Q 42: Poster: Quantum Optics and Photonics II

Time: Wednesday 16:15–18:15 Location: S Atrium Informatik

Q 42.1 Wed 16:15 S Atrium Informatik

Excitation of E1-forbidden Atomic Transitions with Electric, Magnetic or Mixed Multipolarity in Light Fields Carrying Orbital and Spin Angular Momentum — •Ferdinand Schmidt-Kaler[1], Maria Solyanik-Gorgone[2], Andrei Afanasev[2], Carl Carlson[3], and Christian Schmiegelow[4] — [1]QUANTUM, Inst. für Physik, Univ. Mainz — [2]Staudinger Weg 7 — [3]Department of Physics, The College of William and Mary in Virginia, Williamsburg, VA 23187, USA — [4]Departamento de Fisica, FCEyN, UBA and IFIBA, Conicet, Pabellon 1, Ciudad Universitaria, 1428 Buenos Aires, Argentina

Photons carrying a well-defined orbital angular momentum have been proven to modify spectroscopic selection rules in atomic matter. Excitation profiles of electric quadrupole transitions have been measured with single trapped 40Ca+ ions for varying polarizations[1,2]. We further develop the photo-absorption formalism [3] to study the case of arbitrary alignment of the beam's optical axis with respect to the ion's quantization axis and mixed multipolarity. Thus, predictions for M1-dominated 40Ar13+, E3-driven 171Yb+ and 172Yb+, and B-like 20Ne5+ are presented. The latter case displays novel effects, coming from the presence of a strong photon - magnetic dipole coupling.

Ref.: [1] Schmiegelow et al, Nat. Comm. 7, 12998 (2016) [2] Afanasev et al, New J. Phys. 20, 023032 (2018) [3] arxiv 1811.05871

Q 42.2 Wed 16:15 S Atrium Informatik

Towards high-precision EDM measurements of ultracold mercury — •Thorsten Groh and Simon Stellmer — Physikalisches Institut, Nussallee 12, Universität Bonn, 53115 Bonn, Germany

The baryon asymmetry of the universe explained by recent baryogenesis therories requires a degree of CP-violation that exceeds the value predicted by the Standard Model by several orders of magnitude. Such a large CP-violation would result in a sizeable permanent electric dipole moment (EDM) of fundamental particles and might reflect in an atomic EDM whose magnitude is within the sensitivity of future experiments. We report on a new experimental apparatus for the generation of ultracold gases of mercury. For loading a three-dimensional magneto-optical trap ($\lambda = 254\,\mathrm{nm}$) we employ a spatially separate high-flux low-velocity atomic source. This scheme should allow the generation of large statistical samples while still achieving ultra-high vacuum conditions in the science chamber and therefore fulfilling the demands for beyond the state-of-the-art high-precision measurements of the atomic EDM of mercury.

Q 42.3 Wed 16:15 S Atrium Informatik

Competing charge and spin orders in $SU(3)$ fermionic systems — •Mohsen Hafez-Torbati and Walter Hofstetter — Institute of Theoretical Physics, Goethe University, Frankfurt am Main, Germany

Three-component systems with a full $SU(3)$ symmetry can be simulated using ^{6}Li, alkaline-earth atoms and Yb at large magnetic field where nuclear spin and electronic angular momentum get decoupled. We consider the fermionic $SU(3)$ symmetric Hubbard model on the triangular lattice in the presence of a staggered potential and at the filling of one particle per lattice site. Using real-space dynamical mean-field theory we study the competition between the staggered potential and the Hubbard interaction and reveal the phase diagram of the model. Phases such as band insulator, metallic, Mott insulator with 120° spiral order, and charge-ordered Mott insulator are identified.

Q 42.4 Wed 16:15 S Atrium Informatik

Magic wavelength for optical trapping of neutral mercury atoms — •Raluca Aldea and Simon Stellmer — Physikalisches Institut, Nussalle 12, Universität Bonn, 53115 Bonn, Germany

We are investigating samples of neutral mercury atoms due to their potential to realize highly controllable and stable quantum systems. This approach is used to test with high precision the fundamental symmetries and probe for new physics beyond the standard model.

A platform using cooled mercury atoms is a good candidate due to its insensitivity to blackbody radiation. And its electronic configuration of two valence electrons gives it properties similar to the alkaline earth-like elements.

We calculate the polarizabilities of the $^1\mathrm{S}_0$, $^3\mathrm{P}_0$ and $^3\mathrm{P}_1$ states and determine the magic wavelength of the $^1\mathrm{S}_0 \rightarrow {}^1\mathrm{P}_1$ transition along with the Stark shift.

