Q 22: Posters: Quantum Optics and Photonics II

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

Q 22.1 Tue 16:30 Empore Lichthof

Systematic investigations of a 633-nm iodine stabilized diode laser utilizing NICE-OHMS — •Florian Krause, Erik Benkler, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

The wavelength 633 nm is common for interferometry and metrology and helium-neon lasers are the prevalent source. Nevertheless, another laser technique is needed, because the technical know-how for building and maintaining helium-neon lasers is vanishing. Iodine stabilized diode lasers at 633 nm using the Noise-Immune Cavity-Enhanced Optical Heterodyne Spectroscopy (NICE-OHMS) technique are promising candidates for an alternative practical realization of the meter.

An extended-cavity diode laser (ECDL) is stabilized to hyperfine lines of $^{127}I_2$. At an averaging time of 1 s this system reaches a short-term frequency instability of 2.4×10^{-12}, which is better than an iodine stabilized helium-neon laser. However, long-term environmental influences disturb the frequency. Systematic investigations of these influences on the absolute frequency were carried out to enable further improvement of the stability. For example the sensitivity on the mismatch between NICE-OHMS modulation frequency f_{mod} and the Free Spectral Range (FSR) f_{FSR} of the cavity was examined. To avoid this mismatch, the modulation frequency f_{mod} is actively locked to the FSR.

For comparison NICE-OHMS signals were simulated, considering the special structure of the iodine spectrum, which consists many overlapping Doppler-broadened hyperfine lines.

Q 22.2 Tue 16:30 Empore Lichthof

Raman laser system for controlling ^{9}Be$^+$ ion qubits — •Simon Rossmann[1], Timko Dubielzig[1], Sebastian Halama[1], Giorgio Zarantonello[1,2], Henning Hahn[1,2], Amado Bautista-Salvador[1,2], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universtiät Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We operate a cryogenic surface-electrode ion trap setup for ^{9}Be$^+$ ions. In our project, logic operations are typically carried out using integrated near-field microwave conductors; for bootstrapping and ground state cooling, we employ stimulated-Raman laser pulses. The light for this system is provided via sum-frequency generation of two tunable infrared fiber lasers and a subsequent second harmonic generation. The second harmonic stage is realized using a monolithic cavity design, similar to [1]. The generated 313 nm light is power stabilized and split into two beams. Each of those is frequency shifted in a double-pass AOM setup to realize two beams with a frequency difference of 1083 MHz, corresponding to our qubit transition. To avoid beam pointing fluctuations caused by duty cycle dependent temperature changes within the AOMs [2], we have developed a setup that can cancel this jitter.

[1] S. Hannig *et al.*, Rev. Sci. Instrum. **89**, 013106 (2018)
[2] Yiheng Lin, PhD Thesis, CU Boulder (2015)

Q 22.3 Tue 16:30 Empore Lichthof

Design and Implementation of a Spliced CW-Fiber Amplifier for a Brillouin-LIDAR System — •Benedikt Langfeld, Daniel Koestel, and Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, 64289 Darmstadt

In this work, we present a Brillouin-LIDAR system as an alternative to contact-based measuring techniques for the temperature profiles of the oceanic mixed layer (up to 100 m). This is achieved by exploiting the temperature dependent frequency shift of Brillouin-scattered light.

The LIDAR laser system consists of a cw source followed by a series of cw and pulsed fiber amplifiers. An acousto-optic modulator (AOM) between the cw and pulsed stages is used to form pulses with a duration of 10 ns and flexible repetition rate between 1 kHz and 1 MHz. Finally, the pulses are converted into the green spectral range. To measure the frequency shift of the Brillouin-scattered light, we implemented an adjustable edge filter based on an atomic transition of rubidium [1].

To make the operation of the LIDAR system in a helicopter feasible, the system has to be insensitive to vibrations to prevent misalignment of the laser beam. For this reason the system should be completely fiber based. We present a spliced cw-fiber amplifier in a double pass configuration, whose amplified power is used as the basis for the pulse generation by the AOM.

[1] A. Rudolf and T. Walther, Opt. Lett. **37**, 4477-4479 (2012)

Q 22.4 Tue 16:30 Empore Lichthof

Monolithic Fiber Fabry Perot cavities for spectroscopy — •Florin Hemmann, Carlos Saavedra Salazar, Madhavakkannan Saravanan, Hannes Pfeifer, Deepak Pandey, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Rheinische Friedrich-Wilhelms-Universität Bonn, Deutschland

Fiber Fabry Perot cavities (FFPC) have emerged as an interface to enhance light-matter interactions [1]. Fabricating versatile and robust fiber cavities as required for most applications however remains a challenging task. By combining fiber guiding glass ferrules with piezo elements we develop a monolithic FFPC design that exhibits high passive stability and large locking bandwidths combined with a tunability over a full free spectral range.

One promising application of these stable resonators is as a miniaturized system for spectroscopy of gases. We demonstrate the ability to determine various oxygen concentration levels in a prototype experiment.

[1] D. Hunger. New Journal of Physics 12. 065038 (2010)

Q 22.5 Tue 16:30 Empore Lichthof

A laser sytem for sideband cooling of single ^{9}Be$^+$ ions in a Penning trap — •Julian Pick[1], Johannes Mielke[1], Teresa Meiners[1], Matthias Borchert[1,3], Frederik Jacobs[1], Amado Bautista-Salvador[1,2], Juan M. Cornejo[1], Malte Niemann[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN

The BASE collaboration pursues the goal to perform high precision measurements of the (anti-)proton g-factor as tests of CPT invariance in the baryonic sector. Quantum logic inspired cooling and readout techniques based on a co-trapped laser-cooled ^{9}Be$^+$ ion can potentially be applied to contribute to these measurements. However, for many of the proposed methods it is desirable for the ion to be in the motional ground state.

Here we present a Raman laser system for sideband cooling of single ^{9}Be$^+$ ions in a Penning trap. The system consists of three tunable cw infrared fiber-lasers and generates two beams at 313 nm via sum frequency generation and subsequent second harmonic generation. The Raman beams need to bridge the 140 GHz qubit splitting at a magnetic field of 5 T. Phase coherence is ensured by implementing an optical phase-locked loop for the infrared fiber-lasers.

We present recent progress in the implementation and characterization of the laser system, as well as the concepts for the integration of this system into the experiment.

Q 22.6 Tue 16:30 Empore Lichthof

A cw-OPO system for ultimate M-IR frequency resolution — •Ulrich Eismann[1], David B. Foote[2], Matt Cich[2], Walter Hurlbut[2], Felix Rohde[1], and Chris Haimberger[2] — [1]TOPTICA Photonics AG, Lochhamer Schlag 19, D-82166 Graefelfing, Germany — [2]TOPTICA Photonics, Inc., 5847 County Rd. 41, Farmington, NY 14425, USA

Continuous-wave optical parametric oscillators (cw-OPOs) are versatile light sources for quantum technologies. They deliver tunable narrow-band light in a large wavelength range, and output powers ranging from high-flux heralded photon sources up into the multi-10-Watt class have been demonstrated.

Here, we present a commercial cw-OPO (TOPTICA DLC TOPO) emitting up to 4 W in the 1.45–4.0 μm range and results of frequency referencing. The absolute accuracy of our current scheme is in the low 10^{-3} cm^{-1} range ($\approx$ 100 MHz). It is given by the accuracy and resolution of the wavelength meter, and the abundance of nearby reference peaks. Using a frequency comb as a reference, ultimate accuracies can be achieved. At its extreme, the scheme allows phase-coherent links between the M-IR and other wavelength ranges of choice [1]. We will discuss locking of the system to a commercial comb system DFC CORE.

[1] E. V. Kovalchuk et al., Optics Letters 30, 3141-3143 (2005).

Q 22.7 Tue 16:30 Empore Lichthof

Atom Trap Trace Analysis: An ultra-sensitive spectroscopy technique for dating of environmental tracers — •Julian Robertz[1], Lisa Ringena[1], Maximilian Schmidt[1,2], Niccolo Rigi-Luperti[1], Florian Sandel[1], Jeremias Gutekunst[1], Arne Kersting[2], Yannis Arck[2], David Wachs[2], Annabelle Kaiser[2], Werner Aeschbach[2,3], and Markus Oberthaler[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Institute for Environmental Physics, Heidelberg, Germany — [3]Heidelberg Center for the Environment, Heidelberg, Germany

Environmental tracers serve as an important source of information in a wide range of natural sciences. Due to the low relative abundance of some of these tracers an ultra-sensitive detection technique is necessary. In the case of the environmental tracer ^{39}Ar the Atom Trap Trace Analysis (ATTA) allows us to measure relative abundances in the range of 10^{-16}. The isotopic shift in the resonance frequency together with multiple resonant scattering processes grants perfect selectivity. Single atoms are captured and identified in a magneto-optical trap (MOT), while the huge background of abundant isotopes remains unaffected.

This ultra-sensitive spectroscopy technique was successfully used to study groundwater, lake, ocean and ice samples. In order to stretch the available dating range to younger ages, first steps regarding ATTA with ^{85}Kr have been taken. Preliminary investigations for the new laser system will be presented.

