Non-equilibrium Dynamics of Correlated Electron-Systems:

latest theoretical and experimental advances

Book of abstracts

Ambrož, Krvavec, December 18th-20th 2013

Non-equilibrium Dynamics of Correlated Electron-Systems:
latest theoretical and experimental advances

December 18th-20th, 2013
Ambrož, Krvavec, Slovenia

Organized by
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Dynamics of bosons and spins in optical lattices

Ulrich Schollwöck[1]

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In this talk, I will discuss examples of the dynamics of bosons and spins in optical lattices, in the first case in view to understand and quantum simulate the relaxation behaviour of strongly interacting bosons towards thermal equilibrium, with a concomitant build-up of quantum correlations. In the case of spins, I will discuss the behaviour of a spin whose experimentally observed time-evolution can be interpreted, depending on interaction strengths, as a single magnon or a true interacting impurity. Time permitting, I will briefly discuss a recent major improvement in the calculation of long-time dynamics using tDMRG (MPS) at finite temperature, which could be of interest to various communities.

Dynamic Transitions in Interaction Quenches

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We show that the non-equilibrium time-evolution after interaction quenches in the one dimensional, integrable Hubbard model as wel as in its two dimensional counterpart exhibit a dynamical transition in the half-filled case. This transition ceases to exist upon doping. Our study is based on systematically iterated equations of motion. Thus it is controlled for small and moderate times; no relaxation effects are neglected. Remarkable similarities to the quench dynamics in the infinite dimensional Hubbard model are found suggesting dynamical transitions to be a general feature of quenches in such models. The possibility to determine relaxation without resorting explicitly to mixtures is discussed.

Ultrafast laser control of the magnetic exchange interaction

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Magnetic order in condensed matter systems is determined by the exchange interaction J, the strongest force in magnetism. In equilibrium, the value of J is governed by competing exchange mechanisms that depend on the orbital overlaps and Coulomb interaction in the model, as well as on chemical doping. Under nonequilibrium conditions, we can thus attempt to modify J with the electric field of an ultrashort laser pulse. In this talk we discuss two pathways to achieve this goal, which are photo-doping (exciting doublon and hole carriers in a Mott insulator with a laser pulse resonant to the charge-transfer excitation), or coherent control of J with off-resonant laser excitation. The first case is studied using nonequilibrium dynamical mean-field theory (DMFT) for a single-band Hubbard model in the antiferromagnetic Mott insulating phase. After a short laser pulse, the system relaxes to a quasi-stationary photo-doped state. When we simulate the dynamics of the antiferromagnetic phase in the Hubbard model in a transverse magnetic field, the latter leads to a canting of the spins, and a prompt change of J induces precessional motion with a frequency proportional Delta J/J. Modification of J by photo-doping is comparable to what is achieved by chemical doping and can range up to a few per cent. An alternative way to control the exchange interaction in correlated materials uses off-resonant driving with a laser field. In this case, we can study the laser induced change of J analytically, using Floquet theory for small clusters.

Snapshots of the retarded electron-boson interaction in high-temperature superconductors

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The paradigm of conventional solid-state materials is that the low-energy electron dynamics can be reduced to a retarded interaction between the charge carriers (fermions) and collective bosonic excitations, such as vibrations of the lattice (phonons). In correlated materials, this view is challenged by the strong instantaneous Coulomb repulsion between two electrons occupying the same lattice site, that denes a new high-energy scale U. Here we measure with unprecedented time resolution the transient optical conductivity of superconducting copper oxides with doping concentration close to that necessary to attain the largest critical temperature. We directly observe in the time domain the 15 fs build-up of the eective interaction of electrons with bosonic uctuations. This extremely fast timescale, together with the outcome of calculations within the repulsive Hubbard model, strongly points to short-range spin uctuations as the universal class of bosons mediating the interactions in doped copper oxides.

Momentum-selective Mottness of the pseudo gap state of the cuprates revealed by time-resolved spectroscopy

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Non-equilibrium spectroscopies provide us with a new tool to solve this issue. Time-resolved optical spectroscopy and photoemission highlight a clear experimental line. This boundary delimits a pseudogap-like region in which the pump pulses create a transient non-thermal population, with excess excitations in the regions close to the $k = (\pm\Pi, 0)$, $(0, \pm\Pi)$ points of the Brillouin zone (antinodes).

Strikingly, the scattering rate of this pump-induced non-thermal transient state is smaller than that measured at equilibrium. We show that this non-equilibrium physics finds a natural explanation in terms of the Hubbard model treated in Cluster Dynamical Mean-Field Theory, in which short-ranged correlations lead to a k-space differentiation between antinodal Mott-like excitations and nodal quasiparticles in doped Mott insulators.