Q 42.5 Wed 16:15 S Atrium Informatik

Semiclassical Laser Cooling in Strongly Focussed Laser Field Configurations — Thorsten Haase, •Maximilian Schumacher, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 4a, D-64289 Darmstadt

Laser cooling is a widely used technique in experiments in quantum optics and quantum information science. For most purposes of cooling above the Doppler limit laser fields are used which can be modelled by plane running waves. In this regime, the interaction between the radiation field and particles, typically modelled by two-level systems, is well explained by the semiclassical theory of Doppler cooling. Standing waves exhibit a different behaviour with analogies to blue detuned laser cooling at higher intensities [Ci92]. We present simulations of the behaviour of trapped two-level systems and dengerated few-level-systems interacting with different kinds of mode structures, including standing waves and strongly focused waves. We compare the results of our simulations with experimental data from the 4PiPac experiment in Erlangen [Al17], where the ion is trapped around the focus of a parabolic mirror to achieve almost perfect atom-photon coupling.

[Ci92] Cirac et. al, Phys. Rev. A, Vol. 46, No. 5, Sep 1992, 2668-2681

[Al17] Alber et. al, J. Europ. Opt. Soc. Rap. Public. 13, 14 (2017)

Q 42.6 Wed 16:15 S Atrium Informatik

Detecting via Talbot interferometry finite-range correlations in an interacting ultracold bosonic gas in an optical lattice — •Philipp Höllmer[1], Jean-Sébastien Bernier[2], and Corinna Kollath[2] — [1]BCTP, University of Bonn, Nussallee 12, 53115 Bonn, Germany — [2]HISKP, University of Bonn, Nussallee 14-16, 53115 Bonn, Germany

We demonstrate here that, even in the presence of interaction, Talbot interferometry can be used to obtain information on the phase correlations in a bosonic gas confined to an optical lattice. Describing this system using the Bose-Hubbard model and using the Lanczos algorithm to obtain both its ground state and simulate its time evolution after a quench of the lattice potential, we identify that consecutive maxima and minima of the Talbot signal are connected to the ground state phase correlators. In particular, we show how the presence of interaction, which impacts finite-distance phase coherence, influences the structure of the Talbot signal.

Q 42.7 Wed 16:15 S Atrium Informatik

A permanent magnet based Zeeman slower for ytterbium — •Robert J. Rengelink, Etienne Wodey, Wolfgang Ertmer, Dennis Schlippert, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

The Zeeman slowing technique is a standard method to decelerate an atomic beam using radiation pressure and a spatially varying magnetic field. In order to slow an atomic beam of ytterbium atoms we generate a transverse field using permanent magnets arranged in a Halbach configuration. This approach offers several advantages over a more traditional tapered coil setup: 1) Maintaining the field requires no power or cooling which reduces the weight of the setup and requires less maintenance. 2) The magnet configuration can be easily (dis)assembled without breaking vacuum and allows optical access to the beam during operation. 3) The Halbach configuration strongly suppresses the residual field outside the slower. We have implemented a permanent magnet-based slower and have characterized its performance in slowing down a beam of ytterbium atoms. Additionally we are working on a 2D-MOT for the slowed atoms which is also based on permanent magnets. This source of ultracold ytterbium atoms with low maintenance and power consumption is to become part of the very long baseline atom interferometer (VLBAI) setup currently under construction in Hannover.

The VLBAI-Teststand is a major research instrument funded by the DFG. We acknowledge support from the CRCs 1128 "geo-Q" (project A02) and 1227 "DQ-mat" (project B07).

Q 42.8 Wed 16:15 S Atrium Informatik

Efficient creation of a molecular Bose-Einstein condensate of

Lithium-6 using a spatially modulated dipole trap — •Manuel Gerken[1], Markus Neiczer[1], Binh Tran[1], Eleonora Lippi[1], Stephan Häfner[1], Bing Zhu[1,2], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

An ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li is an interesting system for the study of ground state polar molecules due to the large electric dipole moment as well as for the investigation of polarons because of the large mass imbalance and the tuneability of intra- and interspecies interactions. For these studies reaching a doubly degenerate quantum gas is a favorable experimental condition. We design a new cooling and trapping scheme for ^{6}Li which combines a time averaged crossed dipole trap and gray molasses cooling, improving the starting conditions by a factor of 12 in phase-space density compared to previous conditions. We discuss adiabatic potential shape changes and the creation of a molecular Bose-Einstein condensate of ^{6}Li with up to 3×10^5 molecules and a condensate fraction of up to 70%. The enhanced phase space density of ^{6}Li atoms allows for sympathetic cooling of ^{133}Cs, aiming for double degeneracy.

Q 42.9 Wed 16:15 S Atrium Informatik

Lasercooling of dysprosium — Niels Petersen[1,2], •Marcel Trümper[1], Florian Mühlbauer[1], Gunther Türk[1], Lykourgos Bougas[3], Arijit Sharma[3], Dmitry Budker[1,3,4], and Patrick Windpassinger[1,2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany — [3]Helmholtz-Institut Mainz, Johannes Gutenberg-Universität, Staudingerweg 18, 55128 Mainz, Germany — [4]Department of Physics, University of California, Berkley, CA 94720-7300, USA

Dysprosium is a rare-earth element with one of the largest ground-state magnetic moments (10 Bohr magnetons) in the periodic table. Therefore, the dipole-dipole interaction is not a small perturbation but becomes comparable in strength to the s-wave scattering in ultracold dysprosium gases. The physical properties of the trapped atomic sample, such as its shape and stability are significantly influenced by the long-range and anisotropic dipole-dipole interaction.

