Topology and quantum transport in Floquet driven systems

Aya Abouelela

University of Bonn

The topological phases of periodically driven systems have been classified across all dimensions in the periodic table of Floquet topological insulators. The Floquet multiplicity of bands implies the emergence of anomalous edge states which cross bulk gaps that do not occur in static systems. Here, we present our studies on the non-interacting topological Qi-Wu-Zhang model under the influence of a periodic drive, and analyze its drive-induced edge modes in two regimes of the driving frequency Ω; higher or lower than the static bandwidth. For the experimental detection of edge states, we calculate the *dI/dV* spectra at non-zero DC bias voltage V, using the Keldysh-Floquet formalism. We predict quantized conductance plateaus when the transport voltage is within a normal gap (V centered around $V = 0$, normal edge mode) or within an anomalous gap (around $V = \pm\Omega/2$, anomalous edge mode). We also perform a spatially resolved computation of the chiral transmission channels of the finite-size system with finite bias applied, showing that the transport is along an edge and that it is spatially modulated corresponding to the wave number π of the (anomalous) edge mode.

Quantum decisions at tipping points: the quantum Kruskal-Neishdadt-Henrard theorem

James Anglin

Technical University of Kaiserslautern

Adiabatic approximations break down classically when a constant-energy contour splits into two separate contours. A system which has evolved adiabatically under slowly changing conditions must then choose which region of phase space to enter. The Kruskal-Henrard-Neishdadt theorem relates the probability of each choice to the rates at which the phase space areas enclosed by the different contours are changing. This represents a clear connection within closed-system mechanics, and without dynamical chaos, between spontaneous change and increase in phase space volume, as required by the Second Law of Thermodynamics. Quantum mechanically, in contrast, dynamical tunneling allows adiabaticity to persist, for very slow parameter change, through a classical bifurcation of energy contours; the classical and adiabatic limits fail to commute. Here we show that a quantum form of the Kruskal-Henrard-Neishdadt theorem holds nonetheless, due to unitarity.

Non-Markovian Quantum Dynamics in Strongly Coupled Multimode Cavities Conditioned on Continuous Measurement

François Damanet

University of Liège

Atoms in multimode cavity QED provide an ideal platform to study out-of-equilibrium many-body physics, as cavity modes mediate interactions between atoms allowing for the exploration of a wide range of models [1]. From a theory perspective, it is desirable to eliminate the cavity modes to significantly shrink the size of the Hilbert space, but this usually requires going beyond standard Lindblad open system descriptions of the atoms, even in the weak-coupling regime [2]. Here, I present a new stochastic method that describes the exact atomic dynamics beyond standard adiabatic elimination. Moreover, the relevant equations of motion - which correspond to mixed-state quantum trajectories for the atoms - can be interpreted as conditioned by real measurement records of the output light [3]. This provides a direct way to connect experimental measurements to atomic correlation functions and opens possibilities for quantum feedback control beyond Markov.

[1] V. D. Vaidya et al., PRX 8, 011002 (2018).

[2] F. Damanet et al., PRA 99, 033845 (2019). R. Palacino and J. Keeling, PRR 3, 032016 (2021).

[3] V. Link et al., arXiv:2112.09499.

Engineering of Feshbach Resonances by a Floquet Drive

Christoph Dauer

Technical University of Kaiserslautern

Feshbach resonances are a common tool in order to control the scattering length in ultracold quantum gases. In this talk we discuss how time-periodic driving enables to induce novel resonances that are fully controllable by the parameters of the drive. A theory allowing a deeper understanding of these driving induced resonances within the Floquet picture is given. Our method is capable of describing resonance positions and widths for general inter-particle potentials. We demonstrate our results on an experimentally relevant example.

Interarm recoil effects and gray molasses in a ring cavity

Hodei Eneriz

Nice Institute of Physics (Inphyni)

We present a unique setup consisting of a doubly resonant Bow–Tie Cavity, both at 780 and 1560 nm which permits to load and cool atoms inside a deep optical dipole trap using gray molasses. High–finesse at 780 nm in turn allows for collective strong atom-cavity coupling via frequency doubling of the 1560 nm source which is locked to the cavity resonance. Interactions between counter-propagating modes and BECs could reveal the existence of different phases of matter which we would like to explore in the future.

