MA 51: Ultrafast Dynamics of Light-Driven Systems (joint session TT/MA)

Time: Thursday 15:00–17:45 Location: HSZ 201

MA 51.1 Thu 15:00 HSZ 201

Out-of-equilibrium magnetism of Sr_2IrO_4 and La_2CuO_4 — •Ekaterina Paerschke[1], Yao Wang[2], and Cheng-Chien Chen[3] — [1]Institute of Science and Technology Austria, Am Campus 1, 3400 Klosterneuburg, Austria — [2]Department of Physics, Harvard University, Cambridge 02138, USA — [3]Department of Physics, University of Alabama at Birmingham, Birmingham, Alabama 35294, USA

Ultrafast pump-probe spectroscopy is an efficient tool to characterize and control strongly correlated materials due to its accessibility to both low-energy physics of the equilibrium phase and the novel excited states induced by the pump. Here, we investigate the ultrafast control of quantum magnetism in a half-filled Mott insulator, described by an extended Heisenberg model. This study reveals photo-manipulated magnetic properties for two archetypal Mott insulators: iridate Sr_2IrO_4 and cuprate La_2CuO_4. Understanding photo-manipulated spin fluctuations in cuprates and iridates can help to solve the long-standing question of superconductivity absence in the iridates, as spin fluctuations are believed to mediate superconductivity in transitional metal oxides. Starting from a broken-symmetry phase with a (π, π) ordering vector, we find that the various pump conditions can manipulate the competition with the subleading colinear AFM phase. Through the comparison of quantum quench simulations and Floquet analytical theory, we conclude that these manipulations are achieved through transient engineering of effective spin-exchange interactions.

MA 51.2 Thu 15:15 HSZ 201

Ultrafast spectroscopy of the Kitaev magnet $RuCl_3$ — •Raluca Aldea, Rolf B. Versteeg, Fumiya Sekiguchi, Anuja Sahasrabudhe, Kestutis Budzinauskas, Zhe Wang, and Paul H.M. van Loosdrecht — II. Physikalishes Institut, Universität zu Köln, Züplicher Str.77, Köln, Germany

Kitaev materials are a group of spin orbit assisted Mott insulators that bear strong bond-directional exchange interactions. This was discussed to result in a Kitaev liquid, implying that spins fractionalize in exotic Majorana fermion and Z_2 flux excitations. We use pump-probe spectroscopy in order to investigate the magnetization dynamics above and below the zigzag ordering temperature. We discuss the dynamics in terms of coupling between different degrees of freedom.

MA 51.3 Thu 15:30 HSZ 201

Ultrafast jamming transition in a charge-ordered system — •Yaroslav Gerasimenko[1,2], Jaka Vodeb[1], Jan Ravnik[1], Igor Vaskivskyi[1], Michele Diego[1], Viktor Kabanov[1], and Dragan Mihailoivic[1,2] — [1]Jozef Stefan Institute, Ljubljana, Slovenia — [2]CENN Nanocenter, Ljubljana, Slovenia

The combination of STM and in situ ultrafast excitation allows us to explore novel states of matter that can emerge from many-body interactions under highly non-equilibrium conditions. Most of such states are reminiscent of the nearby equilibrium ones. Here we show that a single femtosecond-scale optical pulse, applied to the prototypical transition metal dichalcogenide 1T-TaS2, can convert a perfect hexagonal charge order into a dramatically different metastable jammed state of strongly correlated electrons [1]. The mechanism for its formation is attributed to a dynamical localization of electrons through mutual interactions in absence of atomic disroder. We further build the phase diagaram of this transition as a function of fluence and temperature on multiple timescales. The time evolution of the localized charge pattern together with theoretical calculations [1, 2] confirm that charge order frustration is important for the state's unusual stability.
The work was supported by ARRS P1-0040 and ERC AdG "Trajectory".
[1] Ya. A. Gerasimenko et al., Nature Materials 18, 1078-1083 (2019)
[2] J. Vodeb et al., New J. Phys. 21, 083001 (2019)

MA 51.4 Thu 15:45 HSZ 201

Creating non-equilibrium orders in high-temperature superconductors — •Guido Homann[1], Jayson Cosme[1,2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien und Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, 22761 Hamburg, Germany