This poster reports on the status of our experimental setup and highlights from recent activities in our laboratory. This includes results from sawtooth wave adiabatic passage (SWAP) cooling on dysprosium [1], where we demonstrated that SWAP can slow atoms twice as fast as conventional molasses cooling on the same transition. Further, we present a newly implemented optical dipole trap as well as results from spectroscopic studies on the 1001 nm ground state transition, where the excited state is predicted to have a lifetime of a few milliseconds.

[1] Petersen et al., arXiv:1809.06423, 2018

Q 42.10 Wed 16:15 S Atrium Informatik

Automated control-electronics for dual-species atom interferometers in zero gravity environments. — •Wolfgang Bartosch[1], Manuel Popp[1], Christian Spindeldreier[2], Alexandros Papakonstantinou[1], Thijs Wendrich[1], Ernst-M. Rasel[1], and Wolfgang Ertmer[1] — [1]Institut für Quantenoptik, Hannover — [2]Institut für Mikroelektische Systeme, Hannover

Interferometry experiments with ultra-cold degenerate quantum gases under microgravity conditions offer possibilities to test fundamental laws of physics to unprecedented precision. The MAIUS-2/3 sounding rocket missions are planned to explore dual-species atom interferometry in space. Operation on a sounding rocket poses strict requirements on the mass, volume, reliability and robustness of the payload and the system needs to operate autonomously. Based on our experience from the predecessor mission MAIUS-1, we improved our electronics to match the needs of a mission with two species, for example we developed automated electronics for microwave driven evaporation techniques with two species. We downsized the electronic components used for MAIUS-1 to fit hardware for dual species operation in an apparatus of the same size. With this poster we present our current progress. The QUANTUS/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 42.11 Wed 16:15 S Atrium Informatik

Multimode interactions mediated by Floquet cavity photons — •Christian Johansen and Francesco Piazza — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Optically trapped driven ultracold atoms in cavities present a highly tunable system for exploring many-body physics. Using near-planar cavities the transversal modes (TMs) are typical distanced on order of GHz. As such the atoms will dominantly interact only with the resonant TM of the cavity. This gives rise to an infinite-range effective interaction between the atoms, mediated by the cavity field.

In this project we have theoretically investigated a system where the cavity length is periodically modulated. This is found to make the higher order TMs important for the effective cavity interaction. In particular, this leads to an appreciable and controllable reduction of the interaction-range.

Using a non-equilibrium field theory approach we theoretically investigate how this tunable interaction affects the atomic system.

Q 42.12 Wed 16:15 S Atrium Informatik

Optical transport of ultracold atoms for the production of groundstate RbYb — •Tobias Franzen, Bastian Pollklesener, Christian Sillus, Anna Hülkenberg, and Axel Görlitz — Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf

Ultracold dipolar molecules constitute a promising system for the investigation of topics like ultracold chemistry, novel interactions in quantum gases, precision measurements and quantum information.

Here we report on first experiments in our apparatus for the production of ultracold RbYb molecules. This setup constitutes an improvement of our old apparatus, where the interactions in RbYb and possible routes to molecule production have already been studied extensively [1,2]. In the new setup a major goal is the efficient production of ground state RbYb molecules.

We employ optical tweezers to transport individually cooled samples of ultracold Rb and Yb from their separate production chambers to a dedicated science chamber. Here we transfer the atoms to crossed dipole traps, where further evaporative cooling and overlapping of these traps creates a starting point for the exploration of interspecies interactions of different isotopes and pathways towards ground state molecules.

[1] M. Borkowski et al., PRA 88, 052708 (2013)
[2] C. Bruni et al., PRA 94, 022503 (2016)

Q 42.13 Wed 16:15 S Atrium Informatik

Hybridization of magnetic chip and optical dipole traps for cold atom experiments — •Simon Kanthak[1], Martina Gebbe[2], Matthias Gersemann[3], Klaus Döringshoff[1], Sven Abend[3], Ernst Rasel[3], Markus Krutzik[1], Achim Peters[1], and the QUANTUS team[1,2,3,4,5] — [1]Institut für Physik, HU Berlin — [2]ZARM, Universität Bremen — [3]IQ, LU Hannover — [4]Institut für Physik, JGU Mainz — [5]Ferdinand-Braun-Institut, Berlin

Inertial sensors based on matter wave interferometry highly benefit from low expansion rates and extended interrogation times of ultracold atomic samples enabling precision measurements. While atom chip technology allows for a fast and efficient production of ultra-cold quantum gases, optical dipole traps offer various advantages compared to magnetic traps such as trapping of all magnetic sub-levels, painting potentials, further reduction of the expansion rates via delta-kick collimation with improved harmonic potentials or the application of Feshbach fields to control the atomic interactions.

