concept have so far exclusively employed ultracold alkali atoms. Two-valence electron species, such as ytterbium, offer unique novel features such as narrow-linewidth laser-cooling, optical detection and ionization or long-lived nuclear-spin memory states.

On this poster, we present our ultracold ytterbium setup designed for few-photon Rydberg quantum optics experiments. The system is optimized for fast production of large, thermal ytterbium samples to study the interactions between a large number of Rydberg polaritons simultaneously propagating through a medium with extremely high atomic density. Specifically, we discuss our two-chamber 2d/3d two-color MOT setup, our implementation of narrowline SWAP MOT techniques and Rydberg excitation of optically trapped Ytterbium atoms.

Q 22.63 Tue 16:30 Empore Lichthof

Level statistics and entanglement entropy of Rydberg dressed bosons in a triple-well potential — •Tianyi Yan[1], Matthew Colllins[1], Rejish Nath[2], and Weibin Li[1] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK — [2]Department of Physics, Indian Institute of Science Education and Research, Dr. Homi Bhabha Road, Pune-411008, Maharashtra, India

We study signatures of quantum chaos of Rydberg dressed bosonic atoms in a three-well potential. Dynamics of the atoms are governed by an extended Bose-Hubbard model (EBHM) where long-range nearest-neighbor and next-nearest-neighbor interactions are induced by laser coupling the ground state to Rydberg state. We analyze level statistics of the EBHM with N atoms through numerical diagonalization. In the presence of a tilting potential, the level statistics is a Poissonian distribution when the dressed interaction is weak. It becomes a Wigner-Dyson distribution by increasing the interaction strength, signifying the emergence of quantum chaos. A hybrid distribution is obtained when the dressed interaction is much stronger than the hopping rate. Using Fock basis, we further calculate dynamical evolution of the entanglement entropy. The maximal value (upper bound) of the entanglement entropy is found to be $\ln(N+1)$. The maximum of the time-averaged entanglement entropy appears when the chaos is strong. The location of the maximum as a function of the dressed interaction and tilting potential is independent of N when N is large.

Q 22.64 Tue 16:30 Empore Lichthof

Chiral Rydberg State in cold atoms for chiral sensing. — Stefan Aull[1], Steffen Giesen[2], •Peter Zahariev[1,3], Robert Berger[2], and Kilian Singer[1] — [1]Institut für Physik, Experimentalphysik I , Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]2Fb. 15 - Chemie, Hans- Meerwein-Straße 4, 35032 Marburg — [3]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

It has been shown theoretically [1] that by combining a superposition of Hydrogenic wavefunctions in combination with appropriately adjusted phases, the resulting electronic state can show chiral properties. We are proposing a protocol for experimentally creating those states in a ultra-cold cloud of Rubidium atoms by exciting into a circular Rydberg state and subsequently generating a superposition of different states of almost maximum ℓ and m_ℓ. The results are aimed to be used for chiral discrimination [2] of molecules. Optimized parameters will be determined to maximize the chiral sensitivity.

[1] A. Ordonez, O. Smirnova. Propensity rules in photoelectron circular dichroism in chiral molecules. I. Chiral hydrogen, Phys. Rev. A 99, 043416 (2019)

[2] S Y Buhmann et al, Quantum sensing protocol for motionally chiral Rydberg atoms, New J. Phys. 23, 083040 (2021)

Q 22.65 Tue 16:30 Empore Lichthof

RF spectroscopy of ultracold Rydberg atoms and molecules — Edward Treu-Painter, Martin Trautmann, and •Johannes Deiglmayr — Universität Leipzig, Germany

RF Spectroscopy of Rydberg atoms is an established tool to determine the hyperfine structure [1] and quantum defects [2] of Rydberg atoms. We have recently extended this to the spectroscopy of long-range Rydberg molecules [3].

Here we present recent results on the characterization of the $n^2\mathrm{D}_J$ Rydberg series of Cesium using RF spectroscopy that yielded a new set of quantum defect parameters for the two fine-structure components with highly improved precision and accuracy. We will also present experimental and theoretical results on long-range Rydberg molecules correlated to $n^2\mathrm{D}_J$ Rydberg states that we probe by RF spectroscopy.

