TT 62: Correlated Electrons: Nonequilibrium Quantum Many-Body Systems 1

Time: Thursday 9:30–13:00 Location: HSZ 304

TT 62.1 Thu 9:30 HSZ 304

Proposal for measuring the finite-temperature Drude weight of integrable systems — Christoph Karrasch[1], Tomaz Prosen[2], and •Fabian Heidrich-Meisner[3] — [1]Dahlem Center for Complex Quantum Systems, FU Berlin, Germany — [2]Physics Department, University of Ljubljana, Slovenia — [3]Arnold Sommerfeld Center for Theoretical Physics, LMU Munich, Germany

Integrable models such as the spin-1/2 Heisenberg chain, the Lieb-Liniger or the one-dimensional Hubbard model are known to avoid thermalization, which was also demonstrated in several quantum-quench experiments. Another dramatic consequence of integrability is the zero-frequency anomaly in transport coefficients, which results in ballistic finite-temperature transport, despite the presence of strong interactions. While this aspect of nonergodic dynamics has been known for a long time, there has so far not been any unambiguous experimental realization thereof. We make a concrete proposal for the observation ballistic transport via local quantum quench experiments in fermionic quantum-gas microscopes. Such an experiment would also unveil the coexistence of ballistic and diffusive transport channels in one and the same system and provide a means of measuring finite-temperature Drude weights. The connection between local quenches and linear-response functions is established via time-dependent Einstein relations.

[1] Karrasch, Prosen, Heidrich-Meisner, arXiv:1611.04832

TT 62.2 Thu 9:45 HSZ 304

Dynamics of the transverse-field Ising model in 3D — •Markus Schmitt[1] and Markus Heyl[2] — [1]Institut für Theoretische Physik, Georg-August-Universität, Göttingen — [2]Max-Planck Institute for the Physics of Complex Systems, Dresden

We formulate the dynamics after a quench in the three-dimensional transverse-field Ising model in terms of classical partition sums, which can be evaluated using conventional Monte Carlo methods for classical spin systems with system sizes markedly beyond the capabilities of, e.g., exact diagonalization. In this way, we obtain insights into the time evolution of observables and dynamical quantum phase transitions in the Loschmidt echo, which we analyze in the vicinity of critical times similar to [M. Heyl, Phys. Rev. Lett. 115, 140602 (2015)].

TT 62.3 Thu 10:00 HSZ 304

An impurity solver for nonequilibrium dynamical mean field theory based on hierarchical quantum master equations — •Rainer Härtle[1] and Andrew J. Millis[2] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany — [2]Department of Physics, Columbia University, New York, USA

We present a new impurity solver for real-time and nonequilibrium dynamical mean field theory applications, based on the recently developed hierarchical quantum master equation approach [1,2]. Our method combines a hybridization expansion of the time evolution operator, with an advanced, systematic truncation scheme [2]. Convergence to exact results for not too low temperatures has been demonstrated by a direct comparison to quantum Monte Carlo simulations [3]. The approach is time-local and does not require evolution from an uncorrelated initial condition, giving access to nonequilibrium steady states and to slow dynamics such as occur, e.g., in the presence of magnetic fields or exchange interactions [3–5]. Here, we present first results of this new scheme for the description of strongly correlated materials in the framework of dynamical mean field theory.

[1] Jin *et al.*, JCP 128, 234703 (2008)
[2] Härtle *et al.*, PRB 88, 235426 (2013)
[3] Härtle *et al.*, PRB 92, 085430 (2015)
[4] Härtle *et al.*, PRB 90, 245426 (2014)
[5] Wenderoth *et al.*, PRB 94, 121303R (2016)

TT 62.4 Thu 10:15 HSZ 304

Higgs-modes in non-equilibrium $d_{x^2-y^2}$-wave superconductors — •Andreas P. Schnyder[1], Holger Krull[2], Götz S. Uhrig[2], Nikolaj Bittner[1], and Dirk Manske[1] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart — [2]Technische Univerität Dortmund, 44221 Dortmund

The recently developed time-resolved ARPES technique has made it possible to measure collective modes in non-equilibrium quantum systems. Using an iterated equation of motion approach, we investigate the collective Higgs modes of non-equilibrium $d_{x^2-y^2}$-wave superconductors and simulate the corresponding time-resolved ARPES spectra. We find that in $d_{x^2-y^2}$-wave superconductors two different Higgs modes can be excited by the pump pulse. The relative strength of these two Higgs modes is controlled by the incident angle of the pump pulse. We determine the signatures of these Higgs modes in the time-resolved ARPES response.