In the QUANTUS-1 experiment, we approach a hybrid concept to combine the benefits of both trap types. In this poster, we report on our methods to load a ^{87}Rb BEC from the chip trap into a low power, 1064 nm dipole trap. We discuss trap characteristics and present future prospects such as an optical waveguide atom interferometer and concepts relevant for the spaceborne MAIUS and BECCAL missions.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR50WP1432 and DLR50WM1852.

Q 42.14 Wed 16:15 S Atrium Informatik

Towards the Bose Polaron: A Bichromatic Optical Trap for Ultracold ^{6}Li and ^{133}Cs — •Lauritz Klaus[1], Binh Tran[1], Eleonora Lippi[1], Manuel Gerken[1], Melina Filzinger[1], Bing Zhu[1,2], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

The polaron quasiparticle, an impurity dressed by phonon modes, is a fundamental concept to understand dynamics in a many-body system. While this theory was originally applied to understand the dynamics of an electron in a lattice, it generalizes to condensed matter as well

as atomic physics problems.
In our experiment we immerse a fermionic ^{6}Li impurity into a ^{133}Cs Bose-Einstein condensate (BEC). The high mass imbalance allows us not only to investigate the polaron spectrum but it also gives us insights into the influence of few-body effects on the polarons, namely the Efimov effect. Due to the big difference in the gravitational sag of both species we implement a bichromatic trapping potential consisting of a large optical trap to achieve the Cs BEC and a tightly focused, translatable trap ($< 10\mu m$), to transfer and confine the Li cloud inside the BEC and precisely position it to get the highest possible phase space overlap.

Q 42.15 Wed 16:15 S Atrium Informatik

Rydberg quantum optics in ultracold atomic gases — Philipp Lunt, •Nina Stiesdal, Aksel Nielsen, Mohammad Noaman, Hannes Busche, Simon Ball, and Sebastian Hofferberth — University of Southern Denmark, Odense, Denmark

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. We use this approach to realize effective photon-photon interaction in multiple experimental setups.

Here we present our work on a single Rydberg superatom, an optical medium smaller than a single Rydberg blockade volume, strongly coupled to a probe field with which we can achieve coherent coupling even if the probe contains only few photons. With the superatom we can study the dynamics of a single two level system strongly coupled to a quantized free-space propagating light field, enabling for example the investigation of intrinsic three-photon correlations mediated by a single quantum emitter. We show our experimental progress towards the formation of multiple superatoms coupled to a single probe-mode. We also discuss our development of a new experiment designed to study the interactions between many Rydberg polaritons simultaneously propagating through a medium with extremely high atomic density. Our new setup is the first to use ultracold ytterbium, an alkaline-earth-like element, for Rydberg quantum optics experiments. We discuss details of our experimental implementation and report on the progress towards observation of few-photon nonlinearities in ytterbium.

Q 42.16 Wed 16:15 S Atrium Informatik

Experimental observation of nonlinearity enhancement induced by interactions in Rydberg-EIT medium — •Clément Hainaut[1], Annika Tebben[1], Valentin Walther[2], Yongchang Zhang[2], Renato Ferracini Alves[1], Andre Salzinger[1], Nithiwadee Tchaicharoen[1], Gerhard Zürn[1], Thomas Pohl[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C, Denmark — [3]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

The strong light-matter coupling of a Rydberg gas under Electromagnetically Induced Transparency (EIT) conditions enabled the realization of strong effective photon-photon interaction leading to high nonlinearities at the single photon level opening promising route towards all-optical quantum information processing. In this work, we present a new way to enhance the nonlinearities in a Rydberg-EIT medium.

The usual way to describe a Rydberg-EIT medium consist to solve the system Maxwell-Bloch equation performing an adiabatic elimination of the short lived exited state. This leads to a theory describing well the physical effects where the Rabi frequency of the control beam Ω_c is larger than the probe detuning Δ_p. In this work, we develop a theory which explicitly includes the intermediate state capturing thus the physical phenomena where $\Omega_c \leq \Delta_p$. Doing so we uncover a new resonance feature for $\Omega_c = \Delta_p$ induced by interactions. We report on experimental observations of this resonance.