Ultracold fermions in optical superlattices

Janek Fleper

University of Bonn

The quantum simulation of Fermi-Hubbard models using ultracold atoms in optical lattices has been essential to deepen our understanding of condensed matter systems. With the precise tunability of the model parameters and the possibility to even change the dimensionality of the systems, it allows to investigate many-body quantum phases. In particular, probing spin correlations has been of interest in understanding high-temperature superconductivity. Our experimental setup is based on a three-dimensional optical lattice where a vertical lattice confines the atoms in two-dimensional layers. Recently, the vertical lattice has been extended to a superlattice to implement pairs of layers coupled by interlayer tunneling. To introduce the superlattice capabilities to the two-dimensional layers, we are currently working on the implementation and stabilization of an in-plane superlattice. In the future, we are going to investigate topological systems and transport properties in time-dependent superlattices.

Intracavity Rydberg superatom for optical quantum engineering

Sébastien Garcia

Collège de France, CNRS

We present the first building blocks for quantum engineering of light with an intracavity single Rydberg superatom. Our experimental platform is made of a small (5 µm rms) and cold (2 µK) rubidium ensemble strongly coupled to a medium-finesse running-wave resonator. An Electromagnetically Induced Transparency (EIT) configuration maps photons onto Rydberg excitations. The van-der-Waals interactions are strong enough for the presence of one Rydberg atom to prevent the excitation of others. Thus, the atomic ensemble behaves as a single two-level superatom strongly coupled to the cavity. We implement a coherent control of this superatom via a two-photon Rabi driving. The state of the superatom can be optically detected via the cavity transmission with a 95% efficiency. Finally, we demonstrate that our coupled system induces a 180° phase shift on the light reflected off of the cavity dependent on the superatom's state, allowing us to detect the latter with a 90% efficiency via a homodyne measurement. This 180° phase rotation, together with the coherent control and the single-shot state detection, is a key ingredient for the implementation of a unitary photon-photon interactions.

Resonances in periodically driven magnon systems

Mathis Giesen

Technical University of Kaiserslautern

Floquet theory is used in order to examine resonances in periodically driven systems which are quadratic in bosonic operators. As a central consequence parametric resonances occur if the driving frequency is an integer multiple of two times the energy of the elementary excitation. We apply this theory to study magnons in ferromagnetic systems in order to develop a microscopic understanding of pumping processes. In particular we propose resonances for frequencies below the energy spectrum and unusual patterns in the magnon density. We compare our results with phenomenological approaches and investigate the role damping plays in such systems.

Particle transport on a tight binding chain with two AC-driven impurities

Florin Hemmann

University of Bonn

Using the Floquet formalism the momentum resolved particle transport on a tight binding chain with two AC-driven impurities is studied. The system exhibits a range of tunable parameters such as the driving amplitude, the relative phase between drivings, and the distance between impurities. The effect of these parameters on particle transmission is analyzed in different driving frequency regimes. For high frequencies the system reduces to an effective time-independent model. In this limit eigenstates localized between two static impurities are identified and related to particle transmission max

Enhancement of entanglement at a dissipative phase transition

Dolf Huybrechts

ENS de Lyon

Dissipative phase transitions (DPTs) are driven by the competition between coherent Hamiltonian evolution in many-body systems and the coupling to the environment, and they may be realized in a variety of quantum simulation platforms. A long-standing question concerns the role of quantum effects at these transitions, and specifically of entanglement: indeed one may suspect that a stronger dissipation will always reduce entanglement in the steady state; and that entanglement properties will not be singular at the transition. In this work we can clarify unambiguously this aspect by studying entanglement at an exactly solvable DPT, namely the one of the all-to-all connected XYZ model in the presence of (local or global) spontaneous emission. By calculating collective-spin properties and the quantum Fisher information (QFI) in the steady state, we show that it exhibits multipartite entanglement in the form of spin squeezing, which is also its optimal metrological resource. And we observe that both squeezing and QFI are maximal at the transition — namely, unlike thermal criticality at equilibrium, dissipative criticality can enhance entanglement properties in the steady state.

