DY 7: Correlated Electrons: Nonequilibrium Quantum Many-Body Systems 1 (joint session TT/ DY)

Time: Monday 9:30–13:00 Location: H 0104

Topical Talk DY 7.1 Mon 9:30 H 0104

Entanglement in the Many-Body Localized Phase and Transition — •Jens H. Bardarson — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The study of entanglement, both in eigenstates and its evolution after quenches, has been instrumental in advancing our understanding of many-body localized phases—the interacting analogs of the Anderson insulator. In this talk I will discuss in detail three observations related to the entanglement properties of many-body localized systems: (i) A global quench within the many-body localized phase gives rise to a slowly (logarithmically) increasing entanglement entropy. This is due to interaction induced dephasing that is absent in the Anderson insulator and therefore serves as a unique signature of the many-body localized phase. (ii) A local quench from an eigenstate leads to an extensive increase in the entanglement entropy only at the many-body localization transition itself. And (iii) at the many-body localization transition the distribution of entanglement entropies becomes extensively broad, while it vanishes both in the extended metallic phase and in the localized phases. The width of the entanglement distribution, like the long time limit of the local quench, is therefore a useful diagnostic for a many-body localization transition. I explicitly demonstrate how all these features are observed in microscopic spin chain models of many-body localization, and, in particular, discuss how they can be used to detect a many-body mobility edge.

[1] JHB, Pollmann, and Moore, PRL **109**, 017202 (2012).
[2] Kjall, JHB, and Pollmann, PRL **113**, 107204 (2014).

DY 7.2 Mon 10:00 H 0104

Dynamics of competing orders in YBCO triggered by ultrafast light pulses — •Junichi Okamoto, Robert Höppner, Beilei Zhu, and Ludwig Mathey — Institute for Laser Physics, University of Hamburg, Hamburg, Germany

In the emerging field of optically driven strongly correlated systems, laser-excited high-T_c cuprates are one of the most fascinating topics. In equilibrium, the underdoped region of high-T_c cuprates exhibit various competing orders, e.g., stripes, density-waves and superconductivity. In this talk, we will explore the possibility of optically controlling such competing orders. In particular, we will focus on the underdoped region of YBCO, where d-wave superconductivity and charge-density waves coexist. We will present preliminary results of numerical simulations of optically driven competing orders in the material.

DY 7.3 Mon 10:15 H 0104

Ultrafast dynamics in $CeTe_3$ near the pressure-induced charge-density-wave transition — Jonas Tauch[1], Hanjo Schäfer[1,2], Manuel Obergfell[1], Jure Demsar[1,2,3], Paula Giraldo[4], Ian R. Fisher[4], and •Alexej Pashkin[1,5] — [1]Department of Physics and Center for Applied Photonics, University of Konstanz, Germany — [2]Institute of Physics, Ilmenau University of Technology, Germany — [3]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [4]Geballe Laboratory for Advanced Materials and Department of Applied Physics, Stanford University, USA — [5]Helmholtz-Zentrum Dresden-Rossendorf, Germany

Femtosecond pump-probe spectroscopy is an efficient tool for studying ultrafast dynamics in strongly correlated electronic systems, in particular, compounds with a charge-density-wave (CDW) order. Application of external pressure often leads to a suppression of a CDW state due to an impairment of the Fermi surface nesting.

We combine time-resolved optical spectroscopy and diamond anvil cell technology to study electron and lattice dynamics in tri-telluride compound $CeTe_3$. Around pressures of 4 GPa we observe a gradual vanishing of the relaxation process related to the recombination of the photoexcited quasiparticles. The coherent oscillations of the phonon modes coupled to the CDW order parameter demonstrate even more dramatic suppression with increasing pressure. These observations clearly indicate a transition into the metallic state of $CeTe_3$ induced by the external pressure.

DY 7.4 Mon 10:30 H 0104

Mechanism of Ultrafast Relaxation of a Photo-Carrier in Antiferromagnetic Spin Background — •Lev Vidmar — University of Munich, Germany

Understanding of relaxation dynamics in correlated condensed-matter systems is vital for identification of dominant couplings in pump-probe experiments, as well as for designing setups where ordered phases are manipulated using external fields.. In many cases, phonons represent an important relaxation channel, however, in two-dimensional systems with antiferromagnetic correlations, this relaxation channel may not be the dominant one [1]. By applying state-of-the-art numerical simulations of the t-J model [2] we show that the relaxation due to coupling to antiferromagnetic spin excitations can be very fast [3]. We show that the key relaxation mechanism at very short times corresponds to the creation of high-energy antiferromagnetic excitations in the close proximity of the photo-excited holes. Such a mechanism enables an energy transfer of more than 1 eV on a 10 femtosecond time scale.