Q 42.17 Wed 16:15 S Atrium Informatik

Probing out-of-equilibrium dynamics of Rydberg-spin systems using linear response theory — •Sebastian Geier[1], Renato Ferracini Alves[1], Titus Franz[1], Alexander Müller[1], Andre Salzinger[1], Annika Tebben[1], Nithiwadee Thaicharoen[1], Clément Hainaut[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Dipolar interacting Rydberg atoms constitute controllable platforms to experimentally study out-of-equilibrium phenomena of many-body spin systems. In our experiment the spin-1/2 degree of freedom is represented by two strongly interacting Rydberg states that are coupled by a microwave field. After quenching the system out-of-equilibrium, our goal is to study the relaxation of this state which can show interesting dynamics towards thermal- or nonthermal-fixed points. In this work linear response theory is used as a tool to characterize these dynamics. Utilizing the microwave field, a small perturbation during the relaxation process is applied and the corresponding linear response function of the magnetization is measured by state-selective field ionization. By comparing the systems fluctuation properties to this response function, violations of the fluctuation-dissipation relation could be identified and used to characterize slow relaxation dynamics.

Q 42.18 Wed 16:15 S Atrium Informatik

Exploring atom-fiber interaction by using Rydberg atoms in a compressed cloud — •Parvez Islam[1], Wei Li[1,2], Di Hu[1,2], Maria Langbecker[1], Noaman Mohammad[1], and Patrick Windpassinger[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]School of Instrumentation and Opto-electronic Engineering, Beihang University, XueYuan Road 37, 100191 Beijing, P. R. China

Cold atoms inside hollow-core fibers present a promising candidate to study strongly coupled light-matter systems. Combined with the long range Rydberg interaction which is controlled through an EIT process, a corresponding experimental setup should allow for the generation of a strong and tunable polariton interaction.

We present our measurements of cold Rydberg excitations inside a hollow-core fiber to characterize the Rydberg atom-fiber interaction by using electromagnetically induced transparency (EIT) signals [1]. We investigated the atom-fiber interaction by comparing the EIT signals of cold atomic clouds with different geometry. Rather than using a long quasi 1-D cloud, a small compressed cloud is produced and transported to probe the local electric field distribution along the fiber axis. We also explore non-classical photonic states originating from the strong interaction between highly excited Rydberg atoms, in a room-temperature setup.

[1] M. Langbecker, M. Noaman, N. Kjaergaard, F. Benabid, and P. Windpassinger, Phys. Rev A 96, 041402(R) (2017).

Q 42.19 Wed 16:15 S Atrium Informatik

Perspectives for a Photonic Quantum Gate Based on Cavity-Rydberg-EIT — •Thomas Stolz[1], Valentin Walther[2], Callum Robert Murray[2], Thomas Pohl[2], Steffen Schmidt-Eberle[1], Lukas Husel[1], Stephan Dürr[1], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK 8000 Aarhus C, Denmark

We recently realized a photon-photon π-phase gate based on free-space Rydberg EIT in an ultra-cold atomic ensemble. [1] The performance in terms of efficiency and post-selected fidelity is limited by density dependent dephasing resulting from the interaction between the Rydberg electron and surrounding ground-state atoms. This effect becomes less prominent at low density where the presence of a ground-state atom inside the Rydberg orbit becomes unlikely. Reducing the atomic density in our present scheme would, unfortunately, make it difficult to maintain a π phase shift. Here, we investigate theoretically if better performance can be obtained by placing the ensemble inside an optical resonator. Previous literature has discussed this idea [2,3] but ignored imperfections resulting from dephasing, storage and retrieval, and optical components. Using realistic numbers for these imperfections, we identify optimal system parameters and estimate that the performance should profit drastically.

[1] D. Tiarks et al. Nat.Phys. (2018), doi:10.1038/s41567-018-0313-7
[2] Y. M. Hao et al. Sci. Rep. **5**, 10005 (2015).
[3] S. Das et al. PRA **93**, 040303 (2016).

Q 42.20 Wed 16:15 S Atrium Informatik

Collapse and revival in storage of light caused by ultra-long range Rydberg molecules — •Steffen Schmidt-Eberle, Thomas Stolz, Lukas Husel, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Electromagnetically induced transparency (EIT) with Rydberg states can be used to map the strong interaction between Rydberg atoms to photons. This has recently been used to build a Rydberg-based photon-photon gate [1]. Motivated by the fact that dephasing is a major limitation for the performance of such a gate, we study sources of the dephasing and ways to evade them. We focus on dephasing that occurs in EIT-based storage and retrieval of light and measure the retrieval efficiency as a function of dark time. At a density as low as 5×10^{10} cm^{-3}, we measure a dephasing time exceeding 20 μs for principal quantum number 70. To understand the origin of the dephasing, we also study higher densities, where the dephasing is much faster. As in Ref. [2], we observe oscillations in the retrieval efficiency caused by ultra-long range Rydberg dimers. The phenomenon of collapse and revival caused by the formation of trimers, tetramers, etc. is observed at even higher density. The collapse-and-revival data show good contrast, because in our experiment the light hardly samples inhomogeneities of the atomic density.

[1] D. Tiarks et al., Nat.Phys. (2018), doi:10.1038/s41567-018-0313-7

[2] I. Mirgorodskiy et al., Phys. Rev. A 96, 011402 (2017).

