A 12: Ultra-cold atoms, ions and BEC

Time: Tuesday 16:30–18:30 Location: S Fobau Physik

A 12.1 Tue 16:30 S Fobau Physik

Low-temperature phases in the two-band Hubbard model realized with ultracold atomic four-component mixtures in optical lattices — •Yeimer Zambrano[1], Andrii Sotnikov[2], and Agnieszka Cichy[1] — [1]Adam Mickiewicz University, Poznań, Poland — [2]Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

We study ultracold quantum gases of alkaline-earth-like atoms loaded into three dimensional optical lattice. In particular, we focus on the fermionic mixture of ytterbium-173 atoms due to their unique properties, in particular, low-lying metastable excited (e) electronic state, decoupling of the nuclear spin from the electronic degrees of freedom, and different AC-polarizabilities of the ground- (g-) and e-states. This allows to realize and investigate in detail strongly-correlated many-body physics and emerging low-temperature phases in these mixtures. We focus on the recent realization of the two-band Hubbard model [1,2] and study potential long-rang ordered states. The theoretical analysis is performed in the region of applicability of the tight-binding approximation at different lattice depths and different fillings in the g- and e-bands. By means of dynamical mean-field theory, we obtain dependencies for relevant physical observables, in particular, magnetization, particle density in each band, double occupancy, and compressibility. We construct the phase diagram at finite temeperature and various latice depths.

[1] F. Scazza et al., Nat. Phys. **10**, 779 (2014)
[2] L. Riegger et al., Phys. Rev. Lett. **120**, 143601 (2018)

A 12.2 Tue 16:30 S Fobau Physik

A New Experiment for the Measurement of the Nuclear Magnetic Moment of ^{3}He^{2+} — •Antonia Schneider[1,2], Klaus Blaum[1], Andreas Mooser[1], Alexander Rischka[1], Stefan Ulmer[3], and Jochen Walz[4,5] — [1]Max-Planck-Institute for Nuclear Physics — [2]University of Heidelberg — [3]RIKEN, Ulmer Fundamental Symmetries Laboratory — [4]Institute for Physics, Johannes-Gutenberg University Mainz — [5]Helmholtz-Institute Mainz

We construct a new experiment aiming at the first direct high-precision measurement of the ^{3}He^{2+} nuclear magnetic moment μ_{He} with a relative precision of 10^{-9} or better. The direct measurement of μ_{He} will complement hyper-polarized ^{3}He as an independent magnetometer, which exhibits smaller systematic corrections concerning sample shape, impurities and environmental dependencies compared to water NMR probes. Thus it has the potential to second magnetic field measurements using H_2O as e.g. in the case of the $g-2$ measurement of the muon at Fermilab and J-PARC. In our experiment we will apply methods similar to those used in proton and antiproton magnetic moment measurements [1,2]. If applied to μ_{He} the methods would lead to an insufficient detection fidelity, which is limited by the ions' energy. Thus, we rely on sympathetic laser-cooling to deterministically decrease the ions' energy and a novel Penning trap design optimized for nuclear spin-flip detection. The status of the experiment is presented.

[1] Schneider et al., Science, 1081 (2014)
[2] Smorra et al., Nature, 371 (2017)

A 12.3 Tue 16:30 S Fobau Physik

Fast and dense magneto-optical traps for Strontium — Stepan Snigirev[1], •Annie Jihyun Park[1], André Heinz[1], Immanuel Bloch[1,2], and Sebastian Blatt[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany

Over the last few years, ultracold strontium atoms have become a platform for realizing optical atomic clocks, atom interferometers, and quantum simulators. All such experiments require producing cold and dense strontium samples from an atomic beam at high duty cycles and with large atom numbers to increase their precision. Here, we improve on a recently demonstrated laser cooling method (sawtooth-wave adiabatic passage, SWAP) to dramatically decrease the preparation time, increase the final atom number, and improve the robustness of our sample preparation. By combining SWAP cooling with narrow-line magneto-optical trapping, we create samples at microkelvin temperatures for both bosonic (Sr-88) and fermionic (Sr-87) strontium isotopes. Our preparation step is optimized for fast cooling and large atom number and combines the advantages of previously demonstrated sample preparation methods for both precision measurements (high duty cycle) and quantum simulation (large atom number).