[1] H. Saßmannshausen, F. Merkt, and J. Deiglmayr, *High-resolution spectroscopy of Rydberg states in an ultracold cesium gas*, Phys. Rev. A **87(3)**, 032519 (2013) [2] J. Deiglmayr *et al.*, *Precision measurement of the ionization energy of Cs I*, Phys. Rev. A **93(1)**, 013424 (2016); M. Peper *et al*, *Precision measurement of the ionization energy and quantum defects of* ^{39}K *I*, Phys. Rev. A **100(1)**, 012501 (2019) [3] M. Peper and J. Deiglmayr, *Photodissociation of long-range Rydberg molecules*, Phys. Rev. A **102(6)**, 062819 (2020); M. Peper, and J. Deiglmayr, *Heteronuclear Long-Range Rydberg Molecules*, Phys. Rev. Lett. **126(1)**, 013001 (2021)

Q 22.66 Tue 16:30 Empore Lichthof

Stability of quantum degenerate fermionic polar molecules with and without microwave shielding — •Antun Balaž[1] and Axel Pelster[2] — [1]Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Department of Physics, Technical University of Kaiserslautern, Germany

A stabilization of a fermionic molecular gas towards collapse in attractive head-to-tail collisions and its evaporative cooling below the Fermi temperature has so far been achieved in two ways. Either a strong dc electric field is applied to confine the molecular motion to 2D [1] or inelastic collisions in 3D are strongly suppressed by applying a circularly polarized microwave field [2]. Here we use a Hartree-Fock mean-field theory [3,4] in order to determine the 3D properties of quantum degenerate fermionic molecules. In particular, we compare the stability diagrams occurring with and without microwave shielding, where a dipole-dipole interaction with negative and positive sign is present. In case when the orientation of the electric dipoles with respect to the trap axes is unknown, we outline how to reconstruct it from time-of-flight absorption measurements.

[1] G. Valtolina et al., Nature **588**, 239 (2020).
[2] A. Schindewolf et al., Nature **607**, 677 (2022).
[3] V. Veljić et al., New J. Phys. **20**, 093016 (2018).
[4] V. Veljić et al., Phys. Rev. Research **1**, 012009(R) (2019).

Q 22.67 Tue 16:30 Empore Lichthof

Creating auto-ponderomotive potentials for electron beam manipulation — •Franz Schmidt-Kaler, Michael Seidling, Robert Zimmermann, Nils Bode, and Peter Hommelhoff — Friedrich Alexander Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Advances in complex free electron beam manipulation are shown to be possible based on planar chips using electrostatic fields. In the co-moving frame of the electrons these static fields transform into alternating forces creating an engineered auto-ponderomotive potential.

This confining pseudopotential resembles the one of a radiofrequency-driven Paul trap. Well-designed electrode layouts enable electron beam splitting and curved guiding, which we demonstrated. The applied electron energies range from a few eV to 1.7 keV (splitting) and 9.5 keV (guiding) permitting integration into standard scanning electron microscopes to allow entirely new electron control. Furthermore, we measured the first a-q stable parameter space demonstrating the similarity of our APE design's to Paul trap's potentials.

Q 22.68 Tue 16:30 Empore Lichthof

Coulomb effects in ultrashort few electron pulses — •Stefan Meier, Jonas Heimerl, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Most electron-based microscopy methods benefit from a high spatial coherence of the electron beam used. The smaller the electron source, the higher the spatial coherence, allowing, for example, particularly small foci in the electron microscope. Tungsten needle tips represent such highly coherent electron sources, with effective source sizes in the subnanometer range. Moreover, electron emission can be triggered by femtosecond short laser pulses, providing a source of ultrashort electron pulses. In this contribution, we investigate the transverse coherence properties of such a pulsed source as a function of the emitted current [1]. We show that the effective source size grows due to Coulomb effects already for one emitted electron per pulse on average. In a next step, we consider by postselection only the electron pulses in which two electrons have been emitted. In this case we observe strong energy anticorrelation between both electrons due to the extreme spatial and temporal confinement of the electrons during emission. We report on the current status of these measurements and the implications that arise from them.