As the energy is non-thermally pumped in the system, the antinodal Mottness is partially quenched and antinodal states evolve into more mobile ones thereby reducing their scattering rate. The Mott-like suppression of antinodal charge fluctuations makes this universal correlated ground state naturally prone to the ordered phases that have been hitherto measured in the pseudogap by conventional spectroscopies. However, a proper account of electronic correlations is necessary to study the appearance and stability of these phases.

Peltier effect in strongly driven quantum wires

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We study a microscopic model of a thermocouple device with two connected correlated quantum wires driven by a constant electric field. In such isolated system we follow the time- and position-dependence of the entropy density using the concept of the reduced density matrix. At weak driving, the initial changes of the entropy at the junctions can be described by the linear Peltier response. At longer times the quasiequilibrium situation is reached with well defined local temperatures which increase due to an overall Joule heating. On the other hand, strong electric field induces nontrivial nonlinear thermoelectric response, e.g. the Bloch oscillations of the energy current. Moreover, we show for the doped Mott insulators that strong driving can reverse the Peltier effect.

The Mechanism of Ultrafast Relaxation of a Photo-Carrier in Antiferromagnetic Spin Background

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We propose a microscopic mechanism of an ultrafast energy transfer of the order of 1 eV from a highly excited photo-carrier to spin degrees of freedom on a few-femtosecond time scale [1]. We study the relaxation dynamics in the t-J Hamiltonian on a square lattice and show that the relaxation consists of two distinct stages. The initial ultrafast stage is based on the generation of local spin excitations (string states) in the close proximity of the photo-carrier. By comparison of numerical results with a simplified t-J_z model on a Bethe lattice we show that the relaxation time scales as $\tau \sim (\hbar/t_0)(J/t_0)^{-2/3}$ (where t_0 is the hopping integral and J is the exchange interaction). In contrast, the relaxation time on a quasi-one-dimensional ladder system is an order of magnitude longer due to the lack of string states. This further reinforces the importance of string states for the ultrafast relaxation in the two-dimensional system.
The key ingredients of the primary relaxation are therefore local antiferromagnetic excitations that lead to a strongly non-thermal states of the spin background. In the t-J model with long-range antiferromagnetic correlations, subsequent thermalization of the spin background through propagating magnons represents the secondary, usually much slower stage of the relaxation.

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Optical response of highly excited particles in a strongly correlated system

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In the talk I will present a linear-response formalism for the optical response of a system of strongly correlated electrons out of equilibrium, as relevant for the probe optical absorption in pump-probe experiments. The time dependent optical conductivity $\sigma(\omega, t)$ will be defined in such a way that it represent the causal linear response to an arbitrary electric field pulse $E(t' > t)$, acting on a general nonequilibrium many-body wave function within a tight-binding model of correlated electrons. The definition allows the discussion of the sum rule and a dissipation-less Drude weight. As a nontrivial and experimentally relevant example we will consider a single highly excited charged particle (hole) in the spin background, as described within the two-dimensional t-J model. Results show that the optical sum rule approaches very fast to equilibrium-like one, however the time evolution and the final asymptotic behavior of absorption spectra, with main features being the mid-infrared peak and the Drude weight, still depend on the type of the initial pump perturbation.

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Unusual Two-stage Dynamics of the Spin-Lattice Polaron Formation

J. Kogoj[1*], Z. Lenarčič[1], D. Golež[1], M. Mierzejewski[2,3], P. Prelovšek[1,2] and J. Bonča[1,2]

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Following the formation of a spin-lattice polaron (SLP) after a quantum quench we discover a two-stage relaxation where spin and lattice degrees of freedom represent an integral part of the relaxation mechanism in both stages. In the first stage after the quench the kinetic energy of the SLP relaxes towards its ground state. In the second stage we observe a subsequent energy transfer between lattice and spin degrees of freedom. The second stage relaxation time can be much longer than the initial relaxation of the kinetic energy.