A 12.4 Tue 16:30 S Fobau Physik

Planar diffraction optics on an atom chip — •Hendrik Heine[1], Alexander Kassner[2], Marc C. Wurz[2], Waldemar Herr[1], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Mikroproduktionstechnik, Leibniz Universität Hannover

Atom interferometry with Bose-Einstein condensates (BECs) promises great improvements of atomic gravimeters, especially when combined with an atom chip source. These have proven their ability to create BECs with a high flux in an efficient and reliable way giving access to the BEC's unique properties to utilise large momentum transfer beamsplitters and a reduced spatial expansion rate by delta-kick collimation. Although power and size consumption is already quite reduced with the chip technology, further reduction and simplification is still desirable.

On this poster I will present a prototype that combines optical gratings with an atom chip in order to create a magneto-optical trap above the chip surface from a single beam of light. This will intrinsically increase the robustness and bring chip-scale sensors within reach, paving the way for compact quantum sensors on ground and future missions with ultra cold atoms in space.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under grant number DLR 50WM1650 (KACTUS) and by the Deutsche Forschungsgemeinschaft (DFG) within the SFB 1128 geo-Q.

A 12.5 Tue 16:30 S Fobau Physik

Dynamics and optimization of trapped atomic Sagnac interferometer — •Yijia Zhou[1], Igor Lesanovsky[1,2], Thomas Fernholz[1], and Weibin Li[1,2] — [1]School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD, UK — [2]Centre for the Theoretical Physics and Mathematics of Quantum Non-equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, UK

Sagnac interferometers with massive particles promise unique advantages in achieving high precision measurements of rotation rates over their optical counterparts. Recent proposals and experiments are exploring non-ballistic Sagnac interferometers where trapped atoms are transported along a closed path. This is achieved by using superpositions of internal quantum states and their control with state-dependent potentials. We address emergent questions regarding the dynamical behaviour of Bose-Einstein condensates in such an interferometer and its impact on rotation sensitivity. We investigate complex dependencies on atomic interactions as well as trap geometries, rotation rate, and speed of operation. We find that temporal transport profiles obtained from a simple optimization strategy for non-interacting particles remain surprisingly robust also in the presence of interactions over a large range of realistic parameters. High sensitivities can be achieved for short interrogation times far from the adiabatic regime. This highlights a route to building fast and robust guided ring Sagnac interferometers with fully trapped atoms. [arXiv: 1811.11107]

A 12.6 Tue 16:30 S Fobau Physik

Towards Quantum Simulation of Light-Matter Interfaces with Strontium in Optical Lattices — •Neven Šantić[1], André Heinz[1], Annie Jihyun Park[1], Etienne Staub[1], Rudolf Haindl[1], Stepan Snigirev[1], Jean Dalibard[3], Immanuel Bloch[1,2], and Sebastian Blatt[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany — [3]Collège de France and Laboratoire Kastler Brossel, CNRS, ENS-PSL Research University, UPMC-Sorbonne Universités, 11 place Marcelin Berthelot, 75005 Paris, France

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully explored many different phenomena encountered in strongly correlated condensed matter systems. The latest addition to the quantum simulation toolbox includes quantum gas microscopes with fermionic alkali metal atoms. On the other hand, optical lattice clocks with alkaline earth atoms achieve relative frequency precisions reaching below the 10^{-18} level.

Here we report on the construction of a new quantum gas microscope with Sr atoms prepared in large-mode-volume state-dependent lattices. Our experiment will thus combine the advantages of quantum gas microscopes with the precision control over the internal degrees of freedom enabled by optical lattice clock techniques. With this experimental platform we aim to extend the capabilities of quantum simulators to simulate strongly coupled light-matter interfaces that are challenging or unattainable in real systems.

A 12.7 Tue 16:30 S Fobau Physik

Quench dynamics in Rydberg dressed Bose gases — •Gary McCormack and Weibin Li — School of Physics and Astronomy, and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, University of Nottingham, NG7 2RD, UK

We study the dynamics of three-dimensional Bose Gases in which interactions between atoms are changed by suddenly turning on a detuned laser, coupling the ground state to a Rydberg state. This dressing laser induces an isotropic, long-range interaction between ground state atoms. Using a self-consistent Bogoliubov approach, we numerically investigate dynamical responses of a Bose-Einstein condensate (BEC) to the interaction quench. We find that large momentum states can be excited significantly, which goes beyond the linear dispersion regime. Our self-consistent calculations show that quantum depletion exhibits persistent oscillations even at large times, and its asymptotic value is increased largely when compared to situations of weakly interacting BECs. We show that the dynamical evolution of density-density correlations and number fluctuations depends strongly on the strengths and shapes of the induced long-range interaction.