Auxilliary Particle Field Theory for Generalised and non-Markovian Jaynes-Cummings Models

Michael Kajan

University of Bonn

The interaction of photons with molecules or atoms coupled to vibrations are often described by Jaynes-Cummings or spin-boson models. Commonly, these models are treated via a rate-equation approach due to the non-canonical dynamics of the (spin-like) electronic excitations. However, this approach does not account for non-Markovian dynamics of the internal vibrational states. We introduce a novel auxilliary-particle formulation for the electronic and vibrational state of the molecules. This field-theoretical approach can be applied in and out of equilibrium and can capture non-Markovian dynamics, large reservoir sizes as well as spontaneously broken U(1) symmetry due to Bose-Einstein condensation. We present results for a pump cavity system filled with a dilute dye solution showing a BEC transition of photons. Further generalisations of this formulation can be applied to various open or closed multi-level systems.

Photon gases in microstructured potentials: From 1D to 2D

Kirankumar Karkihalli Umesh

University of Bonn

Bose-Einstein condensate (BEC) of light has been realized at room temperature in a dye-filled microcavity. In such microcavities the longitudinal dimension is frozen out, limiting photons to two transversal directions, which makes them inherently a 2D system. In this system thermodynamic properties, formation dynamics as well as fluctuation properties have been studied in detail in the past. Recently, also the formation of photon condensates in microstructured potentials have been studied. In our project, we intend to study the spatial dimensional cross-over from a 2D photon gas to 1D photon gas, by the tailored asymmetric harmonic potential of varying trap frequencies. While in two dimensions a phase transition to a BEC exists, in one dimension no thermodynamic phase transition is expected in our model system. As in the photon BEC thermalization proceeds via the coupling to a heat bath, namely a dye solution, thermalization here also is observed for the one dimensional case, in which integrability of the system usually suppresses or slows down thermalization. Here, in this poster, I present the latest experiment results for such a spatial dimensional cross-over study.

Particle fluctuations and the failure of simple effective models for many-body localized phases

Maximilian Kiefer-Emmanouilidis

Technical University of Kaiserslautern

This talk contributes to the ongoing debate whether a many-body localized phase (MBL) of a spinless fermion model with potential disorder and nearest-neighbor interactions (t-V model) exists or not. In particular, recent evidence suggests that there is a continuing subdiffusive particle transport even deep in the putative MBL phase [1, 2, 3]. Therefore, we investigate and compare the particle number fluctuations in the many-body localized phase with those in the non-interacting case (Anderson localization) and in effective models where only interaction terms diagonal in the Anderson basis are kept. We demonstrate that these types of simple effective models cannot account for the particle number fluctuations observed in the MBL phase of the microscopic model. As a consequence, it appears questionable if the microscopic model possesses an exponential number of exactly conserved local charges. If such a set of conserved local charges does not exist, then particles are expected to ultimately delocalize for any finite disorder strength.

[1] Phys. Rev. Lett. 124, 243601 (2020)

[2] Phys. Rev. B 103, 024203 (2021)

[3] Annals of Physics 435, 168481 (2021)

Creation of non-classical states of light from Rydberg superatom arrays

Kevin Kleinbeck

University Stuttgart

Cold clouds of Hydrogen-like atoms, excited to large principle quantum numbers, can only store a single excitation due to the Rydberg blockade mechanism. Together with the super-radiant coupling to the light field these clouds effectively behave like two-level atoms in a chiral waveguide, called Rydberg superatoms. We study the photon statistics of light emitted from an array of such superatoms and show the emergence of non-classical states of light.

Random matrix theory for quantum and classical metastability in local Liouvillians

Jimin Li

University of Bonn

We consider the effects of strong dissipation in quantum systems with a notion of locality, which induces a hierarchy of many-body relaxation timescales as shown in [Phys. Rev. Lett. 124, 100604 (2020)]. If the strength of the dissipation varies strongly in the system, additional separations of timescales can emerge, inducing a manifold of metastable states, to which observables relax first, before relaxing to the steady state. Our simple model, involving one or two "good" qubits with dissipation reduced by a factor $\alpha<1$ compared to the other "bad" qubits, confirms this picture and admits a perturbative treatment.