Q 42.21 Wed 16:15 S Atrium Informatik

Road to an all-optical single-photon gate using long-range Rydberg interactions — •Charles Möhl and Charles Adams — Durham University, United Kingdom

Due to their tunable long-range interactions, Rydberg atoms are ideal candidates for realising an all-optical single-photon controlled-z gate. The physical building blocks are electromagnetically-induced transparency (EIT) for photon storage and retrieval as well as Rydberg blockade caused by resonant dipolar or van-der-Waals interactions, both together enabling effective photon-photon interactions. In a previous work our group demonstrated correlations between photons after storage in and retrieval from two spatially separated Rydberg atom clouds (H. Busche et al., 2014, 10.1038/NPHYS4058). The system is further investigated as ways to reach the single-photon blockaded regime are explored.

Q 42.22 Wed 16:15 S Atrium Informatik

Operation of a Microfabricated Planar Ion-trap for Studies of a Yb^{+}– Rb Hybrid Quantum System — Abasalt Bahrami[1], •Matthias Müller[1], Martin Drechsler[1], Jannis Joger[2], Rene Gerritsma[2], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz — [2]Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

In order to study interactions of atomic ions with ultracold neutral atoms, it is important to have sub-μm control over positioning ion crystals. Serving for this purpose, we introduce a microfabricated planar ion trap featuring 21 DC electrodes. The ion trap is controlled by a home-made FPGA voltage source providing independently variable voltages to each of the DC electrodes. To assure stable positioning of ion crystals with respect to trapped neutral atoms, we integrate into the overall design a compact mirror magneto optical chip trap (mMOT) for cooling and confining neutral ^{87}Rb atoms. The trapped atoms will be transferred into an also integrated chip-based Ioffe-Pritchard trap potential formed by a Z-shape wire and an external bias magnetic field. We introduce the hybrid atom-ion chip, the microfabricated planar ion trap and use trapped ion crystals to determine ion lifetimes, trap frequencies, positioning ions and the accuracy of the compensation of micromotion.

Q 42.23 Wed 16:15 S Atrium Informatik

Production and Assembly of a Compact Fiber-Cavity System for CQED with Neutral Atoms — •Lukas Ahlheit, David Röser, Jose Gallego, Deepak Pandey, Eduardo Urunuela, Wolfgang Alt, and Dieter Meschede — Institute for Applied Physics, University of Bonn, Germany

Fiber-cavity systems are excellent interfaces to study light-matter interactions due to their small mode volume and ease of integration. Here we demonstrate the production and assembly of a fiber-cavity system for CQED with Rb atoms [1]. The small mode volume guarantees strong coupling even in the presence of large extraction rates making it a promising platform for a high bandwidth photon-matter interface.

Trapping atoms in a UHV environment requires the integration of high NA lenses to form an optical lattice in the fiber-cavity. The system*s performance thereby relies on their accurate alignment, which is achieved by using a monolithic mount. The cavity mirrors are fabricated directly onto the fiber end facets by CO2 laser ablation and subsequent high reflection coating. Fiber cavity designs with graded-index and multi-mode fibers for enhanced mode matching will be implemented in the near future [2].

[1] J Gallego et al, Appl. Phys. B 122:47, (2016)
doi: 10.1007/s00340-015-6281-z

[2] G Gulati et al, Scientific Reports 7, 5556, (2017)
doi: 0.1038/s41598-017-05729-8

Q 42.24 Wed 16:15 S Atrium Informatik

Towards on-chip Quantum Optics experiments with color centers in nanodiamonds — •Niklas Lettner[1], Konstantin Fehler[1,2], Lukas Antoniuk[1], Anna Ovvyan[3], Wolfram H.P. Pernice[3], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [3]Institute of Physics and Center for Nanotechnology, University of Münster, 48149 Münster, Germany

Color centers in diamond, such as the Nitrogen Vacancy (NV^{-}) and the Silicon Vacancy (SiV^{-}) Center, gained attraction through their outstanding optical and spin coherence times properties. In fusion with classical integrated photonics they offer a promising platform for the realization of quantum repeaters, quantum networks and quantum simulators. We present our progress which paves the way towards on-chip quantum optics experiments.

Q 42.25 Wed 16:15 S Atrium Informatik

Silicon Vacancy centers in nanodiamonds for hybrid quantum technologies — •Lukas Antoniuk[1], Konstantin Fehler[1,2], Lachlan J Rogers[3,4], Ou Wang[1,2], Yan Liu[1], Christian Osterkamp[1,2,5], Valery A. Davydov[6], Viatcheslav N. Agafonov[7], Andrea B. Filipovski[1], Fedor Jelezko[1,2], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [3]Department of Physics and Astronomy, Macquarie University, New South Wales 2109, Australia — [4]ARC Centre of Excellence for Engineered Quantum Systems (EQUS) — [5]Department of Electron Devices and Circuits, University Ulm, Albert Einstein Allee 45, 89069 Ulm, Germany — [6]L.F.Vereshchagin Institute for High Pressure Physics, Russian Academy of Sciences, Troitsk, Moscow, 142190, Russia — [7]GREMAN, UMR CNRS CEA 6157, Universit F. Rabelais, F-37200 Tours, France

Color centers in diamond, such as the Silicon Vacancy (SiV^{-}) Center, gained attraction through their outstanding optical properties stemming from their molecular like energy eigenlevels. Even on the nanoscale the diamond lattice can host these defects with unchanged properties. Nano manipulation techniques enable deterministic positioning and reorientation of these nanodiamonds towards bottom-up approaches of hybrid quantum technologies [1].