A 12.8 Tue 16:30 S Fobau Physik

A ground-based, transportable testbed for space-borne dual species atom interferometers — •Alexander Herbst, Dennis Becker, Kai Frye, Maike D. Lachmann, Baptist Piest, and Ernst M. Rasel — Leibniz Universität Hannover

Space-borne atom interferometers are promising candidates for a new generation of tests of the universality of free fall. After the sounding rocket mission MAIUS-1 which demonstrated the first Bose-Einstein condensate (BEC) in space using Rb-87, we aim to add K-41 and perform two-species atom interferometry on the upcoming missions MAIUS-2 and -3. Due to the complexity of the experiment and the strict requirements for space missions, extensive testing of the experimental procedures is required. We present a ground-based and transportable testbed for the creation of a dual species BEC of Rb-87 and K-41 in the MAIUS-B physics package. The overall layout and the control electronics closely resembles the flight system that will be used for MAIUS-2. The modular, fiber-based design of the laser system allows for independent operation at 780 nm and 767 nm, transportation to different testing facilities and easy extension regarding the tests of future experiments like the upcoming ISS multi-user facility BECCAL.

A 12.9 Tue 16:30 S Fobau Physik

A reaction microscope for few-body Rydberg dynamics — •Max Althön, Kai Hawerkamp, Philipp Geppert, Cihan Sahin, and Herwig Ott — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern

We report on the current status of our MOTRIMS-type reaction microscope experiment. Every experiment cycle starts with the preparation of a sample of ^{87}Rb atoms in a 3D-MOT, which is loaded from a 2D-MOT. The atoms can then be transferred to a crossed optical dipole trap. Using a 3-level excitation scheme, some atoms can be excited to atomic or molecular Rydberg states and photoionized by a short laser pulse from a high power CO_2 laser after a variable evolution time. Following small homogeneous electric fields generated by Wiley-McLaren-type ion optics, the produced ions are subsequently detected by a time and position sensitive micro channel plate detector. This tool allows both momentum- and position-resolved measurements of few-body Rydberg dynamics. In this context, we are especially interested in measuring momentum distributions of Rydberg molecule wavefunctions as well as momenta resulting from internal decay processes. Special focus lies on butterfly and trilobite molecules, which can be addressed efficiently due to the opportunity of exciting Rydberg p- and f-states. Apart from technical details of the fully assembled experimental setup, first results are presented.

A 12.10 Tue 16:30 S Fobau Physik

Rydberg atoms in ultracold gases: from electrons to ion impurities — •Marian Rockenhäuser, Thomas Dieterle, Felix Engel, Christian Hölzl, Sophia Ten Huisen, Robert Löw, Tilman Pfau, and Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We report on our endeavour to exploit Rydberg impurities immersed in degenerate atomic gases for investigating the interaction of the Rydberg electron and the Rydberg core-ion with the quantum gas. Specifically, we have recently demonstrated access to the interaction of the core-ion with the surrounding ground state-atoms at temperatures well below a microkelvin. For this, we suppress the typically dominant electron-neutral interaction by exciting a giant Rydberg atom (n=190) to reach a regime where the Rydberg orbit exceeds the size of the atomic sample by far. Evidence for ion-atom interaction is found in the analysis of the Rydberg excitation spectra. This may allow investigation of charged quantum impurities and associated polaron physics. Further, we make use of a novel two-photon ionisation scheme to create very low-energy ions and study the interaction of a single ion with a single Rydberg atom. By applying high-precision electric fields we control the ion's motion probe the ion induced blockade of a Rydberg excitation for a range of principle quantum numbers. Furthermore, this high level of electric field control can pave the way for controlling cold collisions or studying the chemistry of ultracold hybrid atom-ion systems or charge mobilities in ion-atom mixtures.

A 12.11 Tue 16:30 S Fobau Physik

A deterministic single-ion source for microscopy and implantation — Felix Stopp, Luis Ortiz-Gutierrez, •Henri Lehec, and Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

We developed a deterministic single ion source based on cold ions extracted from a Paul trap and demonstrated a beam focus of 5.8(1.0) nm [1]. Using this first generation ion source, implantation of single N_2^+ in diamond and Pr^+ in YAG [2] was performed, with an accuracy of about 20 nm. In this poster, the development of a second generation single ion source will be presented. This apparatus is more compact, highly stable, and modular. We aim for a focus spot of 1 nm and we envision a single ion extraction rate of 1 kHz for fast data acquisition. Our source will be used to implant arrays of single phosphorus ion in silicon surfaces in collaboration with the Australian cluster of excellence [3,4].