[1] S. Meier and P. Hommelhoff, ACS Photonics **9**, 3083 (2022)

Q 22.69 Tue 16:30 Empore Lichthof

Coherent Light-Electron Interaction in an SEM — •Maxim Sirotin, Tomáš Chlouba, Roy Shiloh, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

The coherent interaction of light and free electrons was experimentally demonstrated over a decade ago in a transmission electron microscope (TEM) in the form of photon-induced near-field electron microscopy (PINEM). Until today, it has found many fundamental scientific applications such as attosecond quantum coherent control, free electron quantum state generation and photon statistics reconstruction. So far, all PINEM experiments used ultrafast TEMs rather than scanning electron microscopes (SEM), mainly because the required high-resolution spectrometer is not commercially available. However, SEMs allow access to the yet unexplored subrelativistic energy range from ∼0.5 to 30 keV which provides potentially higher electron-light coupling efficiency. Also, SEMs offer spacious and easily-configurable experimental chambers for extended optical setups, potentially boasting thousands of photon-electron interaction sites. We built a compact magnetic high-resolution electron spectrometer and experimentally demonstrated the quantum coherent coupling between electrons and optical nearfields in an SEM at unprecedentedly low, sub-relativistic energies [1]. This demonstration of PINEM in an SEM opens a new avenue to fundamental research in electron-photon quantum interactions.

[1] R. Shiloh, T. Chlouba, and P. Hommelhoff, Physical Review Letters **128**, 235301 (2022)

Q 22.70 Tue 16:30 Empore Lichthof

Simulation of expanding BECs and matter-wave lensing — •Nico Schwersenz and Albert Roura — Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm

The extended microgravity conditions afforded by cold-atom experiments in space enable free-evolution times of many seconds, which can be exploited in high-precision measurements based on atom interferometry. However, in order to reach such long evolution times, it is necessary to employ ultracold atoms combined with matter-wave lensing techniques, and a detailed modeling is required. Here we present the results of 3D numerical simulations of BECs freely expanding for tens of seconds. As an application, we investigate the long-time behaviour of a BEC whose expansion has been collimated through matter-wave lensing. In particular, we examine the role played by the repulsive mean-field interaction and by quantum effects due to Heisenberg's uncertainty principle and the finite size of the BEC. Their relative importance is compared under different conditions.

Q 22.71 Tue 16:30 Empore Lichthof

High-order harmonic generation in gases with μJ laser pulses — •Matthias Meier[1], Philip Dienstbier[1], Yuya Morimoto[2], Francesco Tani[3], and Peter Hommelhoff[1] — [1]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [2]RIKEN Cluster for Pioneering Research (CPR), RIKEN Center for Advanced Photonics (RAP), Japan — [3]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany

Pump-probe schemes involving strong few-cycle driving pulses in the infrared in combination with attosecond probe pulses in the extreme ultraviolet are a powerful spectroscopic tool to investigate the ultrafast dynamics of electrons inside materials. For many spectroscopic schemes, it is desirable or even necessary to provide pump and probe pulses at high repetition rates for sufficient statistics and signal-to-noise ratios in the detection. Here, we present a laser system delivering infrared near infrared 8 fs pulses with 18 μJ energy and repetition rates up to 1 MHz. The few-cycle pulses are obtained by shortening 210 fs pulses from an Ytterbium laser amplifier with stable carrier-envelope phase. For this we use a two-stage compressor based on two argon-filled hollow-core photonic crystal fibers. The pulses are then delivered to a vacuum chamber which is set up for generating and characterizing isolated attosecond pulses.

Q 22.72 Tue 16:30 Empore Lichthof

The Parity Interferometer — •Freyja Ullinger[1,2] and Matthias Zimmermann[1] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany — [2]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, 89081 Ulm, Germany

The quantum-mechanical parity operator enables the reconstruction of the phase space representation of a quantum state [1,2,3,4]. However, the implementation of the parity operation is a subtle issue.

In this poster, we reveal the intrinsic relation between the parity operator and the quantum-mechanical harmonic oscillator. In particular, we present two methods for its realization: (i) we rely on a continuous time evolution in a harmonic potential, and (ii) we employ a combination of pulsed harmonic potentials and free propagation.

By exploiting these methods, we construct a novel parity interferometer. The output of our device measures the parity of a given initial state.