[1] Rogers, Lachlan J., et al. arXiv:1802.03588[v4] (2018).

Q 42.26 Wed 16:15 S Atrium Informatik

Spatio-Temporal Higher-Order Photon Correlations of a Few-Atom System — •Lukas Götzendörfer[1,2], Simon Mährlein[1], Kevin Günther[3,1], Jörg Evers[4], and Joachim von Zanthier[1,2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Universität Erlangen-Nürnberg, 91052 Erlangen, Germany — [3]Max Planck Institute for the Science of Light (MPL), 91058 Erlangen, Germany — [4]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

We study a particular model for Single Photon Emitters (SPE) and the resulting multi-photon interferences in space and time: Investigating the time evolution of two-level atoms spontaneously emitting photons gives rise to a time dependent electric field amplitude in the far field. By utilizing field intensity correlations we are able to calculate the collective emission properties of the atomic system manifesting themselves in modified spontaneous decay rates. The correlations are studied for a system of three atoms, with two atoms in close vicinity to each other such that they interact via dipole-dipole interaction. Although the residual atom is separated by a large distance and hence does not interact with the other two atoms it can be used to alter the systems' emission properties by measurement-induced entanglement. This model system can be interpreted as a generalized free-space Hong-Ou-Mandel setup where the probability of measuring three photons not only depends on space but also on time.

Q 42.27 Wed 16:15 S Atrium Informatik

Linear and non-linear transmission properties of fiber-coupled atomic ensembles — •Jakob Hinney[1], Adarsh Prasad[1], Samuel Rind[1], Philipp Schneeweiss[1], Jürgen Volz[1], and Arno Rauschenbeutel[1,2] — [1]TU Wien, Atominstitut, Stadionallee 2, 1020 Wien, Austria — [2]Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin, Germany

Atoms trapped above the surface of optical nanofibers can exhibit strong coupling to fiber-guided light which can lead to non-linearities in the transmission of resonant light. We study this process experimentally with laser-cooled Cesium atoms stored in a two-color nanofiber-based dipole trap and analyse the transmission of a resonant probe field through an atomic ensemble with large optical depth. One goal is to investigate non-linear photon-transport through the ensemble as recently suggested by Mahmoodian et al. [1]. There, resonant photon pairs are converted into off-resonant pairs with opposite detuning relative to the resonance. These are then transmitted through the ensemble while single photons are extinguished due to linear absorption leading to bunching in the light exiting the ensemble. This may open a new avenue toward generating non-classical states of light.

[1] S. Mahmoodian et al., Phys. Rev. Lett. 121, 143601 (2018)

Q 42.28 Wed 16:15 S Atrium Informatik

An open-source platform for digital control-loops in quantum-optical experiments — •Christian Darsow-Fromm, Luis Dekant, Stephan Grebien, Maik Schröder, Roman Schnabel, and Sebastian Steinlechner — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Experiments in quantum optics often require a large number of control loops, e.g. for length-stabilization of optical cavities and control of phase gates. These control loops are generally implemented using one of three approaches: commercial (digital) controllers, self-built analog circuitry, or custom solutions around “maker-style” projects based on FPGAs and microcontrollers. Each of these approaches has individual drawbacks, such as high cost, lack of scalability and flexibility, or high maintenance effort. Here we present a solution based on the ADwin digital control platform that is able to deliver in excess of 8 simultaneous locking loops running with 200 kHz sampling frequency, and offers five second-order filtering sections per channel for optimal control performance. A comprehensive software package written in Python, together with a web-based GUI, makes the system as easy to use as commercial products, while giving the full flexibility of open-source platforms.