[1] G. Jacob et al., Phys. Rev. Lett. 117, 043001 (2016)
[2] K. Groot-Berning et al., to be published
[3] B.E. Kane, Nature 393, 133 (1998), G. Tosi et al., Nat. Comm. 8, 450 (2017)
[4] www.cqc2t.org

A 12.12 Tue 16:30 S Fobau Physik

A versatile strontium quantum gas machine with a microscope — •Sergey Pyatchenkov, Oleksiy Onishchenko, Alex Urech, Ivo Knotternus, Carla Sanna, Georgios Siviloglou, Robert Spreeuw, and Florian Schreck — Institute of Physics, University of Amsterdam

Ultracold quantum gases provide an opportunity to engineer Hamiltonians that model condensed matter phenomena in a well-controlled environment. Strontium, being an alkaline-earth element, has narrow intercombination lines, metastable excited electronic states, and ten collisionally-stable SU(N)-symmetric nuclear spin states. These properties open new perspectives for Hamiltonian engineering, studying quantum simulation of many-body systems and quantum optics.

To enrich the existing toolbox to manipulate Sr atoms, we have determined the frequency of the mHz-linewidth $^1S_0$-$^3P_2$ transition to within 250 kHz relative to molecular iodine lines. This transition is useful for quantum simulation since it enables nuclear spin state dependent light shifts, Raman couplings, and more. We are currently integrating a microscope objective into our apparatus, which will initially enable the preparation and detection of single Sr atoms in optical tweezers and ultimately will lead to a Sr quantum gas microscope.

A 12.13 Tue 16:30 S Fobau Physik

Quantum simulation of dynamical gauge fields: Experimental approach — •Apoorva Hegde, Alexander Mil, Andy Xia, Fabian Olivares, Markus Oberthaler, and Fred Jendrzejewski — Kirchhoff Institute of Physics, Im Neuenheimer Feld 227, 69120 Heidelberg

Gauge theories are the fundamental aspects of the Standard Model of High Energy Physics. They are essential for the description of the dynamics between the matter particles, the fermions and the force carriers, the bosons with which the gauge fields are associated. Here we discuss experimental methods to simulate these dynamic gauge fields using an ultracold mixture of sodium and lithium atoms, following the proposals by Kasper and Zache [1, 2]. In this approach, we use an optical lattice structure with alternatingly populated sites of sodium and lithium. The fermionic matter field is described by the lithium atoms whereas the bosonic gauge field is described by the sodium atoms. The gauge coupling is engineered by interspecies spin changing collision between sodium and lithium. Importantly this interaction locally conserves angular momentum therefore satisfying Gauss' law. In this poster, I will present our progress towards the realization of simple lattice gauge theories within ultracold atomic gases.

[1] Kasper et al. NJP 19, 023030 (2017).
[2] Zache et al. Quantum Sci. Technol. 3, 034010 (2018).

A 12.14 Tue 16:30 S Fobau Physik

A new Na-K apparatus for simulating quantum many-body phenomena — •Rohit Prasad Bhatt, Lilo Höcker, Jan Kilinc, Alexander Hesse, and Fred Jendrzejewski — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, D-69120 Heidelberg

Ultracold atomic gases present a high control over experimental parameters which makes them an ideal candidate to simulate a wide variety of physical systems. Ultracold atomic mixtures expand these horizons by covering an even greater range of quantum many body phenomena like dynamical gauge fields, effect of spin impurity presence in a lattice (Kondo effect) etc. In this poster, we present the new Na-K experiment at Heidelberg, which we are setting up as a platform to study some of those problems.

A 12.15 Tue 16:30 S Fobau Physik

Coherent oscillations between anisotropic Bose-Einstein condensates — •Marc Ruben Momme, Yuriy Mikhailovich Bidasyuk, and Michael Weyrauch — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

Josephson effects in Bose-condensed atomic gases receive a considerable interest from experimental and theoretical studies as a prominent manifestation of quantum coherence on macroscopic scale.

The common theoretical description for such systems is the two-mode model. Its validity relies on the assumption that the coupling between two BECs is much weaker then the energy required to create excitations inside each condensate. However if such excitations are present in the same low-energy region, the two-mode model may no longer be valid.