[1] A. Royer, Phys. Rev. A **15**, 449 (1977)

[2] S. Haroche, M. Brune, and J. M. Raimond, J. Mod. Opt. **54**, 2101 (2007)

[3] R. J. Birrittella, P. M. Alsing and C. C. Gerry, AVS Quantum Sci. **3**, 014701 (2021)

[4] S. Kleinert, 'Relativity, States and Quantum Evolutions in Atom Interferometry', Ph.D. thesis (Ulm University, Ulm, 2018)

Q 22.73 Tue 16:30 Empore Lichthof

Dynamics of quantum gases mixtures in space experiments — •Annie Pichery[1,2], Matthias Meister[3], Eric Charron[2], and Naceur Gaaloul[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Institut des Sciences Moléculaires d'Orsay, Université Paris-Saclay, France — [3]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm, Germany

Ultra-cold atomic ensembles are a prime choice for sources in quantum sensing experiments. Space provides an environment where these clouds can float for extended times of several seconds, thus boosting the precision of these sensors. It also enables the operation of Bose-Einstein Condensate (BEC) mixtures for dual interferometers in miscibility conditions not possible on ground.

Simulating such dynamics of interacting dual species BEC mixtures presents however computational challenges due to the long expansion times. In this contribution, scaling techniques to overcome these limits are presented and illustrated in the case of space experiments on the ISS and aboard sounding rockets.

We acknowledge financial support from the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under Grant No. CAL-II 50WM2245A/B.

Q 22.74 Tue 16:30 Empore Lichthof

Deep Learning Accelerated FDFD Simulations in Context of Inverse-Design Algorithms — •Lukas Schulte, Marco Butz, and Carsten Schuck — Center for Soft Nanoscience, Münster, Germany

Deep learning (DL) methods have shown tremendous success in various disciplines related to the design of photonic integrated circuit components. Likewise various fields of simulation, such as fluid dynamics, DL might be used to accelerate electromagnetic first-order simulations, as well.

To numerically access the photonic properties of metamaterials, efficient electromagnetic simulation algorithms are obligatory. In order to simulate the propagation of light through nanophotonic devices, various numerical methods, such as the finite-difference frequency-domain method (FDFD), have been developed. Requiring to solve large sparse linear systems iteratively, these methods come at the cost of being computationally expensive processes.

Here, we show how DL can be employed to decrease the computational effort of consecutive FDFD simulations, for example, encountered in inverse-design algorithms. Leveraged by the U-Net architecture our method is capable of predicting the electromagnetic response of a nanophotonic device. We use this prediction as a starting point for iterative refinement using FDFD, thus decreasing the required iteration and computation time drastically. Hereby, we minimize the overall time required by inverse-design algorithms to reach convergence and thus enable more sophisticated device layouts.

Q 22.75 Tue 16:30 Empore Lichthof

Stability of bound states in the continuum in one-dimensional resonator — •Ekaterina Maslova, Mikhail Rybin, Andrey Bogdanov, and Zarina Sadrieva — Saint-Petersburg, Russia

Bound states in the continuum (BIC) are resonances with infinite radiative quality (Q) factor. Although infinite Q factor is a mathematical abstraction, high-Q supercavity modes whose origin corresponds to genuine BIC can be excited in real samples. We consider Q-factor of BIC in one-dimensional resonators consisting of dielectric blocks. We investigate the dependence of the Q-factor on the structural disorder in symmetric and asymmetric structures. Symmetric structure unit cell consists of two similar blocks, while in asymmetric case there are two types of blocks with different size parameters. We studied electromagnetic waves in a finite array of blocks, which were calculated using the numerical simulation by finite difference method. The results show that in an asymmetric system the Q-factor is resistant to the introduction of structural disorder.

Q 22.76 Tue 16:30 Empore Lichthof

Deep Learning Accelerated FDFD Simulations in Context of Inverse-Design Algorithms — •Lukas Schulte[1,2,3], Marco Butz[1,2,3], and Carsten Schuck[1,2,3] — [1]Center for Soft Nanoscience, Münster, Germany — [2]Center for Nanotechnology, Münster, Germany — [3]Institute of Physics, University of Münster

Deep learning (DL) methods have shown tremendous success in various disciplines related to the design of photonic integrated circuit components. Similarly, DL may be used to accelerate electromagnetic first-order simulations. To numerically access the photonic properties of metamaterials requires efficient electromagnetic simulation algorithms. In order to simulate the propagation of light through nanophotonic devices, various numerical methods, such as the finite-difference frequency-domain method (FDFD), have been developed. Requiring to solve large sparse linear systems iteratively, these methods come at the cost of being computationally expensive processes. Here, we show how DL can be employed to decrease the computational effort of consecutive FDFD simulations, for example, encountered in inverse-design algorithms. Leveraging the U-Net architecture our method is capable of predicting the electromagnetic response of a nanophotonic device. We use this prediction as a starting point for iterative refinement using FDFD simulation, thus decreasing the required iteration and computation time drastically. Hereby, we minimize the overall time required by inverse-design algorithms to reach convergence and thus enable more efficient and compact device layouts.

