Q 58: Poster: Quantum Optics and Photonics III

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

Q 58.1 Thu 16:15 S Atrium Informatik

Short Pulse Photonic-Phononic Memory — •Johannes Piotrowski[1,2], Mikołaj K. Schmidt[1], Birgit Stiller[3], Christopher Poulton[4], and Michael Steel[1] — [1]Macquarie University — [2]Universität Potsdam — [3]University of Technology Sydney — [4]University of Sydney

Stimulated Brillouin Scattering (SBS) coherently transfers energy between optical and acoustic fields confined in waveguides. The acoustic wave acting as a moving grating is scattering light between two optical fields, while their interference pattern induces density fluctuations in the waveguide via electrostriction, building a feedback loop.

SBS is increasingly important in fibre and chip-based optics, with a variety of applications in signal processing necessary for future optical circuits for fast telecommunication, including the option of storing light. Pumping a signal with a counter-propagating strong laser pulse transfers (writes) power of the signal into an acoustic wave travelling at much lower speeds. A second 'read' pulse depletes the acoustic excitation and retrieves the signal. First demonstrations of chip-integrated photonic-phononic memory based on this principle prompt questions about achievable data rate, delay time and storage efficiency.

We extend the analytical description of governing nonlinear coupled-mode equations of SBS beyond the usual slowly varying envelope approximations, including the novel regime of short acoustic pulses down to the picosecond scale. A numerical symmetrized split-step method is implemented to simulate the process, predicting necessary system parameters and explaining spectral features found in experiments.

Q 58.2 Thu 16:15 S Atrium Informatik

Atom interferometers with specular reflection — •Fabio Di Pumpo[1], Alexander Friedrich[1], Enno Giese[1], Albert Roura[1], Wolfgang P. Schleich[1,2], Daniel M. Greenberger[3], and Ernst M. Rasel[4] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm — [2]Hagler Institute for Advanced Study and Department of Physics and Astronomy, Institute for Quantum Science and Engineering (IQSE), Texas A&M AgriLife Research, Texas A&M University, College Station, TX 77843-4242, USA — [3]City College of the City University of New York, New York, NY 10031, USA — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

Effects based on quantum clock interference rely on atom interferometers with a non-vanishing proper time difference. We propose an atom interferometer consisting of two beam splitters to separate and recombine the two branches of the interferometer, and two specular mirrors in the middle that invert the incoming momentum. We show that with the help of specular reflection the difference in proper time between the two branches of the resulting geometry is non-vanishing, in contrast to the familiar Mach-Zehnder interferometer with mirrors that rely on a diffractive mechanism. Finally, we propose a realization of specular mirrors by strongly detuned evanescent light fields. The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM1556 (QUANTUS IV).

Q 58.3 Thu 16:15 S Atrium Informatik

Single-pulse large momentum transfer with double Raman diffraction — •Sabrina Hartmann, Jens Jenewein, Albert Roura, Wolfgang P. Schleich, and the QUANTUS team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm

Large momentum transfer (LMT) pulses are a topic of current interest in atom interferometry since a large interferometric area leads to an increased sensitivity and are often realized by a multiple-pulse sequence [1]. Here we present a theoretical analysis of double Raman beam splitters in a retroreflective geometry. Specifically, we focus on a scheme that generates a momentum-space splitting of $12\hbar k$ between both arms by a single pulse. Thus, the area is increased by two effects: double diffraction and higher-order diffraction. Moreover, we present a numerical study that investigates fidelity, diffraction efficiency and the influence of Stark shifts. Finally, we compare these results to already existing configurations using Bragg diffraction [2,3].

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Energy (BMWi) under grant number 50WM1556 (QUANTUS IV).

[1] T. Lévêque, et al. *Phys. Rev. Lett.* **103**, 080405 (2009).
[2] E. Giese, et al. *Phys. Rev. A* **88**, 053608 (2013).
[3] H. Ahlers, et al. *Phys. Rev. Lett.* **116**, 173601 (2016).

Q 58.4 Thu 16:15 S Atrium Informatik

Analysis of atomic Bragg and Raman diffraction — •Eric P. Glasbrenner[1], Alexander Friedrich[1], Enno Giese[1], Ernst M. Rasel[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm. — [2]Institut für Quantenoptik, Leibniz Universität Hannover.

Light-pulse atom interferometry has become a standard tool for the realization of high-precision experiments and in quantum-sensing applications as well as tests of fundamental physics. Nowadays such interferometers rely on either Raman or Bragg diffraction, realized via a retro-reflective setup with two counter-propagating lasers. In order to analyze this arrangement it is necessary to use numerics on the one hand, and on the other appropriate asymptotic methods. In our poster we showcase an asymptotic approach, the canonical method of averaging which allows us to obtain analytical insights and results which compare well with our purely numerical considerations. Using these methods we analyze the light-shift contribution to the interferometer phase induced by off-resonant two-photon transitions in the presence of the AC-Stark shift and their dependence on the form of the pulse envelope.

The QUANTUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1556 (QUANTUS IV).

Q 58.5 Thu 16:15 S Atrium Informatik

Atom interferometry with branch-dependent light pulses — •Enno Giese, Fabio Di Pumpo, Alexander Friedrich, and Wolfgang P. Schleich — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm.

