TT 51: Nonequilibrium Quantum Many-Body Systems I (joint session TT/DY)

Time: Wednesday 9:30–13:00 Location: H 3010

Invited Talk TT 51.1 Wed 9:30 H 3010
Electronic Squeezing of Pumped Phonons: Negative U and Transient Superconductivity — •Dante M. Kennes[1], Eli Y. Wilner[1], David R. Reichman[2], and Andrew J. Millis[1] — [1]Department of Physics, Columbia University, New York, New York 10027, USA — [2]Department of Chemistry, Columbia University, New York, New York 10027, USA

Advances in light sources and time resolved spectroscopy have made it possible to excite specific atomic vibrations in solids and to observe the resulting changes in electronic properties but the mechanism by which phonon excitation causes qualitative changes in electronic properties, is still under debate. Here, we show that the dominant symmetry-allowed coupling between electron density and dipole active modes implies an electron density-dependent squeezing of the phonon state which provides an attractive contribution to the electron-electron interaction, independent of the sign of the bare electron-phonon coupling and with a magnitude proportional to the degree of laser-induced phonon excitation. Reasonable excitation amplitudes lead to non-negligible attractive interactions that may cause significant transient changes in electronic properties including superconductivity. The mechanism is generically applicable to a wide range of systems, offering a promising route to manipulating and controlling electronic phase behavior in novel materials. Building on these results we analyze the nonequilbrium response of the electronic system and discuss implications for experimentally accessible observables, such as optical conductivity.

TT 51.2 Wed 10:00 H 3010
Photoinduced non-thermal insulator-to-metal transition in NbO_2 epitaxial thin films — •Rakesh Rana[1], John Klopf[1], Joerg Grenzer[1], Harald Schneider[1], Manfred Helm[1,2], and Alexej Pashkin[1] — [1]Helmholtz-Zentrum-Dresden-Rossendorf, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

The ultrafast insulator-to-metal transition in the correlated oxides such as vanadium dioxide (VO_2) has been extensively explored for its rich physics and potential applications. In this regard, its isovalent counterpart niobium dioxide (NbO_2) with considerably higher transition temperature (T_C = 1080 K) can be envisaged as a potential alternative. We have performed time-resolved optical pump-terahertz (THz) probe measurements on NbO_2 epitaxial thin-film at room temperature. The onset of the THz conductivity is followed by an exponential decay on a timescale of 400 fs. The photoinduced change in THz transmission at later delay times exhibits an excitation threshold of 17.5 mJ/cm^2. Notably, in contrast to VO_2, the pump energy required for the switching into a metastable metallic state is smaller than the energy necessary for heating NbO_2 up to T_C providing strong evidence for the non-thermal character of the photo induced insulator-to-metal transition in this system. The transient optical conductivity in the metastable state can be modelled using the Drude model confirming its metallic character.

TT 51.3 Wed 10:15 H 3010
Emergent CDW order in a 1D correlated electron system with underlying magnetic microstructure — Thomas Köhler, Sebastian Paeckel, and •Salvatore Manmana — Institut f. Theoretische Physik, U. Göttingen

We address the question of charge density wave order (CDW) emerging in a nonequilibrium situation in the course of a photo excitation. Using time-dependent matrix product states (tMPS), we model a pump excitation using Peierls substitution in a Hubbard chain at quarter filling, which is in the presence of an alternating magnetic background field. This magnetic microstructure is obtained for a 1D toy-manganate system, in which the t_{2g} electrons form a frozen lattice of Zener polarons, but do not participate in the charge transport. We investigate the interplay of the magnetic microstructure and the Hubbard U term for the dynamics of the system and discuss possible realizations with ultracold atoms on optical lattices.

We acknowledge financial support by DFG through research unit FOR1807 (project P7) and SFB/CRC1073 (project B03).

TT 51.4 Wed 10:30 H 3010
Non-monotonic response and light-cone freezing in gapless-to-(partially) gapped quantum quenches of fermionic systems — •Sergio Porta[1,2], Filippo Maria Gambetta[1,2], Niccolò Traverso Ziani[3], Dante Marvin Kennes[4], Maura Sassetti[1,2], and Fabio Cavaliere[1,2] — [1]Dipartimento di Fisica, Università di Genova, Genova, 16146 Italy — [2]SPIN-CNR, Genova, 16146 Italy — [3]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [4]Department of Physics, Columbia University, New York, NY 10027, USA