[1] L. Vidmar, J. Bonca, T. Tohyama, and S. Maekawa, Phys. Rev. Lett. 107, 246404 (2011).
[2] M. Mierzejewski, L. Vidmar, J. Bonca, and P. Prelovsek, Phys. Rev. Lett. 106, 196401 (2011).
[3] D. Golez, J. Bonca, M. Mierzejewski, and L. Vidmar, Phys. Rev. B 89, 165118 (2014).

DY 7.5 Mon 10:45 H 0104

Pattern formation in non-equilibrium correlated electronic systems — •Pedro Ribeiro[1], Andrey Antipov[2], and Alexey Rubtsov[1] — [1]Russian Quantum Center, Business-center "Ural", Novaya street 100A, Skolkovo village, Odintsovo district, Moscow area, 143025 Russia — [2]Department of Physics University of Michigan, Randall Laboratory, 450 Church Street, Ann Arbor, MI 48109-1040

Strong non-equilibrium conditions eventually drive a system away from its linear response regime, deeply affecting the properties of the underlying equilibrium phase. A well known example is the Rayleigh-Bernard convection arising for classical fluids that develop convection rolls of a specific wave-length. We report on recent results regarding effects of large bias voltages applied across a half-filled Hubbard chain. At equilibrium this system shows a charge gap and strong antiferromagnetic correlations. We show that out of equilibrium the wavevector maximizing the spin-susceptibility shifts from its equilibrium antiferromagnetic value $q = \pi$ as a function of the applied voltage and temperature. We describe a rich set of phases induced by the interplay between electron-electron interactions and non-equilibrium conditions. Some of phases found are examples of non-equilibrium-induced spacial pattern formation. We comment on the properties and stability of these phases. Finally we argue that, although no symmetry breaking arises in the 1D system, these results suggest that a spatially modulated charge gap may be observed experimentally by STM in engineered atomic chains and nano-wires.

DY 7.6 Mon 11:00 H 0104

Time-dependent Gutzwiller wave function for the Hubbard model in nonequilibrium — •Marcus Kollar[1] and Christian Gramsch[1,2] — [1]Theoretische Physik III, Universitität Augsburg — [2]I. Institut für Theoretische Physik, Universität Hamburg

In previous studies the time-dependent Gutzwiller wave function (GWF) has been applied to the fermionic Hubbard model in nonequilibrium [1], using the Gutzwiller approximation which is known to become exact in the limit of infinite lattice dimension. As an alternative, we employ the variational formalism for the GWF which applies in arbitrary dimensions, recovering the dynamics obtained in Ref. [1]. We present results for the one-dimensional Hubbard model, for which exact evaluations of the GWF are available. In particular we find that the GWF captures the transient momentum distribution on short timescales [2].

[1] M. Schiró and M. Fabrizio, Phys. Rev. Lett. **105**, 076401 (2010).
[2] S. A. Hamerla and G. S. Uhrig, Phys. Rev. B **87**, 064304 (2013).

15 min. break.

DY 7.7 Mon 11:30 H 0104

Nonequilibrium dynamics of screening in the extended Hubbard model — •Denis Golež and Philipp Werner — University of Fribourg

We will present a study of the non-equilibrium dynamics in the extended Hubbard model on the square lattice using time-dependent extended dynamical mean-field theory. The short-time effect of the dynamical screening due to the photo-doping is the reduction of the effective static interaction. On the same time scale the fully screened interaction is transformed from the single to double mode structure due to photo-doped charge carriers. At longer times the the dynamical screening enhance the relaxation dynamics.

DY 7.8 Mon 11:45 H 0104

Continuous monitoring of a quantum many-body system — •Thomas Kiendl[1], Vinay Ramasesh[2], Shay Hacohen-Gourgy[2], Irfan Siddiqi[2], and Florian Marquardt[1] — [1]Institut for Theoretical Physics, Universität Erlangen-Nürnberg, Staudtstraße 7, D-91058 Erlangen, Germany — [2]QNL, University of California, Berkeley

At the heart of quantum mechanics lies the fact that a measurement causes back-action on the system itself. A prominent example is the quantum Zeno effect. Observing a system continuously with a large measurement strength freezes the system's dynamics. We explore how such phenomena transfer to a quantum many-body system, employing a chain of qubits as an experimentally relevant example. Using the concept of weak, continuous measurements we investigate new timescales caused by continuous monitoring of the chain. In this context, we present new results on relaxation dynamics and thermalization for both integrable and non-integrable Hamiltonians.