Light pulses are a versatile tool for the manipulation of ultracold quantum gases. In this context, they have become a standard method to generate beam splitters as well as mirrors for atom interferometers and have opened the pathway to high-precision atom interferometry. However, intrinsic limitations to the applicability of light pulses arise because the light always interacts simultaneously with both branches of an interferometer. This effect is of particular relevance for state-of-the-art large-momentum transfer schemes. At the same time, the analysis of two-photon light shifts and diffraction phases in retroreflective geometries is essential for high-precision interferometry.

In our contribution, we discuss the possibility of using light pulses that address only one interferometer branch to generate schemes akin to guided atom interferometers. We investigate novel interferometer geometries that can be generated by these technique and compare them to conventional schemes. Our interferometer provides a new platform to investigate relativistic effects and poses a complementary approach towards quantum-clock interferometry.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1556 (QUANTUS IV).

Q 58.6 Thu 16:15 S Atrium Informatik

Compact and stable potassium laser system for dual species atom interferometry in microgravity — •Julia Pahl[1], Julien Kluge[1], Aline N. Dinkelaker[1], Christoph Grzeschik[1], Achim Peters[1,2], Markus Krutzik[1], and The QUANTUS Team[1,3,4,5,6,7] — [1]HU Berlin — [2]FBH Berlin — [3]U Bremen — [4]LU Hannover — [5]JGU Mainz — [6]U Ulm — [7]TU Darmstadt

QUANTUS-2 is a mobile high-flux BEC source performing atom-chip based Rubidium BEC experiments at the drop tower in Bremen. For future studies of dual-species quantum gases in extended free fall, it is designed to simultaneously operate with Potassium.

This poster presents the laser system architecture for ultracold atom experiments with ^{41}K and ^{87}Rb. Our compact and robust distributed feedback diode laser based system withstands DC accelerations of up

to 40 g in operation and temperature changes up to 10 Kelvin with only minor adjustments over several drop campaigns. Micro-integrated master oscillator power amplifier (MOPA) modules in conjunction with miniaturized, tailored, free space opto-mechanics are integrated on a platform with 70 cm diameter. We will further report on the laser system performance, as well as the latest results of qualification tests at the Bremen drop tower.
This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant number DLR 50WM1552-1557.

Q 58.7 Thu 16:15 S Atrium Informatik

Correlation functions of electrons from independent sources
— •Mona Bukenberger[1], Stefan Richter[1,2], Anton Classen[1,2], Raul Corrêa[3], 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]Universidade Federal de Minas Gerais, 30161-970, Belo Horizonte, MG, Brazil

The Hong-Ou-Mandel (HOM) and Hanbury Brown and Twiss (HBT) experiment show second-order interference of independent photons. Both rely on the bosonic nature of indistinguishable photons and commutator relations upon exchange of bosons[1]. HBT-/HOM- like experiments have also been conducted with massive bosonic/ fermionic particles like atoms, for which the effects are likewise well understood [3,4]. However, though electrons, in some settings, attain an imaging resolution far beyond the one achieved with photons, investigations of higher-order correlations of electrons have been scarce. We develop a model describing the spatio-temporal two-electron correlations for statistically independent electron sources. Contrary to (neutral) atoms, Coulomb-interaction must be taken into account, requiring full treatment of the particle-particle interaction. The methods used to solve this problem stem from scattering theory in non-relativistic quantum mechanics. Result is a predictive model waiting for experimental tests.
[1] R. J. Glauber, Phys. Rev. 130, 2529 (1963); [2] R. G. Dall et al., Nat. Phys. 9, 341 (2013); [3] S. Fölling et al., Nature 434, 481 (2005).

Q 58.8 Thu 16:15 S Atrium Informatik

Quantum optimal control of the dissipative production of a maximally entangled state
— •Karl Horn[1], Florentin Reiter[2], Yiheng Lin[3,4], Dietrich Leibfried[5], and Christiane P. Koch[1] — [1]Theoretische Physik, Universität Kassel, Heinrich-Plett-Straße 40, D-34132 Kassel,Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA — [3]CAS Key Laboratory of Microscale Magnetic Resonance and Department of Modern Physics, University of Science and Technology of China, Hefei 230026, China — [4]Synergetic Innovation Center of Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei 230026, China — [5]National Institute of Standards and Technology, Boulder, Colorado 80305, USA

Entanglement generation can be robust against certain types of noise in approaches that deliberately incorporate dissipation into the system dynamics. The presence of additional dissipation channels may, however, limit fidelity and speed of the process. Here we show how quantum optimal control techniques can be used to both speed up the entanglement generation and increase the fidelity in a realistic setup, whilst respecting typical experimental limitations. For the example of entangling two trapped ion qubits [Lin et al., Nature 504, 415 (2013)], we find an improved fidelity by simply optimizing the polarization of the laser beams utilized in the experiment. More significantly, an alternate combination of transitions between internal states of the ions, when combined with optimized polarization, enables faster entanglement and decreases the error by an order of magnitude.

