Q 54: Posters: Quantum Optics and Photonics IV

Time: Thursday 16:30–18:30 Location: Empore Lichthof

Q 54.1 Thu 16:30 Empore Lichthof

Towards the production of groundstate RbYb — Tobias Franzen, •Bastian Pollklesener, Christian Sillus, 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 Rb and Yb from their separate production chambers to a dedicated science chamber. Here we start to study interspecies interactions of different isotopes by overlapping crossed optical dipole traps. We report of first results of implementing a 3D lattice and using photoassociation spectroscopy on the way towards groundstate molecules.

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

Q 54.2 Thu 16:30 Empore Lichthof

Effects of multiple lattices on atomic light-pulse diffraction — •Jens Jenewein[1], Sabrina Hartmann[1], Enno Giese[1], Albert Roura[1,2], Wolfgang P. Schleich[1,2], and and the QUANTUS Team[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89069 Ulm, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Söflinger Str. 100, D-89077 Ulm, Germany

We study in detail the differences between Raman and Bragg diffraction for different regimes in a retro-reflective geometry [1]. Moreover, we demonstrate the transition between double and single diffraction for an increasing Doppler detuning. Besides the intrinsic limitations of the efficiency of a double-Bragg mirror pulse, imperfections in the orthogonality of the polarizations pose an even more important problem in large-momentum-transfer atom interferometry, as found in related experiments by the QUANTUS project. In order to circumvent these difficulties and to enhance the efficiency, we provide an alternative diffraction technique for mirrors based on standing waves which can be understood as a second-order single-Bragg pulse and demonstrate the robustness against polarization imperfections.

The QUANTUS and BECCAL projects are supported by the German Aerospace Center (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant numbers 50WM1956 and 50WP1705.

[1] S. Hartmann, J. Jenewein et al., arXiv:1911.12169 [quant-ph]

Q 54.3 Thu 16:30 Empore Lichthof

From idealized to *realistic* atomic beam splitters - theoretical studies in 3D — •Antje Neumann and Reinhold Walser — Technische Universität Darmstadt, Germany

We analyze the response and aberrations of atomic beam splitters with spatio-temporal laser beam envelopes in three dimensions.

Atomic beam splitters are a central component of matter-wave interferometers, which provide the opportunity of high-precision rotation and acceleration sensing. Therefore, ultracold atoms are the ultimate quantum sensors. Potential applications range from tests of fundamental physics to inertial navigation. In the QUANTUS (Quantum Gases in Microgravity) free-fall experiments atom interferometry is the central method as well [1].

Like optical systems matter-wave devices require exact specifications and ubiquitous imperfections need to be quantified. Therefore, we study the performance of 3D atomic beam splitters in the velocity selective quasi Bragg configuration numerically as well as analytically, finally confirmed by experimental data [2]. We characterize the non-ideal behavior due to spatial variations of the laser beam profiles and wave front curvatures, regarding realistic Gaussian laser beams instead of ideal plane waves. Especially, we study the effect of slightly decentered and tilted lasers. Different temporal pulse shapes are considered.

This work is supported by the German Aeronautics and Space Administration (DLR) through grant 50 WM 1957.

[1] D. Becker et al., Nature 562, 391-395 (2018)
[2] M. Gebbe, Universität Bremen, Zarm, private communication.

Q 54.4 Thu 16:30 Empore Lichthof

On chip electron guiding — •Robert Zimmermann, Michael Seidling, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

The current status of beam guiding experiments based on to microstructured chips is reported.

Q 54.5 Thu 16:30 Empore Lichthof

Collimation of atomic ensembles in space — •Annie Pichery[1,2], Waldemar Herr[1], Matthias Meister[3], Patrick Boegel[3], Wolfgang P. Schleich[3], Ernst M. Rasel[1], Eric Charron[2], Naceur Gaaloul[1], and Nicholas P. Bigelow[4] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Institut des Sciences Moléculaires d'Orsay, Université Paris-Saclay, France — [3]Institut für Quantenphysik, Universität Ulm, Germany — [4]University of Rochester, New York, USA

Ensembles of cold atoms behave as matter-waves and are routinely used as input states for atom interferometers. The free expansion and the inherent atomic density drop make the signal detection difficult. By analogy with light, it is possible to collimate the clouds with atomic lenses, using the delta-kick collimation technique. In this contribution, we study a protocol for controlling the expansion of an atomic cloud applied to experiments in the NASA Cold Atom Laboratory (CAL) on board of the International Space Station. Such clouds collimated with the delta-kick technique could be observed over long periods of almost 400 ms. Other important techniques towards the preparation of atomic sources for precision atom interferometry in space are reported.

We acknowledge financial support from the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under Grant No. 50WM1861/2, and by *Niedersächsisches Vorab* through the QUANOMET initiative-project QT3, and financial support from NASA through CUAS RSAs including 1585910.

Q 54.6 Thu 16:30 Empore Lichthof

Spatial coherence properties of laser-triggered electron pulses towards higher currents — •Stefan Meier and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Tungsten needle tips represent well-suited electron sources for various applications, like electron microscopy or holography. In cold field emission, these tips provide a highly coherent electron beam, a key parameter for any electron-optical application. When ultrashort femtosecond laser pulses are focused on the tip, the electron emission can occur on timescales down to a few femtoseconds, leading to an ultrafast pulsed electron source. In recent experiments, we could show that the pulsed electron emission is spatially as coherent as cold field emission from the same tip [1]. Usually, femtosecond laser-triggered emission currents are below one electron per laser pulse to avoid electron-electron interaction within the small emission area and time. In this work, we investigate the properties of the spatial coherence towards one electron per pulse and show the current progress.

[1] S. Meier *et al.*, Appl. Phys. Lett. **113**, 143101 (2018).

Q 54.7 Thu 16:30 Empore Lichthof

T^3-interferometry — •Matthias Zimmermann[1], Maxim A. Efremov[1,2], Omer Amit[3], Frank A. Narducci[4], Wolfgang P. Schleich[1,2], and Ron Folman[3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, Ulm, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany — [3]Department of Physics, Ben-Gurion University of the Negev, Be'er Sheva, Israel — [4]Department of Physics, Naval Postgraduate School, Monterey, USA

By exploiting the Kennard phase [1], we have proposed an atom interferometer [2] probing a linear potential and having a phase shift that scales as T^3, in contrast to conventional atom interferometers in the Mach-Zehnder configuration with a phase scaling as T^2, where T denotes the total interferometer time [3]. In this scheme we make use of two magnetic sensitive atomic states $|1\rangle$ and $|2\rangle$ leading to respective state-dependent accelerations a_1 and a_2 when the atom is exposed to a magnetic field gradient.

We present our unique Stern-Gerlach interferometer that enabled the successful observation of the cubic phase scaling [4]. As our device utilizes magnetic field gradients instead of light pulses for the beam-splitting process, it may serve as a unique probe for the study of surface properties.