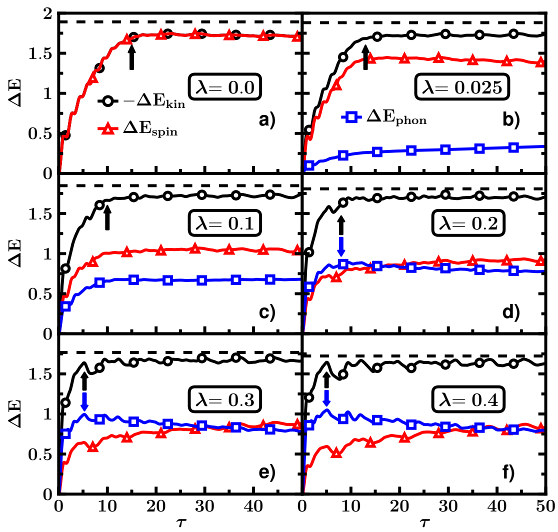

Figure 1: The time evolution after the quench for different values of electron-phonon coupling. The energy flow from lattice to spin degrees of freedom is observed at $\lambda > 0.1$, and backwards for $\lambda = 0.025$.

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Theory of quantum groups and nonequilibrium steady states

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We present analytical construction of certain far-from-equilibrium steady states of open quantum spin chains with integrable interaction by employing a powerful concept of so-called quantum symmetries. Quantum groups are algebras associated to continuous deformation of Lie symmetries, representing algebraic objects which give rise to infinitely many integrals of motion and are thus an essential piece of the theory of quantum integrability. Curiously, they can also be linked to some interesting current-carrying steady state density operators of Markovian quantum dissipative dynamics which have been recently constructed.

Electron-phonon coupled systems in strong electric fields

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We use a recently developed dynamical mean field approach to study the Mott insulating Holstein-Hubbard model, which is driven out of equilibrium by strong electric fields. Both DC electric fields (dielectric breakdown) and few-cycle field pulses (photo-doping) will be considered, and the results compared to the case without electron-phonon coupling. Electron-phonon scattering leads to a rapid cooling of the field excited carriers and for large doping to the appearance of in-gap states. We also consider the transport properties of the photo-doped insulator.

Witnessing quasi-particles in a strongly correlated electron system

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This presentation will focus on our recent results in PumpProbe broadband spectroscopy on cuprates. The interaction between phonons and high-energy excitation of electronic origin in cuprates is studied in two compounds. In a archetypal strongly correlated charge-transfer insulator (La2CuO4), with the aid of a general theoretical framework (Hubbard Holstein Hamiltonian), we show that the interaction between electrons and bosons manifest itself directly in the photo-excitation processes that pilots the formation of itinerant quasi-particles which are suddenly dressed (¡100 fs) by the coupled bosonic field. In optimally doped YBCO we combine coherent vibrational time-domain spectroscopy with density functional and dynamical mean field theory calculations to establish a direct link between the c-axis phonon modes and the in-plane electronic charge excitations in optimally doped YBCO.

On the mechanism of photoinduced collective states in condensed matter: The case of the hidden CDW state in 1T-TaS_2

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Ever since early attempts of achieving photoinduced superconductivity, both experimentalists and theorists have tried to achieve collectively ordered states in condensed matter systems. Unfrotunately most experimental attempts have yielded metastable states, with lifetimes on the order of microseconds or commonly much less. However, a few notable examples exist, where remarkable stability is achieved. One such case is the phoinduced hidden state in 1T-TaS2, where collective electonic order is achieved with photoexcitation by sub-5ps pulses. The crucial requirement for such a phenomenon to occur is that a transient electron-hole asymmetry exists for sufficiently long that a collective electronic order can be established in the meantime. The collective nature of the new state gives rise to its remarkable stability. I discuss the relevant mechanisms which are operative in achieving photoinduced saitching to the hidden state and the origin of the remarkable stability of the hidden state.

Photo-induced electron dynamics in one-dimensional extended Hubbard model

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One-dimensional extended Hubbard model at half filling shows a spin-density-wave (SDW) state and charge-density-wave (CDW) state depending on the relative strength of on-site Coulomb interaction (U) and inter-site Coulomb interaction V. We investigate the photo-induced electrons dynamics and nonequilibrium process of the model driven by transient laser pulse by using the time-dependent Lanczos method.

In the case of large U and $U \sim 2V$, the SDW and CDW phases are separated by a first order phase transition. When the system is subjected to the irradiation of a laser pulse in the SDW phase near the phase boundary, a sustainable charge order enhancement can be realized with proper laser frequency and strength, while local spin correlations remains [1]. Analogously, from the CDW side, the suppression of long-range charge order is accompanied with a local spin correlation enhancement. We analyze the conditions and investigate possible mechanisms of the emerging order enhancements.