Q 58.9 Thu 16:15 S Atrium Informatik

Measurement-induced nonlinearities in two-mode systems.
— •Matvei Riabinin, Polina Sharapova, Tim J. Bartley, and Torsten Meier — University of Paderborn, Warburger Strasse 100, Paderborn D-33098, Germany

In optics, nonlinear effects can lead to various transformations of light. Parametric down-conversion (PDC) and Four-Wave mixing (FWM) are nonlinear effects that can generate entangled photons, quadrature squeezing and other nonclassical effects. The generation of these effects typically requires strong light intensities. Another way of creating such non-linear transformations in quantum optics is creating so-called measurement-induced nonlinearities, where nonlinear effects can be acquired by applying detection. The detection provides a photon subtraction and might result in various nonlinear transformations. The advantage of using detection compared to PDC and FWM is that fewer incident photons are required to generate nonclassical effects. However, acquired effects have a probabilistic nature. In our work, we model a two-mode interferometer where we input different states such a coherent state, a single photon state, and others and apply detection to each channel. We analyze the acquired nonclassical properties such as entanglement and two-mode squeezing at the output. With certain combinations of system parameters, the detection leads to two-mode squeezing which is absent without detection. These results will be used for a theoretical description of quantum photonic chips with superconducting detectors embedded into an integrated platform.

Q 58.10 Thu 16:15 S Atrium Informatik

Assembly and characterization of a rigid fiber Fabry-Pérot cavity
— •Carlos Saavedra, David Röser, Deepak Pandey, Hanes Pfeifer, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstrasse 8, 53115 Bonn, Germany

Optical fiber cavities present a versatile system to confine light in small mode volumes for a broad range of applications such as cavity-QED, filtering or sensing. We present a monolithic fiber cavity assemblies, which offers high passive stability in a compact mount. We outline the general procedure of our rigid cavity fabrication and characterization process and show how resonance wavelength tuning mechanism for this cavities can be implemented.

Q 58.11 Thu 16:15 S Atrium Informatik

Towards Terahertz quantum sensing: Measurement of spontaneous parametric down conversion in the terahertz frequency range.
— •Mirco Kutas[1,2], Björn Haase[1,2], Daniel Molter[1], and Georg von Freymann[1,2] — [1]Fraunhofer-Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern (TUK), 67663 Kaiserslautern

We show an experimental setup to measure spontaneous parametric down conversion (SPDC) in the terahertz and even sub-terahertz frequency range. The signal and idler pairs are generated in periodically poled $LiNbO_3$ (PPLN) using a frequency-stable solid-state laser at 660nm as pump source. Detection is achieved by extremely narrow-band volume Bragg gratings suppressing the pump photons after the crystal while transmitting the slightly frequency shifted signal photons. As detector we use an uncooled scientific CMOS camera with a comparatively low quantum efficiency and high dark count rate. Using a highly efficient transmission grating, we resolve a frequency angular spectrum of the signal photons. It shows backward and forward generation of terahertz and sub-terahertz photons by SPDC as well as conversion of thermal radiation and higher order quasi phase-matching.
[Kitaeva, G.K. et al. Applied Physics B, **116**(4), 929–937, (2014)], [Kornienko, V.V. et al. APL Photonics **3**, 051704, (2018)]

Q 58.12 Thu 16:15 S Atrium Informatik

Beyond input-output models in x-ray cavity QED
— •Dominik Lentrodt, Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The input-output formalism has been one of the main theoretical models in cavity QED, since it allows to describe the atom-cavity dynamics in terms of a few constants, such as resonance energies and decay time scales of the cavity. This is invaluable in understanding the mechanisms behind experimental results, since the constants can be fitted to data. However, in particular in the bad cavity regime or when multiple cavity modes are involved in the dynamics, this method does not always yield a unique explanation of the underlying processes. Indeed the use of input-output formalism for loss-dominated cavities has been debated theoretically and spectroscopic experiments using x-ray cavities doped with Mössbauer nuclei have shown that heuristic extensions to the input-output formalism, such as additional phase shifts, are required in order to successfully model collective Lamb shifts in the system [1,2].

We employ a recently developed method that links ab-initio quantisation to the input-output formalism to predict x-ray spectra in the nuclei-cavity system from the cavity geometry. Within this formalism, the additional phase shifts can now be understood as a multi-mode interference effect, enabled by crucial differences to standard assumptions in the input-output model approach.
[1] Röhlsberger, R. et al. (2010). Science, 328, 1248-1251. [2] Heeg, K. P. & Evers, J. (2015).

Phys. Rev. A, 91, 063803.

Q 58.13 Thu 16:15 S Atrium Informatik

How accurately can we measure the Photon-Exchange Phase? — Konrad Tschernig[2], •Malte Smoor[1], Tim Kroh[1], Chris Müller[1], Armando Perez-Leija[2], Kurt Busch[1,2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin Institut für Physik, 12489 Berlin, Germany — [2]Max-Born-Institut, 12489 Berlin, Germany

The bosonic nature of photons is an essential result of quantum electrodynamics. So far it has been only measured indirectly, e.g. through experiments using the photon bunching effect (a.k.a. Hong-Ou-Mandel effect) [1]. At the most fundamental level, the statistical properties of fermions and bosons differ in the exchange phase ϕ. When two identical particles are exchanged, the wave function acquires an additional factor $\exp(i\phi)$ with a value of $\phi = 0$ for bosons and $\phi = \pi$ for fermions. A third possibility would be the exotic Anyon, for which the exchange phase ϕ takes a value different from 0 or π. Recently, protocols for measuring the exchange phase using massive particles, have been proposed [2].