[1] G. Rozenman et al., Phys. Rev. Lett. **122**, 124302 (2019)
[2] M. Zimmermann et al., Appl. Phys. B **123**, 102 (2017)
[3] M. Zimmermann et al., New J. Phys. **21**, 073031 (2019)
[4] O. Amit et al., Phys. Rev. Lett. **123**, 083601 (2019)

Q 54.8 Thu 16:30 Empore Lichthof

Large-Momentum-Transfer Atom Optics from a Floquet-Bloch viewpoint — •Eric P. Glasbrenner[1], Alexander Friedrich[1], Enno Giese[1], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), D-89077 Ulm, Söflinger Str. 100, Germany

Atom interferometers have evolved into high-precision instruments and are used nowadays in numerous applications as gravimeters, rotation sensors and in general inertial sensing tasks. The development rapidly moves towards compact setups aimed at the commercialization of atom interferometers. For such applications, both high precision and sensitivity are essential. One technique to increase the sensitivity is to use Large-Momentum-Transfer (LMT) methods such as double Bragg diffraction, sequential pulses or Bloch oscillations. In this contribution we propose a semi-analytical approach towards the description of light-pulse beam splitters and mirrors as well as Bloch oscillations in a unified framework. Specifically, we develop a Floquet-Bloch theory to model diffraction as well as Bloch oscillations which allows us to discuss e.g. the effects of parasitic lattices caused by imperfect polarization.

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Q 54.9 Thu 16:30 Empore Lichthof

State- and branch-dependent atom interferometry — •Enno Giese[1] and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt, Söflinger Str. 100, D-89077 Ulm, Germany

Light-pulse atom interferometry has evolved into a versatile and powerful tool for high-precision measurements of inertial forces. Whereas this sensitivity relies on the external degree of freedom, the internal structure of atoms gives another degree of freedom that makes them susceptible to relativistic effects [1,2]. In such a framework, the light-matter interaction takes place locally on each branch of the interferometer, making a branch-dependent formalism [3] a convenient and essential tool for the description of atom interferometers. Since the exact diffraction mechanism [4] as well as the specific geometry [3] determine the proper-time difference between the two branches, branch-dependent diffraction will have a similar effect. In our contribution we discuss atom interferometry from a branch-dependent perspective as well as the influence of different internal states and transitions.

The QUANTUS project is supported by the German Aerospace Center (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1956.

[1] arXiv:1810.06744 (2018) [3] New J. Phys. **16**, 123012 (2014)
[2] Sci. Adv. **5**, eaax8966 (2019) [4] Phys. Rev. A **99**, 013627 (2019)

Q 54.10 Thu 16:30 Empore Lichthof

Gravitational redshift in atomic clocks and atom interferometers — •Fabio Di Pumpo[1], Christian Ufrecht[1], Alexander Friedrich[1], Albert Roura[2], Wolfgang P. Schleich[1,2], and Enno Giese[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Söflinger Straße 100, D-89077 Ulm

The question of which atom-interferometer geometries can be used to test the gravitational redshift is at the center of a long-standing debate. We compare in this contribution classical redshift tests through the synchronization of two atomic clocks with the measurement results found in atom interferometers relying on i) quantum clock interference [1] or ii) internal state transitions during the interferometer [2]. For this purpose, we introduce a dilaton model which consistently parametrizes violations of the Einstein equivalence principle. Based on this model, we derive the corresponding phase shifts for atomic clocks and atom interferometers and study their differences. Consequently, we identify a large class of atom-interferometer geometries which measure violations of the universality of the gravitational redshift.

[1] Nat. Commun. **2**, 505 (2011) [2] arXiv:1810.06744 (2018)

The QUANTUS project is supported by the German Aerospace Center (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) due to an enactment of the German Bundestag under grant number DLR 50WM1956 (QUANTUS V).

Q 54.11 Thu 16:30 Empore Lichthof

Atomic Raman diffraction from a relativistic perspective — •Butrint Pacolli[1], Alexander Friedrich[1], Enno Giese[1], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt, Söflinger Str. 100, D-89077 Ulm, Germany

Atom interferometers are not only based on spatial superpositions of different branches that cause interference, but due to their internal structure they also possess an additional degree of freedom. The superposition of internal states has led to the concept of quantum clock interferometry [1] with the measurement of special-relativistic effects [2] and schemes susceptible to the gravitational redshift with transitions during the interferometer sequences [3]. One method to simultaneously manipulate both the external and internal degrees of freedom is Raman diffraction. For a consistent description, and to achieve the needed sensitivity for such measurements, this process has to be treated relativistically. We introduce a relativistic treatment for atomic Raman diffraction based on different masses associated with each internal state and discuss consequences for the diffraction process.

The QUANTUS project is supported by the German Aerospace Center (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1956.

[1] Nat. Commun. **2**, 505 (2011) [3] arXiv 1810.06744, (2018)
[2] Sci. Adv. **5**, eaax8966 (2019)

Q 54.12 Thu 16:30 Empore Lichthof

Double Raman diffraction for atom optics — •Sven Abend[1], Matthias Gersemann[1], Martina Gebbe[2], Simon Kanthak[3], Christian Schubert[1], Ernst M. Rasel[1], and the QUANTUS Team[1,2,3,4,5,6] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt — [6]Institut für Physik, JGU Mainz

Atom interferometry based on Raman diffraction is a well-proven tool for precise measurements of gravity, rotation, and fundamental constants. While in free fall, Raman diffraction using a two photon process occurs in a single direction, under vanishing atomic velocity so-called symmetric double diffraction occurs by scattering four photons of a retro-reflected laser beam. We report on a novel realization of a compact and highly integrated laser system based on established telecom fiber technology, electro-optic modulation and frequency doubling for Raman double diffraction of ^{87}Rb atoms. We efficiently drive Raman diffraction with this laser system and perform high contrast atom interferometry using delta-kick collimated condensed atoms generated on an atom chip.

Supported by DLR with funds provided by the BMWi under Grant No. DLR 50WM1552-1557 (QUANTUS-IV-Fallturm) and 50RK1957 (QGYRO), the VDI with funds provided by the BMBF under Grant No. VDI 13N14838 (TAIOL), the CRC 1227 DQmat within projects A05 and B07 and the QUEST-LFS. Funded by the DFG under Germany's Excellence Strategy, EXC-2123-B02.

Q 54.13 Thu 16:30 Empore Lichthof

Compact diode laser system and ground testbed for dual-species atom interferometry with Rb and K on an sounding rocket — •Oliver Anton[1], Victoria Henderson[1], Klaus Döringshoff[1], Julia Pahl[1], Simon Kanthak[1], Benjamin Wiegand[1], Moritz Mihm[3], Ortwin Hellmig[4], André Wenzlawski[3], Patrick Windpassinger[3], Markus Krutzik[1,2], Achim Peters[1,2], and The MAIUS Team[1,2,3,4,5,6] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]Institut für Physik, JGU Mainz — [4]ILP, Universität Hamburg — [5]ZARM, Universität Bremen — [6]IQO, Leibniz Universität Hannover

The MAIUS 2/3 missions will perform dual-species atom interferometry with Bose-Einstein condensates onboard sounding rockets. This suborbital platform enables longer timescales of microgravity than any ground based facility, paving the way towards high-precision tests of Einstein's Equivalence principle. A laser system for such conditions requires special designs for vibrational loads as well as the need for fast autonomous control. This contribution presents the design of our laser system for these missions in detail including key components of the laser system such as micro-integrated diode lasers and Zerodur-based optical benches. Additionally, recent developments of our ground testbed activities in establishing a Rb/K dual-species quantum gas experiment will be described. 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.

Q 54.14 Thu 16:30 Empore Lichthof

Simulations of Integrated Laser-Guided Atom Interferometers — •Matthew Glaysher, Florian Fitzek, Sina Loriani, Ernst Maria Rasel, and Naceur Gaaloul — Leibniz Universität Hannover, Institute of Quantum Optics, Germany

Atom interferometry provides a highly accurate measurement tool, its applications ranging from inertial sensing and navigation to tests of fundamental physics. High precision interferometry is achieved either by Large Momentum Transfer or long interrogation times. Whereas the more common light pulse interferometer schemes can produce the necessary momentum transfer, guided interferometers can achieve long interrogation times. For guided ensembles it is essential to understand the internal interactions, as well as the inherent systematics they cause, to realize a phase-sensitive interferometer. For this purpose we compute the dynamics of Bose-Einstein Condensates (BECs) by numerically solving the Gross-Pitaevskii-Equation. We specifically investigate beam-splitting mechanisms and the phase evolution of BECs in a guided system, realized by dynamically shaped cavity modes or painted potentials.