Our results focus on one particular example of such a system: a BEC in a highly anisotropic, cigar-shaped harmonic trap with a barrier parallel to the long axis. The dynamics are modeled within a mean-field framework of the two-dimensional Gross-Pitaevskii equation. We compare the predictions of the two-mode model with the spectrum of the Bogoliubov-de Gennes equation and we show how the lowest Bogoliubov excitations contribute to the dynamics of the system.

A 12.16 Tue 16:30 S Fobau Physik

A dipolar quantum gas of Dysprosium: superfluidity and droplets — •Mingyang Guo, Fabian Böttcher, Jan-Niklas Schmidt, Matthias Wenzel, Tim Langen, Julian Kluge, Viraatt Anasuri, Jens Hertkorn, Arup Bhomwick, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Ultracold dipolar gases have great potential to realize novel quantum many-body phases arising from the long-range and anisotropic dipolar interactions, distinct from the mostly studied contact interaction. The existence of strongly dipolar interactions directly induce modifications to the superfluid properties, including the anisotropic critical velocities and collective excitations.

Furthermore, tuning the contact interaction weaker than the dipolar interaction, we observed formation of quantum droplets instead of collapse, predicted by the mean-field theory, due to the corrections from quantum fluctuations. By changing the external confinement, we can realize droplet arrays as well as a single self-bound droplet. The self-bound droplets possess saturated peak densities and small compressibility, similar to the properties of classical fluids. The critical atom number for the self-bound droplets is also measured over a wide range of scattering length with almost an order change of the critical number.

A 12.17 Tue 16:30 S Fobau Physik

Rydberg-excited bosons in frustrated optical lattices: numerical study of quantum phases emerging due to the long-range interaction — •Jaromir Panas[1], Andreas Geissler[1,2], and Walter Hofstetter[1] — [1]Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]University of Strasbourg and CNRS, 67000 Strasbourg, France

Recent experiments with ultracold Rydberg-excited atoms have shown that long-range interactions can give rise to spatially ordered structures. Observation of such crystalline phases in a system with Rydberg atoms loaded into optical lattices is also within reach. Theoretical studies have been conducted for Rydberg-dressed bosons in a square lattice. A rich phase diagram has been obtained, with a series of supersolid and density wave phases characterized by different spatial orderings. Here we present results of equilibrium numerical calculations performed for long-range interacting bosons in a triangular lattice within state-of-the-art bosonic dynamical mean-field theory. We discuss differences between the frustrated and square lattice geometries. We also investigate a method of extending lifetime of the system, which is finite due to decay and dephasing inherent to the Rydberg excitations.

A 12.18 Tue 16:30 S Fobau Physik

Non-equilibrium dynamics induced by interaction quenches in ultra-cold Fermi gases — •Benjamin Rauf[1], Andreas Kell[1], Martin Link[1], Kuiyi Gao[1], Johannes Kombe[2], Jean-Sebastien Bernier[2], Corinna Kollath[2], Timothy-Joseph Harrison[1], Alexandra-Bianca Behrle[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Bonn, Germany — [2]HISKP, University of Bonn, Bonn, Germany

Ultra-cold Fermi gases with tuneable interactions have gathered much interest in the last decade as an excellent tool for the investigation of the BEC-BCS crossover. The Cooper-pairing dynamics and thermalisation in a strongly interacting Fermi gas are not well understood, as the non-equilibrium dynamics upon a quench of the interaction strength $1/k_F a$ are difficult to study both in theory and in experiment. We present our recent measurement results on the dynamics observed in fast changes of the interaction parameter.

A 12.19 Tue 16:30 S Fobau Physik

Magnetic Polarons and Spin-Charge Separation in Fermi-Hubbard Systems — •Sarah Hirthe[1], Jayadev Vijayan[1], Joannis Koepsell[1], Pimonpan Sompet[1], Guillaume Salomon[1], Dominik Bourgund[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Ludwig-Maximilians-Universität München

Ultracold fermions in optical lattices have emerged as a powerful tool in the quantum simulation of the Fermi-Hubbard model. With access to full density and spin resolution, our quantum gas microscope has enabled the study of the interplay between spin and charge in doped antiferromagnets. In 1D, the phenomena of spin-charge separation decouples the spin and charge degrees of freedom, creating holons and spinons. We probe this phenomena by locally quenching an antiferromagnet to form holons and spinons and dynamically observing their propagation. In 2D, the competition between the spin and charge degrees of freedom leads to the formation of a polaron. We identify the formation of such a polaron by looking at the dressed spins around a dopant.