Q 22.8 Tue 16:30 Empore Lichthof

High-precision spectroscopy enhanced with squeezed light — •Jonas Junker[1,2,3], Dennis Wilken[1,2,3], Elanor Huntington[4], and Michèle Heurs[1,2,3] — [1]Max Planck Institute for Gravitational Physics, and Institute for Gravitational Physics, Germany — [2]QuantumFrontiers — [3]PhoenixD — [4]Centre for Quantum Computation & Communication Technology and Research School of Engineering, The Australian National University, Australia

Highly sensitive spectroscopic measurements require suppression of intrinsic noise within the apparatus. At low frequencies, active control can reduce dominant technical noise sources down to the fundamental shot noise limit. In addition to noise reduction, the achieved signal-to-shot-noise ratio can also be improved by increasing the laser power, at least up to the damage threshold of the probe. Here, we demonstrate an alternative approach that improves the signal-to-shot-noise ratio without increasing the laser power. Technical noise sources can be avoided by phase modulating the signal. In order to additionally decrease the shot noise, the signal is superimposed with high-frequency non-classical states of light. The goal is to detect small phase or amplitude signals at kHz frequencies that can be masked by technical noise sources, but also by shot noise. With our approach, we can uncover these signals without increasing the laser power. We present experimental results and the theoretical derivations supporting them. Our proposed technique is interesting for such applications as high-precision cavity spectroscopy, in particular for explosive trace gas detection where the specific gas may set a limit for the used laser power.

Q 22.9 Tue 16:30 Empore Lichthof

Tunable vacuum ultaviolet laser setup for first nuclear spectroscopic measurements on thorium — •Philip Mosel, Uwe Morgner, and Milutin Kovacev — Institut für Quantenoptik, Cluster of Excellence PhoenixD and QuantumFrontiers, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

The metastable transition from the nuclear ground state to the first excited state of the thorium isotope ^{229}Th with a calculated lifetime in the range of 10^{-4}s [1] is a promising candidate for the realization of the first optical nuclear clock. Due to its extraordinarily low excitation energy of about 8.26 eV, corresponding to a wavelength of about 150 nm [2], it is reachable by laser systems in the vacuum ultraviolet (VUV). Here we present a laser system based on four-wave mixing in Xenon of a tunable pulsed Ti:Sapphire and its third harmonic. This scheme allows for an efficient fifth harmonic generation in the VUV (140 - 160 nm). The system provides a suitable source for the precisely determination of the transition energy by laser-based conversion electron-Mössbauer spectroscopy (CEMS) in thin layer of neutral ^{229}Th atoms [3]. The exact knowledge of the excitation energy is crucial for laser spectroscopy of individual thorium ions in Paul traps and for the development of an optical single ion nuclear clock.

[1] N. Minkov and A. Palffy, Phys. Rev. Lett. **118**, 212501 (2017).
[2] B. R. Beck *et al.*, Phys. Rev. Lett. **98**, 142501 (2007).
[3] L. von der Wense *et al.*, Phys. Rev. Lett. **119**, 132503 (2017).

Q 22.10 Tue 16:30 Empore Lichthof

Cryogenic sapphire cavities as ultrastable optical frequency references for improved laboratory test of Lorentz invariance — •Erich Günter Leo Pape, Achim Peters, and Evgeny Kovalchuk — HU Berlin AG QOM, Newtonstraße 15, 12489 Berlin

We present the latest updates on our cryogenic sapphire cavities as ultrastable frequency references, which will be used for an improved laboratory test of Lorentz invariance in electrodynamics by testing the isotropy of the speed of light at the 10^(-20) level. We integrated two cavities into out closed-cycle cryostat at 4K with free beam propagation and active beam point stability control and with fiber-coupled beam propagation using fiber phase noise compensation and detection within the cryostat to minimize effects of residual amplitude modulation as well as to improve SNR.

Q 22.11 Tue 16:30 Empore Lichthof

Cross-Phase Modulation Artifacts in Femtosecond Stimulated Raman Scattering — •Thomas Würthwein[1], Niklas M. Lüpken[1], and Carsten Fallnich[1,2] — [1]Institute of Applied Physics, University of Münster, Corrensstraße 2, 48149 Münster, Germany — [2]MESA+ Institute for Nanotechnology, University of Twente, Enschede 7500 AE, The Netherlands

Coherent Raman scattering techniques, such as femtosecond stimulated Raman scattering (FSRS), show a great potential for a number of applications due to an enhanced signal-strength in comparison to spontaneous Raman scattering. FSRS is free of a non-resonant background but is affected by two-photon absorption as well as cross-phase modulation (XPM) and temperature-induced refractive index changes. The resulting artifacts in SRS become relevant for high pulse energies and ultrashort pulses, necessary for super-resolution experiments. Here, we present a systematic study in order to investigate the influences of XPM on FSRS in the regime of high pulse energies by varying the most crucial parameters for XPM, namely the pulse duration, the temporal overlap, the peak intensity, and the nonlinear refractive index of the sample.

Q 22.12 Tue 16:30 Empore Lichthof

Deep learning phase reconstruction from dispersion scan traces — •Sven Kleinert[1,2], Ayhan Tajalli[1,2], Tamas Nagy[3], and Uwe Morgner[1,2,4] — [1]Institute of Quantum Optics, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Cluster of Excellence PhoenixD (Photonics, Optics, and Engineering Innovation Across Disciplines), Hannover, Germany — [3]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Straße 2a, 12489 Berlin, Germany — [4]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany

For applications of femtosecond laser pulses the knowledge of their temporal shape plays a crucial role. Many different techniques for measuring these information have been developed during the last decades. The recently proposed dispersion scan (d-scan) is a simple technique to fully characterize ultrashort pulses. The reconstruction of the temporal shape of the pulses from a d-scan trace is an inverse problem as it is usually the case for the characterization techniques, which benefit from an inherent redundancy in the measurement. Conventionally, time-consuming optimization algorithms are used to solve these inverse problems. Here, we show the retrieval of femtosecond pulses from d-scan traces using a deep neural network. This neural network is trained with artificial and noisy dispersion scan traces from randomly shaped pulses. After the training, the phase reconstruction takes only 16 ms enabling video-rate pulse characterization. This retrieval shows a great tolerance against noisy conditions, delivering reliable retrievals from traces with up to 20% of noise.

Q 22.13 Tue 16:30 Empore Lichthof

Near-field phase diagnostics of intense ultrashort laser pulses — •Sergej Poplavski, Bastian Hagmeister, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Intense ultrashort laser pulses with pulse durations in the 10 fs regime have gained increasing relevance in experimental physics and accomplished applicability in many different fields; from a mere diagnostics tool over time resolution in ultrashort physics to next generation particle accelerators. Yet even small aberrations cause large uncertainties of the spatial and temporal intensity in the focal region of ultrashort laser pulses. Hence the precise knowledge of the pulse shape is of utmost importance for reproducible and reliable experiments.

Since diagnostics in the focus is impractical and often even unfeasible, we present an indirect approach to focus diagnostics: The field is characterized with respect to its amplitude and phase in the near-field with spectral and spatial resolution, allowing a conclusion onto the pulse's properties in the focus. We compare methods for retrieving the required data and discuss the calibration procedure and the reliability of the transformation from the near-field to the far-field.

Q 22.14 Tue 16:30 Empore Lichthof

Gap-size dependence of optical near-fields in a variable nanoscale two-tip junction — •Jonas Heimerl, Takuya Higuchi, Maximilian Ammon, M. Alexander Schneider, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Optical field enhancement of metallic nanostructures under illumination with near-infrared fs-laser pulses enables nonlinear electron emission with comparably low pulse energies. When two nanostructures are brought into nanometer vicinity, the optical near-fields of both structures couple and the field is even more enhanced. Here we demonstrate an ambient-conditioned STM-setup allowing us to align two metal needle tips on the sub-nanometer scale facing each other. By measuring the photocurrent as a function of the gap size, we can retrieve the peak electric field at the tip apices. We observe field enhancement up to 15.9 at one tip apex, being four-times larger than for a single tip. Moreover, by scanning the laser focus near this gap junction, we show that field enhancement is well localized to the gap junction, which we can separate from mainly thermal expansion effects visible when we illuminate the tip shank.

Q 22.15 Tue 16:30 Empore Lichthof

Investigations toward diffraction imaging by High Harmonics — •Kai Lennard Rose, Dirk Hemmers, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

High Harmonic Generation (HHG) by ultrashort laser pulses is a useful way of generating spatially coherent directed radiation in the vacuum and extreme ultraviolet (VUV to XUV) spectral range. Especially the so-called water window (2.3 nm - 4.4 nm) with its high transmission by oxygen and strong absorption by carbon is an advantageous region for imaging of organic materials and is often used with other radiation sources. Applying harmonic radiation in this range promises new opportunities by employing its coherence properties with phase-related diagnostic techniques. We performed feasibility studies on diffraction imaging of μm-scale test objects by harmonics in the micrometer-range produced by the few-cycle Ti:Sa-system PHASER in Düsseldorf. First experimental results together with analytical and numerical simulations are presented. These results show that the coherence of the harmonic radiation carries a large potential for further developments.

Q 22.16 Tue 16:30 Empore Lichthof

Parametric studies of High Harmonic Generation in gases in the few-nm range — •Natascha Thomas, Dirk Hemmers, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

High Harmonic Generation (HHG) in gaseous media is a convenient technique for generating coherent, laser-like radiation ranging from the VUV to the soft X-ray regime. Specific interest lies on the so-called water window (wavelengths between 2,3 nm and 4,4 nm), where oxygen is transparent and carbon highly absorptive with important applications in biology and medicine. Previously, this range has been accessed via driving lasers in the IR. We present elaborate HHG parameter studies using the PHASER few-cycle Ti:Sa-system in Düsseldorf, which aim at optimizing the harmonic output in the few-nm range. We show how the spectral cutoff can be shifted systematically by combined variation of multiple parameters, most of all the precise optimization of intensity in the interaction region by means of our new pulse attenuator.