Candidate for a self-correcting quantum memory in two dimensions

Simon Lieu

National Institute of Standards and Technology *(*NIST)

An important direction in the field of quantum error correction is to find a robust "self-correcting quantum memory," defined as an encoded qubit coupled to an environment which naturally wants to correct errors. To date, a quantum memory stable against finite temperature effects is only known in four dimensions or higher. Here, we take another route to realize a stable quantum memory by engineered dissipation. We propose a new model which appears to self-correct against both bit-flip and phase-flip errors in two dimensions.

Dissipation-engineered family of nearly dark states in many-body cavity-atom systems

Rui Lin

ETH Zurich

Three-level atomic systems coupled to light have the capacity to host dark states. We study a system of V-shaped three-level atoms coherently coupled to the two quadratures of a dissipative cavity. The interplay between the atomic level structure and dissipation makes the phase diagram of the open system drastically different from the closed one. In particular, it leads to the stabilization of a continuous family of dark and nearly dark excited many-body states with inverted atomic populations as the steady states. The multistability of these states can be probed via their distinct fluctuations and excitation spectra, as well as the system's Liouvillian dynamics which are highly sensitive to ramp protocols. Our model can be implemented experimentally by encoding the two higher-energy modes in orthogonal density-modulated states in a bosonic quantum gas. This implementation offers prospects for potential applications like the realization of quantum optical random walks and microscopy with subwavelength spatial resolution.

Majorana end-modes in a spinful particle conserving model

Franco Lisandrini

University of Bonn

We show the presence of Majorana edge modes in an interacting fermionic ladder with spin in a number conserved setting. The interchain single particle hopping is suppressed and only a pair hopping is present between the different chains of the ladder. Additionally, the hopping along the chains is spin imbalanced and a transverse magnetic field is applied breaking time-reversal invariance. We study the robustness of the topological phase with respect to an on-site interaction between the spin-up and spin-down fermions and the spin dependent imbalance of the hopping. The main result of the present work is that the phase survives for a finite region in the parameter space and we were able to identify the other phases present around the topological phase. In particular, the localized Majorana edge modes seems to be more stable in the case when the on-site interaction is an attraction.

Fast rotation and decay of a superfluid

Laurent Longchambon

Université Sorbonne Paris Nord, Laboratoire de Physique des Lasers

Superfluidity is a rich quantum dynamical phenomenon with striking manifestations such as the existence of a critical velocity for the creation of excitations and the appearance of quantized vortices when set into rotation. We are experimentally able to produce a fast rotating superfluid (Bose-Einstein condensate) confined onto the surface of a shell-shaped radiofrequency-dressed trap. When increasing the effective rotation rate of the BEC, one observes the setting of an ordered array of vortices, until the lattice destabilizes for a large number of vortices. For higher rotation rates, the trap anharmonicity causes the superfluid to deform into a rotating ring. This system is highly out-of-equilibrium as its velocity reaches up to 18 times the critical velocity and lasts 60s, despite a nonvanishing residual trap anisotropy. The study of dissipation processes, by superimposing a controlled defect on the rotating ring, would shed a new light on theoretical and recent experimental work that have shown that obstacles moving at velocities far exceeding the Landau critical velocity do not necessarily create a significant amount of excitations.

Quantum energetics: connecting an open- and a closed-system approach

Maria Maffei

Institut Neel, Cnrs Grenoble

Establishing consistent notions of work and heat for quantum systems is a fundamental goal of quantum thermodynamics. In open-systems driven by a classical source, and coupled to a bath, the system exchange work with the source, and dissipates heat into the bath. We compare this open-system perspective to an alternative, closed-system one, whose notions of work and heat rely on the dynamical structure of each subsystem. We consider a qubit coupled to a 1D waveguide injected with a coherent field as a test-bed system to compare the two different notions of work. We show that the dissipator of the qubit master equation (Optical Bloch Equation) contains a Hermitian (entropy preserving) component that the closed-system perspective takes as an additional unitary driving on the qubit. This driving is exerted by the field that the qubit itself emits in the waveguide, and hence is proportional to the coherence of its state. For this reason, this self-driving, and the associated energy change, the self-work, remain even in the absence of an input field, enabling one to define work exchanges during the spontaneous emission process.