The presented work is supported by the VDI with funds provided by the BMBF under Grant No. VDI 13N14838 (TAIOL)

Q 54.15 Thu 16:30 Empore Lichthof

Universal atom interferometry simulator for precision sensing — •Florian Fitzek[1,2], Jan-Niclas Siemss[1,2], Holger Ahlers[2], Ernst M. Rasel[2], Klemens Hammerer[1], and Naceur Gaaloul[2] — [1]Institut für Theoretische Physik, LU Hannover — [2]Institut für Quantenoptik, LU Hannover

Quantum sensors based on light-pulse atom interferometers allow for high-precision measurements of inertial and electromagnetic forces, accurate determination of fundamental constants as the fine structure constant α or to test foundational laws of modern physics as the equivalence principle. The full potential, i.e. sensitivity of these schemes unfolds when large interrogation times or macroscopic arm separation could be implemented. Both directions, however, imply a substantial deviation from an ideal interaction of light with atomic systems. Indeed, real-life complications as finite pulse areas and fidelities, momentum width broadening of the cold clouds, atomic interactions or light fields distortions limit the measurements but more dramatically hinder a reasonable systematics study. This is mainly due to the limited number of analytical cases and to the realistic numerical calculations being intractable.

In this study, we contribute to the precise formulation and simulation of the aforementioned effects by employing a position space solver of the Gross-Pitaevskii equation. We specifically target problems connected to gravity sensing as well as the dephasing in trapped atom interferometers. The work is supported by the VDI with funds provided by the BMBF under Grant No. VDI 13N14838 (TAIOL).

Q 54.16 Thu 16:30 Empore Lichthof

Challenging General Relativity with Matter Wave Interferometry — •Thomas Hensel[1], Christian Schubert[1], Christian Ufrecht[2], Dennis Schlippert[1], Ernst Rasel[1], Enno Giese[2], and Naceur Gaaloul[1] — [1]Institute of Quantum Optics, Leibniz University Hanover, Welfengarten 1, D-30167 Hanover — [2]Institut für Quantenphysik (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm

Two decades ago the first data for a free-fall comparison of a quantum object and a macroscopic object has been taken, paving the way towards tests of the Universality of Free Fall in the quantum realm. Yet it was debated, whether this constitutes an atom interferometric redhsift test.

We conduct a study of tests of the Einstein Equivalence Principle with Matter Wave Interferometry with a focus on the Universality of the Gravitational Redshift and investigate experimental implementations in the VLBAI facility in Hannover. An analysis of the systematic errors lets us conclude that tests of the Universality of the Gravitational Redshift utilizing atom interferometers are in principle possible.

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Q 54.17 Thu 16:30 Empore Lichthof

Path-dependent wave-packet propagation for atom interferometry — •Amelie Mayländer[1], Alexander Friedrich[1], Enno Giese[1], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069, Germany — [2]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt, Söflinger Str. 100, D-89077 Ulm, Germany

Light-pulse atom interferometers have become an instrument for high-precision measurements of accelerations and rotations by determining the phase difference between two branches of the interferometer. Efficient calculation schemes are required to predict and investigate experimental results.

In our contribution we focus on the influence of time- and space-dependent potentials on atom interferometers. We present a numerical method based on comoving frames along each branch to efficiently calculate the impact of an arbitrary potential on the propagation of atomic wave packets in an atom interferometer.

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Q 54.18 Thu 16:30 Empore Lichthof

Efficient modeling and numerics for matter-wave beamsplitters in 3D — •Samuel Böhringer[1], Alexander Friedrich[1], Enno Giese[1], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069, Germany — [2]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt, Söflinger Str. 100, D-89077 Ulm, Germany

Light-pulse atom interferometers have evolved into capable sensors for inertial and electromagnetic forces and are now routinely used to test the foundations of physics. Most matter-wave interferometers use Raman or Bragg diffraction in combination with large-momentum-transfer techniques for for atomic diffraction. Typically, beamsplitters have multiple sources of imperfection such as mirror vibrations, polarization imperfections or general imperfections in their optical beams. In order to analyze and quantify the consequences in detail, full 3d models of these processes are necessary. However, due to the interplay of multiple effects the analytic treatment becomes cumbersome. In order to gain a deeper understanding of these effects a numerical treatment is necessary and needs to be efficient. In our contribution we discuss the modeling of Raman diffraction with physical beam shapes and other imperfections of the lasers involved.

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Q 54.19 Thu 16:30 Empore Lichthof

Non-perturbative treatment of quasi-Bragg diffraction phases for atom interferometry — •Jan-Niclas Siemss[1,2], Florian Fitzek[2], Sven Abend[2], Ernst M. Rasel[2], Naceur Gaaloul[2], and Klemens Hammerer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Bragg diffraction is a cornerstone of light-pulse atom interferometry. High-fidelity Bragg pulses for atomic sources with a finite velocity distribution typically operate in the quasi-Bragg regime. While enabling an efficient population transfer, the diffraction phase and its dependence on the pulse parameters are currently not well characterized despite playing a key role in the systematics of the interferometer.

In our work, we formulate Bragg diffraction in terms of scattering theory. We provide an intuitive understanding of the Bragg condition and derive a unitary scattering matrix in case of adiabatic driving with Gaussian pulses. We find, that perturbations of the adiabatic solution are well described by Landau-Zener physics. Furthermore, we include the effects of linear Doppler shifts applicable to narrow atomic velocity distributions on the scale of the photon recoil of the optical lattice.

As an illustration, with our comprehensive microscopic model we study diffraction phase shift fluctuations caused by laser intensity noise affecting the sensitivity of a Mach-Zehnder atom interferometer.

This work is supported by the CRC 1227 DQmat (A05) and by the VDI with funds provided by the BMBF under Grant No. VDI 13N14838 (TAIOL).

Q 54.20 Thu 16:30 Empore Lichthof

Detecting gravitational waves with atom interferometers — •Christian Schubert, Dennis Schlippert, Sven Abend, Sina Loriani, Naceur Gaaloul, Wolfgang Ertmer, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, 30167 Hannover

The combination of two atom interferometers enables geometries sensitive to the strain induced by a gravitational wave. This contribution will introduce the operation principle of atom interferometers for gravitational wave detection and highlight the key parameters which can e.g. be adjusted to close the gap between the laser interferometers Virgo, aLIGO, and LISA. Addressing this scenario, the contribution will discuss advantages and disadvantages of specific interferometer schemes, experimental demonstration activities, and put these into perspective for the proposed European infrastructure ELGAR.

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Q 54.21 Thu 16:30 Empore Lichthof

Towards light induced dipole-dipole interaction — •Marion Mallweger[1], Mira Maiwöger[1], Filippo Borselli[1], Tiantian Zhang[1], Jörg Schmiedmayer[1], Matthias Sonnleitner[2], and Philipp Haslinger[1] — [1]Atominstitut TU Vienna, Vienna, Austria — [2]Universät Innsbruck, Innsbruck, Austria

Atom interferometers have proven to be an ideal platform for measuring extremely small forces. However, their high sensitivity to potential energy changes can also be used to measure interactions between atoms. A particular case of these are light-induced dipole-dipole interactions, which are predicted to even be caused by incoherent, off-resonant light fields. We will present our preliminary findings and discuss, in an intuitive way, the geometry of our interferometer design.