Q 22.17 Tue 16:30 Empore Lichthof

Third harmonic generation in thin film layers — •David Zuber[1,2], Holger Badorreck[2,3], Morten Steinecke[3], Marco Jupé[2,3], and Uwe Morgner[1,2,3] — [1]Institute of Quantum Optics, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Cluster of Excellence PhoenixD (Photonics, Optics, and Engineering Innovation AcrossDisciplines), Hannover, Germany — [3]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany

Cascaded third harmonic generation (THG) of NIR lasers is a state of the art technique for the generation of ultrashort pulses in the UV spectral region. This approach suffers from several obstacles, mainly the high complexity and phasematching restraints. For many applications, both problems can be circumvented by using direct THG from thin films. THG from thin films is known to be strongly dependent on the thickness of the layer. Here, these thickness dependence is experimentally studied by measuring the backward and forward direction THG from thin layers on top of a substrate. The samples were specially manufactured as gradient layers with continously varying thickness ranging from a few nanometers to a few micrometers. The results are compared to simulations with and without internal interference effects to determine regimes, where those effects have to be included to predict the THG correctly. The results will be used to estimate the $\chi^{(3)}$ value of the layers materials. Furthermore, the influence of the substrate and the surrounding medium on the THG will be studied by using different substrate materials and surrounding gasses.

Q 22.18 Tue 16:30 Empore Lichthof

Electron Emitter Arrays on a Chip — •Constantin Nauk, Constanze Gerner, Philip Dienstbier, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen- Nürnberg (FAU), 91058 Erlangen

High-density gold tip arrays are promising candidates for femtosecond laser electron emission, suitable for a variety of applications. Single sharp tips with small radii (5-10nm) have proven good field emission characteristics such as high brightness and coherence but lack large currents. We present the current status of sharp gold tips (radii below 20nm) processed in array arrangements on a chip to face this issue. Among others, these cathodes could serve as emitters in photonics-based particle accelerators. We show the fabrication and characterization of 26 gold tips/μm^2 as well as first femtosecond laser-driven emission experiments.

Q 22.19 Tue 16:30 Empore Lichthof

Investigation of time dynamics of atom-light interaction in the superstrong coupling regime — •Martin Blaha[1], Aisling Johnson[1], Philipp Schneeweiss[2], Arno Rauschenbeutel[2], and Jürgen Volz[2] — [1]TU Wien, 1020 Wien, Austria — [2]HU Berlin, 12489 Berlin, Germany

We report on the observation of superstrong coupling between a cloud of cold atoms and a 50-m long nanofiber-based fiber ring resonator[1]. This novel regime of light-matter coupling is reached when the collective coupling strength between a cloud of laser-cooled Cesium atoms and the light field exceeds the free spectral range (FSR) of the resonator leading to simultaneous strong coupling of the atoms with more than one longitudinal resonator mode[2].

In a next step, we investigate the dynamics of the atom-resonator interaction in this regime. For this we probe the system with a few nanosecond long pulse shorter than the dynamical time scales in the resonator. We monitor the time-dependent response of the coupled system and observe a direction-dependent and collective decay in forwards direction while the dynamics in backwards direction is equivalent to the decay time of a free-space atom.

[1] A. Johnson et al., arXiv:1905.07353(2019).
[2] D. Meiser et al., Phys. Rev. A 74, (2006).

Q 22.20 Tue 16:30 Empore Lichthof

Fiber based Mode Matching for Fabry-Pérot Cavities — •Pritom Paul, Timon Eichhorn, and David Hunger — Physikalisches Institut (PHI), Karlsruher Institut für Technologie, Wolfgang-Gaede-Str.1, 76131 Karlsruhe, Germany.

Fiber Fabry-Pérot Cavities(FFPC) with micro mirrors fabricated on the end facets of optical fibers combine a high finesse with a small mode volume and full tunability [1]. Due to these properties, FFPCs can be beneficially used e.g. for sensing of nanoparticles, cavity optomechanics, and for solid-state based quantum information. For all applications, efficient excitation and collection of light in the cavity mode with a single mode fiber is desirable. However, restricted spatial mode matching substantially lowers the overall coupling efficiency for fully fiber-based FFPCs. To overcome this problem, the aim of this work is to fabricate a fiber based mode matching assembly. As it was shown for fiber cavities targeting large mirror separations e.g. for ion trap experiments, splicing together a single mode, a multimode and a graded-index fiber can serve as mode matching optics [2]. Here, we adapt this approach for FFPC with minimized mode volume and mode cross section as desired for e.g. experiments with solid-state quantum emitters. We report the current status of the project.

[1] Hunger, D. et al. A Fiber Fabry-Pérot with High Finesse, New Journal of Physics 12, 065038 (2010).

[2] Gulati, G K. et al. Fiber Cavities with Integrated Mode Matching Optics, Scientific Reports 7, 5556 (2017)

Q 22.21 Tue 16:30 Empore Lichthof

Towards Cavity-Enhanced Spectroscopy of Single Europium Ions in Yttria Nanocrystals — Timon Eichhorn[1], Kelvin Chung[1], Sören Bieling[1], •Tobias Krom[1], Bernardo Casabone[2,3], Julia Benedikter[1,3,4], Thomas Hümmer[3,4], Alban Ferrier[5,6], Philippe Goldner[5,6], Hugues De Riedmatten[2,7], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]ICFO-Institut de Ciencies Fotoniques — [3]Max-Planck-Institut für Quantenoptik — [4]Fakultät für Physik, Ludwig-Maximilians-Universität — [5]Université PSL, Chimie ParisTech, CNRS — [6]Sorbonne Université — [7]ICREA-Institució Catalana de Recerca i Estudis Avançats

A promising approach for realizing scalable quantum registers lies in the efficient optical addressing of qubits in a solid state host. Within the EU Quantum Flagship project SQUARE we tackle this problem by coupling the fluorescence of Eu^{3+} ions doped into Y_2O_3 nanoparticles (NPs) to a high-finesse fiber-based Fabry-Pérot microcavity. As a first step towards efficient readout of single rare earth ions, we present cavity-enhanced spectroscopy measurements of a few europium-ions as published in New J. Phys. **20** (2018) 095006. We furthermore report our efforts towards Purcell-enhanced single ion detection with high-resolution excitation spectroscopy. Therefore, we are currently setting up a reference cavity to narrow down the laser linewidth. Simultaneously we are working on a new method to place single NPs inside a passively stable, low-temperature fiber-fiber microcavity.

Q 22.22 Tue 16:30 Empore Lichthof

Overlapping modes effects in X-ray cavity QED — •Dominik Lentrodt, Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In recent years, a new platform for quantum optics has emerged: nuclear cavity QED, where Mössbauer nuclei are placed in nano-cavities and driven by hard X-ray sources. Due to the unique properties of these nuclei, such as exceptionally long decoherence times, and the high photon energies of hard X-rays, this system constitues one of the highest quality quantum systems in nature, with possible applications ranging from metrology and precision spectroscopy to materials and even quantum information science. In this poster, we show novel cavity QED effects that arise in this system due to the overlapping modes stucture of the cavities in use, and how to harness them for quantum optical purposes. In particular, we outline how these effects can be described theoretically within the framework of ab initio few-mode theory [1], which provides access to new interpretations of the collective Lamb shift [2], which was famously discovered in this system, and an EIT phenomenon [3], which is promising with regards to achieving non-linear effects at current and upcoming X-ray facilities [4].

[1] Lentrodt & Evers (2018) arXiv:1812.08556 [quant-ph] [2] Röhlsberger et. al. *Science* **328** 5983 (2010), Heeg et. al. *Phys. Rev. Lett.* **114** 207401 (2015) [3] Röhlsberger et. al. *Nature* **482** 199203 (2012), Heeg & Evers *Phys. Rev. A* **91** 063803 (2015) [4] Heeg, Keitel & Evers (2016) arXiv:1607.04116 [quant-ph]

Q 22.23 Tue 16:30 Empore Lichthof

Towards cavity-enhanced single ion spectroscopy of Yb^{3+}:Y_2O_3 — •Jannis Hessenauer[1], Sören Bieling[1], Tobias Krom[1], Philippe Goldner[2,3], and David Hunger[1] — [1]Karlsruher Institut für Technologie, Physikalisches Institut — [2]Université PSL, Chimie ParisTech, CNRS — [3]Sorbonne Université

Rare-earth ions are promising candidates for optically addressable spin qubits, owing to their long optical and spin coherence times. Yb^{3+} is of special interest among the rare earth ions due to its simple energy level scheme, comparably strong transition oscillator strength and its paramagnetic properties. An efficient spin-photon interface for quantum information technology requires the coupling of single ions to a high finesse cavity, which serves to enhance the transitions via the Purcell effect and to increase the emission into a single, well-collectible cavity mode. The goal of our experiment is to address single Yb^{3+} ions in Y_2O_3 nanoparticles (NPs) by placing them inside a high finesse fiber based Fabry-Pérot cavity at cryogenic temperatures. To characterize the nanoparticles, we perform ensemble spectroscopy in an all-fiber setup. For quick sample preparation, we investigate picking and placing of single NPs on the end facet of optical fibers. An external reference cavity is set up to stabilize the laser linewidth below the homogenous linewidth of Yb^{3+}, which will enable selective addressing of single Yb^{3+} ions.