Cavity-QED Quantum Simulator of Random Spin Models

Francesca Orsi

EPFL

In my poster, I will present a cavity QED experiment where we use 6Li atoms to perform quantum simulations of random spin models.

The atom-cavity system realizes a spin chain with random transition frequencies coupled to an extended photon mode,with controlled disorder realized by a local light-shift of the excited state of the atoms. We study the competition between the collective many-body physics and the disorder in two regimes: in the near-resonant regime, N spins with random energies are coupled to a bosonic model. In the dispersive regime, one can adiabatically eliminate the cavity to obtain long-range spin-exchange interactions. The effective Hamiltonian can be rewritten in terms of N spins precessing around an external magnetic field with random inhomogeneities. We measure the magnetic susceptibility of the system as a function of the disorder strength.

Last, I will discuss possible perspectives of using our light-shifting technique for the quantum simulation of holographic matter such as SYK-type model.

Periodically Driven Quantum-Many-Body Spin System: A Real-Time Approach using Exact Diagonalization (ED) Method

Aslam Parvej

Technical University of Kaiserslautern

A time-periodically driven quantum system is particularly interesting due to its existence of unconventional states of matter and quantum engineering. The interplay of many-body correlations and their time-periodic manipulations predict a whole set of new phenomena which is not seen in its equilibrium counterpart and it is extremely difficult to study theoretically and numerically beyond high-frequency approximation. We propose a promising real-time approach with adiabatic time-evolution protocol using a numerical exact diagonalization method to study the time-periodic spin-1/2 Heisenberg antiferromagnetic chain with periodic boundary condition. Our focus is to explore and tune the Floquet steady state from low to high-frequency regime. We notice some peculiarities of the quantum correlation in the phase space of driving frequency and driving amplitude of the system under study. The possible experimental realization would be an ultra-cold experimental systems where one can see the effect of time dependent single impurity atom in the bath of interacting fermion.

Stability of Quantum Degenerate Fermionic Polar Molecules Without and With Microwave Shielding

Axel Pelster

Technical University of Kaiserslautern

A stabilization of a fermionic molecular gas towards collapse in attractive head-to-tail collisions and its evaporative cooling below the Fermi temperature has so far been achieved in two ways. Either one applies a strong dc electric field and confines the molecular motion to 2D [1] or one strongly suppresses inelastic collisions in 3D by applying a circular polarized microwave field [2]. Here we use a Hartree-Fock mean-field theory [3,4] in order determine the 3D properties of quantum degenerate fermionic molecules. In particular, we compare the stability diagrams occurring without (with) mirowave shielding, where a (negative) dipole-dipole interaction (DDI) applies. And in case that the orientation of the electric dipoles with respect to the trap axes is unknown, we outline how to reconstruct it from time-of-flight absorption measurements.

[1] G. Valtolina, et al., Nature 588, 239 (2020)

[2] A. Schindewolf, et al., arXiv:2201.05143 (2022)

[3] V. Veljic, et al., New J. Phys. 20, 093016 (2018)

[4] V. Veljic, A. Pelster, and A. Balaz, Phys. Rev. Res. 1, 012009 (2019)

Quantum nonlinear optics in atomic arrays

Thomas Pohl

Aarhus University

Two-dimensional arrays of atoms have emerged as extraordinary light-matter interfaces with remarkable optical properties. In particular, the collective interaction of light with extended sub-wavelength arrays enables strong coupling to individual free-space photonic modes at greatly reduced losses. This many-body nature of the light-matter interaction, however, renders the optical interface linear under most circumstances.

This contribution presents different routes to achieving large nonlinearities and strong photon interactions by employing atomic Rydberg states and multiple arrays. The driven many-body dynamics that emerges in this open system will be discussed in different regimes, from few to many interacting photons. We will present different schemes to generate and control quantum states of light via such nonlinear atomic arrays and discuss future applications. Similarities to two-dimensional solid-state materials will also be explored.