Here, we present a theoretical-experimental framework to directly measure the exchange phase of photons (massless particles). Our experimental setup consists of two coupled Mach-Zehnder interferometers fed by indistinguishable photon pairs generated in a bright source based on cavity-enhanced parametric downconversion [3].

[1] C. K. Hong et al., Physical Review Letters 59, 2044, 1987
[2] C. F. Roos et al., Physical Review Letters 119, 160401, 2017
[3] A. Ahlrichs et al., Applied Physics Letter 108, 021111, 2016

Q 58.14 Thu 16:15 S Atrium Informatik

Coherence of individual neutral impurities immersed in an ultracold bath — •Daniel Adam[1], Quentin Bouton[1], Jennifer Koch[1], Tobias Lausch[1], Daniel Mayer[1], Jens Nettersheim[1], Felix Schmidt[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

Impurities in an ultracold bath with adjustable interaction strength from a versatile system for experimentally studying fundamental quantum phenomena. A prominent question regards the quantum coherence of individual quantum bits (qubits) when coupled to various baths. Experimentally we realize such a paradigm immersing individual neutral Cs atoms into an ultracold cloud of Rb atoms.

We investigate the coherence properties of single impurity qubits in an ultracold cloud of Rb atoms. Experimental control allows preparation of arbitrary qubit states within the ground-state hyperfine manifolds. Additionally, Feshbach resonances at ultralow energies enable us to selectively tune the elastic interaction strength for internal qubit states. We trace the thermalization of the impurities on the one hand, and coherence properties of impurity superpositions on the other hand. We discuss the current state of the project unraveling the competition between thermal relaxation and decoherence.

Q 58.15 Thu 16:15 S Atrium Informatik

Laser-driven ion acceleration in the ultra-relativistic Breakout-Afterburner regime — •Shikha Bhadoria, Naveen Kumar, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, Heidelberg

Laser-accelerated ion beams have a multitude of applications with a particularly interesting one being hadron therapy that is essential for cancer treatment. Breakout-Afterburner (BOA) is one of the high-performance laser-driven-ion acceleration mechanisms capable of accelerating ions to relatively higher values with the same intensities of a laser. In this scenario, an initially opaque (overdense), ultra-thin target (with a width comparable to the laser skin depth) turns transparent to the incoming laser pulse, due to relativistically induced transparency which leads to a phase of extreme ion acceleration that is known to be aided by Buneman instability [1]. The impact of radiation reaction and Breit-Wheeler pair production on the acceleration of fully ionized Carbon ions and protons driven by an ultra-intense linearly-polarised laser pulse has been investigated in the ultra-relativistic BOA regime using multidimensional PIC simulations. [1] L. Yin et al. Three-dimensional dynamics of breakout afterburner ion acceleration using high-contrast short-pulse laser and nanoscale targets. Phys. Rev. Lett., 107:045003, Jul 2011.

Q 58.16 Thu 16:15 S Atrium Informatik

Towards the realisation of an atom trap in the evanescent field of a WGM-microresonator — •Luke Masters[1], Elisa Will[1], Michael Scheucher[1], Jürgen Volz[1], and Arno Rauschenbeutel[1,2] — [1]Atominstitut der TU Wien, Austria — [2]Humboldt Universität zu Berlin, Germany

Whispering-gallery-mode (WGM) resonators guide light by total internal reflection and provide ultra-high optical quality factors in combination with a small optical mode volume. Coupling a single atom to the evanescent field of a WGM microresonator thus allows one to reach the strong coupling regime [1]. Furthermore, such resonators provide chiral, i.e. propagation direction dependent, light-matter coupling which can be employed for realising novel quantum protocols as well as nonreciprocal quantum devices [2]. However, trapping atoms in the evanescent field of such resonators has not yet been demonstrated, which severely limits the atom-resonator interaction time. We aim to trap single 85Rb atoms in the vicinity of a bottle-microresonator using a standing wave optical dipole trap which is created by retroreflecting a tightly focused beam on the resonator surface [3]. In order to load atoms into the trap, we employ an FPGA-based electronics which allows us to react in 150 ns to an atom arriving in the resonator field and thus to switch on the trap. We will present characterisation measurements of the trap and discuss strategies for optimising the trapping lifetime.

[1] C. Junge et al. Phys. Rev. Lett. 110, 213604 (2013)
[2] M. Scheucher et al. Science 354, 1577 (2016)
[3] J. D. Thompson et al. Science 340, 1202 (2013)

Q 58.17 Thu 16:15 S Atrium Informatik

Investigating Transport in a Rydberg Medium with Interaction Enhanced Imaging — •Andre Salzinger[1], Titus Franz[1], Annika Tebben[1], Nithiwadee Thaicharoen[1], Clement 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

We study the coherent transport of Rydberg excitations in a cold atomic cloud. A single excitation to an impurity Rydberg state couples via resonant dipole-dipole interactions to the background atoms, which are dressed with another Rydberg state via electromagnetically induced transparency. The transparent background is therefore rendered absorptive around the impurity. This allows direct optical detection of transport dynamics. The imaging process presents a tunable degree of decoherence, which enables the study of different transport regimes.