Q 22.24 Tue 16:30 Empore Lichthof

High finesse fiber cavity as a light matter interface for quantum optics application — •Patrick Maier, Stefan Häussler, Gregor Bayer, Richard Waltrich, and Alexander Kubanek — Institut für Quantenoptik, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm

Quantum network applications based on entangled photons suffer from losses over large distances as well as classical applications. To overcome those losses quantum repeaters based on solid-state quantum emitters offer one promising solution. In particular color centers in diamond like the silicon vacancy (SiV^-) and germanium vacancy (GeV^-) in diamond and defect centers in tailored 2D materials are favourable due to their outstanding optical properties.

We demonstrate the feasibility of experiments with high rate of coherent photons using a coupled system of a high quality Fabry Perot microcavity and different color centers. We furthermore investigated and compared different color center host materials covering different spectral regions. As a next step the cavity setup is upgraded to a bath cryostat compatible design, especially considering stability and tuneability of the system.

Q 22.25 Tue 16:30 Empore Lichthof

Implementation of Optical Tweezers in a Small Scale Cavity-QED Setup — •Saibin Zhou, Bo Wang, Nicolas Tolazzi, Christopher Ianzano, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Optical tweezers with the capability to manipulate single atoms have recently been achieved[1][2]. Here we seek to implement the microscopic optical tweezers method in our strongly-coupled atom-cavity system and manipulate the spatial position of individual ^{87}Rb atoms trapped in an optical lattice. To have control over the exact locations of atoms within the cavity is crucial, as the coupling strength between the electromagnetic field mode and the atom depends heavily on position. This is especially important in our case where we have a strong atom-cavity coupling on both the D_1 and D_2 lines of ^{87}Rb, requiring an independent longitudinal mode of the cavity for each transition[3]. Having precise control over the position of an atom within the cavity would therefore allow for tuning of each coupling strength independently. It also provides the ability to manipulate multiple atoms individually and simultaneously. Compared to a tweezers setup in free space, our system has very limited optical access due to the proximity of the Fabry-Pérot mirrors. Therefore, we present a special design for our optical tweezers system together with detailed results.

[1] Daniel Barredo et al., Science, **354**, 1021(2016).
[2] Manuel Endres et al., Science, **354**, 1024(2016).
[3] Christoph Hamsen et al., Nature Physics, **14**, 885(2018).

Q 22.26 Tue 16:30 Empore Lichthof

Coupling a single trapped atom to a WGM microresonator — •Luke Masters[1], Elisa Will[2], Michael Scheucher[2], Jürgen Volz[1], and Arno Rauschenbeutel[1] — [1]Department of Physics, Humboldt-Universität zu Berlin, Germany — [2]Vienna Center for Quantum Science and Technology, TU Wien - Atominstitut, Austria

Strongly coupling single quantum emitters to the guided light field of Whispering-gallery-mode (WGM) resonators allows one to reach the strong coupling regime [1]. Furthermore, this setting provides chiral, i.e. propagation direction-dependent, light-matter coupling which can be employed for realising novel quantum devices [2, 3]. However, trapping atoms close to such resonators has not yet been demonstrated.

We demonstrate the trapping of single ^{85}Rb atoms in the evanescent field of a bottle-microresonator using a standing wave optical dipole trap which is created by retroreflecting a tightly focused beam on the resonator surface [4]. Atoms confined in such trapping fields will experience a spatially varying ac-Stark shift that can exceed the resonator linewidth considerably. To remove this position-dependent shift of the transition frequency of the trapped atom, we implement a dual-colour magic-wavelength trapping technique. This allows one to tune the atomic transition back into resonance with the WGM resonator.

[1] C. Junge et al. Phys. Rev. Lett. 110, 213604 (2013)
[2] M. Scheucher et al. Science 354, 1577 (2016)
[3] O. Bechler et al. Nat. Phys. 14, 996 (2018)
[4] J. D. Thompson et al. Science 340, 1202 (2013)

Q 22.27 Tue 16:30 Empore Lichthof

Towards virtual-state superradiant lasing from cold ytterbium atoms — •Dmitriy Sholokhov, Hannes Gothe, Anna Breunig, and Jürgen Eschner — Universität des Saarlandes, Campus E2 6, 66123 Saarbrücken, Germany

We analyze atom-cavity interaction and lasing from cold Ytterbium-174 atoms that are magneto-optically trapped inside a high-finesse cavity. Lasing from a 399-nm ($^1S_0-^1P_1$) MOT was previously characterized for its power, frequency and polarization properties [1]. Here, we study a possibility of implementing a similar lasing process in a superradiant, or "bad-cavity", regime by employing narrower atomic transitions. We transport the atoms from blue ($^1S_0-^1P_1$) to green ($^1S_0-^3P_1$) MOT and characterize the associated dynamics of trapped atoms and spectral properties of the light emitted by the cavity under various conditions.

[1] H. Gothe, D. Sholokhov, A. Breunig, M. Steinel, J. Eschner, Phys. Rev. A 99, 013415 (2019)

Q 22.28 Tue 16:30 Empore Lichthof

Ultra-sensitive hyperspectral imaging with a high-speed scanning microcavity — •Evgenij Vasilenko[1], Thomas Hümmer[2], Theodor Wolfgang Hänsch[2], Alexander Högele[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie, Karlsruhe — [2]Ludwig-Maximilians-Universität, München

Tunable open-access Fabry-Perot microcavities [1] enable the combination of cavity enhanced spectroscopy with high resolution imaging [2,3]. Here we describe a custom-developed scanning microcavity that enables measurements of low absorption and scattering signals at the ppm level at high rates. We analyze the stability, speed, achievable sensitivity and background limitations of the system. As an example system, we investigate individual single-walled carbon nanotubes and demonstrate quantitative extinction spectroscopy of exciton resonances, revealing the heterogeneity of E11 transitions.

[1] D. Hunger et al., New J. Phys. 12, 065038 (2010)
[2] M. Mader et al., Nature Commun. 6, 7249 (2015)
[3] T. Hümmer et al., Nature Commun. 7, 12155 (2016)

Q 22.29 Tue 16:30 Empore Lichthof

Cumulant expansion method applied to a cascaded system — •Kasper Kusmierek, Sahand Mahmoodian, and Klemens Hammerer — Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover

Many particle systems are in general not exactly solvable, therefore the need for approximation methods arises. This work deals with such a method, called the cumulant expansion method, and its application to a cascaded system.

Q 22.30 Tue 16:30 Empore Lichthof

Climbing the Dark State Ladder of Cavity EIT — •Bo Wang[1], Christopher Ianzano[1], Nicolas Tolazzi[1], Celso Villas-Boas[2], and Gerhard Rempe[1] — [1]Max Planck Institute for Quantum Optics — [2]Universidade Federal de Sao Carlo

Dark states in atomic physics are a well-known phenomenon where normally resonant transitions are rendered *dark.* One of the most common examples of this is in a lambda-type electromagnetically induced transparency system, where laser fields drive two transitions with the same excited state. The transition amplitudes interfere destructively, preventing excitation and forming a superposition of ground states. This dark state is fragile, and is typically destroyed by additional resonant fields. Adding a strongly-coupled cavity makes the dark state more robust to perturbations and generates an infinite harmonic ladder of dark states separated by one cavity photon. A coupling field between the ground states of the lambda system accesses higher rungs of the dark state ladder by driving transitions between dark states while generating photons as the system climbs and decays from states in the ladder. Because higher lying photon number states experience both a weaker driving and an increased decay, for weak driving the system cannot surpass the one-photon dark state. An increase in the driving strength will lift this blockade and higher states will become more accessible. We demonstrate the existence of this dark-state ladder, which can be seen by a change in photon statistics between the weak- and strong-driving regimes, as well as a significantly lower population in the excited state compared to a free space atom.

Q 22.31 Tue 16:30 Empore Lichthof

A cryogenic surface-electrode ion trap apparatus for high-fidelity microwave quantum simulations — •Sebastian Halama[1], Timko Dubielzig[1], Giorgio Zarantonello[2,1], Henning Hahn[2,1], Amado Bautista-Salvador[2], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We report on the latest results achieved in our cryogenic surface-electrode ion trap with integrated microwave conductors for near-field quantum control of $^9Be^+$. These traps are promising systems for analog quantum simulators and for quantum logic applications. Our group developed a trap with an integrated meander-like microwave guide for driving motional sidebands on a $^9Be^+$ ion. In a room temperature apparatus, we have shown, that this kind of trap is capable of supporting entangling two-qubit gates with a fidelity of over 99 % [1]. To improve this result even further our trap operates in a cryogenic vacuum chamber. This will suppress electrical field noise, acting on the ion and originating from thermal effects [2], which could finally lead to fault tolerant quantum computation in a ion-trap based scalable architecture. We will discuss the vibration isolated closed cycle cryostat and the design of the vacuum chamber with all electrical supplies necessary to operate the trap.

[1] arXiv:1911.03954 [quant-ph] (2019)
[2] Phys. Rev. A **89**, 012318 (2014)

Q 22.32 Tue 16:30 Empore Lichthof

Optimal control for cat state preparation — •Matthias G. Krauss[1], Sabrina Patsch[1,2], Daniel M. Reich[1,2], and Christiane P. Koch[1,2] — [1]Universität Kassel, Theo. Physik III, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Freie Universität Berlin, Theo. Physik, Arnimallee 14, 14195 Berlin, Germany

Schrödinger cat states are non-classical superposition states that are useful in quantum information science, for example for computing or sensing. Optimal control theory provides a set of powerful tools for preparing such superposition states, for example in experiments with superconducting qubits [Ofek *et al.*, Nature 536, 441445 (2016)]. In general, the preparation of specific cat states is considered to be a hard problem in terms of numerical effort [Kallush *et al.*, New J. Phys. 16, 015008 (2014)]. Since many applications do not rely on a particular cat state, it can be beneficial to optimize towards an arbitrary n-fold cat state instead. In particular, we are interested in two types of cat states, a superposition of two coherent states in a harmonic oscillator and a superposition of two spin-coherent states in a spin system. We propose functionals for either system, which provide more freedom to the optimization algorithms, in comparison to state-to-state functionals. To analyze the practical performance of these functionals, we exemplify their use in conjunction with Krotov's method [Reich *et al.*, J. Chem. Phys. 136, 104103 (2012)].