We simulate far-out-of-equilibrium dynamics in cuprate superconductors, such as YBCO, employing a semiclassical approach. Our approach combines relativistic c-field theory with a $U(1)$ lattice gauge theory, resulting in a 3D lattice of intrinsic Josephson junctions. Our description includes dissipation and thermal fluctuations. It constitutes an extension of 1D sine-Gordon models, due to the inclusion of amplitude dynamics and of in-plane fluctuations. We implement a variety of driving protocols, which address the plasmonic or phononic degrees of freedom, and explore the resulting non-equilibrium scenarios. As a central example, we apply our method to transient phenomena induced in pump-probe protocols, and compare to observed phenomena. This work extends and builds on previous studies reported in [1,2], and has its main focus on the creation of metastable superconducting states.
[1] J. Okamoto, A. Cavalleri, L. Mathey, Phys. Rev. Lett. **117**, 227001 (2016).
[2] J. Okamoto, W. Hu, A. Cavalleri, L. Mathey, Phys. Rev. B **96**, 144505 (2017).

MA 51.5 Thu 16:00 HSZ 201

Detecting superconductivity out-of-equilibrium — •Sebastian Paeckel[1], Benedikt Fauseweh[2,3], Alexander Osterkorn[1], Thomas Kohler[4], Dirk Manske[3], and Salvatore R. Manama[1] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart, Germany — [4]Department of Physics and Astronomy, Uppsala University, Box 516, S-751 20 Uppsala, Sweden

Recent pump-probe experiments on underdoped cuprates and similar systems suggest the existence of a transient superconducting state above T_c. This poses the question how to reliably identify the emergence of long-range order, in particular superconductivity, out-of equilibrium. We investigate this point by studying a quantum quench in an extended Hubbard model and by computing various observables, which are used to identify (quasi-)long-range order in equilibrium. Our findings imply that, in contrast to current experimental studies, it does not suffice to study the time evolution of the optical conductivity to identify superconductivity. In turn, we suggest to utilize time-resolved ARPES experiments to probe for the formation of a condensate in the two-particle channel.

15 min. break.

MA 51.6 Thu 16:30 HSZ 201

Phase-sensitive analysis of Higgs oscillations in quenched superconductors with time- and angle-resolved photo emission spectroscopy — •Lukas Schwarz and Dirk Manske — Max Planck Institute for Solid State Research

Higgs oscillations in nonequilibrium superconductors provide a unique tool to obtain information about the underlying order parameter. Several quantities like the absolute value, existence of multiple gaps and the symmetry of the order parameter can be encoded in the Higgs oscillation frequency. Most works so far concentrate on experiments, where momentum averaged quantities like the optical conductivity or third-harmonic effects in the transmitted light field are investigated, which does not allow to access all possible information contained in the Higgs oscillations. Here, we study the time-resolved spectral function measured in angle-resolved photo emission spectroscopy after quenching the system using a general approach. We analyze the induced oscillations all over momentum space to study the creation process of collective Higgs oscillations and we extract phase information of the order parameter from the oscillations of the spectral function.

MA 51.7 Thu 16:45 HSZ 201

Controlling subdominant pairing symmetries in pumped unconventional superconductors — •Marvin A. Müller[1], Pavel A. Volkov[1,2], Indranil Paul[3], and Ilya Eremin[1,4] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44801 Bochum, Germany — [2]Department of Physics and Astronomy, Center for Materials Theory, Rutgers University, Piscataway, New Jersey 08854, USA — [3]Laboratoire Matériaux et Phénomènes Quantiques, Université de Paris, CNRS, F-75013 Paris, France — [4]Institute of Physics, Kazan

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We investigate the short-time dynamics in superconductors with multiple attractive pairing channels out of equilibrium. Studying a single-band square lattice model with a spin-spin interaction as an example, we find the signatures of collective excitations of the subdominant pairing symmetries (known as Bardasis-Schrieffer modes) as well as the order parameter amplitude (Higgs mode) in the short-time dynamics of the spectral gap and quasiparticle distribution after an excitation by a pump pulse. We show that the polarization and intensity of the pulse can be used to control the symmetry of the nonequilibrium state as well as frequencies and relative intensities of the contributions of different collective modes. We find particularly strong effects of the Bardasis-Schrieffer mode in the dynamics of the quasiparticle distribution function and propose possible signatures in trARPES experiments.