Q 58.18 Thu 16:15 S Atrium Informatik

Geometry optimization for Casimir-Polder calculations using the discontinuous Galerkin time domain method — •Bettina Beverungen[1], Philip Kristensen[1], and Kurt Busch[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany

Many properties of light-matter interaction depend on the geometry of the system to be analyzed and might exhibit improved performance for nontrivially shaped structures. These kinds of problems are typically not analytically tractable and involve large parameter spaces, therefore lending themselves to black box optimization methods, which do not require knowledge of the objective function's explicit functional form. In this work, we implemented a genetic algorithm for geometry optimization of nanophotonic structures simulated via the discontinuous Galerkin time domain (DGTD) method.

We employ the genetic algorithm in combination with a numerical DGTD calculation of Casimir-Polder forces for arbitrarily shaped objects. These forces are typically attractive, as in the case of a small polarizable particle interacting with a plate. However, specialized geometries can lead to the introduction of repulsive forces under particular circumstances. As an example application, we explore the use of complex geometrical shapes to increase the repulsive force.

Q 58.19 Thu 16:15 S Atrium Informatik

Giant Cross-Kerr Nonlinearity induced by a Strong Coupled Single Atom Cavity System — •Bo Wang, Nicolas Tolazzi, Jonas Neumeier, Christoph Hamsen, Tatjana Wilk, and Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Cross Kerr nonlinearities have always been fascinating, especially in the context of modulating one light field with another, as this might have applications in quantum nondemolition measurements and quantum logic gates. In our setup, two separate transitions of a four level atom in an N-type scheme are strongly-coupled to two longitudinal modes of a cavity that are driven by light fields at wavelengths 780 nm and 795 nm[1]. The strong interaction between both light fields and the atom induced by cavity QED results in a huge nonlinearity on the level of individual photons. In out experiment, the signal light at 780nm is detuned by 30 MHz from atomic resonance and induces an AC-Stark shift on the atomic transition of up to about 200 kHz per photon, without absorption. This light shift manifests itself on a shift of the two photon resonance frequency in electromagnetically induced transparency(EIT) created by the probe light at 795nm. A cross-phase modulation(XPM) of 0.5 rad per photon between probe light and signal light is achieved.

C.Hamsen et al., Nature Physics 14, 885-889 (2018)

Q 58.20 Thu 16:15 S Atrium Informatik

Two single photon sources for rubidium transitions — •Eduardo Urunuela[1], Wolfgang Alt[1], Yan Chen[2], Robert Keil[2], Tobias Macha[1], Deepak Pandey[1], Hannes Pfeifer[1], Lothar Ratschbacher[1], Michael Zopf[2], Fei Ding[2], Oliver G. Schmidt[2], and Dieter Meschede[1] — [1]Institut für Angewandte Physik, Uni Bonn, Germany — [2]Leibniz IFW, Dresden, Germany

We compare an atom-cavity based single-photon source with the emission of a frequency-stabilized quantum dot [1]. While the solid-state system offers single-photon generation at a high rate, a rubidium atom coupled to a fiber-based, high-bandwidth optical resonator [2] gives the possibility to design the temporal envelope of the photons.

In the adiabatic limit, we use optimized control pulses for single-photon generation by adapting the impedance-matching based storage scheme of Dilley et al. [3] and the concept of time-reversal symmetry [4]. We achieve probabilities of 66 % for generating a single, arbitrarily-shaped photon into the cavity mode upon a trigger signal. Furthermore, the system serves as a memory for short coherent pulses beyond the adiabatic limit. As a second source of single-photon emission, strain-tunable semiconductor quantum dots (QDs) are presented. Their emission is fixed to the D_1 line of rubidium by realizing a rate-based frequency-stabilization to an atomic reference. The indistinguishability of photons from two separate, stabilized QDs is verified in a Hong-Ou-Mandel experiment.

[1] PRB **98**, 161302 (2018). [2] PRL **121**, 173603 (2018). [3] PRA **85**, 023834 (2012). [4] PRA **76**, 033804 (2007).

Q 58.21 Thu 16:15 S Atrium Informatik

Optomechanical entanglement detection — Jason Hoelscher-Obermaier[1], Sebastian Hofer[1], Ramon Mogadas-Nia[1], Claus Gaertner[1,3], •Corentin Gut[1,2], Klemens Wrinkler[1], Adrian Steffens[4], Jens Eisert[4], Witlef Wieczorek[5], Markus Aspelmeyer[1], and Klemens Hammerer[2] — [1]Univeristy of Vienna, Vienna, Austria — [2]Leibniz University Hannover, Hannover, Germany — [3]Delft University of Technology, Delft, Netherlands — [4]Free University of Berlin, Berlin, Germany — [5]Chalmers University of Technology, Goeteborg, Sweden

We consider an optomechanical (OM) system driven continuously close to resonance. The OM interaction generates correlation between light and mechanical motion: OM entanglement. The same correlation is encoded in the two sidebands of the cavity output field. Detecting entanglement on two appropriate light modes reveals the presence of OM entanglement.

We present a scheme that is portable to various optomechanical setups, for instance membrane in the middle or levitated particles. The tools developed can treat the presence of multiple mechanical modes in the frequency response of the OM system.

Fully analytical study of the Langevin eq. and simulations of realistic situation predict entanglement for accessible parameter regime.