Q 22.77 Tue 16:30 Empore Lichthof

Inverse design of dielectric laser accelerators and Smith-Purcell radiators — •Manuel Konrad, Michael Seidling, Urs Haeusler, Roy Shiloh, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Computational design and especially the inverse design approach are powerful tools for the design of nanophotonic structures. In inverse design, the structure is optimized according to an objective function, using an arbitrarily large number of parameters. The great advantage of inverse design over other schemes lies in the independence of the computational effort from the number of parameters, meaning one can efficiently explore a large parameter space. This often results in complex structures, which differ drastically from designs based on human intuition. With this design tool, various applications have already been demonstrated, such as highly efficient waveguides, complex optical demultiplexers, and different kinds of optical circuitry [1], but also for quantum correlations [2] and highly efficient light coupling to photonic nanostructures, used in dielectric laser acceleration of electrons [3]. We apply inverse design to the dielectric laser acceleration of electrons and Smith-Purcell radiation [4], while staying within the well-tested confines of silicon photonics. Our aim is to improve the performance of the current generation of structures with this novel technique.

[1] Molesky et al. Nature Photon 12, 659 (2018) [2] Dahan et al. Science 373, eabj7128 (2021) [3] Sapra et al. Science 367, 79 (2020) [4] Haeusler et al. ACS Photonics, 9, 2, 664 (2022)

Q 22.78 Tue 16:30 Empore Lichthof

Suppression of soliton-fission by a Zeno-like effect — •Niklas Bahr, Stephanie Willms, Ihar Babushkin, Uwe Morgner, Oliver Melchert, and Ayhan Demircan — Leibniz University Hannover, Cluster of Excellence PhoenixD, Hannover, Germany

The quantum mechanical Zeno-effect states that the spontaneous decay of an unstable quantum system can be inhibited by continuous measurements. We consider pulse propagation in nonlinear waveguides in terms of a generalized nonlinear Schrödinger equation, wherein linear loss assumes the role of continuous measurements within the quantum context. Under presence of perturbations, e.g. third order dispersion, a higher order soliton tends to decay in fundamental solitons. The reason for this is a process called soliton fission where, due to the spectral expansion of the soliton, energy is transferred to a phase matched resonant frequency. In this work, we show that upon tailoring the absorption characteristics so that the resonant frequency experiences loss, the breakup of higher-order solitons can be slowed down or even suppressed. We further show that this approach also applies to modulation instability induced soliton fission.

Q 22.79 Tue 16:30 Empore Lichthof

Bandwidth Optimization of SNSPDs Cryogenic Readout for Low-Jitter — •Roland Jaha[1,2], Wolfram Pernice[3], and Simone Ferrari[3] — [1]Institute of Physics, Münster 48149, Germany — [2]Center for Soft Nanoscience, Münster 48149, Germany — [3]Kirchhoff-Institute of Physics, Heidelberg 69120, Germany

High temporal resolution is a crucial performance metric of superconducting nanowire single-photon detectors (SNSPDs), as it would allow for increased rates in quantum key distribution (QKD) and optical sampling scopes with superior bandwidth. In recent years, considerable effort was made to improve the timing precision and sub-5 ps jitter has been demonstrated in the near-infrared. However, achieving this high temporal resolution goes in most cases at the cost of other performance metrics, such as detection efficiency. Therefore, while the community has been mainly invested in improving the detector geometry or material composition, we shift our focus towards the optimization of the electrical readout. We believe that in this way we can obtain low jitter while leaving other specifications relatively untouched. For our experiments, we design and fabricate cryogenic low-noise amplifiers (C-LNAs) with different readout bandwidths. The cryogenic operation allows for a significant reduction of the voltage noise, which is one of the main contributors to the timing jitter. Moreover, by tuning the amplifier bandwidth we are able to further improve the temporal resolution of the detector. We demonstrate that enhancing the low-frequency cutoff of the amplifier from 1 MHz to 200 MHz it is possible to reduce the timing jitter by more than 15 ps.