Non-local correlation and entanglement of ultracold bosons in the two-dimensional Bose-Hubbard lattice at finite temperature

Sayak Ray

University of Bonn

We investigate the temperature-dependent behavior emerging in the vicinity of the superfluid (SF) to Mott insulator (MI) transition of interacting bosons in a two-dimensional optical lattice, described by the Bose-Hubbard model. The equilibrium phase diagram at finite temperature is computed by means of the cluster mean-field theory (CMF) including finite cluster size scaling. The SF, MI, and normal fluid (NF) phases are characterized as well as the transition or crossover temperatures between them are estimated by computing the SF fraction, compressibility and sound velocity using CMF method. The nonlocal correlations in a cluster, when extrapolated to infinite size, leads to quantitative agreement of the phase boundaries with quantum Monte Carlo (QMC) results and with experiments. Moreover, we show that the von Neumann entanglement entropy in a cluster corresponds to entropy density which enhances near the SF-MI quantum critical point (QCP) and at the SF-NF boundary. Behavior of the transition lines near this QCP, at and away from the particle-hole (p-h) symmetric tip of a Mott lobe, is also discussed.

Reference: U. Pohl, S. Ray and J. Kroha, Ann. Phys. (Berlin), 2100581 (2022).

Driven Bose-Einstein condensate with tailored dissipation and potentials

Marvin Röhrle

Technical University of Kaiserslautern

We experimentally investigate a weakly interacting Bose-Einstein condensate of Rb atoms with temporally engineered potentials, coherent drive, and local dissipation.

We present results about a driven-dissipative condensate in a 1-D optical lattice. By tuning the tunnel coupling between the sites, we can observe a first order dissipative phase transition in a single lossy site. The system exhibits two metastable states and a fast switching behavior between the two states, where hundreds of atoms tunnel within a few tunneling times. We measure the effective Liouvillian gap and characterize the switching behaviour.

In a second experiment we have realized a Kapitza pendulum for ultracold atoms. We harmonically modulate an optical potential from attractive to repulsive with a vanishing time average. The corresponding Floquet Hamiltonian results in an effective time independent potential, with a confining, i.e. stable, trap in the center. We analyze the lifetime and the stability of the trap, depending on the driving frequency of the potentials.

Engineering Dynamical Tunneling in a Superradiant Quantum Gas

Rodrigo Rosa-Medina

ETH Zurich

Dynamic transients are a natural ingredient of non-equilibrium quantum systems. One paradigmatic example is Dicke superradiance, describing the collectively enhanced population inversion of an ensemble of two-level atoms coupled to a single mode of the electromagnetic vacuum. Here, we present a new experimental approach, which exploits superradiance in a quantum degenerate gas to engineer dynamical currents in a synthetic lattice geometry. Our experiments are based on a spinor Bose-Einstein condensate coupled to a high-finesse optical cavity. Two transverse lasers induce cavity-assisted Raman transitions between discrete momentum states of two spin levels, which we interpret as tunneling in a momentum lattice. In particular, the tunneling events are mediated by cavity photons and evolve dynamically with the atomic state. By heterodyning the cavity leakage, we locally resolve them in real time and benchmark their collective nature. Our results provide prospects to explore dynamical gauge fields in non-Hermitian quantum systems.

Controlled Dephasing and Two-Time Correlations in Rydberg Qubits

Andre Salzinger

University of Heidelberg

Engineering open system dynamics relies on restricted degrees of freedom of a larger system. Equivalently, master equations can be derived by averaging over realisations of stochastic processes. We present experimental results for qubit rotations subjected to random phase walks, which are sampled from 1D Brownian motion. The observed realisation average follows a Lindblad description with decay parameter γ given by the variance of sampled phase walks. We use this controlled dephasing in a linear-response scheme to extract the unequal-time anticommutator in an ensemble of driven two-level systems by coupling to an ancilla level. This acts as a first benchmark for future measurements in many-body systems far from equilibrium, where unequal-time commutator and anticommutor probe fluctuation-dissipation relations.

Floquet-engineered pair and single particle filter in the Fermi Hubbard model

Ameneh Sheikhan

University of Bonn

We investigate the Fermi-Hubbard model with a Floquet-driven impurity in the form of a local time-oscillating potential. For strong attractive interactions a stable formation of pairs is observed. These pairs show a completely different transmission behavior than the transmission that is observed for the single unpaired particles. Whereas in the high frequency limit the single particles show a maximum of the transition at low driving amplitudes, the pairs display a pronounced maximum transmission when the amplitude of the driving lies close to the ratio of the interaction U and the driving frequency ω. We use the distinct transmission behaviour to design filters for pairs or single particles, respectively. For example one can totally block the transmission of single particles through the driven impurity and allow only for the transmission of pairs. We quantify the quality of the designed filters.