The properties of prototypical examples of one-dimensional fermionic systems undergoing a sudden quantum quench from a gapless state to a (partially) gapped state are analyzed. By means of a Generalized Gibbs Ensemble analysis or by numerical solutions in the interacting cases, we observe an anomalous, non-monotonic response of steady state correlation functions as a function of the strength of the mechanism opening the gap. In order to interpret this result, we calculate the full dynamical evolution of these correlation functions, which shows a freezing of the propagation of the quench information (light cone) for large quenches. We argue that this freezing is responsible for the nonmonotonous behaviour of observables. In continuum non-interacting models, this freezing can be traced back to a Klein-Gordon equation in the presence of a source term. We conclude by arguing in favour of the robustness of the phenomenon in the cases of non-sudden quenches and higher dimensionality.
[1] arXiv:1708.09320

TT 51.5 Wed 10:45 H 3010
The non-equilibrium Peierls transition in thermodynamic unbalanced system — •Pedro Ribeiro[1] and Stefan Kirchner[2] — [1]Affiliation: CeFEMA, Instituto Superior Técnico, Universidade de Lisboa Av. Rovisco Pais, 1049-001 Lisboa, Portugal — [2]Center for Correlated Matter, Zhejiang University, Hangzhou, Zhejiang 310058, China

Spin- and charge density waves are a common phenomenon in condensed matter physics. Charge density waves were predicted by R. Peierls who showed that due to the electron-phonon coupling a one-dimensional lattice may become unstable and undergoes a transition into an ordered. Away from thermal equilibrium, much less is known about this transition. In this talk, we address the fate of this instability under non-equilibrium conditions created by imposing a finite voltage across the system. In particular, we explore the possibility of changing the ordering wave vector away from its equilibrium position by a finite voltage drop across the system.

TT 51.6 Wed 11:00 H 3010
Photoinduced absorptions inside the Mott gap in the two-dimensional extended Hubbard model — Kazuya Shinjo and •Takami Tohyama — Department of Applied Physics, Tokyo University of Science, Tokyo 125-8585, Japan

We theoretically investigate pump-probe optical responses in the two-dimensional extended Hubbard model describing cuprates by using a time-dependent Lanczos method. At half filling, pumping generates photoinduced absorptions inside the Mott gap. A part of low-energy absorptions is attributed to the independent propagation of photoinduced holons and doublons. The spectral weight just below the Mott gap increases with decreasing the on-site Coulomb interaction U. We find that the next-nearest-neighbor Coulomb interaction V1 enhances this U dependence, indicating the presence of biexcitonic contributions formed by two holon-doublon pairs. Photopumping in hole-doped systems also induces spectral weights below remnant Mott-gap excitations, being consistent with recent experiments. The induced weights are less sensitive to V1 and may be related to the formation of a biexcitonic state in the presence of hole carriers.

15 min. break.

TT 51.7 Wed 11:30 H 3010
Multiple particle-hole pair creation in the Fermi-Hubbard model — •Friedemann Queisser, Nicolai ten Brinke, Uwe Bovensiepen, and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47057 Duisburg, Germany

We study the Fermi-Hubbard model in the strongly correlated Mott phase under the influence of a harmonically oscillating hopping rate

$J(t) = J_0 + 4Jcos(\omega t)$. If ω is near an integer multiple of the gap we find higher-order resonances where multiple particle-hole pairs are created. The creation of these pairs depends crucially on the specific form of the underlying lattice geometry. We discuss the microscopic mechanism for multiple pair creation in small lattices.

[1] N. ten Brinke, M. Ligges, U. Bovensiepen and R. Schützhold, *Phys. Rev. B* **95**, 195123 (2017)

TT 51.8 Wed 11:45 H 3010

Nonequilibrium gas-liquid transition in the driven-dissipative photonic lattice — Matteo Biondi[1], Gianni Blatter[1], Hakan Tureci[2], and •Sebastian Schmidt[1] — [1]ETH Zurich, Institute for Theoretical Physics, Switzerland — [2]Princeton University, Department of Electrical Engineering, USA

We study the nonequilibrium steady state of the driven-dissipative Bose-Hubbard model with Kerr nonlinearity. Employing a mean-field decoupling for the intercavity hopping J, we find that the steep crossover between low and high photon-density states inherited from the single cavity transforms into a gas-liquid bistability at large cavity-coupling J. We formulate a van der Waals-like gas-liquid phenomenology for this nonequilibrium setting and determine the relevant phase diagrams, including a new type of diagram where a lobe-shaped boundary separates smooth crossovers from sharp, hysteretic transitions. Calculating quantum trajectories for a one-dimensional system, we provide insights into the microscopic origin of this many-body bistability.