A 12.20 Tue 16:30 S Fobau Physik

Feshbach spectroscopy, Feshbach molecule creation and molecular spectroscopy in an ultracold bosonic mixture of ^{23}Na and ^{39}K — •Philipp Gersema, Kai Konrad Voges, Jannis Schnars, Torsten Hartmann, Torben Alexander Schulze, Eberhard Tiemann, Alessandro Zenesini, and Silke Ospelkaus — Institute of Quantum Optics, Leibniz University Hannover

Ultracold mixtures of alkaline atoms are a versatile tool to investigate mixture phenomena and can be used to create ultracold polar ground state molecules, utilizing the STIRAP technique. Among the alkali atoms, sodium and potassium serve as ideal candidates for the production and investigation of such molecules. Cooling strategies for both species are well explored and NaK molecules in their rovibrational ground state feature a large dipole moment as well as chemical stability against exchange reactions. While the fermionic isotope combination ^{23}Na^{40}K has been subject to several previous studies, investigations of bosonic combinations have remained elusive.

We present a detailed study of 21 different scattering features in various spin state combinations of ^{23}Na^{39}K up to a magnetic field strength of 750 G. These comprise Feshbach resonances, zero crossings of the scattering length as well as inelastic loss channels. With this results we refine the potential energy curves for the NaK molecule, giving an improvement not only for the bosonic but also the fermionic case. Furthermore we use this knowledge to create Feshbach molecules and perform spectroscopy to the excited $B^1\Pi$ and $c^3\Sigma$ manifold and the $X^1\Sigma$ ground state of the NaK molecule.

A 12.21 Tue 16:30 S Fobau Physik

Repumping a strontium Zeeman slower — •Jens Samland[1,2], Rodrigo Gonzalez Escudero[1], Chun-Chia Chen[1], Shayne Bennetts[1], Benjamin Pasquiou[1], and Florian Schreck[1] — [1]Van der Waals - Zeeman Institute, Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands — [2]Physik-Department, Technische Universität München, Munich, Germany

We study a new repumping scheme for Sr aiming to reduce atom loss in Zeeman slowers (ZS). Typically, Sr atoms are laser-cooled in a ZS using the 5s5s1S0-5s5p1P1 transition. This transition is not fully cycling and about 1 in 50 000 atoms fall from the upper 5s5p1P1 state into the 5s4d1D2 state. There, they cannot be addressed and are therefore not decelerate and ultimately lost. Using the 448nm 5s4d1D2-5s8p1P1 transition we calculate that 98% of atoms can be repumped back to the 5s5s1S0 ground state within ~3 μs. To test this theory we are building a 448 nm external cavity diode laser which can be incorporated with the ZS of our steady-state atom laser experiment to measure any flux improvement [1]. The demonstration of an efficient repumper for strontium ZS could provide a performance boost for the rapidly expanding global fleet of strontium quantum gas and optical clock machines.

[1] S. Bennetts et al., Phys. Rev. Lett. 119, 223202 (2017).

A 12.22 Tue 16:30 S Fobau Physik

Few ultracold fermions in a two-dimensional trap — •Ram-Janik Petzold — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Systems of ultracold atoms are one of the best experimental demonstration platforms for the investigation of various quantum phenomena appearing at low temperatures. Such artificial quantum simulators offer a high controllability through tunable interparticle interaction strength, particle density as well as trapping potential, together with a high-fidelity state preparation and detection.

Here a novel experimental setup is presented, which was designed to explore the emergence of many-body quantum effects of ultracold fermion gases in two dimensions starting from the few particle level. It mainly consists of a quasi-two-dimensional optical dipole trap for a system of countable few fermionic ^{6}Li atoms. The trap is created by two red-detuned laser beams interfering in their crossing region and providing a strong vertical confinement by a standing wave pattern. An additional single focused beam trap on top of the light-sheet structure allows the independent control over the radial restriction of the harmonic trapping potential. Furthermore, the setup should enable the accurate control over the absolute number of particles in the trap and spin-resolved single-atom detection, which has already been demonstrated in a quasi-one-dimensional configuration.

It is expected, that this experimental simulator will allow the analyses of quantum phenomena in two dimensions by mapping out correlations in position and momentum space.