Q 22.33 Tue 16:30 Empore Lichthof

Numerical Studies of the Quantum Game of Life — •Peter-Maximilian Ney[1], Giovanna Morigi[1], and Simone Montangero[2] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Dipartimento di Fisica e Astronomia "G.Galilei", Università di Padova, 35131 Padova, Italy

We numerically analyze the dynamics of a quantum model of the one dimensional game of life introduced in Ref. [1]. We draw analogies and differences with the classical reversible version. The simulation is done both using exact Runge-Kutta methods and matrix product state methods. Furthermore, we will concentrate on entanglement and quantum correlation structures generated by the dynamics.

[1] D. Bleh, et al., EPL 97, 20012 (2012).

Q 22.34 Tue 16:30 Empore Lichthof

Nonlocal potential of quantum measurements — •Lucas Tendick, Hermann Kampermann, and Dagmar Bruss — Institut für TheoretischePhysik III, Heinrich-Heine-Universität Düsseldorf, D-40225Düsseldorf, Germany

The usefulness of different quantum states has been analyzed in-depth with respect to Bell nonlocality ever since the foundation of quantum information theory. Various methods to quantify the nonlocality of given quantum states have been proposed and studied in the past. However, analogous analysis with focus on the measurement side are less prevalent. We analyze the potential of given measurement operators in the context of Bell nonlocality. Specifically, we attempt to quantify how useful specific sets of quantum measurements are in terms of Bell violation, trace distance to the local polytope, the volume of nonlocality, and robustness.

Q 22.35 Tue 16:30 Empore Lichthof

Sections of generalized probabilistic theories — •Jonathan Steinberg and Matthias Kleinmann — University of Siegen, Germany

Generalized probabilistic theories (GPTs) allow us to write quantum theory in a purely operational language and enable us to formulate other, vastly different theories. Sections of GPTs can serve as a description of subsystems [1] and in general provide relations between GPTs. We investigate the structure and properties of sections of GPTs and give a complete characterization of low dimensional sections of arbitrary quantum systems. As an application we study Spekkens toy model [2] as a section. In addition, we combine the notion of sections with the dynamics in a GPT and consider the implications for quantum theory.

[1] M. Kleinmann et al., Phys. Rev. Lett. **110**, 040403 (2013)
[2] R. Spekkens, Phys. Rev. A **75**, 032110 (2007)

Q 22.36 Tue 16:30 Empore Lichthof

Lie-algebra-based estimation of the quantum speed limit — •Fernando Gago Encinas[1], Christiane Koch[1], and Thomas Chambrion[2] — [1]Institute of Theoretical Physics, Freie Universität Berlin, 14195 Berlin, Germany — [2]Institut de Mathématiques de Bourgogne, Université de Bourgogne, 21000 Dijon, France

In this work we study the needed time for a set of initial states to evolve into other target states using some of the tools typical of controllability theory. We are able to do so by using the concept of available speed $S(v) = \exp(-vB)A\exp(vB)$ which is defined for a system with a Hamiltonian $H = A + uB$ and an integral $v = \int u\,dt$ over the control. It is possible then to compute the convex hull defined by the available speed in every possible direction of the Lie algebra. Finally an optimisation algorithm is later used to tell which direction is best for reaching our goal, thus obtaining a measurement for the expected time.

Q 22.37 Tue 16:30 Empore Lichthof

Fundamental Bounds for Qubit Reset — Daniel Basilewitsch[1], •Jonas Fischer[1,2,3], Daniel M. Reich[1,3], Dominique Sugny[2], and Christiane P. Koch[1,3] — [1]Theo. Physik, Universität Kassel, D-34132 Kassel, Germany — [2]Lab. ICB, Université de Bourgogne-Franche Comté, F-21078 Dijon Cedex, France — [3]Freie Universität Berlin, Theo. Physik, Arnimallee 14, 14195 Berlin, Germany

One of the most fundamental tasks in the field of quantum technology is the purification or reset of a qubit. This process is interesting from a theoretical point of view because it raises the question of how fast entropy can be exported from a system, as well as for applications like quantum computing or quantum cryptography.

We consider a controllable qubit in contact with an environment. The environment can be mapped onto a representative pseudo-mode, decaying into a weakly coupled heat bath [D. Basilewitsch *et al*, New J. Phys. **19**, 113042 (2017)], which does not play a role for the speed limit and can be neglected. Because qubit and ancilla can be flexibly engineered, we investigate which sort of coupling and control is optimal for the reset task and search for a global speed limit.

Using the Cartan decomposition we can deduce necessary conditions for the interaction and control. We give the optimal choice for the control field depending on the coupling and also determine the overall speed limit.

Q 22.38 Tue 16:30 Empore Lichthof

Dissipative Ising model simulations with trapped ions in surface-electrode microtraps. — •Nicolás Pulido[1,2], Giorgio Zarantonello[1,2], Tim Pistorius[3], Jonathan Morgner[1,2], Amado Bautista-Salvador[2,1], Henning Hahn[1,2], Hendrik Weimer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]PTB, Bundesallee 100, 38116 Braunschweig — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover

Quantum simulations are the first possible applications for simple quantum information processing devices and trapped ions are a promising platform to achieve this goal. In this poster we will present a scheme for simulating the dynamics of a dissipative Ising model [1] using our current setup. The implementation will use an approach based on microwave near fields [2] and employ microwave conductors embedded in our surface-electrode trap.

[1] V. Overbeck *et al.*, Phys. Rev. A **95**, 042133 (2017)
[2] C. Ospelkaus *et al.*, PRL **101**, 090502 (2008)

Q 22.39 Tue 16:30 Empore Lichthof

Analysis of restricted Boltzmann machine quantum states — •Sebastian Syrkowski and Martin Gärttner — Kirchhoff-Institut für Physik, Heidelberg, Deutschland

For simulations of quantum many-body systems such as the transverse-field Ising model a major challenge one has to face is the exponentially growing complexity of the wave function with the number of particles prohibiting a simulation of larger systems on classical computers. Generative neural networks in the form of restricted Boltzmann machines (RBMs) have been shown to be able to represent such a quantum state more efficiently. In order to better understand the limits of this representation with respect to the complex optimization problems of ground state search and time evolution we are analyzing the topological structure of the underlying manifold of the RBM weight parameters using dimensionality reduction techniques. This allows us to test different optimization algorithms for their susceptibility to local minima.

Q 22.40 Tue 16:30 Empore Lichthof

On the notions of bound entanglement — •Michael Gaida and Matthias Kleinmann — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany

The notion of bound entanglement has been widely used since the seminal work of Horodecki [Phys. Rev. Lett. 80, 5239]. However, rigorous definitions of distillability are sparse and they are not necessarily based on operational principles like LOCC. We revisit this problem and consider different definitions of distillability and the relation among them. We recover how most of those definitions are equivalent or compatible with the central theorem regarding bound entanglement.

Q 22.41 Tue 16:30 Empore Lichthof

Simulation der Zweiphotoneninterferenz am Strahlteiler — •Martin Kernbach[1], Oliver Benson[1] und Andreas Schell[2,3] — [1]Institut für Physik, AG Nano-Optik, Humboldt-Universität zu Berlin, Newtonstraße 15, Germany — [2]Institut für Festkorperphysik, Leibniz Universitat Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Zeitaufgelöste Hong-Ou-Mandel Interferenz von parallel polarisierten frequenzverstimmten Singlemodephotonen sowie Multimodephotonen.

Q 22.42 Tue 16:30 Empore Lichthof

Entanglement Generation Using Multiport Beam Splitters — •Shreya Kumar, Nico Sieber, Matthias Bayerbach, and Stefanie Barz — Universität Stuttgart, Stuttgart, Germany

Multiphoton entanglement is an integral part of optical quantum technologies. Entanglement between two photons can be either generated in sources directly or through interference of single photons at beam splitters and post-selection. We present a scheme to generate multi-photon entanglement through a balanced multiport fiber beam splitter (tritter). The balanced tritter erases the which-path information, resulting in interference, which leads to entanglement; tuning the input to the device lead to different entanglement classes. We demonstrate the scheme using three photons and generate cluster states and W-states.

Q 22.43 Tue 16:30 Empore Lichthof

Trapping, sympathetic cooling and focusing of single cerium ions for deterministic nanoresolved implantation — •Luis Ortiz-Gutiérrez, Karin Groot-Berning, Felix Stopp, Henri Lehec, and Ferdinand Schmidt-Kaler — Johannes Gutenberg-Universität Mainz

Single spins in a solid state matrix are of particular interest as a physical platform for quantum computation and quantum communication, due to its unique scalability features. Implantation of single ions in a crystal is a deterministic and precise way to realize this goal[1]. From an external ion source, doping $^{140}\mathrm{Ce}^{+}$ ions are captured in a Paul trap and sympathetically cooled. The Paul trap allows a wide range of storage and cooling between light ions such as N_2^+ up to a mass of $^{232}Th^+$[2]. We extract the cerium ions and focus them to nm regime for implantation into a YAG crystal. This doped crystal has the capability of being carefully characterized by superresolution microscopy techniques as STED, in close collaboration with our partners at Univ. Stuttgart [2,3]. In addition to YAG, ions can be implanted in TiO_2, an also interesting candidate as host crystal which has a low natural abundance of nuclear spins[4]. In a new design, we aim to further improve spatial precision and the rate of implantation with different dopant ions, as well as the possibility of retrapping the extracted ions.