Q 54.22 Thu 16:30 Empore Lichthof

Space-borne quantum test of the weak equivalence principle at the 10^{-17} level — •Sina Loriani, Sven Abend, Dennis Schlippert, Christian Schubert, Ernst Maria Rasel, and Naceur Gaaloul — Institut für Quantenoptik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Welfengarten 1, D- 30167 Hannover, Germany

Matter wave interferometry provides a unique access to the interface of quantum theory and gravity and is well suited for probing various aspects of general relativity, ranging from its postulates as the equivalence principle to its implications such as gravitational waves. In this contribution, we present a dedicated satellite mission for testing the universality of free fall to 10^{-17} as proposed for the ESA Voyage 2050 initiative. The theoretical advances and technological maturity that would allow reaching this performance will be highlighted.

We acknowledge financial support from DFG through CRC 1227 (DQ-mat), project B07, CRC 1128 geo-Q, EXC-2123 Quantum Frontiers, the German Space Agency (DLR) with funds provided by the BMWi due to an enactment of the German Bundestag under grant nos. 50WM1641, 50WM1556, 50WM1956, and 50WM0837, as well as by "Niedersächsisches Vorab" through the QUANOMET initiative (QT3) and through "Förderung von Wissenschaft und Technik in Forschung und Lehre" for the initial funding of research in the new DLR-SI Institute. D.S. acknowledges funding by the Federal Ministry of Education and Research through the funding program Photonics Research Germany under contract number 13N14875.

Q 54.23 Thu 16:30 Empore Lichthof

Setup for a transportable quantum gravimeter — •Jannik Wesche[1], Nina Heine[1], Jonas Matthias[1], Maral Sahelgozin[1], Waldemar Herr[1], Sven Abend[1], Jürgen Müller[2], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Erdmessung, Leibniz Universität Hannover

The transportable quantum gravimeter QG-1 strives for unprecedented accuracy opening up new geodetic applications, for example in hydrology. This poster will give an overview of the transportable QG-1 setup utilising matter-wave interferometry with Bose-Einstein condensates (BECs) of ^{87}Rb atoms. The BEC is created at the top of a dropping tube using atom chip technology. The atoms, acting as test masses for the measurement, are released into free fall under precise control of their external and internal degrees of freedom. To manipulate and interrogate the atoms a fibre-based miniaturised laser system is used. Together with the control electronics, it is integrated into a temperature stabilised rack. The presented compact design and the mobile rack integration grant QG-1 the possibility to measure local gravity at sites of interest for geodesy and geoscience.

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Q 54.24 Thu 16:30 Empore Lichthof

Characterisation of adhesive integration technologies for miniaturized optical setups in UHV — •Anne Stiekel[1,2], Marc Christ[1,2], and Markus Krutzik[1,2] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [2]Institut für Physik, Humboldt-Universität zu Berlin

Quantum technologies based on cold atoms allow for applications (e.g. timekeeping, sensing and communications) in the field and on space-based platforms. To access non-laboratory platforms, miniaturization of these systems into compact, rugged devices is an essential requirement. Besides physics package and electronics, this also includes miniaturization of the optical distribution and beam manipulation systems, ideally to be used in the UHV environment. Hence the used materials, components and integration technologies have to meet challenging demands regarding thermal and mechanical durability, as well as ultra-low outgassing.

To qualify the UHV-compatibility, an versatile system is being set up for residual gas analysis and measurement of total gas rates down to $5 \cdot 10^{-10}$ mbar l s^{-1}. This poster gives an overview of the UHV-system architecture, first results from its commissioning and our qualification test on optical components and integration technologies.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant number DLR 50WM1648, 50WM1949 and 50RK1978.

Q 54.25 Thu 16:30 Empore Lichthof

Entwicklung und Charakterisierung eines hochpräzisen Werkzeugs zur Laserstrahlausrichtung — •Kim Niewerth, Lea Bischof, Stefan Ast, Max Rohr, Daniel Penkert, Katharina-Sophie Isleif, Oliver Gerberding, Karsten Danzmann und Gerhard Heinzel — Albert-Einstein-Institut, Hannover, Deutschland

In Forschungsmissionen wie LISA oder Grace Follow-on werden präzise und hochauflösende Messmethoden zur Vermessung von Gravitationswellen sowie des Erdschwerefelds genutzt. Dabei ermöglichen optische Systeme in Form von monolithischen Interferometern die Messung von Verschiebungen mit Pikometer- und Nanometerauflösung. Das Albert-Einstein-Institut in Hannover verwendet in seinen Reinraumanlagen hochpräzise Werkzeuge für den Bau von Prototypen der Flughardware. Im Bauprozess werden diese Werkzeuge benötigt, um die hohen technischen Anforderungen von Pikometerstabilität zu erfüllen. Eines dieser Hilfsmittel ist eine kalibrierte Quadrantenphotodiode (cQP), an der zurzeit gearbeitet wird. Diese soll es ermöglichen, den Verlauf von Laserstrahlen zu bestimmen. Bei diesem Verfahren ist die aktive Fläche einer Photodiode in vier Quadranten unterteilt. Durch den Ausgleich der Leistungen in den vier einzelnen Quadranten kann die Position des Strahls auf der Photodiode zentriert werden. Mithilfe einer Koordinatenmessmaschine wird durch einen komplexen Kalibrierungsprozess die Position des Strahls ermittelt. Um die Vorteile des cQP zu nutzen, wird ein Hexapod verwendet, der die Positionierung und Manipulierung im um-Bereich ermöglicht.

Q 54.26 Thu 16:30 Empore Lichthof

Simulation of femtosecond pulse in a Kerr-lens mode-locked Ti:sapphire laser — •Nomin-Erdene Erdenebat, Khosochir Tsogvoo, Munkhbaatar Purevdorj, Baatarchuluun Tsermaa, and Davaasambuu Jav — Laser Research Center, National University of Mongolia, Mongolia

The Kerr-lens mode-locking (KLM) is known as a suitable method for generation of femtosecond pulses and mode-locked Ti:sapphire laser is now widely used sources of stable, energetic femtosecond pulses. We will present the simulation of KLM in Ti:sapphire laser cavities with a folded-cavity four-mirror by applying the ABCD ray-tracing technique for a Gaussian beam. Simulations will be performed for an asymmetric resonator design. Based on the numerical analysis, we will find the optimum design parameters (slit position, gain cavity spacing, gain medium position) for KLM. This work has been done with financial support of the Mongolian Foundation for Science and Technology.

Q 54.27 Thu 16:30 Empore Lichthof

Experimental Realisation of PT-Symmetric Flat Bands — •Tobias Biesenthal, Mark Kremer, Matthias Heinrich, and Alexander Szameit — Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, 18059 Rostock, Germany

Shaping the flow of light remains one of the core objectives in optics, and is inextricably linked to the concept of flat dispersion bands. At the same time, parity-time symmetric photonics provides new insights into the interplay of the real- and imaginary parts of complex potentials. We experimentally demonstrate that flat bands and compact localized states can be established at exceptional points of PT-symmetric lattices. Hence, even in scenarios aiming to arrest the propagation and diffractive broadening of optical signals, losses are not necessarily detrimental, and can serve as key ingredient in achieving photonic flat band responses in non-Hermitian environments.