DY 7.9 Mon 12:00 H 0104

Influence of quadrupolar interactions in the anisotropic central spin model — •Johannes Hackmann and Frithjof B. Anders — Technische Universität Dortmund, Lehrstuhl für theoretische Physik II, 44221 Dortmund, Germany

We have investigated spin noise in an ensemble of semiconductor quantum dots (QDs). A single electron (or hole) doped QD is described by the anisotropic central spin model. Additionally, the quadrupole moments of the nuclei couple to strain induced electric fields in the QD. We investigated the influence of these quadrupolar couplings on the central spin dynamics, that are calculated via the correlation functions $\langle S^z(t)S^z\rangle$ and $\langle S^z(\omega)S^z\rangle$. We demonstrate that our results are in good agreement with recent experiments and show that quadrupolar interactions have a large impact on measurements on hole doped QDs, while they almost are negligible for the case of electron doped QDs.

DY 7.10 Mon 12:15 H 0104

The generic fixed point model for pseudo-spin-1/2 quantum dots in nonequilibrium: Spin-valve systems with compensating spin polarizations — Stefan Göttel[1,2], Frank Reininghaus[1,2], and •Herbert Schoeller[1,2] — [1]Institute for Theory of Statistical Physics, RWTH Aachen — [2]JARA-Fundamentals of Future Information Technology

We study a pseudo-spin-1/2 quantum dot in the cotunneling regime close to the particle-hole symmetric point. For a generic tunneling matrix we find a generic fixed point with interesting nonequilibrium properties, characterized by effective reservoirs with compensating spin orientation vectors weighted by the polarizations and the tunneling rates. At large bias voltage we study the magnetic field dependence of the dot magnetization and the current. The fixed point can be clearly identified by analysing the magnetization of the dot. We characterize in detail the universal properties for the case of two reservoirs.

DY 7.11 Mon 12:30 H 0104

First order dynamical phase transitions — •Elena Canovi[1], Philipp Werner[2], and Martin Eckstein[1] — [1]Max Planck Research Department for Structural Dynamics, University of Hamburg (CFEL), Building 99, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland

Recently, dynamical phase transitions have been identified based on the non-analytic behavior of the Loschmidt echo in the thermodynamic limit [1]. By introducing conditional probability amplitudes, we show how dynamical phase transitions can be further classified, both mathematically, and potentially in experiment. This leads to the definition of first-order dynamical phase transitions. Furthermore, we develop a generalized Keldysh formalism which allows to use nonequilibrium dynamical mean-field theory to study the Loschmidt echo and dynamical phase transitions in high-dimensional, non-integrable models. We find dynamical phase transitions of first order in the Falicov-Kimball model and in the Hubbard model.

[1] Heyl et al., Phys. Rev. Lett. 110, 135704 (2013).

DY 7.12 Mon 12:45 H 0104

Holography of the toric code — •Johannes Oberreuter and Stefan Kehrein — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

Dynamics of quantum-many-body systems at weak coupling can be effectively described by quasi-particles. At strong coupling, the quasiparticle picture breaks down. Instead of resorting to numerics one can use a duality, which relates strongly coupled (conformal) field theories to classical, weakly coupled (Einstein) gravity in one dimension higher, the so-called gauge/gravity duality or AdS/CFT-correspondence. The correlation functions of the field theory can then in principle be computed from a calculation in classical gravity. The correspondence, however, in general only applies to conformal field theories and it is difficult to describe systems of interest in condensed matter theory. The observation of similarities in calculating the entanglement entropy in AdS/CFT and in MERA, a particular tensor network of a quantum state, has led to the conjecture that MERA might be a discrete version of the gauge-gravity duality. It is in principle possible to represent any quantum state in MERA. We investigate this idea in the toric code, where the representation is known exactly [1] and comment on the non-generic behaviour of this model including its dynamics.

[1] M. Aguado, G. Vidal, Phys. Rev. Lett. 100, 070404 (2008).