[1] Jacob *et al.*, Phys. Rev. Lett. 117, 043001 (2016)
[2] Groot-Berning *et al.*, Phys. Rev. Lett. 123, 106802 (2019)
[3] Kolesov *et al.*, Phys. Rev. Lett. 120, 033903 (2018)
[4] Phenicie *et al.*, arXiv:1909.06304v1 (2019)

Q 22.44 Tue 16:30 Empore Lichthof

Dynamics of a single-ion heat engine: towards a sensitive bath sensor — •Bo Deng[1], Moritz Goeb[1], Erik Torrontegui[2], Amikam Levy[3,4], Samuel Dawkins[1], Kilian Singer[1], and Daqing Wang[1] — [1]Experimentalphysik I, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Instituto de Fisica Fundamental IFF-CSIC, Calle Serrano 113b, E-28006 Madrid, Spain — [3]Department of Chemistry, University of California Berkeley, Berkeley, California — [4]The Raymond and Beverly Sackler Center for Computational Molecular and Materials Science, Tel Aviv University, Tel Aviv 69978, Israel

Recently, a single-ion heat engine was demonstrated [1]. Here, we present analytical and numerical modelling of its dynamical behaviors under the driving of thermal and non-thermal baths. A convenient and sensitive method to characterize unknown heat baths is developed. To realize the measurement, a controlled bath with a known temperature is required for reference. The unknown bath to be tested and the reference bath interact with the ion periodically. The characterization of the unknown bath is extracted from the evolution of the ion's axial oscillation. The sensitivity of this method is analyzed and compared to traditional methods of temperature measurement. Recent experimental progress is presented.

[1] J. Rossnagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler and K. Singer, Science 352 325 (2016).

Q 22.45 Tue 16:30 Empore Lichthof

Constructing U(1) gauge symmetry in electronic circuits — •Hannes Riechert[1], Erez Zohar[2], and Fred Jendrzejewski[1] — [1]Heidelberg University, Germany — [2]Hebrew University of Jerusalem, Israel

Classical electronic circuits have proven powerful to study several topological lattice structures (Ningyuan et al., PRX 5, 2015; Imhof et al., Nat. Phys. 14, 2019). Here, we study electronic circuits that may be described by a lattice Hamiltonian with local U(1) symmetry experimentally and explore the extent to which a classical physical simulator in the form of an electronic circuit might be useful as a stepping stone for lattice gauge theories like SU(2).

Q 22.46 Tue 16:30 Empore Lichthof

Regrouping invariance of lattice systems in a rational magnetic field — Tobias Geib, •Pablo Tieben, and Reinhard F. Werner — Institut für theroetische Physik, Leibniz Universität Hannover, Hannover, Deutschland

The traditional way of analyzing lattice systems in a magnetic field is to choose the fluxes for one cell to be rational. Then a suitable periodic grouping makes the system translation invariant, and therefore susceptible to the usual methods of band structure analysis. This method works for Hamiltonian (continuous time) systems as well as discrete time systems, so called quantum walks. Typical results obtained in this way are Hofstadter*s butterfly, representing the spectrum as a function of the field parameter, and the characterization of bands by Chern numbers.

A problem with this approach is that the results depend prima facie on the chosen regrouping. E.g. in two dimensions the regrouping can always be chosen along the x- or y- axis, but also other partitions into skew parallelograms can be used.

We show that under a technical assumption, namely the existence of a periodic gauge for the chosen regrouping, not only the spectrum is independent of the regrouping, but also the isomorphism class of the vector bundles over the Brillouin zone associated with the bands. In particular, the Chern numbers mentioned earlier are invariants. The technical assumption can be satisfied for some regroupings in any lattice dimension, and for all regroupings of two dimensional lattices. We conjecture the latter is true in every dimension.

Q 22.47 Tue 16:30 Empore Lichthof

Correlations in 2D strongly interacting fermionic systems — •Carl Heintze, Luca Bayha, Marvin Holten, Keerthan Subramanian, Philipp Preiss, and Selim Jochim — Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Many body quantum effects like superconductivity rely on the microscopic interactions of fermions. We prepare samples of ultra cold Li6-atoms confined to two dimensions to investigate the many body behavior in those systems by tuning the fermionic inter-particle interactions. In the non-interacting system, the spatial distribution of fermions is determined by the Pauli-exclusion principle and the fermions arrange themselves in a so called Pauli-crystal. Starting from non-interacting systems, we plan to observe the N-body correlations in a strongly interacting superfluid.

Even though the Pauli-crystal itself is theoretically well understood, the experimental control poses several difficulties concerning both detection and preparation. We plan to observe the spatial distribution of a six particle Pauli-Crystal using spin-sensitive and single particle resolved fluorescence imaging. By finding the correlations predicted for the non-interacting gas, we want to benchmark our setup to be able to proceed to correlations in strongly interacting systems. On this poster I want to present the experimental procedure and first results of our experiment.

In the future we want to address systems with higher particle numbers and investigate higher order correlations and pairing effects for increasing interactions.

Q 22.48 Tue 16:30 Empore Lichthof

An experiment to study small Fermi-Hubbard systems — Martin Schlederer, •Alexandra Mozdzen, Phillip Wieburg, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Hamburg, Deutschland

We report on an experiment designed to create small Hubbard systems site by site.

The apparatus contains two microscope objectives located inside the vacuum chamber featuring a numerical aperture of 0.75, enabling us to load single 40K atoms into individual optical tweezers and flexible tweezer arrays. This bottom-up approach will allow us to observe the emergence of many-body effects with increasing system size or particle number. We will discuss the current status of the project.

Q 22.49 Tue 16:30 Empore Lichthof

Disorder-induced Floquet topological insulator phases with Falicov-Kimball interaction — •Michael Pasek[1], Tao Qin[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität, D-60438 Frankfurt/Main, Germany — [2]Department of Physics, School of Physics and Materials Science, Anhui University, Hefei, Anhui Province 230601, People's Republic of China

We study topological properties of fermions in a two-dimensional circularly-shaken honeycomb lattice in the presence of a Falicov-Kimball-type interaction. In particular, we investigate whether the addition of on-site potential disorder can lead to disorder-induced Floquet topological insulator phases and whether such phases are robust against interaction effects. We use real-space non-equilibrium Floquet dynamical mean-field theory (DMFT) to obtain the steady-state of the periodically driven interacting system. To probe topological properties of the steady-state, we use the Laughlin charge pump setup on a cylinder threaded with flux, a technique well-adapted to interacting disordered systems. Finally, we show the effect of interactions by comparing results from the charge pump protocol with the predictions of the bulk topological invariant (Bott index) in the non-interacting limit.

Q 22.50 Tue 16:30 Empore Lichthof

Few ultracold fermions in a two-dimensional trap — •Ram-Janik Petzold, Jan Hendrik Becher, Ralf Klemt, Philipp Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

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

It is expected that this experimental simulator will allow to study the onset of quantum many-body physics in two dimensions by mapping out correlations in position and momentum space.

Q 22.51 Tue 16:30 Empore Lichthof

Sound propagation and damping in a homogeneous two-dimensional Fermi gas — •Markus Bohlen[1,2,3], Lennart Sobirey[1,2], Niclas Luick[1,2], Hauke Biss[1,2], Thomas Lompe[1,2], and Henning Moritz[1,2] — [1]Institut für Laserphysik, Universität Hamburg — [2]The Hamburg Center for Ultrafast Imaging, Universität Hamburg — [3]École Normale Supérieure, Paris

Understanding transport in strongly interacting systems remains one of the major challenges in quantum many-body physics. In this context, two-dimensional systems are particularly intriguing due to their strong quantum fluctuations and their approximate scale invariance. Here, we present measurements of the sound propagation in a strongly interacting 2D Fermi gas across the 2D BEC-BCS crossover. We excite particle currents by imprinting a phase step onto homogeneous Fermi gases trapped in a box potential and measure the resulting density oscillations. We extract the speed of sound across the BEC-BCS crossover and compare the resulting dynamic measurement of the compressibility equation of state to a static measurement based on recording density profiles as well as a QMC calculation and find reasonable agreement between all three. Finally, we also measure the damping of the sound mode and find a clear minimum in the strongly interacting regime in agreement with quantum limited transport.

Q 22.52 Tue 16:30 Empore Lichthof

Correlation measurements of mesoscopic two-dimensional Fermi systems — Ralf Klemt, •Philipp Lunt, Jan Hendrik Becher, Ram-Janik Petzold, Philipp Preiss, and Selim Jochim — Physics Institute, Heidelberg University, Germany

Understanding strongly correlated quantum matter on a fundamental level requires both access to microscopic correlations of individual constituents and macroscopic observables of the full system.

In recent years, we developed experimental methods to study global observables in macroscopic two-dimensional Fermi systems of ultracold lithium-6 atoms in the BEC-BCS crossover by phase coherence [1] and pairing energy [2] measurements. Furthermore, utilizing local observables on the single atom level, we can characterize microscopic quantum systems by their correlation and entanglement properties [3, 4].

Combining these two approaches, we study the crossover regime between microscopic and macroscopic systems which features already rich many-body physics, however with correlations measurements on the single particle level still feasible. We present first results on preparing and probing very dilute, yet strongly correlated, low entropy states of a few 100 atoms characterized by measurements on density and density correlations.