Q 58.22 Thu 16:15 S Atrium Informatik

Semiclassical rotation dynamics of rigid rotors — •Birthe Papendell, Benjamin A. Stickler, and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen

Recent progress in the optical manipulation [1,2] of levitated nanoparticles and the prospect of cooling them into their ro-translational ground state [3] open the door for rotational quantum experiments with nanoscale objects [4]. However, calculating the exact rotational quantum dynamics of such particles is numerically intractable due to the high number of involved rotation states. Here, we present semiclassical approximation methods for planar and linear rotors with several thousand occupied angular momentum states revolving in the presence of an external potential.

[1] T. M. Hoang, Y. Ma, J. Ahn, J. Bang, F. Robicheaux, Z.-Q. Yin and T. Li, Phys. Rev. Lett. 117, 123604 (2016)

[2] S. Kuhn, B. A. Stickler, A. Kosloff, F. Patolsky, K. Hornberger, M. Arndt and J. Millen Nat. Commun. 8, 1670 (2017)

[3] B. A. Stickler, S. Nimmrichter, L. Martinetz, S. Kuhn, M. Arndt and K. Hornberger, Phys. Rev. A 94, 033818 (2016)

[4] B. A. Stickler, B. Papendell, S. Kuhn, B. Schrinski, J. Millen, M. Arndt and K. Hornberger, New J. Phys. (in press) (2018)

Q 58.23 Thu 16:15 S Atrium Informatik

Phase-locking of optically levitated nanoparticles — •Henning Rudolph, Benjamin Stickler, and Klaus Hornberger — Universitaet Duisburg-Essen

Optically trapping, cooling, and manipulating dielectric nanoparticles offers an attractive route towards ultra-precise sensors and fundamental tests of quantum physics. Here we demonstrate theoretically that two spherical nanoparticles, simultaneously trapped in an optical cavity, can synchronize their dynamics via the resonator mediated interaction. We characterize the coupled dynamics, identify under which conditions phase-locking occurs and investigate how rotational synchronization of two trapped nanorotors can be achieved.

Q 58.24 Thu 16:15 S Atrium Informatik

Optomechanical locking of a large linewidth membrane-in-the-middle cavity using the optical spring effect — Tobias Wagner[1], •Jakob Butlewski[1], Philipp Rohse[1], Clara Schellong[1], Hai Zhong[2], Alexander Schwarz[2], Roland Wiesendanger[2], Klaus Sengstock[1], and Christoph Becker[1] — [1]ZOQ-Center for Optical Quantum Technologies, Luruper Chaussee 149, 22761 Hamburg — [2]Institute of Applied Physics, University of Hamburg, Jungiusstraße 9-11, 20355 Hamburg

We present a new method for locking the cavity length of a microscopic all-fiber based membrane-in-the-middle optomechanical setup. Our scheme is based on the fact that the so-called optical spring effects leads to a small change of the resonance frequency of the mechanical oscillator as a function of the cavity length. In our locking scheme, we detect this frequency change using a demodulated balanced homodyne signal and feed the corresponding error signal to a PI controller that actuates one of the fiber tips via a piezo tube. We present a detailed characterization of the lock and discuss prospects and limitations. Our locking scheme is beneficial compared to standard locking techniques based on frequency modulation in the case of very short low finesse cavities with correspondingly very large linewidths. This work is supported by the DFG via grants of Wi1277/29-1, BE 4793/2-1, SE 717/9-1 and by the CUI.

Q 58.25 Thu 16:15 S Atrium Informatik

Applications of Zerodur based optical benches in quantum optics microgravity missions — •Jean Pierre Marburger[1], Moritz Mihm[1], Sören Boles[1], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], Patrick Windpassinger[1], and the MAIUS and BECCAL team[1,3,4,5,6,7] — [1]Institut für Physik, JGU, Mainz — [2]ILP, UHH, Hamburg — [3]Institut für Physik, HU Berlin, Berlin — [4]FBH, Berlin — [5]IQ & IMS, LUH, Hannover — [6]ZARM, Bremen — [7]Institut für Quantenoptik, Universität Ulm, Ulm

A great variety of fundamental physics experiments greatly benefit from a microgravity environment, as can be found aboard a sounding rocket or a satellite. To enable quantum optics experiments on these platforms, a laser system is required that exhibits high thermal stability, is mechanically very robust and compact. To this end, we have developed an optical bench technology based on the glass-ceramic Zerodur, which exhibits an almost negligible coefficient of thermal expansion. The presented technology was successfully implemented in the scope of the sounding rocket missions KALEXUS, FOKUS and MAIUS-1, and will enable future missions such as MAIUS-2/3, as well as the NASA-DLR BECCAL mission aboard the ISS. The poster discusses the optical modules used in these missions and how they have been used to help achieve major experimental milestones such as the first creation of a Bose-Einstein condensate in space.

Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50 WP 1433 and 50 WP 1703.

Q 58.26 Thu 16:15 S Atrium Informatik

Towards pure quantum states of motion of 0.1 kg pendulum suspended mirrors — •Jan Petermann, Alexander Franke, and Roman Schnabel — Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The ERC funded project *MassQ* aims to test and to confirm quantum theory in the macroscopic world of massive, human-world sized objects. We seek the experimental generation of rather pure coherent states of motion of a single 0.1 kg mirror that is suspended as a pendulum as well as of Einstein-Podolski-Rosen entanglement of two such systems. Using radiation pressure forces inside an interferometer, the centre of mass positions and momenta can be entangled if the uncertainty of the radiation pressure affects the mirror movement. This can be achieved using high intensity laser light. We use a Michelson-Sagnac type interferometer with power recycling to reach a light power of 1 kW on the mirrors.