TT 51.9 Wed 12:00 H 3010

Frustration-induced quasi-long-range order in a photonic system — •Matteo Biondi, Gianni Blatter, and Sebastian Schmidt — Institut für Theoretische Physik, Wolfgang-Pauli-Str. 27 8093 Zürich Switzerland

We investigate the interplay of geometric frustration and interactions in a nonequilibrium photonic lattice system exhibiting a photonic flat band as described by the driven-dissipative Bose-Hubbard model. We propose how to engineer quasi-long-range order in a quasi one-dimensional frustrated system by pumping the photonic lattice incoherently. Using a filter qubit to modulate the bandwidth of the pump, we demonstrate how to obtain a quasi-pure density-wave state of photons characterized by a polynomial decay of density-density correlations. We provide analytic results together with finite-size simulations of the Lindblad master equation using exact diagonalization and propose a state-of-the-art photonic realization of our system within cavity QED.

[1] M. Biondi, G. Blatter and S. Schmidt, in preparation.
[2] M. Biondi, E. v. Nieuwenburg, G. Blatter, S. Huber, and S. Schmidt, PRL 115, 143601 (2015).
[3] F. Baboux, L. Ge, T. Jacqmin, M. Biondi, E. Galopin, A. Lemaitre, L. Le Gratiet, I. Sagnes, S. Schmidt, H. E. Türeci, A. Amo and J. Bloch, PRL 116, 066402 (2016).

TT 51.10 Wed 12:15 H 3010

Thermalization of isolated Bose-Einstein condensates by dynamical heat bath generation — •Anna Posazhennikova[1], Mauricio Trujillo-Martinez[2], and Johann Kroha[2] — [1]Royal Holloway University of London, Egham, Surrey, UK — [2]Physikalisches Institut, Universität Bonn, Germany

If and how an isolated quantum system thermalizes despite its unitary time evolution is a long-standing, open problem of many-body physics. The eigenstate thermalization hypothesis (ETH) postulates that thermalization happens at the level of individual eigenstates of a system's Hamiltonian. However, the ETH requires stringent conditions to be validated, and it does not address how the thermal state is reached dynamically from an initial non-equilibrium state. We consider a Bose-Einstein condensate (BEC) trapped in a double-well potential with an initial population imbalance. We find that the system thermalizes although the initial conditions violate the ETH requirements. We identify three dynamical regimes. After an initial regime of undamped Josephson oscillations, the subsystem of incoherent excitations or quasiparticles (QP) becomes strongly coupled to the BEC subsystem by means of a dynamically generated, parametric resonance. When the energy stored in the QP system reaches its maximum, the number of QPs becomes effectively constant, and the system enters a quasi-hydrodynamic regime where the two subsystems are weakly coupled. In this final regime the BEC acts as a grand-canonical heat reservoir for the QP system (and vice versa), resulting in thermalization. We term this mechanism dynamical bath generation (DBG).

TT 51.11 Wed 12:30 H 3010

State engineering and out of equilibrium dynamics of spin models with cold bosonic atoms — •Araceli Venegas-Gomez and Andrew John Daley — University of Strathclyde, Glasgow, UK

The macroscopic control over cold atoms in optical lattices offers an excellent platform to study the out-of-equilibrium behaviour of strongly correlated systems, such as spin models, which are usually motivated by solid state physics. This offers us opportunities to study fundamental properties away from equilibrium and to probe states of the spin models, as well as providing tools to prepare states of lower temperature and entropy. We theoretically investigate a generalised Bose-Hubbard model for two-component bosonic atoms in an optical lattice, exploring the dynamics in corresponding spin-1/2 and spin-1 models. Investigating the magnetically ordered quantum states that can be engineered, we develop adiabatic state preparation techniques to achieve states with very low entropy starting from a known occupation number of particles per site. We explore this process, and ways to use non-equilibrium dynamics to probe the resulting states, using numerical methods based on tensor networks, focussing on parameters accessible in current experiments.

TT 51.12 Wed 12:45 H 3010

Reconstructing quantum states of cold atomic quantum simulators from non-equilibrium dynamics — •Marek Gluza[1], Thomas Schweigler[2], Bernhard Rauer[2], Christian Krumnow[1], Joerg Schmiedmayer[2], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Systems of ultra-cold atoms on atom chips provide an architecture to probe aspects of out-of-equilibrium quantum many-body physics including equilibration, thermalization and pre-thermalization. We present a novel tomographic reconstruction method for these quantum simulators allowing to access the expectation value of quadrature operators which are inaccessible from direct measurements but capture crucial characteristics of the elementary excitations of cold atomic systems. Specifically, we use interferometric data of non-equilibrium phase fluctuations to reconstruct the covariance matrix – including density fluctuations – of eigenmodes of the corresponding mean-field models. Experimentally, we observe quench dynamics in the non-interacting regime of particles in harmonic or box potentials. Formally, we use that one can efficiently keep track of the evolution and employ signal processing and semi-definite programming to perform a reliable reconstruction of covariance matrices. This method opens a new window into the study of dynamical quantum simulators – an insight that we exploit and discuss at the hand of several examples, including Gaussifying quantum many-body dynamics.