[1] P. Murthy et al. Science 365, 268-272 (2019) [2] P. Murthy, M. Neidig, R. Klemt et al. Science 359, 452-455 (2018) [3] A. Bergschneider, V. Klinkhamer et al. Phys. Rev. A 79, 063613 (2018) [4] P. Preiss et al. Phys. Rev. Lett. 122, 143602 (2019)

Q 22.53 Tue 16:30 Empore Lichthof

Floquet engineering of strongly correlated fermions in optical lattices — •Kilian Sandholzer, Joaquín Minguzzi, Anne-Sophie Walter, Konrad Viebahn, Frederik Görg, and Tilman Esslinger — ETH Zürich, Switzerland

The successful implementation of Floquet engineering in the field of cold atoms has enabled the study of Hamiltonians which would be out of reach in static systems. However, introducing strong interactions to these systems makes them susceptible to absorbing energy from the external drive which prevents the buildup of strong correlations.

We use an interaction-tunable Fermi gas in a periodically modulated hexagonal lattice to realize the driven Fermi-Hubbard model. In the static analog, for low temperatures nearest-neighbor spin correlations develop as a consequence of the interplay between particle hopping and onsite interactions. By driving the system close to the interaction energy, we can either enhance antiferromagnetic or induce ferromagnetic correlations. In the case of a two-frequency scheme, we demonstrate the implementation of an occupation-dependent gauge field. For these systems, a study of the evolution of doubly occupied sites shows that the heating due to the drive is not limiting the investigation of low-energy physics. In comparison to dynamical mean field theory we verify the validity of the experiments and theoretical calculations. Furthermore, we can show that the lifetime of spin correlations in a driven system can be made identical to the static system by applying coherent control to avoid heating into higher bands.

Q 22.54 Tue 16:30 Empore Lichthof

Pairing on the BEC side of a fermionic system — •Manuel Jäger[1], Thomas Paintner[1], Daniel Hoffmann[1], Wolfgang Limmer[1], Michele Pini[2], Pierbagio Pieri[2], Giancarlo Strinati[2], and Johannes Hecker Denschlag[1] — [1]Universität Ulm, Institut für Quantenmaterie, Deutschland — [2]University of Camerino, School of Science and Technology, Physics Division, Italy

We investigate the pair formation in a two-component fermionic system on the BEC side of unitarity. In the limit of weak interaction and low density, those "preformed pairs" can be approximately described by a bound state of two fermions of opposite spin. In the vicinity of the Feshbach resonance, however, the many-body character of the pairs becomes important. This strongly interacting many-body regime is still not fully understood.

For investigating this system experimentally, we use a spin-balanced mixture of the two lowest ^{6}Li Zeemann states and set their interaction strength by means of the Feshbach resonance at 832 G. We then measure the fraction of paired atoms at different temperatures and interaction strengths using optical spectroscopy. Our results are compared with an *ab initio* t-matrix calculation and a self-consistent thermal equilibrium model based on quantum statistics and effective mean field interaction. Our comparison reveals a separation between the molecular two-body and the many-body regime, although the measured pairing fraction is a thermodynamic quantity, rather than a dynamical one such as the pseudo-gap. In addition our results are used to further improve our statistical model.

Q 22.55 Tue 16:30 Empore Lichthof

Local Chern marker of smoothly confined Hofstadter fermions — •Urs Gebert, Bernhard Irsigler, and Walter Hofstetter — Goethe Universität, Frankfurt, Deutschland

The engineering of topological non-trivial states of matter, using cold atoms, has made great progress in the last decade. Driven by experimental successes, it has become of major interest in the cold atom community. In this work we investigate the time-reversal invariant Hofstadter model with an additional confining potential. By calculating a local spin Chern marker we find that topologically non-trivial phases can be observed in all considered trap geometries. This holds also for spin-orbit coupled fermions, where the model exhibits a quantum spin Hall regime at half filling. Using dynamical mean-field theory, we find that interactions compete against the confining potential and induce a topological phase transition depending on the filling of the system. Strong interactions furthermore yield a magnetic edge, which is localized through the interplay of the density distribution and the underlying topological band structure.

Q 22.56 Tue 16:30 Empore Lichthof

Fermi-Hubbard physics in 1d and bilayer systems — •Dominik Bourgund[1], Joannis Koepsell[1], Sarah Hirthe[1], Pimonpan Sompet[1], Jayadev Vijayan[1], Petar Bojovic[1], Guillaume Salomon[1], Christian Gross[1,2], and Immanuel Bloch[1,3] — [1]Max-Planck-Institut für Quantenoptik, München, Germany — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Germany — [3]Ludwig-Maximilians-Universität München, Germany

Ultracold atoms have emerged as a powerful platform to realize the Fermi-Hubbard model in a fully controlled environment. Our quantum gas microscope gives access to full spin and density resolution and thus allows for the study of the interplay between spin and charge in doped antiferromagnets. In a one-dimensional system we observe the phenomenon of spin-charge separation by locally quenching an antiferromagnetic chain via the removal of an atom. A recent upgrade of our system now allows the study of the bilayer Fermi-Hubbard model which is of special interest in the context of high-Tc superconductivity. We investigate the bilayer phase diagram by probing the metal to band insulator as well as the Mott insulator to band insulator transition. We confirm the expected transition point at an interlayer coupling of four times the intralayer coupling. By making use of the full control over the lattice potential we employ topological charge pumping to achieve single-site resolution of each layer. This technique is benchmarked by spin resolving a 2d antiferromagnetic system.

Q 22.57 Tue 16:30 Empore Lichthof

Phase Coherence and Superfluidity in Ultracold 2D Fermi Gases — •Hauke Biss[1,3], Niclas Luick[1,3], Lennart Sobirey[1,3], Markus Bohlen[1,3,4], Vijay Pal Singh[2,3], Ludwig Mathey[2,3], Thomas Lompe[1,3], and Henning Moritz[1,3] — [1]Institut für Laserphysik, Universität Hamburg, Hamburg, Germany — [2]Zentrum für optische Quantentechnologien, Universität Hamburg — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Hamburg, Germany — [4]Laboratoire Kastler Brossel, ENS-PSL Research University, CNRS, Sorbonne

In this contribution we present our studies of phase coherence and superfluidity in strongly interacting two-dimensional Fermi gases. We demonstrate phase coherence by realizing a Josephson junction in the BEC-BCS crossover. We measure the frequency of Josephson oscillations as a function of the phase difference across the junction and find excellent agreement with the sinusoidal current phase relation of an ideal Josephson junction. We probe superfluidity by dragging a red-detuned lattice through the system and observing the characteristic onset of dissipation above a critical velocity. We measure the critical velocity over the crossover at varying interaction strengths. In the limit of tightly bound molecules, as expected from the Landau criterion, the critical velocity approaches the speed of sound, whereas in the BCS limit, pair breaking excitations are the lowest mode of dissipation.

Q 22.58 Tue 16:30 Empore Lichthof

Thermoelectric transport properties of an ultracold Fermi gas — •Philipp Fabritius, Samuel Häusler, Martin Lebrat, Jeff Mohan, Laura Corman, and Tilman Esslinger — Department of Physics, ETH Zurich, 8093 Zurich, Switzerland

On this poster we present a comparison between the thermoelectric transport properties of a non-interacting Fermi gas and a unitary Fermi gas flowing through a quasi two-dimensional channel or a quantum point contact (QPC. In a first experiment we probe the thermoelectric effects induced by a temperature difference across the QPC by measuring the evolution of temperature and particle number in the reservoirs. The transport properties of channel and reservoir can be changed individually via a attractive gate beam and a narrowly focused, repulsive wall beam which changes the zero mode energy of the channel. These two tuning knobs allow to change the particle flow from hot-to-cold to cold-to-hot. This corresponds to tuning the effective Seebeck coefficient. In another experiment we probed the thermoelectric properties of a unitary Fermi gas close to the superfluid transition flowing through a QPC. Here we found that the Lorentz number does not agree with the value given by the Wiedemann-Frantz law which indicates non-Fermi liquid behavior, while the measured, non-zero Seebeck coefficient is not expected for a superfluid. Together this leads to a greatly enhanced thermoelectric efficiency. These results and recent experiments implementing local spin-filter open the way to study systems where not only heat- and particle transport is coupled but also spin.

Q 22.59 Tue 16:30 Empore Lichthof

Ergodicity breaking in tilted one-dimensional optical lattices — •Thomas Kohlert[1,2,3], Sebastian Scherg[1,2,3], Bharath Hebbe Madhusudhana[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstr. 4, 80799 München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

We study interacting ultracold Fermions in a tilted 1D optical lattice to investigate how non-ergodic dynamics can emerge in a system even in the absence of disorder. Using a superlattice to create an initial charge-density wave, we measure the population imbalance between even and odd sites as a local probe of localization. At short times, we observe spin-resolved and parity-projected real-space Bloch oscillations, which are used as benchmark for the experimental parameters such as tunneling rate, tilt and external harmonic confinement in the single-particle case. In the presence of interactions we observe an interaction-dependent amplitude modulation and dephasing of the Bloch oscillations. The long-time dynamics reveal a robust steady state imbalance over about 300 tunneling times, whose value depends on the interaction strength. Finally, we couple adjacent 1D systems to probe the crossover from a non-ergodic 1D to an ergodic 2D system and find a decay of the imbalance depending on the transverse coupling strength.