Q 54.28 Thu 16:30 Empore Lichthof

Theoretical description of the plasmon-exciton coupling in organic-metallic hybrid systems — •Fabian G. Dröge[1,2], Alexander Schubert[1,2], and Stefanie Gräfe[1,2] — [1]Institut für Physikalische Chemie, Helmholtzweg 4, 07743 Jena, Germany — [2]Abbe Center of Photonics, Albert-Einstein-Str. 6, 07745 Jena, Germany

Nanoplasmonics is a new field of research emerging on the interface of atomic, molecular, and solid-state physics as well as (nano-)chemistry. Here, the interaction between metallic nanoparticles, electromagnetic fields, and an adjacent molecular system are described and evaluated.

We focus on the development of a self-consistent theoretical treatment of coupled metallic-organic hybrid materials from an electromagnetic, quantum chemical & dynamical perspective for an in-depth understanding of the dynamics of the combined hybrid system.

In this contribution we present the first results of our simulation of a coupled excitonic-plasmonic hybrid model system. Upon interaction with a time-dependent laser field, the inorganic metal model gives rise to a localised surface plasmon while a Frenkel exciton is formed on the organic molecular aggregate. The coherent temporal evolution of the coupled system is then simulated by numerically solving the time-dependent Schrödinger equation. Possible approaches towards the implementation will be discussed and the underlying approximations critically evaluated.

Q 54.29 Thu 16:30 Empore Lichthof

Simulations of Dipole Emitters Coupled to Inverted Cone Nanopillar Diamond Structures — •Cem Güney Torun[1] and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

Single, optically active quantum systems, such as single photon sources and quantum memories are building blocks for quantum technologies. In order to achieve sensitive quantum sensors, or quantum communication devices with high communication rates, we require efficient optical coupling to such quantum systems. In this work, we focus on a device that is simple in design and easy to produce but still enables photon extraction efficiencies as high as in more complex designs. In particular, we optimize numerically coupling efficiencies of a dipole emitter inside an inverted diamond nanocone to a single mode optical fibre. From our simulations we determine dipole to fibre mode coupling efficiencies of up to 86% extracted from overlap integrals between far-field intensity distribution and Gaussian fibre mode.

Q 54.30 Thu 16:30 Empore Lichthof

Integration of organic macromolecular compounds with nanophotonic waveguides — Alexander Eich[1], •Christian A. Strassert[2], and Carsten Schuck[1] — [1]Institute of physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]2 Institute of inorganic and analytic chemistry, University of Münster, Corrensstr. 28, 48149 Münster, Germany

The integration of quantum emitters with nano-photonic circuits enables quantum optic experiments on monolithic silicon chips. However, controlling the positioning of single nano-scale emitters or arrays of single emitters relative to nanophotonic structures is a major challenge for realizing integrated quantum light sources supplying photonic integrated circuits with single-photons.

In our work, we employ Silicon(IV) Phthalocyanine (SiPc) molecules as nano-emitters, which show distinguished photostability [1]. We embed SiPc molecules into a PMMA host matrix, which allows for thin-film application on top of prefabricated tantalum pentoxide (Ta2O5) waveguides. Lithographic patterning of the PMMA-thin film then achieves the desired overlay accuracy with respect to the nanophotonic devices. Here we report on the excitation of the molecules and collection of their fluorescent light through nano-photonic waveguides, thus paving the way for integrated quantum photonic experiments.

[1] A. J. Pearson et al., Journal of Materials Chemistry C 5.48, doi: 10.1039/c7tc03946h (2017)

Q 54.31 Thu 16:30 Empore Lichthof

Design of a cryogenic Low Noise Amplifier — •Roland Jaha[1,2,3], Manuel Delgado-Restituto[4,5], Jorge Fernández-Berni[4,5], Ricardo Carmona Galán[4,5], Matthias Häussler[1,2,3], Martin A. Wolff[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]SoN - Center for Soft Nanoscience, Busso-Peus-Str. 10, 48149 Münster, Germany — [4]University of Seville, C/S. Fernando 4, 41004 Seville, Spain — [5]Instituto de Microelectrónica IMSE-CNM, Cl Américo Vespucio 28, 41092 Seville, Spain

Microwave low noise amplifiers (LNAs) are essential signal processing components of a very large number of scientific systems that are naturally concerned with low temperature environments. However, state-of-the-art LNAs are typically operated at room temperature and suffer from high noise temperatures in the radio frequency (RF) range. Here we show how significantly reduced noise temperatures below 15 K can be achieved with cryogenic LNAs. We exploit the high carrier mobility and low loss of silicon-germanium heterojunction bipolar transistors at cryogenic temperatures and optimize amplifier designs for RF signals originating from superconducting nanowire single photon detectors. We achieve LNA designs providing >4 GHz bandwidth signal amplification with up to 45 dB gain, dissipating only 5 mW of power. Our results will allow for significantly enhanced small-signal processing at cryogenic temperatures with minimal impact on the thermal budget.

Q 54.32 Thu 16:30 Empore Lichthof

Self-focusing of Bose-Einstein condensates — •Patrick Boegel[1], Matthias Meister[1], Jan-Niclas Siemss[2], Naceur Gaaloul[2], Maxim A. Efremov[3], and Wolfgang P. Schleich[1,3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Ulm, Germany — [2]Institut für Quantenoptik, Leibniz University Hannover, Hannover, Germany — [3]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Ulm, Germany

The standard way to control the position and the strength of maximal focusing of a matter-wave is to use a lens which imprints a position-dependent phase on the initial wave. However, quantum mechanics allows focusing even without a lens [1,2], based on diffractive focusing, where the initial wave function is a real-valued one with a non-Gaussian shape. Hence, the problem of optimal focusing translates into finding an appropriate initial wave function [3]. We explore the phenomenon of diffractive focusing of an atomic Bose-Einstein condensate (BEC) in the regime, where the resonant atom-atom interaction plays a key role, and describe this effect in phase space within the Wigner function approach.

This project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under the grant numbers 50WP1705 and 50WM1862.

[1] Case, W.B. et al. Optics Express 20, 27253 (2012)
[2] Weisman D. et al. Phys. Rev. Lett. 118, 154301 (2017)

[3] Vogel, K. et al., Chem. Phys. 375, 133-143 (2010)

Q 54.33 Thu 16:30 Empore Lichthof

Anomalous Floquet topological phases in periodically-driven hexagonal lattices — •Karen Wintersperger[1,2], Christoph Braun[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstraße 4, 80799 München — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Ultracold atoms in periodically-driven optical lattices can be used to simulate systems with nontrivial topological properties. Due to the periodic driving, energy conservation is relaxed which makes it possible to realize systems with properties that go beyond those of conventional static systems. For instance, chiral edge modes can exist even if the bulk is topologically trivial [1].

We study such anomalous Floquet phases experimentally using a BEC of K39 in an optical honeycomb lattice with periodically modulated tunnel couplings. By monitoring the closing and reopening of energy gaps in the band structure we are able to track the transitions between different Floquet phases. Moreover, we probe the topological porperties of the bulk by measuring the Hall deflection induced by local changes in the Berry curvature. Combining these measurements enables us to extract the topological invariants of the bulk bands and the energy gaps, which are both required to accurately classify the topological phases of Floquet systems [2, 3].