Q 58.27 Thu 16:15 S Atrium Informatik

Parametrically Damped High-Q Mechanical Pendulum with Interferometric Readout — •Daniel Hartwig and Roman Schnabel — Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Low-frequency high-precision optomechanical experiments like interferometric gravitational-wave detectors rely on test masses that are suspended as pendula with very low mechanical friction to isolate them from environmental perturbations and measure extremely small distance changes through interferometry. This poster describes a model setup for such a pendulum and evaluates the performance of an active oscillation damping system that relies only on parametric damping. This means modulating one or more of the oscillation parameters and not exerting any forces in the direction of movement. In this case only the resonance frequency is modulated by vertically accelerating the pendulum suspension to reduce the oscillation amplitude. The precise readout of oscillation parameters necessary for parametric damping is provided by an optical measurement system that uses interferometry and displacement measurement on a laser beam reflected by the test mass. With this system a reduction of the pendulum's quality factor from 3300 to 930 could be achieved. The minimum reachable oscillation amplitude was limited by seismic noise to 8 μm peak-to-peak.

Q 58.28 Thu 16:15 S Atrium Informatik

High-reflectivity AlGaAs-based optomechanical devices — •Sushanth Kini M[1], Shu Min Wang[2], Jamie Fitzgerald[3], Philippe Tassin[3], and Witlef Wieczorek[1] — [1]Quantum Technology Laboratory, Department of Microtechnology and Nanoscience, Chalmers University of Technology, Gothenburg, Sweden — [2]Photonics Laboratory, Department of Microtechnology and Nanoscience, Chalmers University of Technology, Gothenburg, Sweden — [3]Department of Physics, Chalmers University of Technology, Gothenburg, Sweden

A major challenge in the field of optomechanics remains accessing a strong interaction on the level of single quanta between light and mechanical motion, which would, for example, allow for the non-destructive detection of single photons. The concept of multi-element optomechanics has been proposed to reach the necessary single photon strong coupling regime. In the present work, we use mechanical devices in an AlGaAs heterostructure to realise this concept. We show initial results on simulation and fabrication of free-free-type mechanical resonators, which minimize undesired clamping loss and thus, realise large mechanical quality factors. Additionally, the mechanical resonator is patterned with a photonic crystal array that results in an out-of-plane reflectivity close to unity. We present simulation and measurement results thereof. Our device concept should allow for a fully integrated realization of multi-element optomechanical system in the near future.

Q 58.29 Thu 16:15 S Atrium Informatik

Robust and miniaturized Zerodur based optical and vacuum systems for quantum technology applications — •Sören Boles[1], Jean Pierre Marburger[1], Moritz Mihm[1], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], and Patrick Windpassinger[1] — [1]Institut für Physik, JGU, Mainz — [2]Institut für Laserphysik, UHH, Hamburg

Space based quantum optics experiments face harsh operating conditions in terms of thermal and mechanical fluctuations, while giving strong limitations to payload mass and volume.

We developed miniaturized optical bench systems based on Zerodur glass ceramics allowing for laser beam manipulation, beam switching and frequency stabilization in extreme environments. Suitability of these optical systems has been demonstrated in the successful sounding rocket missions FOKUS, KALEXUS and MAIUS.

On this poster, we present elaborated developments of optical technologies, comprised of optical benches with free-space optics combined with fiber components. Furthermore, we report on current investigations of Zerodur based vacuum systems, providing a miniaturized and mechanically stable vacuum technology, while paving the way to a fully integrated quantum optical system.

Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant number 50 WP 1433, 50 WM 1646 and JGU Stufe 1 Funding.

Q 58.30 Thu 16:15 S Atrium Informatik

Biphoton generation in ultrathin layer of lithium niobate — •Tomás Santiago-Cruz[1,2], Cameron Okoth[1,2], Andrea Cavanna[1,2], and Maria Chekhova[1,2,3] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, 91058 Erlangen, Germany — [2]University of Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Department of Physics, M.V. Lomonosov Moscow State Univeristy, Leninskie Gory, 119991 Moscow, Russia

We report for the first time the generation of photon pairs in a micron-thick layer of lithium niobate through spontaneous parametric down conversion (SPDC) without requiring momentum conservation. We have characterized the source by measuring coincidences between photon pairs and the respective single- and two-photon spectrum. The biphoton source exhibits a broad spectrum and correspondingly ultrashort correlation time. Additionally, due to the lack of momentum conservation, the degree of temporal and spatial entanglement is estimated to be very high. Moreover, the generation of SPDC without momentum conservation is not limited to lithium niobate, instead it opens the possibility to use highly nonlinear materials that can improve further the efficiency. Our source is suitable for applications that require the aforementioned properties, such as quantum imaging and distant-clock synchronization.