Q 42.29 Wed 16:15 S Atrium Informatik

Phase synchronization in bistable quantum oscillators — •Matthew Jessop[1,2], Weibin Li[1,2], and Andrew Armour[1,2] — [1]School of Physics and Astronomy, University of Nottingham, UK — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, University of Nottingham, UK

We introduce a simple model system to study synchronization in quantum oscillators that are not simply in limit-cycle states, but rather display a more complex bistable dynamics. Our oscillator model is purely dissipative, with single and three phonon loss processes balanced by two phonon gain. When the gain rate is low, the loss processes are dominant and the oscillator has a very low phonon number. In contrast, for large gain rates, the oscillator is driven into a limit-cycle state where the occupation numbers are large though the system has no preferred phase. In between these limits an interesting bistable regime emerges in which the steady-state of the oscillators is a mixture of the low phonon occupation number and limit-cycle states, leading to a bimodal distribution in the phonon occupation probabilities. The bistability is clearly seen as intermittency in quantum jump trajectories of the system. When two such oscillators are coupled via a phonon exchange process, a locking of relative phases occurs. The pattern of phase synchronization that occurs is found to be strongly dependent on the motional state of each oscillator. Therefore this allows us to control the synchronization through engineering dissipation.

Q 42.30 Wed 16:15 S Atrium Informatik

Quantum network transfer and storage with compact localized states — Malte Röntgen[1], •Christian Morfonios[1], Ioannis Brouzos[2], Fotios Diakonos[2], and Peter Schmelcher[1,3] — [1]Centre for Optical Quantum Technologies, University of Hamburg, 22761 Hamburg, Germany — [2]Department of Physics, University of Athens, 15771 Athens, Greece — [3]Centre for Ultrafast Imaging, University of Hamburg, 22761 Hamburg, Germany

We propose modulation protocols designed to generate, store and transfer compact localized states in a quantum network. Induced by parameter tuning or local reflection symmetries, such states vanish outside selected domains of the complete system and are therefore ideal for information storage. Their creation and transfer is here achieved either via amplitude phase flips or via optimal temporal control of inter-site couplings. We apply the concept to a decorated, locally symmetric Lieb lattice where one sublattice is dimerized, and also demonstrate it for more complex setups. The approach allows for a flexible storage and transfer of states along independent paths in lattices supporting flat energetic bands. The generic network and protocols proposed can be utilized in various physical setups such as atomic or molecular spin lattices, photonic waveguide arrays, and acoustic setups. [arXiv:1811.02950]

Q 42.31 Wed 16:15 S Atrium Informatik

Many-body Floquet dynamics in driven optical lattices — •Konrad Viebahn, Michael Messer, Kilian Sandholzer, Frederik Görg, Joaquín Minguzzi, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, CH-8093 Zurich

Periodic driving has proven very powerful in realising paradigmatic hamiltonians with ultracold atoms. Examples include the topological Haldane model, and the control over the magnitude and sign of magnetic correlations in a Fermi-Hubbard system. However, the validity of the Floquet description in the many-body context is not yet fully understood. Long evolution times pose a natural limit as the system will inevitably heat to infinity due to interactions which break ergodicity. It is therefore crucial to identify relevant timescales on which the effective (static) Floquet hamiltonian remains valid. In this experiment we study the dynamics and timescales of a periodically driven Fermi-Hubbard model in a three-dimensional hexagonal lattice. The evolution of the Floquet many-body state is analysed and compared to an equivalent undriven system. The dynamics of double occupancies for the near- and off-resonant driving regime indicate that the effective Hamiltonian picture is valid for several orders of magnitude in modulation time. Furthermore, we identify a strong dependence of the heating performance on the lattice geometry. A hexagonal-type lattice proves particularly advantageous, even when driving at resonance with the interaction energy, allowing for modulations times of up to $\sim$1 s, which corresponds to hundreds of tunnelling times.

Q 42.32 Wed 16:15 S Atrium Informatik

Sympathetic Cooling of Quantum Simulators — •Meghana Raghunandan[1], Fabian Wolf[2], Christian Ospelkaus[2,3], Piet O. Schmidt[2,3], and Hendrik Weimer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]QUEST Institut, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

We discuss the possibility of maximizing the cooling of a quantum simulator by controlling the system-environment coupling such that the system is driven into the ground state. We numerically solve the quantum master equation for Ising and Heisenberg chains consisting of N spins coupled to a radiation field. We maximize the cooling by finding the dependence of the effective rate of transitions of the various excited states into the ground state. We show that adding a single dissipative qubit already results in efficient cooling which is robust against decoherences.

Q 42.33 Wed 16:15 S Atrium Informatik

Microwave-based beam manipulators for a quantum electron microscope — •Michael Seidling, Robert Zimmermann, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

The current status of development of a beam splitter and resonator for guided low-energy electrons (eV range) is reported. The beam manipulation is based on microwave electric fields applied to micro-structured chips. A possibility to guide electrons is provided by the Paul trap principle, in which electrons are confined in the two directions perpendicular to the direction of motion by fast alternating electric fields. With a slightly more complex electrode arrangement, a beam splitter for guided electrons can be attained. For various applications, coherent beam splitting would be desirable to have. We discuss a new beam splitter design for coherent beam splitting and the current status of the resonator guide structure. Therefore, We have built a laser-triggered electron microscope, whose electron triggering laser pulses are phase-locked to the electron guide's microwave driving fields. This way, the electrons can be injected in to guide at a certain microwave phase.