Q 22.80 Tue 16:30 Empore Lichthof

Integrated optical waveguides for the near-ultraviolet to blue visible spectral range for chip-based trapped-ion quantum computers — •Pascal Gehrmann[1,2], Anastasiia Sorokina[1,2], Carl-Frederik Grimpe[3], Guochun Du[3], Tunahan Gök[6,7], Radhakant Singh[6,7], Pragya Sah[6,7], Babita Negi[7], Maxim Lipkin[6,7], Stephan Suckow[6], Elena Jordan[3], Steffen Sauer[1,2], Tanja Mehlstäubler[3,4,5], and Stefanie Kroker[1,2,3] — [1]Institut für Halbleitertechnik, Technische Universität Braunschweig, Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, Braunschweig, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [5]Laboratorium für Nano- und Quantenengineering, Hannover, Germany — [6]AMO GmbH, Advanced Microelec-

tronic Center Aachen, Aachen, Germany — [7]Chair of Electronic Devices, RWTH Aachen University, Aachen, Germany

Photonic integrated circuits (PICs) for on-chip light manipulation can be employed in scalable chip-based trapped-ion quantum computers. Trapped ions are used as qubits and are controlled by multiple wavelengths ranging from the near-ultraviolet (NUV) up to the near-infrared (NIR). The design of UV-PICs is a challenging task, since smaller dimensions and higher propagation losses are inevitable. This contribution covers the design of single-mode integrated optical waveguides on different material platforms for selected NUV and VIS wavelengths of an Yb^+ ion. To improve the scalability, multi-wavelength operation is investigated.

Q 22.81 Tue 16:30 Empore Lichthof

Anisotropic properties of light-propelled microswimmers

— •Elena Vinnemeier[1], Matthias Rüschenbaum[1], Cornelia Denz[1,2], and Jörg Imbrock[1] — [1]Institut für Angewandte Physik, Münster, Deutschland — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Deutschland

Self-propelled particles enable versatile applications in various fields like in colloidal systems or in biomedicine. Utilizing light as an energy source is advantageous, since a fuel-free and highly controllable motion is possible. We demonstrate a novel propulsion mechanism relying solely on refraction of light, while an asymmetric particle shape and a symmetry-broken refractive index profile lead to a directional propulsion force. For fabrication of microswimmers direct laser writing by two-photon polymerization is employed. We compare the performance of these light-propelled particles with respect to velocity and directionality for different geometries and refractive index gradients.

Q 22.82 Tue 16:30 Empore Lichthof

Photonic integrated receiver concept for quantum communication

— •Marco Dietrich[1,2], Bastian Hacker[1], Jonas Pudelko[1,2], Ömer Bayraktar[1,2], Francesco Morichetti[3], and Christoph Marquardt[1,2] — [1]Max Planck Institut für die Physik des Lichts, Staudstr. 2, 91058 Erlangen — [2]Institut für Optik, Information und Photonik, FAU Erlangen-Nürnberg, Staudstr. 7, 91058 Erlangen — [3]Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Milan, Italy

Quantum Key Distribution (QKD) in free space requires the efficient reception of distorted optical modes. We investigate an interferometer mesh on a Photonic Integrated Chip (PIC) with the goal to correct the individual optical phases of several spatial input regions and coherently combine an arbitrary incident wavefront into a single fiber mode. Active elements allow for dynamical adaption to a changing input mode. This approach provides good passive stability and offers high scalability. We study this concept in the context of quantum communication with a realistic cubesat payload.

Q 22.83 Tue 16:30 Empore Lichthof

Ultra-low-loss non-reciprocal devices based on acousto-optic interaction in fiber null-couplers

— •Riccardo Pennetta, Martin Blaha, Jürgen Volz, and Arno Rauschenbeutel — Department of Physics, Humboldt Universität zu Berlin, 12489 Berlin, Germany

The introduction of low-loss optical fibers probably represents the single most important advance in the growth of our telecommunication system. To meet our needs for secure communications, it is likely that our classical network will soon be operating alongside what is known as a quantum network. The latter is very sensitive to loss and thus poses new constraints to the performance of current fiber components. In particular, recent quantum network prototypes underlined the surprising absence of low-loss non-reciprocal fiber-based devices. Here, we present a solution to this issue by the proof-of-principle demonstration of ultra-low-loss (<0.1 dB) non-reciprocal devices (both isolators and circulators) based on so-called fiber null-couplers. The splitting ratio of these couplers can be controlled via acousto-optic interaction of the propagating light field with flexural acoustic waves that one launches along the coupling region. Fabricated from standard single-mode fibers, these devices are compatible with existing optical networks and could represent one important ingredient for the transmission and processing of optically encoded quantum information.