TT 62.5 Thu 10:30 HSZ 304

Towards Mott-Insulator based Photovoltaic devices — •Max Sorantin[1], Antonius Dorda[1], Wolfgang von der Linden[1], Karsten Held[2], and Enrico Arrigoni[1] — [1]Institute for theoretical physics, TU Graz, Austria — [2]Institute for solid state physics, TU Vienna, Austria

Recently, Mott-insulating heterostructures have been proposed as candidates for highly efficient solar cells [1] owing to impact ionisation processes [2]. Previous works have investigated the doublon dynamics in such systems within time-dependent DMFT by looking at the time evolution after a photoexcitation [3]. In the present work we focus on the (quasi-) steady state of periodically driven correlated lattice systems within Floquet DMFT. We employ the Auxiliary Master Equation Approach (AMEA) [4] to solve the time averaged impurity problem and assess the validity of this approximation by comparison with Iterated Perturbation Theory (IPT) [5]. Our model consists of a correlated layer, subject to a periodic driving via a homogeneous electric field, coupled to leads with an applied bias voltage. Furthermore, we generalize the system to a multilayer structure where the additional layers are used to model an electric field gradient. Investigating the results for the double accupancy, current and Spectralfunction in dependence of the external driving frequency suggests that impact ionization plays a domniant role in the steady state dynamics.

[1] E. Assman et al., PRL 110 (2013)
[2] J. Coulter et al., PRB 90 (2014)
[3] M. Eckstein et al., PRL 113 (2014);
P. Werner et al., PRB 90 (2014)
[4] E. Arrigoni et al., PRL 110 (2013)
[5] A. Joura et al., PRB 91 (2015)

TT 62.6 Thu 10:45 HSZ 304

Thermoelectric response of the correlated layer - non-equilibrium DMFT study — •Irakli Titvinidze, Antonius Dorda, Wolfgang von der Linden, and Enrico Arrigoni — Institute of theoretical and computational physics, Graz Univeristy of Technology, 8010 Graz, Austria.

Here we investigate the effect of the interaction on the thermoelectric properties of a system, consisting of the single correlated layer sandwiched between two metallic leads. First we investigate linear response. We present our results for the seebeck coefficient, electrical and thermal conductance. Later on, we consider a finite temperature difference between the left and right leads. We study dependence of the current on the electronic filing of the central layer for zero bias voltage and current-voltage characteristics close to the half-filling. We obtain that strong interactions enhance thermoelectric effects, in both cases. Our results are obtained via non-equilibrium dynamical mean-field theory [1]. As an impurity solver we use auxiliary master equation approach [2], which addresses the impurity problem within an auxiliary system consisting of a correlated impurity, a small number of uncorrelated bath sites, and two Markovian environments described by a generalized master equation.

[1] P. Schmidt and H. Monien, ArXiv:cond-mat/0202046;
J. K. Freericks, Phys. Rev. B 77, 075109 (2008)
[2] E. Arrigoni et al, Phys. Rev. Lett. 110, 086403 (2013);
A. Dorda et al, Phys. Rev. B. 89, 165105 (2014);
I. Titvinidze et al., PRB 92, 245125 (2015)

15 min. break.

Invited Talk TT 62.7 Thu 11:15 HSZ 304

Optical Control of Complex Quantum Materials — •Stefan Kaiser — Max Planck Institut für Festkörperforschung und 4. Physikalisches Institut, Universität Stuttgart, Germany

Advanced ultrafast nonlinear optical methods open new ways of controlling complex solid-state materials on unprecedented timescales. In quantum materials, finding new ways of manipulating the complex interplay of electronic phases or effectively tuning electronic interactions opens new avenues in controlling physical properties and designing new functionalities. I will show how we investigate different scenarios like the balancing between competing phases triggered by ultrashort light pulses or possibilities of dynamical stabilization of new states of matter in periodically driven light fields. A remarkable effect are possibilities to induce superconductivity in high temperature cuprate superconductors at temperatures far above T_c [1-3]. Tuning local interactions [4,5] and possible light-induced superconductivity in the doped fullerides K_3C_{60} [6] will serve as important example that inducing such intriguing effects is a more general effect and not restricted to the rather specialized class of cuprate systems.

[1] D. Fausti et al. Science 331, 189 (2011)
[2] S. Kaiser et al. Phys. Rev. B 89, 184515 (2014)
[3] W. Hu et al. Nature Materials 13, 705 (2014)
[4] R. Singla et al. Phys. Rev Lett. 115, 187401 (2015)
[5] S. Kaiser et al. Sci. Rep. 4, 3823 (2014)
[6] M. Mitrano et al. Nature 530, 461 (2016)

TT 62.8 Thu 11:45 HSZ 304

Hund's exchange out of equilibrium — •Hugo Strand[1], Denis Golež[1], Martin Eckstein[2], and Philipp Werner[1] — [1]Department of Physics, University of Fribourg, Fribourg, Switzerland — [2]Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL, Hamburg, Germany

We study the canonical model for strongly correlated Hund's metals, the two band Hubbard model with local density-density and Hund's exchange interaction. Using real-time dynamical mean-field theory and a first- and second-order strong coupling expansion impurity solver we find novel dynamical features as compared to the single band model. We study the Mott insulator at half-filling and the strong influence of the local doublon spin degrees of freedom on the relaxation dynamics after an excitation pulse.