[1] T. Kitagawa et al., Phys. Rev. B 82, 235114 (2010) [2] M. Rudner et al., PRX 3, 031005 (2013) [3] N. Ünal et al., PRL 122, 253601 (2019)

Q 54.34 Thu 16:30 Empore Lichthof

Ground state and dynamics of shell-shaped BEC mixtures — •Alexander Wolf[1], Matthias Meister[1], Maxim A. Efremov[2], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ$^{\mathrm{ST}}$), Universität Ulm, D-89069 Ulm, Germany — [2]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt (DLR), D-89077 Ulm, Germany

Recently, there has been great interest in the properties of hollow Bose-Einstein condensates (BECs), which are generated nowadays with radio-frequency (rf) dressing [1]. As an alternative method, we propose to realize hollow BECs by utilizing a dual-species mixture. A proper choice of the parameters allows us to create a ground state where one species is in the center and generates a repulsive effective potential for the second species, giving rise to a shell-shaped BEC [2]. In order to obtain the main properties of this setup, in particular the width of the outer shell, we employ the Gross-Pitaevskii equation within the Thomas-Fermi approximation. Moreover, we investigate the spectrum of collective excitations with an emphasis on the transition from a filled to a hollow geometry. In the latter case, a new inner boundary appears, leading to a change of the collective mode spectrum.

This 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 50WP1705.

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Q 54.35 Thu 16:30 Empore Lichthof

Stabilization of a dark soliton by localised dissipation — •Alexandre Gil Moreno[1], Christian Baals[1,2], Jens Benary[1], Marvin Röhrle[1], Jian Jiang[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany

We numerically study the stability of a dark soliton in a 3D system using the Gross-Pitaevskii equation with an imaginary potential. Our starting point is the ground state of a Bose-Einstein condensate in an elongated harmonic trap with a dark soliton. This initial state decays due to the sneaking instability, which means that the dark soliton eventually turns into a vortex ring. By applying local losses (i.e. a local imaginary potential) at the centre, we observe a slow down of the decay with increasing imaginary potential. Above a critical dissipation strength, the soliton becomes stabilised (within our computational time).

Q 54.36 Thu 16:30 Empore Lichthof

High fidelity two-qubit quantum gate with neutral atoms — •Hui Sun[1,2], Bing Yang[1,2], Han-yi Wang[1,2], Zhen-sheng Yuan[1,2], and Jian-wei Hui[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Cold neutral atoms hold great promise for constructing a quantum device that outperform the classical computer. However, the imperfections of gate operations hinder the implementation of fault-tolerant quantum computing, which requires the operation error to be lower than the threshold 10^{-2}. Here, we report on a high-fidelity two-qubit gate entangling 1250 pairs of neutral atoms in parallel with a operation error of $7(1) \times 10^{-3}$. By improving the precision of controlling the lattice potential, the gate operation driven by the second-order superexchange interaction achieve the same energy scale as the on-site interaction of the Hubbard model. The coherence time is prolonged and the decoherence of entanglement in optical lattice is mainly governed by the intrinsic light scattering. We calibrate the gate fidelity to be 99.3(1)% by measuring spin correlations of the quantum state after multiple gates performed on the atom pairs. Our experiment represents a benchmark towards fault-tolerant quantum computing with neutral atoms.

Q 54.37 Thu 16:30 Empore Lichthof

Phasonic Spectroscopy of a Quantum Gas in a Quasicrystalline Lattice — Shankari V. Rajagopal[1], Toshihiko Shimasaki[1], Peter Dotti[1], •Mantas Raciunas[2], Ruwan Senaratne[1], Egidijus Anisimovas[2], André Eckardt[3], and David M. Weld[1] — [1]Department of Physics, University of California, Santa Barbara, California 93106, USA — [2]Institute of Theoretical Physics and Astronomy, Vilnius University, Sauletekio 3, LT-10257 Vilnius, Lithuania — [3]Max-Planck-Institut fur Physik komplexer Systeme, Nothnitzer Str. 38, 01187 Dresden, Germany

Phasonic degrees of freedom are unique to quasiperiodic structures, and play a central role in poorly-understood properties of quasicrystals from excitation spectra to wavefunction statistics to electronic transport. However, phasons are challenging to access dynamically in the solid state due to their complex long-range character and the effects of disorder and strain. We report phasonic spectroscopy of a quantum gas in a one-dimensional quasicrystalline optical lattice. We observe that strong phasonic driving produces a nonperturbative high-harmonic plateau strikingly different from the effects of standard dipolar driving. Tuning the potential from crystalline to quasicrystalline, we identify spectroscopic signatures of quasiperiodicity and interactions and map the emergence of a multifractal energy spectrum, opening a path to direct imaging of the Hofstadter butterfly.

Q 54.38 Thu 16:30 Empore Lichthof

Dirty Fermions — •André Becker and Axel Pelster — Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

We consider fermionic atoms in a harmonic trapping potential and analyze the impact of a frozen random environment in the BCS regime. To this end we investigate the effect of either laser speckles or impurity disorder upon the Cooper pairing of fermions without population imbalance. In close analogy to the corresponding case study [1] in the BEC regime, we treat disorder perturbatively as well as non-perturbatively, and focus, in particular, upon the question how the Thomas-Fermi radii of the cloud depend on the disorder strength. Finally, we discuss our findings in view of Anderson's theorem which states that superconductivity is robust with respect to non-magnetic disorder in the host material [2].

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[2] P.W. Anderson, J. Phys. Chem. Solids. **11**, 26 (1959)

Q 54.39 Thu 16:30 Empore Lichthof

Towards a Lithium Quantum Gas Microscope for Tailored Few-Body Systems — •Mathis Fischer, Andreas Kerkmann, Michael Hagemann, Justus Brüggenjürgen, Tobias Petersen, Klaus Sengstock, and Christof Weitenberg — Institute for Laser Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We are setting up a new quantum gas microscope for the preparation and detection of degenerate samples of ^{6}Li/^{7}Li atoms to study strong correlations in small quantum systems.

Our setup features a compact 2D-/3D-MOT loading scheme, subsequently followed by a lambda-enhanced gray molasses. This allows for an all optical cooling approach of our atomic samples to degeneracy in a crossed optical dipole trap. Since we avoid an additional atom transport, this setup supports short cycle times.

We report on the realization of a molecular BEC of fermionic ^{6}Li atoms in the focal plane of a high-resolution imaging setup by using a well-controlled intensity ramp for the evaporation that circumvents thermal effects in acousto-optical modulators. In addition, we will present the loading of the BEC into a 2D triangular lattice and a 1D accordion lattice.

In the future, we will look at few-body systems in specifically tailored optical potentials to study new regimes, e.g., ionization dynamics in artificial atoms or fractional Quantum Hall physics in rotating microtraps. In this poster, we provide information about the details of the design, the current status of the experiment and our future plans.

Q 54.40 Thu 16:30 Empore Lichthof

Topological effects in Floquet-engineered ultracold matter — Luca Asteria[1], •Henrik Zahn[1], Marcel Kosch[1], Bojan Hansen[1], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut für Laserphysik, Universität Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany

Ultracold atoms in optical lattices constitute a versatile platform to study the fascinating phenomena of gauge fields and topological matter. Periodic driving can induce effective Floquet Hamiltonians with non-trivial Chern number and thus paradigmatic models, such as the Haldane model on the honeycomb lattice, can be directly engineered. Here we present our recent experiments, in which we realized new approaches for measuring the Chern number in this system and map out the Haldane phase diagram. This includes quantized circular dichroism as a dissipative analog of the quantized Hall conductance as well as time-resolved Bloch-state tomography allowing for the observation of a dynamical linking number. These experiments define an excellent starting point for the exploration of interacting topological phases with ultracold atoms.

Q 54.41 Thu 16:30 Empore Lichthof

Floquet-phases in Optical Kagome Lattices — •Marcel Kosch[1], Luca Asteria[1], Henrik Zahn[1], Bojan Hansen[1], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany

The Kagome lattice is a hexagonal lattice with a three-atomic basis and has received considerable interest due to its flat band, which should give rise to spin liquid phases. While naturally the uppermost of the three bands is flat, this structure can be inverted by applying Floquet shaking.