Q 58.31 Thu 16:15 S Atrium Informatik

Stable single light bullets in cold Rydberg gases — •Zhengyang Bai[1,2], Weibin Li[2], and Guoxiang Huang[1] — [1]State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

Realizing single light bullets and vortices that are stable in high dimensions is a long-standing goal in the study of nonlinear optical physics. On the other hand, the storage and retrieval of such stable high dimensional optical pulses may offer a variety of applications. Here we present a scheme to generate such optical pulses in a cold Rydberg atomic gas. By virtue of electromagnetically induced transparency, strong, long-range atom-atom interaction in Rydberg states is mapped to light fields, resulting in a giant, fast-responding nonlocal Kerr nonlinearity and the formation of light bullets and vortices carrying orbital angular momenta, which have extremely low generation power, very slow propagation velocity, and can stably propagate, with the stability provided by the combination of local and the nonlocal Kerr nonlinearities. We demonstrate that the light bullets and vortices obtained can be stored and retrieved in the system with high efficiency and fidelity. Our study provides a new route for manipulating high-dimensional nonlinear optical processes via the controlled optical nonlinearities in cold Rydberg gases.

Q 58.32 Thu 16:15 S Atrium Informatik

Waveguide-integrated superconducting nanowire single-photon detectors with photon number resolution — •Martin A. Wolff[1,2,3], Jonas Schütte[1,2], Matthias Häussler[1,2,3], and Carsten Schuck[1,2,3] — [1]Physics Institute, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]CeNTech - Center for NanoTechnology, Heisenbergstr. 11, 48149 Münster, Germany — [3]MNF - Münster Nanofabrication Facility, Heisenbergstr. 11, 48149 Münster, Germany

Superconducting nanowire single-photon detectors (SNSPDs) have recently developed into the leading detector technology with single-photon sensitivity as they offer efficient counting with high repetition rate, short timing jitter and low dark count rate [1]. The integration of

these detectors with wide-band Si3N4 nanophotonics [2] allows for implementing quantum optical experiments both at visible and infrared wavelengths on-chip. However, many multi-photon applications such as linear optical quantum computing (LOQC), quantum emitter characterization, light detection and ranging (LIDAR) would benefit from detectors with photon number resolving (PNR) capabilities. Here we employ a parallel resistor approach [3] to realize PNR superconducting nanowire detectors. We fabricate detectors from niobium nitride (NbN) on Si3N4 waveguides that allow for resolving up to four simultaneously arriving photons at telecommunication wavelength (1550 nm).
[1] S. Ferrari et al., Nanophotonics, 7, 1725 (2018), [2] C. Schuck et al., Appl. Phys. Lett., 102, 051101 (2013), [3] F. Mattioli et al., Supercond. Sci. Technol., 28, 104001 (2015)

Q 58.33 Thu 16:15 S Atrium Informatik

Nitrogen-Vacancy Based Electron Spin Resonance Spectroscopy in Diamond — •Florian Böhm[1,2], Niko Nikolay[1,2], Nikola Sadzak[1,2], Bernd Sontheimer[1,2], and Oliver Benson[1,2] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Germany — [2]IRIS Adlershof, Humboldt-Universität zu Berlin, Germany

The nitrogen-vacancy (NV) center is the most prominent defect in diamond due to its outstanding properties as a quantum light source and its manipulable electron spin. NV applications range from quantum information processing to high sensitivity nano-magnetometry.

We present the spectroscopy of the local paramagnetic spin bath in nitrogen-15 delta-doped (111) diamond using single shallow nitrogen-vacancy centers as sensors and probe the spin bath dynamics with double spin resonance schemes.

Furthermore, we discuss recent progress in population swapping via microwave Raman transitions in the multilevel electronic ground state of the NV center.

Q 58.34 Thu 16:15 S Atrium Informatik

Harmonic generation in laser-driven tight-binding models employing the Kwant Python package. — •Francisco Javier Ortega Dueñas and Dieter Bauer — Institute for Physics, University of Rostock, 18051 Rostock

Strong-field laser-driven condensed matter systems can be simulated on various levels of rigour. The simplest and most flexible approach is the coupling of tight-binding models to external laser fields.

We discuss how to use the Kwant Python package [1] for the efficient set-up of the tight-binding Hamitonian matrix for a spatially finite system, possibly having leads, and how to employ Kwant's output for the time evolution of the system in a laser field. We discuss how to couple the laser field to the system and calculate high-harmonic spectra. The role of topological effects in the strong-field dynamics and harmonic spectra is discussed for exemplary model systems.

Q 58.35 Thu 16:15 S Atrium Informatik

Fabrication of a 2D nuclear spin lattice for a NV based solid state quantum simulator — •Karolina Schüle[1], Nikolas Tomek[1], Philipp Vetter[1], Johannes Lang[1], Paul Listunov[1], Boris Naydenov[3], and Fedor Jelezko[1,2] — [1]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, Ulm 89081, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), Albert-Einstein-Allee 11, Ulm 89081, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, Berlin 14109, Germany

Realizing a quantum simulator will enable us to study the behaviour of complex correlated many-body systems exceeding the limits of classical simulations. The idea is to use a solid state spin lattice as such a quantum simulator, a 2D semiconductor. Here we demonstrate the transfer of a 2D semiconductor onto the surface of an isotopically enriched ^{12}C bulk diamond containing shallow implanted nitrogen vacancy (NV) centers. These NVs can then be used to detect and manipulate the polarization of the dipolar coupled nuclear spins at room temperature.