Spectral imaging of the anomalous π mode in periodically driven plasmonic waveguide arrays

Anna Sidorenko

University of Bonn

Evanescently coupled waveguides serve as a convenient platform for simulation of diverse tight-binding systems. The basis for this is the mathematical identity between the coupled mode theory equations and the discrete Schrödinger equation in the tight-binding approximation. Here, we realize the time-periodic Su-Schrieffer-Heeger model using arrays of dielectric loaded surface plasmon polariton waveguides. By precisely tailoring parameters of periodic driving, we investigate its effect on the transport of surface plasmon polaritons and the resulting band structure. We present real and Fourier space observation of the anomalous π mode appearing in the time-periodic Su-Schrieffer-Heeger model.

Relaxation to a biorthogonal generalized Gibbs ensemble after a quantum quench in a parity-time symmetric driven and open Kitaev chain

Elias Starchl

Institute for Theoretical Physics Innsbruck

After a quench, isolated thermalizing quantum many-body systems relax locally to an equilibrium state that is universally determined by conservation laws and the principle of maximum entropy. In contrast, open quantum systems, subjected to Markovian drive and dissipation, typically evolve toward nonequilibrium steady states that are highly model-dependent. However, focusing on a driven-dissipative Kitaev chain, we show that relaxation after a quantum quench can be described by a maximum entropy ensemble, if the Liouvillian governing the dynamics has parity-time (PT) symmetry. We dub this ensemble, which is determined by the biorthogonal eigenmodes of the adjoint Liouvillian, the biorthogonal generalized Gibbs ensemble. Resembling isolated systems, thermalization becomes manifest in growth and saturation of entanglement, and the relaxation of local observables. In contrast, the directional pumping of fermion parity represents a phenomenon that is unique to relaxation dynamics in driven-dissipative systems. We expect that our results apply rather generally to integrable, driven-dissipative bosonic and fermionic quantum many-body systems with PT symmetry.

Hamiltonian Formulation of Thermo-Optic Photon-Photon Interaction in Photon BECs

Enrico Stein

Technical University of Kaiserslautern

Photon Bose-Einstein condensates are created in a microcavity filled with a dye solution in which photons are trapped. The dye continually absorbs and re-emits these photons causing the photon gas to thermalise at room temperature and finally to form a Bose-Einstein condensate. Because of a non-ideal quantum efficiency, these cycles heat the dye solution, creating a medium in which effective photon-photon interaction takes place. However, a full Hamiltonian formulation of this process has yet to be derived. In this contribution, we focus on a Hamiltonian description of the effective photon-photon interaction that includes the thermal cloud. Using an Exact Diagonalisation approach, we work out how the effective photon-photon interaction modifies the spectrum of the photon gas and how it affects the condensate width. As a second case study, we apply our theory to the dimensional crossover from 2D to 1D. In this scenario, we focus on a comparison with a plain variational approach based on the Gross-Pitaevskii equation and explicitly work out the contribution of the thermal cloud.

Time evolution of an interacting chain in cavity with artificial neural networks

Tomasz Szoldra

Jagiellonian University in Krakow

We apply the time-dependent variational principle for open quantum systems with artificial neural networks [Reh et al., PRL 127, 230501 (2021)] to perform numerical time evolution of an interacting chain coupled to an electromagnetic cavity mode (for bosons, see e.g. [Halati et al., PRL 125, 093604 (2020)]). The density matrix of the system is represented by probabilities of the SIC-POVM measurement outcomes and, subsequently, parametrized by an autoregressive neural network ansatz. Time evolution of the mixed state corresponds to updates of the network parameters according to the Lindblad master equation in the POVM formulation. Our software serves as an extension of the jVMC codebase to chain-cavity systems.

Fermionic many-body self-organization in dissipative cavities

Luisa Tolle

University of Bonn

The complexity of open interacting many body quantum systems makes it very appealing to gain control over the quantum states to tailor the properties of the system.