Already at smaller shaking amplitudes, a circular shaking induces topological bands analogous to the Haldane model in the driven honeycomb lattice, however, with a more favorable flatness ratio between the band width and band gap. It is therefore a promising starting point for the study of interacting topological phases.

In this poster, we present a numerical study of the topological phase diagram of the driven optical Kagome lattice. We also recall how it can be realized as a hexagonal superlattice from two commensurate wavelengths and describe how it will be realized in our setup of ultracold fermionic and bosonic quantum gases.

Q 54.42 Thu 16:30 Empore Lichthof

Manipulating the complex-valued temporal shape of a photon — •Stefan Langenfeld, Olivier Morin, Matthias Körber, Philip Thomas, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Single photons are the most used carrier to transfer qubits over a quantum network. Over the last decades many platforms were developed in order to absorb and emit single photons. To stay in the quantum regime, the success of these operations relies on the perfect control of all degrees of freedom of the electromagnetic field. The temporal mode function is explicitly challenging to handle experimentally. Most platforms do not offer large and accurate flexibility on this particular degree of freedom making the connection of multiple devices difficult. Here, we investigate thoroughly the possibilities offered by a cavity quantum electrodynamics (QED) system, namely a single ^{87}Rb atom in a high finesse cavity. Starting from previous theoretical works [1,2], we developed a comprehensive and exhaustive model of our system [3]. Thanks to this, we experimentally demonstrate a very high control of the temporal mode of a single photon in amplitude and phase. This opens up various possibilities as for instance modifying the temporal shape by 3 orders of magnitude in bandwidth. It also shows that our platform can be compatible with many others and can even be used as a photon shape converter.

[1] A. Gorshkov *et al.*, Phys. Rev. A **76**, 033804 (2007).
[2] L. Giannelli *et al.*, New J. Phys. **20**, 105009 (2018).
[3] O. Morin *et al.*, Phys. Rev. Lett. **123**, 133602 (2019).

Q 54.43 Thu 16:30 Empore Lichthof

Measuring the temporal mode function of photonic states — •Olivier Morin, Stefan Langenfeld, Matthias Körber, Philip Thomas, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

Quantum physics, and quantum information in particular, relies on the accurate control of the quantum states. For optical states, while some well-establish techniques exist for the characterization of polarization and spatial degrees of freedom, it remains a non-trivial task to measure the temporal mode function of a quantum state. Here we present an easy-to-implement and accurate solution [1]. Our method is based on homodyne measurements. We show that the proper processing of the auto-correlation function can give access to any complex-valued temporal mode function. Beyond the theoretical principle, we also consider the experimental constraints and provide the key aspects to obtain a trustworthy reconstruction. We have tested our method on an advanced temporal shape and reach a fidelity as high as 99.4%. This technique has also been used to characterize the complex-valued temporal shape of a single photon emitted from a CQED system. Hence, we believe that this method can be applied to many other systems and become a standard routine in quantum optics laboratories.

[1] O. Morin et al., ArXiv 1909.00859 (2019)

Q 54.44 Thu 16:30 Empore Lichthof

Generation of non-classical light states with an optical cavity — •Lukas Hartung[1], Severin Daiss[1], Bastian Hacker[1,2], Stephan Welte[1], Stephan Ritter[1,3], Lin Li[1,4], Emanuele Distante[1], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Present address: Max-Planck-Institut für die Physik des Lichts, Staudtstr. 2, 91058 Erlangen — [3]Present address: TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Gräfelfing, Germany — [4]Present address: School of Physics, Huazhong University of Science and Technology, Wuhan, China

Engineering quantum states of light is a long standing goal in quantum optics which finds significant applications in quantum communication and quantum information technologies. On this poster, we demonstrate the production of different non-classical light states. Our protocol is based on the interaction of an impinging laser pulse with a single atom trapped in a high-finesse optical resonator. As a result of this interaction, the light pulse gets entangled with the internal state of the atom. A suitable subsequent measurement on the atomic state can be used to engineer different output light states. This allows us to produce single photons out of coherent input light with arbitrary temporal mode profiles [1] as well as to generate optical cat states [2].

[1] Daiss, Welte, Hacker, Li and Rempe, Phys. Rev. Lett. 122, 133603 (2019)
[2] Hacker, Welte, Daiss, Shaukat, Ritter, Li and Rempe, Nat. Photon. 13, 110 (2019)

Q 54.45 Thu 16:30 Empore Lichthof

Satellite- vs Ground-based quantum networks and the role of quantum repeaters — •Carlo Liorni, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität, Düsseldorf, Germany

Entanglement distribution over global distances (thousands of km) is a very daunting task. The exponential losses experienced during the propagation of light in optical fibres limit the achievable distances to ~ 200 km in practice. A possible solution consists in the use of quantum repeaters, based on entanglement swapping or quantum error correction. Satellite-based optical links can be very advantageous in this case, as the losses scale only quadratically with the distance, when atmospheric effects are small. In this work, we analyse a scheme that combines these two ingredients, ground-based quantum repeaters and satellite-based links in the downlink configuration, in order to achieve long distance entanglement distribution. The performance of this repeater chain is assessed in terms of the secret key rate achievable by the BB-84 cryptographic protocol, that depends on both the entanglement distribution rate and the quality of the final shared state. The comparison with the fibre-based implementation shows that the satellite-mediated scheme performs better in almost every situation. Finally, we propose an augmented scheme that takes advantage of orbiting quantum repeater stations in order to achieve higher key rates, reliability and flexibility. The integration between satellite-based links and ground repeater networks can be envisaged to represent the backbone of the future Quantum Internet.

Q 54.46 Thu 16:30 Empore Lichthof

Single trapped atoms coupled to crossed fiber cavities — •Pau Farrera[1,2], Dominik Niemietz[1], Manuel Brekenfeld[1], Gianvito Chiarella[1], Joseph Dale Christesen[1,3], and Gerhard Rempe[1] — [1]Max Planck Institute of Quantum Optics, 85748 Garching, Germany — [2]ICFO-The Institute of Photonic Sciences, Barcelona, Spain — [3]NIST, Boulder, Colorado 80305, USA

Recent experimental advancement in the field of optical cavity QED comprises two directions of development: a further reduction of the mode volumes of the resonators, as with the development of fiber-based Fabry-Perot cavities (FFPCs) [1], and an increase in the number of well-controlled modes the emitters can couple to [2,3]. We have set up a new experiment that combines these two experimental advancements in a single platform with single neutral atoms trapped at the center of two crossed FFPCs. This novel setup provides new challenges and capabilities, such as the fabrication and assembling of high-finesse fiber cavities, the strong coupling of single atoms to both cavity modes for long trapping times, the atom imaging system, or the microwave manipulation of the atomic states. Some of the mentioned capabilities were recently used to implement a passive, heralded and high fidelity optical quantum memory. In the future, they will enable the development of other novel quantum information processing schemes based on two-mode cavity QED.