A 12.23 Tue 16:30 S Fobau Physik

Ultracold and Ultrafast: Probing Quantum Gases with Femtosecond Laser Pulses — •Mario Neundorf[1,2], Tobias Kroker[1,2], Bernhard Ruff[1,2], Donika Imeri[1], Philipp Wessels[1,2], Markus Drescher[1,2], Klaus Sengstock[1,2], and Juliette Simonet[1,2] — [1]Zentrum für Optische Quantentechnologien (ZOQ), Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

Combining ultracold atoms with ultrashort laser pulses offers novel experimental possibilities such as the instantaneous creation of hybrid quantum systems by local ionization of quantum gases.

Here we present a quantum gas machine allowing to simultaneously detect atoms, electrons and ions after photoionization of ultracold gases. After evaporative cooling in a combined magnetic quadrupole and dipole trap, the ultracold atomic gas is transferred into the interaction region by optical transport within 1.7 seconds. A femtosecond laser beam with actively stabilized beam pointing is focused down to 1 μm allowing for local ionization of Bose-Einstein condensates in a crossed dipole trap. High-speed micro-channel plate and phosphor screen detectors surround the interaction region. To reduce external perturbations on the photoelectron trajectories, an active magnetic field compensation has been set up.

A 12.24 Tue 16:30 S Fobau Physik

Nitrogen vacancy centers as a sensor for active magnetic field stabilization — •Alexander Hesse[1], Kerim Köster[1], Jakob Steiner[2], Julia Michl[2], Jörg Wrachtrup[2], Durga Dasari[2], and Fred Jendrzejewski[1] — [1]Kirchhoff Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]3. Physikalisches Institut, Center for Applied Quantum Technologies and IQST, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In recent years the nitrogen-vacancy (NV) center in diamond has emerged as a versatile sensor for magnetic fields, temperature, pressure or electric fields.

As a large quantity of them can be contained in a single diamond, NV centers are especially suitable for performing high precision measurements in very confined spaces. Such highly sensitive local probes would allow for interesting applications in ultracold quantum gas experiments when placed in immediate vicinity to the atoms.

In this poster we present our first steps towards this, using Nitrogen-Vacancy centers to stabilize and control the magnetic fields in our experiment up to 500 G.

A 12.25 Tue 16:30 S Fobau Physik

Fast transport of single atoms in optical lattices using quantum optimal control — •Manolo Rivera[1], Natalie Peter[1], Thorsten Groh[1], Carsten Robens[1], Wolfgang Alt[1], Antonio Negretti[2], Tommaso Calarco[3], Simone Montagero[3], Dieter Meschede[1], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [3]Institut für komplexe Quantensysteme, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

We report on fast, high-fidelity transport of single atoms in spin-dependent optical lattices. To transport atoms spin dependently, we use a high-precision polarization synthesizer, which allows us to displace the lattice potentials with angstrom precision with MHz bandwidth. The transport sequences computed from quantum optimal control theory are believed to reach the fundamental speed limit of our optical lattice system, corresponding to one lattice site displacement in 30μs. During transport operations close to the quantum speed limit, the atoms are excited by several motional quanta, but are refocused back to the ground state at the end of the transport. This is confirmed by measuring after transport the fraction of atoms in the ground state using a novel detection scheme based on microwave sideband spectroscopy. Finally, we demonstrate applications of fast atom transport in atom interferometry and quantum walks.

A 12.26 Tue 16:30 S Fobau Physik

Strongly interacting Ytterbium Fermi gases for impurity physics — •Oscar Bettermann[1,2], Nelson Darkwah Oppong[1,2], Luis Riegger[1,2], Giulio Pasqualetti[1,2], Moritz Höfer[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, Munich, Germany

As an alkaline-earth-like atom, ytterbium features a metastable "clock" state which allows for the implementation of Fermionic gases with orbital degree of freedom. State-dependent lattices enable the realization of two-orbital Hamiltonians such as Kondo-type systems, where particles in the two orbital states interact with spin-exchanging interactions. We have characterized the interaction properties of fermionic ytterbium, which we have shown to be tuneable.

In ytterbium-173, an interorbital Feshbach resonance between one atom in the ground state and another in the clock state enables the study of strongly interacting two-orbital many-body systems. By preparing a gas in a 1D optical lattice with extreme spin-imbalance and with the spin components in separate orbitals, a system of impurity particles interacting strongly with the surrounding Fermi sea is realized. We characterize the spectrum of these two-dimensional quasi-particles as a function of the interaction parameter and identify the attractive and repulsive Fermi polaron branches. We also investigate the quasi-particle residue as well as the lifetime of the repulsive polaron, finding good agreement with a two-orbital many-body theory.