We investigate many body dynamics of the self ordering phase transition present in quantum matter coupled to quantum light. We consider ultracold interacting fermionic atoms on a chain coupled to the field of a dissipative cavity. The model features many competing energy scales, from the atomic short-range interaction to the global coupling to the cavity mode and the interplay with an external bath through photon losses. To study the steady states and self-ordering processes, we developed a quasi-exact numerical method based on time dependent matrix-product state methods that is able to capture the full dynamics of the complex atoms-cavity coupled system. The newly elaborated method allows to treat a short range interacting quantum many-body system coupled to a lossy bosonic mode and can potentially be adapted to a broad range of systems.

With this method, going beyond the mean field level, we are able to investigate the influence of fluctuations on the coupling between atoms and cavity field.

Kondo systems with periodically driven dipole transitions

Michael Turaev

University of Bonn

In this work, we study the effects of light irradiation on a magnetic impurity.

The impurity is modelled by the single impurity Anderson model, where the local impurity is coupled to the conduction electrons via dipole coupling. Therefore, the application of a strong laser field induces a time-periodic hybridization. This can be treated within Floquet Green's function method combined with the slave boson non-crossing approximation [1]. What we see is that the Kondo peak is robust against small driving strengths, and then it gets strongly suppressed when the driving strength increases. Moreover, we find that the destruction of the Kondo effect occurs at a much lower driving strength compared to a situation where the energy level of the impurity is itself driven independently.

[1] B. H. Wu and J. C. Cao, Physical Review B 81, 085327 (2010).

Atoms in the lowest Landau level of a synthetic atomic erbium quantum Hall system

Arif Warsi Laskar

University of Bonn

We have realized artificial magnetic fields for a cloud of ultracold erbium atoms using a configuration consisting of one spatial dimension and one synthetic dimension given by the Zeeman quantum number.

We determine the Hall drift of the system, which reveals distinct bulk and edge behavior, and observe cyclotron orbits upon employing excitations. To characterize the topological properties of the system, the local Chern marker of the lowest Landau level has been successfully determined.

Room-temperature exciton polaritons in an atomically-thin WS2 crystal

Matthias Wurdack [1,2] E. Estrecho,[1,2] C. Schneider,[3] A. G. Truscott,[2] and E. A. Ostrovskaya[1,2]

[1]ARC Centre of Excellence in Future Low-Energy Electronics Technologies

[2]Department of Quantum Science and Technology, Research School of Physics, The Australian National University, Canberra, ACT 2601, Australia

[3]Institut für Physik, Carl von Ossietzky Universität Oldenburg, Ammerländer Heerstraße 114-118, 26126 Oldenburg, Germany

The Australian National University

Monolayer transition metal dichalcogenide crystals (TMDCs) hold great promise for semiconductor optoelectronics because their bound electron-hole pairs (excitons) are stable at room temperature and interact strongly with light. When TMDCs are embedded in an optical microcavity, their excitons can hybridise with cavity photons to form exciton polaritons (polaritons herein), which are promising for enabling future applications.

In this presentation, we will show that room temperature polaritons in high-quality monolayer WS_2-based planar microcavities experience strong motional narrowing, which enables them to propagate ballistically (without loss of energy) over tens of micrometers in the “thermal” regime. Further, we will demonstrate how to assemble a trap for the polaritons and why such confinement enhances their partial coherence and ground state population. These phenomena allow us to inject partially coherent trapped polaritons indirectly with free polaritons outside of the trapping region, which marks an important step towards realising electrically-injected coherent light sources based on TMDCs, e.g. with ring-contacts.

Many-body localization regime for cavity induced long-range interacting models

Jakub Zakrzewski

Jagiellonian University

Many-body localization (MBL) features are studied here for a large spin chain model with long-range interactions. The model corresponds to cold atoms placed inside a cavity and driven by an external laser field with long-range interactions coming from rescattering of cavity photons. Earlier studies were limited to small sizes amenable to exact diagonalization. It is shown that nonergodic features and MBL may exist in this model for random disorder as well as in the presence of tilted potential on experimental timescales also for experimentally relevant system sizes.