Q 22.60 Tue 16:30 Empore Lichthof

Local spin manipulation inside an atomic quantum point contact — •Philipp Fabritius, Martin Lebrat, Samuel Häusler, Jeff Mohan, Laura Corman, and Tilman Esslinger — Department of Physics, ETH Zurich, 8093 Zurich, Switzerland

We report on the control of spin inside a QPC using a local effective magnetic field. The versatility of cold-atom techniques allows us to precisely define a QPC using light potentials, to directly measure particle and spin currents and to tune interatomic interactions. In a first experiment performed with weakly interacting atoms, we locally lift the spin degeneracy of atoms inside the QPC using an optical tweezer tuned very close to atomic resonance which introduces a tunable effective Zeeman shift. We observe quantized, spin-polarized transport that is robust to dissipation and sensitive to interaction effects on the scale of the Fermi length. Using resonant light we measured the local loss around the quantum point contact which allowed us to reconstruct a two-dimensional density map similar to a scanning microscope. In a second experiment we investigate a unitary Fermi gas and the change of its transport properties when interacting with an effective Zeeman shift and spin-selective dissipation.

Q 22.61 Tue 16:30 Empore Lichthof

Learning quantum structures in compact localized eigenstates — •Giedrius Zlabys, Mantas Raciunas, and Egidijus Anisimovas — Institute of Theoretical Physics and Astronomy, Vilnius University, Sauletekio 3, LT-10257 Vilnius, Lithuania

Application of machine learning techniques for complex quantum systems provides new numerical tools to probe quantum phenomena. These tools can potentially outperform traditional methods due to their high tunability and efficient information encoding. The faithful representability of many-body states by artificial neural networks (ANNs) is now becoming established as an empirical fact and is supported by analytical evidence. On the other hand, the optimizability of a neural net remains an open issue: it is not a priori clear which models and features are well suited for machine learning techniques.

We apply ANNs to study the emergence of quantum structures in interacting bosonic systems on a lattice. We focus on the simplest one- and two-dimensional geometries that support dispersionless energy bands and the the formation of compact localized states spanning just a few neighboring sites. In the presence of interactions and at suitable values of the filling, these systems demonstrate a transition to a charge density wave. The goal is to explore how successful ANNs can be in learning quantum structures defined by compact localized states. We find that while being guided only by the noisy signal of Monte-Carlo estimates of the ground-state energy, ANNs are able to learn the defining features of quantum structures with the accuracy comparable or even superior to that of ground-state energy itself.

Q 22.62 Tue 16:30 Empore Lichthof

A driven-dissipative Bose-Einstein condensate in a 1-D optical lattice — •Marvin Röhrle[1], Jens Benary[1], Christian Baals[1,2], Alexandre Gil Moreno[1], Jian Jiang[1], and Herwig Ott[1] — [1]Department of Physics and OPTIMAS research center, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 55128 Mainz, Germany

We experimentally investigate the behavior of a driven-dissipative Bose-Einstein condensate of weakly interacting ^{87}Rb atoms in a 1-D optical lattice. The dissipation is induced by the electron beam of a scanning electron microscope(SEM) setup, which allows us to observe a single site time resolved. Tunneling from the neighboring sites makes up the driving force. By changing the tunnel coupling J of the lattice, a first order quantum phase transition, from a coherent super fluid phase to an incoherent phase, can be seen. In between the two phases, both branches coexist in a bistable region and depending on the initial state the final state of the system changes. The filling of individual realizations of every experimental run shows a digital behavior. One site is prepared in either the super fluid phase or the incoherent resistive phase and can switch to the other branch within a few tunneling times. When observing the average dynamics over many experimental realizations a critical slowing down can be seen. Furthermore starting from an initially filled site, the losses induce a superfluid current which keeps the site filled. This complete extinction of a matter wave within a medium indicates Coherent Perfect Absorption(CPA).

Q 22.63 Tue 16:30 Empore Lichthof

Controllable Josephson junction for photon Bose-Einstein condensates — •Mario Vretenar, Ben Kassenberg, Shivan Bissesar, and Jan Klaers — University of Twente, Enschede, The Netherlands

Josephson junctions are the basis for many important fields, such as ultrafast electronics with magnetic flux quanta and superconducting quantum computing. The physical predictions of Josephson junctions are highly universal and can be observed in systems as diverse as coupled superconductors, atomic Bose-Einstein condensates, and others. We experimentally demonstrate tunable tunneling between two photon Bose-Einstein condensates by a targeted shaping of the potential landscape acting on the photons during the tunneling process. The investigated device realizes an optical analogue of a 0,π-Josephson junction, which can act as a building block for an ultrafast all-optical spin glass simulator. Such a simulator is expected to solve hard optimization problems orders of magnitude faster and more energy efficient than conventional supercomputers. The potential landscape in our photon Bose-Einstein condensate Josephson junctions is realized by a combination of direct laser writing for permanent mirror nanostructuring, and heating a thermosensitive polymer for runtime fine tuning of couplings.

Q 22.64 Tue 16:30 Empore Lichthof

Density-matrix renormalization group study of quench dynamics in the extended Bose-Hubbard model — •Sebastian Stumper, Junichi Okamoto, and Michael Thoss — Insitute of Physics, University of Freiburg, Freiburg, Germany

Dynamical quantum phase transitions (DQPTs), defined as kinks of the rate function of the Lohschmidt-echo after a global quench of the Hamiltonian, have attracted much interest over the past years. For a broad class of non-intreacting systems the occurrence of DQPTs is well established, if the initial and final Hamiltonian belong to topologically distinct phases (Phys. Rev. B 91, 155127 (2015)). On the other hand, this relation does not hold in interacting systems. The one-dimensional extended Bose-Hubbard model presents an example of an interacting model, which hosts a symmetry protected topological phase, the Haldane insulator phase, along with two trivial insulating phases, Mott insulator and density wave. We numerically investigate the dynamics of this model for quenches across phase boundaries by density-matrix renormalization group. We discuss the finite size scaling of the rate function, and show possible candidates for DQPTs.

Q 22.65 Tue 16:30 Empore Lichthof

Nonequilibrium density wave order in driven atom-cavity system — •Christoph Georges, Hans Kessler, Phatthamon Kongkhambut, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany

Competing Phases and their driving are subject of interest in the field of light-induced phase in heavy-fermion systems [1] such as in light-induced superconductivity. However, because of their complex nature, materials like cuprates are delicate to theoretical grasp. Recent efforts lead to quantum gas experiments emulating simplified models for solid-state phenomena.

An ultracold gas of atoms inside a high-finesse optical cavity is one example of a versatile platform for exploring non-equilibrium phenomena and dynamical driven phase transitions in many-body systems [2]. We observe the formation of a new competing non-equilibrium density wave order in a resonantly driven Bose-Einstein Condensate coupled to the light field of a high finesse cavity. Without driving, the system organizes in a density wave that supports Braggscatting into the cavity and stabilizes itself. Meanwhile, when driving is applied, it suppresses this density wave, and a non-equilibrium density wave can be excited. This new density wave does not support further scattering into the cavity. We report on this new emerging phase in respect of driving parameters and its temporal evolution.

[1] Kogar et al. Nat. Phys. s41567-019-0705-3 (2019)
[2] C. Georges et al. Phys. Rev. Lett. 121, 220405 (2018)

Q 22.66 Tue 16:30 Empore Lichthof

Continuous feedback and spin-changing processes in a quantum gas coupled to a cavity — •Francesco Ferri, Fabian Finger, Katrin Kroeger, Rodrigo Rosa-Medina, Nishant Dogra, Marcin Paluch, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We realize a driven-dissipative version of the Dicke model by coupling a Bose-Einstein condensate (BEC) to an optical cavity, and illuminating it with a transverse pump laser. Above a critical pump strength, the system undergoes a phase transition to a superradiant phase exhibiting self-ordering of the atomic density. The system's state can be accessed non-destructively by detecting the photons leaking from the cavity.

Here, we report on two recent advances in this context. First, we describe the implementation of an active feedback scheme to stabilize the mean intra-cavity photon number in the superradiant phase, by acting back on the pump strength. Feedback allows to approach the phase transition with a high degree of control and to extend the lifetime of the system close to criticality. Our results are a first step towards more complex feedback schemes leading to exotic many-body phases, such as limit cycles or Floquet time crystals.

In a second set of experiments, a double-frequency pump laser induces cavity-assisted Raman transitions between different spin and motional states of the BEC. An extended, fully tunable Dicke model is realized, where competing coherent and incoherent spin-changing processes occur. This scheme opens new avenues for investigating longrange spin interactions and novel magnetic phases.

Q 22.67 Tue 16:30 Empore Lichthof

Controlling spin-exchange collisions between individual neutral impurities and an ultracold quantum gas — •Sabrina Burgardt[1], Quentin Bouton[1], Daniel Adam[1], Jens Nettersheim[1], Daniel Mayer[1], and Artur Widera[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany

Individual neutral atoms in an ultracold bath are a paradigmatic model of quantum impurity physics. The microscopic interaction mechanisms can be employed to use them as single-atom quantum probes, mapping information of their environment onto quantum mechanics states[1]. Individual impurities with resonant spin-exchange are the fundamental building block of the (Bose) Kondo effect, forming correlated states of the impurity with its environment.

We report a method to adjust the energy detuning in the spin-exchange dynamics of individual neutral Caesium atoms with total spin F=3 in an ultracold Rubidium gas with total spin F=1. Controlling the AC-Zeeman-Shift, induced by an off-resonant microwave or laser field, enables a selective tuning between inelastic endo- and exoergic spin-exchange collisions between the impurities and the bath. We show parameter regimes that allow tuning spin-exchange processes to resonance. This will furthermore enable future studies of impurity-bath interaction with tuneable dissipation.

[1] Q. Bouton et al., arxiv: 1906.00844, 2019