Q 22.84 Tue 16:30 Empore Lichthof

Fabrication of Computer-Generated Nanophotonic Devices

— •David Lemli, Marco Butz, and Carsten Schuck — Institute of Physics, University of Münster, Germany

The increasingly sophisticated functionalities and performance requirements of photonic integrated circuit components produced by modern inverse design algorithms are practically difficult to achieve due to limitations of state-of-the-art nanofabrication processes. The main challenge consists in producing irregular computer-generated structures with 10s of nanometer resolution and high aspect ratios. In this work, we address this challenge with a holistic approach that combines electron-beam lithography and focused-ion-beam milling techniques with biasing deep-learning-based design algorithms to account for arbitrary fabrication constraints while minimizing the impact on individual device performance. We employ our methods for fabricating a wide range of pixel-discrete inversely designed nanophotonic structures and compare the measured performances with simulation based predictions. Our findings pave the way for fast and exact prototyping of novel and challenging nanophotonic devices for applications in information and communication technology, including photonic quantum technology.

Q 22.85 Tue 16:30 Empore Lichthof

Optical reservoir computing with incoherent optical memory

— •Mingwei Yang[1,2], Elizabeth Robertson[1,2], Leon Messner[1,3], Norman Vincenz Ewald[1], Luisa Esguerra[1,2], and Janik Wolters[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institute of Optical Sensor Systems, Rutherfordstraße 2, Berlin, Germany. — [2]Technische Universität Berlin, Berlin, Germany. — [3]Humboldt-Universität zu Berlin, Berlin, Germany.

Reservoir computing is a machine learning method that is particularly suited for dynamic data processing. A fixed reservoir projects the input information to a high-dimensional feature space, and only the readout weights need to be trained, allowing fast data processing with low energy consumption [1]. In this work, we demonstrate an optical reservoir computing using incoherent memory in a cesium vapor cell to predict time-series data. The information is stored in the reservoir by controlling the pump and probe process on the Cs D2 transitions. The coupling between the reservoir and both the input and output data is realized by acousto-optic modulators. [1] G. Tanaka, T. Yamane, J. B. Héroux, R. Nakane, N. Kanazawa, S. Takeda, H. Numata, D. Nakano, and A. Hirose, *Recent advances in physical reservoir computing: A review,* Neural Networks 115, 100*123 (2019). [2] L. Jaurigue, E. Robertson, J. Wolters, and K. Lüdge, *Photonic reservoir computing with non-linear memory cells: interplay between topology, delay and delayed input,* in Emerging Topics in Artificial Intelligence (ETAI) 2022, vol. 12204 (SPIE, 2022), pp. 61*67.

Q 22.86 Tue 16:30 Empore Lichthof

Structuring hydrogels by two-photon lithography inside microfluidic channels for cell migration experiments

— •Elena Bekker[1], Dustin Dzikonski[1], Riccardo Zamboni[1], Jörg Imbrock[1], and Cornelia Denz[1,2] — [1]Insitute of Applied Physics, University of Münster, Corrensstraße 2-4, 48149 Münster, Germany — [2]Physikalisch-Technische Bundesanstalt, Budesallee 100, 38116 Braunschweig, Germany

Hydrogels are highly swellable polymers which generally possess excellent biocompatibility and tissue-like properties. They can be structured via direct laser writing by two-photon lithography (2PL), enabling the fabrication of three-dimensional arbitrary structures with high resolution and spatial complexity. Using this technique, the microenvironment of cells can be mimicked with a high degree of control and reproducibility, whilst allowing variation in the physical properties of the structured gels. We perform 2PL fabrication inside channel systems of microfluidic devices, which provide a three-dimensional culture chamber for cells and allow the generation of chemical gradients to stimulate directed migration towards chemoattractant species. In this way, we investigate cell migration in confined three-dimensional environments.