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[2] Leonard et al.,Nature 543, 87 (2017)
[3] Hamsen et al., Nat. Phys. 14, 885 (2018)

Q 54.47 Thu 16:30 Empore Lichthof

Wavelength Conversion of Single Photons between the UV and Near-Infrared — •Marcel Hohn and Simon Stellmer — Physikalisches Institut der Universität Bonn, Nussallee 12, 53115 Bonn

The Cluster of Excellence ML4Q (Matter and Light for Quantum Computing), a cooperation between the universities of Cologne, Aachen, Bonn, as well as the Research Center Jülich, aims to develop new computing and networking architectures. Several hardware platforms for quantum computing, such as spin qubits and trapped ions, are investigated in the course of the collaboration. The coupling of these systems via single photons for long-distance quantum information transport allows for the development of a heterogeneous network. The interconnection of distinct platforms additionally requires the conversion of the single photons between the respective wavelengths of the systems while preserving quantum correlations. Here we report on the development of a quantum frequency conversion (QFC) setup between the Yb^+ dipole transition at 369.5 nm and InGaAs quantum dots at around 850 nm using sum- and difference frequency generation (SFG/DFG) in a periodically poled potassium titanyl phosphate (PPKTP) waveguide structure.

Q 54.48 Thu 16:30 Empore Lichthof

Towards a coherent spin photon interface for quantum repeaters using color centers in diamond — •Maximilian Pallmann[1], Jonathan Körber[1], Rainer Stöhr[2], Evgenij Vasilenko[1], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Universität Stuttgart

Building a long distance quantum network is one of the big challenges in the field of quantum communication, which requires the development of a quantum repeater. A crucial component of this is an efficient, coherent spin-photon interface, and coupling single color centers in diamond to a microcavity is a promising approach therefor. In our experiment, we integrate a diamond membrane to an open access fiber-based Fabry-Perot microcavity to attain emission enhancement of color centers into a single well-collectable mode as well as spectral filtering. Simulations predict the feasibility of a strong enhancement of the ZPL emission efficiency, reaching values of up to 80% for NV centers. We present a spatially resolved characterization of a coupled cavity-membrane device and report on the current status of the experiment.

Q 54.49 Thu 16:30 Empore Lichthof

Tight bound on the eavesdropper's information in a multipartite device-independent scenario — •Federico Grasselli, Glaucia Murta, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, Düsseldorf, Germany

The security of device-independent (DI) quantum key distribution (QKD) holds independently of the actual functioning of the quantum devices and is based on the observation of a Bell inequality violation. In the seminal work by Pironio et al. [New J. Phys. 11, 045021 (2009)], the authors derive a tight bound on the eavesdropper's information which only depends on the violation of the Clauser-Horne-Shimony-Holt (CHSH) inequality observed by two parties. In a DI conference key agreement (CKA), the goal is to establish a conference key among several users by relying on a multipartite Bell inequality violation. So far, the security of such protocols either adapts the result of Pironio et al. (tightness not being guaranteed) or relies on loose numerical procedures (Navasqués-Pironio-Acin hierarchy). In this work, we obtain a tight bound on the eavesdropper's information when three parties observe a violation of the Mermin-Ardehali-Belinskii-Klyshko (MABK) inequality. The bound and its derivation can find applications in DICKA protocols. In order to obtain it, we also derive an analytical bound on the maximal violation of the MABK inequality achieved by an arbitrary three-qubit state.

Q 54.50 Thu 16:30 Empore Lichthof

Towards long coherence times for a single atom in a standing-wave dipole trap — •Derya Taray[1], Tim van Leent[1], Robert Garthoff[1], Kai Redeker[1], Matthias Seubert[1], Wei Zhang[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

Long-distance entanglement distribution is the key ingredient in future quantum networks, which will enable distributed quantum computing and quantum communication. To reach long distances, quantum memories with prolonged coherence times are required. Currently we entangle two Rubidium 87 atoms separated by 400 meters via the entanglement swapping protocol [1,2]. Yet, for increasing the separation by at least one order of magnitude the atomic state coherence is the limiting factor, mainly due to position-dependent dephasing in the strongly focused dipole trap.

In this work, we present results towards the implementation of a standing-wave dipole trap, in which the longitudinal field components, causing the dephasing cancel. Two counter-propagating dipole trap beams are focused to 2 micrometer by high-NA objectives, with active phase and directional stabilization of one beam. This should increase the coherence time to several ms, enabling distribution of atom-photon entanglement with a fidelity of 90% over a distance of 100 km.

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Q 54.51 Thu 16:30 Empore Lichthof

Quantum Key Distribution with Small Satellites — •Peter Freiwang[3], Lukas Knips[3,5], Leonhard Mayr[3], Wenjamin Rosenfeld[3], QUBE consortium[1,2,3,4,6], and Harald Weinfurter[3,5] — [1]Center for Telematics (ZfT), Würzburg — [2]German Aerospace Center (DLR) IKN, Oberpfaffenhofen — [3]Ludwig-Maximilian-University (LMU), Munich — [4]Max Planck Institute for the Science of Light (MPL), Erlangen — [5]Max Planck Institute of Quantum Optics (MPQ), Garching — [6]OHB System AG, Oberpfaffenhofen

Future global secure communication networks will rely on QKD with satellites. After the first successful demonstration by the Chinese satellite MICIUS, the question arises how small a satellite can be designed. We report on the progress to build a BB84 QKD payload for the nano-satellite mission QUBE. Faint laser pulses from four VCSELs at 850 nm are polarized using an array of polarizer foils and focused into a waveguide chip, which couples the four input modes into a single mode fiber. The QKD optics which will be mounted onto a 9x9 cm^2 PCB well suites as small and robust unit for the cube-satellite system. Together with a second quantum payload for CV-QKD and quantum random number generation, this mission will study the feasibility of cost effective QKD with nano-satellites in low-earth-orbits ($\sim$ 500 km altitude). In the first phase, the satellite with a planned size of only

30x10x10 cm^3 is equiped with an optical terminal (OSIRIS, aperture 20 mm) for the downlink to the optical ground station (Ø 80 cm) and will allow important tests of space capable QKD hardware.

Q 54.52 Thu 16:30 Empore Lichthof

Time-domain wavefront shaping for secure communication — •Matthias C. Velsink and Pepijn W.H. Pinkse — MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

Recently, we applied wavefront shaping techniques to implement quantum-secure readout of a physical unclonable key for authentication [1] and communication [2]. Unfortunately, spatial wavefront shaping is unsuitable for long-distance use. We therefore propose to use wavefront shaping in the time domain using a single spatial mode. We show spatiotemporal control of a pulse through a complex medium. Furthermore, we investigate a secure communication method based on physical unclonable functions in the time domain. We will report on the progress.

Reference

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[2] R. Uppu *et al.*, Asymmetric cryptography with physical unclonable keys, *Quantum Sci. Technol.* **4**, 045011 (2019).

Q 54.53 Thu 16:30 Empore Lichthof

Design and impelementation of a segmented ion trap with an integrated fiber cavity — •Omar Elshehy, Stephan Kucera, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, Campus E2.6, 66123 Saarbrücken

Efficient atom-photon interfaces are a basic requirement for any quantum network [1,2]. The efficiency of such interfaces has been shown to increase significantly by the use of cavities [3]. We present a segmented ion trap design for $^{40}Ca^{+}$ ions with an integrated fiber cavity. The trap design is optimized for the implementation of the Mølmer Sørensen gate [4] for quantum repeater applications. The fiber cavity is incorporated into the center electrodes of the trap and mounted inside intrinsically stable ferrules. Additionally, micro-structured multimode fibers are fitted for efficient photon collection. A prototype of the trap is presented along with simulation results of the trap potential. In addition, we show results of the cavity transmission and its stability, as well as microscope images of the micro-structured multimode fibers and their analysis.

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[2] M. Bock et al., Nat. Commun. **9**, 1998 (2018)
[3] T. G. Ballance et al., Phys. Rev. A **95**, 033812 (2017)
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