TT 62.9 Thu 12:00 HSZ 304

Quantum Mutual Information as a Probe for Many-Body Localization — •Giuseppe De Tomasi, Soumya Bera, Jens Bardarson, and Frank Pollmann — MPI-PKS , Dresden Germany

We demonstrate that the quantum mutual information (QMI) is a useful probe to study many-body localization (MBL). First, we focus on the detection of a metal–insulator transition for two different models, the noninteracting Aubry-André-Harper model and the spinless fermionic disordered Hubbard chain. We find that the QMI in the localized phase decays exponentially with the distance between the regions traced out, allowing us to define a correlation length, which converges to the localization length in the case of one particle. Second, we show how the QMI can be used as a dynamical indicator to distinguish an Anderson insulator phase from an MBL phase. By studying the spread of the QMI after a global quench from a random product state, we show that the QMI does not spread in the Anderson insulator phase but grows logarithmically in time in the MBL phase.

TT 62.10 Thu 12:15 HSZ 304

Quantum quenches in many-body localized systems — •Johannes Hauschild[1], Fabian Heidrich-Meisner[2], and Frank Pollmann[1] — [1]Fakultät für Physik, Technische Universität München, D-85748 Garching — [2]Department of Physics and Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, D-80333 München

The field of many-body localization has recently attracted considerable theoretical and experimental interest. Many-body localized phases occur in interacting systems and are characterized by the absence of transport, the lack of thermalization, as well as the existence of quasi local integrals of motions. Ultra cold atoms have proven to be an ideal experimental test bed to test theoretical predictions. Most of the experiments involve the real time evolution of an initial state prepared by sudden changes in system parameters. First, we numerically investigate signatures of many-body localization by studying the melting of a domain wall after a quantum quench [1]. Second, we consider a dynamical system in which we couple initially hot and cold regions. We show that it is possible to extract characterizing properties like the localization length and the critical disorder strength.

[1] J. Hauschild et al., Phys. Rev. B 94, 161109(R)

TT 62.11 Thu 12:30 HSZ 304

Density propagator for many-body localization: finite size effects, transient subdiffusion, (stretched-)exponentials — •Soumya Bera[1], Giuseppe De Tomasi[1], Felix Weiner[2], and Ferdinand Evers[2] — [1]MPI-PKS, Dresden — [2]Institute of Theoretical Physics, University of Regensburg

We investigate charge relaxation in the spin-less disordered fermionic Hubbard chain ($t{-}V$-model). Our observable is the time-dependent density propagator, $\Pi_\varepsilon(x,t)$, calculated in windows of different energy density, ε, of the many-body Hamiltonian and at different disorder strengths, W, not exceeding the critical value W_c. The width $\Delta x_\varepsilon(t)$ of $\Pi_\varepsilon(x,t)$ exhibits a behavior $d\ln\Delta x_\varepsilon(t)/d\ln t{=}\beta_\varepsilon(t)$, where the exponent function $\beta_\varepsilon(t){\lesssim}1/2$ is seen to depend strongly on L at all investigated parameter combinations. (i) We confirm the existence of a region in phase space that exhibits subdiffusive dynamics in the sense that $\beta_\varepsilon(t){<}1/2$ in large window of times. However, subdiffusion might possibly be transient, only, finally giving way to a conventional diffusive behavior with $\beta_\varepsilon{=}1/2$. (ii) We cannot confirm the existence of many-body mobility edges deep in the delocalized phase. (iii) (Transient) subdiffusion $0 < \beta_\varepsilon(t) \lesssim 1/2$, coexists with an enhanced probability for returning to the origin, $\Pi_\varepsilon(0,t)$, decaying much slower than $1/\Delta x_\varepsilon(t)$. Correspondingly, the spatial decay of $\Pi_\varepsilon(x,t)$ is far from Gaussian being exponential or even slower. On a phenomenological level, our findings are broadly consistent with effects of strong disorder and (fractal) Griffiths regions.

TT 62.12 Thu 12:45 HSZ 304

Occupation spectrum after a global quench in the many-body localized phase — Talía Lezama Mergold Love[1], Soumya Bera[1,3], and •Jens Hjorleifur Bardarson[1,2] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Department of Theoretical Physics, KTH Royal Institute of Technology, Stockholm, SE-106 91 Sweden — [3]Department of Physics, IIT Bombay, India

Closed disordered interacting quantum systems can exhibit many-body localization (MBL). When disorder is sufficiently strong, such systems enter into a nonergodic regime known as the many-body localized phase, resulting in an ideal insulator with zero charge and thermal conductivities at finite energy densities. The emergent integrability of the MBL phase can be understood in terms of localized quasiparticles. As a result, the occupations of the one-particle density matrix (OPDM) in eigenstates show a fermi-liquid like discontinuity. In this work, we numerically explore the dynamics of the MBL phase generated by a global quench from a charge density state, in terms of the OPDM occupation spectrum. In particular, we show that in the steady state, the occupation discontinuity is smeared to a continuous distribution in a similar way as finite temperature smears the discontinuity in a fermi liquid, but the occupation spectrum remains highly non-thermal in the thermodynamic limit.