MA 51.8 Thu 17:00 HSZ 201

Revealing Hund's multiplets in Mott insulators under strong electric fields — •Nagamalleswararao Dasari[1], Jiajun Li[1], Philipp Werner[2], and Martin Eckstein[1] — [1]Department of Physics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany — [2]Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland

We investigate the strong-field dynamics of a paramagnetic two-band Mott insulator using real-time dynamical mean-field theory. We demonstrate that strong electric fields can lead to a transient localization of electrons. This nonequilibrium quantum effect allows to reveal specific signatures of local correlations in the time-resolved photoemission spectrum. In particular, we demonstrate that the localization can be strong enough to produce atomic-like spin multiplets determined by the Hund's coupling J, and thus provide a way of measuring J inside the solid. Our simulation also fully incorporates non-linear field-induced tunnelling processes, which would lead to a dielectric breakdown in the steady state limit. A careful analysis of these processes however shows that they remain weak enough and do not prevent the measurement of the transiently localized spectra.

MA 51.9 Thu 17:15 HSZ 201

Ultrafast electronic correlations in ordered phases — •Riku Tuovinen[1], Denis Golež[2], Martin Eckstein[3], and Michael A. Sentef[4] — [1]QTF Centre of Excellence, Turku Centre for Quantum Physics, Department of Physics and Astronomy, University of Turku, 20014 Turku, Finland — [2]Center for Computational Quantum Physics, Flatiron Institute, 162 Fifth Avenue, New York, NY 10010, USA — [3]Department of Physics, University of Erlangen-Nürnberg, 91058 Erlangen, Germany — [4]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany

We consider many-body correlations in an excitonic-insulator system acting as a prototypical ordered-phase material [1]. Out-of-equilibrium dynamics in such systems with a symmetry-broken ground state has been shown to be extremely sensitive to all the intricacies in the electronic structure [2]. For an accurate description of the important and interesting mechanisms we take into consideration strong external fields, many-body correlations, and transient effects at an equal footing by the nonequilibrium Green's function technique [3]. We drive the system out-of-equilibrium by a laser pulse, and we compare the resolved dynamics between the Kadanoff-Baym equations and the computationally less expensive generalized Kadanoff-Baym Ansatz [4].

[1] S. Mor et al. Phys. Rev. Lett. 119, 086401 (2017)
[2] R. Tuovinen et al. Phys. Status Solidi B 256, 1800469 (2018)
[3] G. Stefanucci and R. van Leeuwen, Nonequilibrium Many-Body Theory of Quantum Systems, CUP (2013)
[4] R. Tuovinen et al. in preparation

MA 51.10 Thu 17:30 HSZ 201

Ultrafast metal-to-insulator switching in a strongly correlated system — •Francesco Grandi and Martin Eckstein — Department of Physics, University of Erlangen-Nürnberg, 91058 Erlangen, Germany

Several experiments have shown the possibility to induce an ultrafast insulator-to-metal phase transition in correlated materials. Instead, it remains debated how to experimentally realize an ultrafast phase transition in the opposite direction, i.e. a metal-to-insulator phase change. Developing a protocol that can lead to such a transition is relevant for the realization of a Mottronic device able to operate at the ultrafast time scales. A possible candidate for the realization of this scenario is the oxygen-enriched $LaTiO_{3+x}$, a correlated metal close to the Mott insulator $LaTiO_3$.

Here, we consider an effective model that we believe captures the main physical properties of $LaTiO_{3+x}$. We describe the photo-doping of electrons into the valence bands of the material from the low-lying oxygens 2p-derived band using non-equilibrium Dynamical Mean-Field Theory. By applying a suitably designed chirped-pulse that leads to dipolar excitations, we analyze how fast we can induce the metal-to-insulator transition and how far the final state is from a thermal configuration.