A 12.27 Tue 16:30 S Fobau Physik

Two-compnent spinor Bose-Einstein condensate coupled with twisted light — •Yuriy Bidasyuk — Physikalisch Technische Bundesanstalt, Braunschweig, Germany

Twisted light beams and their interactions with matter atract considerable attention within last years. In the present work we investigate the interaction of twisted light with atomic Bose-Einstein condensates (BEC). To this end we analyze the stationary states of the two-component spinor BEC with coherent coupling by the twisted light beam. Such Rabi coupling has a nontrivial spatial dependence of both amplitude and phase. We develop a simplified analytical model for a ring-shaped BEC and compare it's predictions with a full numerical calculations based on the system of coupled Gross-Pitaevskii equations. Performing a comprehensive study of a ground-state phase portrait of the system we reveal several distinct phases and characterize corresponding phase transitions.

A 12.28 Tue 16:30 S Fobau Physik

Flat band physics in an optical kagome lattice — •Max Melchner — University of Cambridge, United Kingdom

We are currently building a cold-atom experiment to study ultracold atoms in an optical kagome lattice. In the tight-binding approximation, the three lowest motional bands of the kagome lattice are separated from higher-lying bands by a large energy gap. The third lowest energy band is analytically flat. We aim to populate the flat band with ultracold atoms, which should allow us to study effects that arise in strongly correlated many-body systems (e.g. the spin liquid state).

One of the major experimental challenges will be to stabilize the atomic cloud in the flat band of the kagome lattice. Since the flat band is not the lowest band, it will not be occupied by an ultracold atomic gas. There are two basic ways of occupying the flat band: Either one changes the sign of hopping, thereby inverting the band structure such that the flat band is the lowest, or one creates a stable population inversion. In the experiment we are building, we want to do the latter. By using attractive interactions in potassium, we intend to set an upper bound on energy, which will naturally lead to a negative temperature state.

With our experiment we will be able to study transport in a flat motional band. With the addition of interactions and the ability of switching between fermionic and bosonic atoms, we believe this to be an extremely versatile platform for research into single- and many-body localization as well as frustration effects and macroscopic degeneracy.

A 12.29 Tue 16:30 S Fobau Physik

3D ground state cooling in a polarization synthesized optical lattice — •Gautam Ramola, Richard Winkelmann, Muhib Omar, Karthik Chandrashekara, Weiqi Zhou, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — Institute for Applied Physics, University of Bonn

Cooling atoms to their motional ground state allows us to prepare ensembles of indistinguishable atoms. Moreover, it extends their coherence times in interferometric applications. We use two polarization synthesized lattice beams to transport Cs atoms deterministically along the x- and y-directions, based on their internal state [1]. State-dependent shifts of our lattice potentials allow us to drive microwave sideband transitions with a tunable Frank-Condon factor, which in turn are used to cool atoms to the ground state along the two dimensions. Alongside microwave sideband cooling, we use a pair of Raman lasers to cool the atoms along the third dimension. With a 3D ground state population of more than 90%, we plan to perform a direct interferometric measurement of the exchange phase for identical quantum particles [2].

[1] C. Robens, S. Brakhane, W. Alt, D. Meschede, J. Zopes and A. Alberti,*Fast, High-Precision Optical Polarization Synthesizer for Ultracold-Atom Experiments*, Phys. Rev. Applied **9** (2018)
[2] C. F. Roos, A. Alberti, D. Meschede, P. Hauke and H. Häffner, *Revealing Quantum Statistics with a Pair of Distant Atoms*, Phys. Rev. Lett. **119** (2017)

A 12.30 Tue 16:30 S Fobau Physik

Light-Induced Coherence in an Atom-Cavity System — •Christoph Georges, Jayson Cosme, Ludwig Mathey, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg

We demonstrate a light-induced formation of coherence in a cold atomic gas system that utilizes the suppression of a competing density wave (DW) order. The condensed atoms are placed in an optical cavity and pumped by an external optical standing wave, which induces a long-range interaction mediated by photon scattering and a resulting DW order above a critical pump strength. We show that the light-induced temporal modulation of the pump wave can suppress this DW order and restore coherence. This establishes a foundational principle of dynamical control of competing orders analogous to a hypothesized mechanism for light-induced superconductivity in high-Tc cuprates.