We also investigate the ultrafast optical response of the model exposed to two successive laser pulses [2]. We find that following the first pulse, the excitation and deexcitation process between the ground state and excitonic states can be precisely controlled by the relative temporal displacement of the pulses. The underlying physics can be understood in terms of a modified Rabi model. Our simulations clearly demonstrate the controllability of ultrafast transition between excited and deexcited phases in strongly correlated electron systems.

These works are done in collaboration with Hantao Lu, Janez Bonča, Sigetoshi Sota, and Hiroaki Matsueda.

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Nonthermal fixed point in the antiferromagnetic Hubbard model

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Recent progress in ultrafast optical spectroscopies has enabled one to study real-time dynamics of symmetry broken phases in the intrinsic microscopic time scale. Motivated by these, we discuss nonequilibrium dynamics of the antiferromagnetic Hubbard model. The time evolution is obtained via the nonequilibrium dynamical mean-field theory. We find that the antiferromagnetic order stays to be a nonzero value for a relatively long time after excitation even when the excitation energy amounts to a temperature larger than the thermal critical temperature. This implies that the system is trapped to a symmetry-broken nonthermal fixed point. The transient dynamics is governed by a nonthermal (quasi)critical point, where a nonequilibrium universal behavior emerges.

Prethermalization and thermalization of weakly interacting quantum systems

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After being forced out of equilibrium, an isolated quantum many-body system is expected to relax to thermal equilibrium, unless it is integrable and retains memory of the initial state due to a large number of constants of motion. For weak interactions a large number of approximate constants of motion leads to a short-time prethermalization regime [1], which we discuss for several interacting systems. We then use a weak-coupling kinetic theory [2] to describe both the initial prethermalization regime as well as the subsequent crossover towards the thermal state.

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Walking graph states and exact steady state solution of nonequilibrium Fermi-Hubbard chain

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I will discuss current carrying non-equilibrium steady state of an open fermionic Hubbard chain that is strongly driven by markovian incoherent processes localized at the chain ends. An explicit form of exact many-body density operator for any value of the coupling parameter is presented. The structure of a matrix product form of the solution [1] - walking graph state - is encoded in terms of a novel diagrammatic technique which should allow for generalization to other integrable non-equillibrium models.
As a by-product of such solution one is able to provide a strict lower bound on the high-temperature spin/charge diffusion constants in terms of a quadratically-extensive almost-conserved quantity which derives from the coupling expansion of the steady-state density operator [2].

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Theory of electron relaxation in metals excited by an ultrashort optical pump

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The theory of the electron relaxation in metals excited by an ultrashort optical pump is developed on the basis of the solution of the linearized kinetic equation. The kinetic equation includes both the electron-electron and the electron-phonon collision integrals. The widely used two temperature model follows from the theory as the limiting case, when the thermalization due to the electron-electron collisions is fast with respect to the electron-phonon relaxation. It is demonstrated that the energy relaxation has two consecutive processes. The first and most important step describes the emission of phonons by the photo-excited electrons. It leads to the relaxation of 90% of the energy before the electrons become thermalized among themselves. The second step describes electron-phonon thermalization and may be described by the two temperature model. The second stage is difficult to observe experimentally because it involves the transfer of only a small amount of energy from electrons. Thus the theory explains why the divergence of the relaxation time at low temperatures was never observed experimentally.

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Femtosecond quasi-particle relaxation dynamics in electron doped iron-based pnictides

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The richness of the iron-based-pnictides phase diagram is reflected also in the transient optical response. Systematic investigations[1, 2, 3, 4] of the photoexcited quasiparticle relaxation in electron doped 1111 and 122 iron-based pnictides by all-optical methods and their implications regarding the tetragonal-orthorhombic structural transition, spin-density ordering, nematic fluctuations in the normal state and superconductivity will be briefly reviewed and discussed.

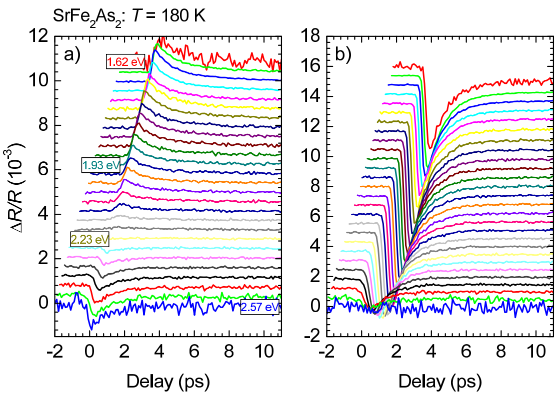

Figure 1: The probe-photon energy dependence of the photoinduced reflectivity transients in $SrFe_2As_2$ just below the orthorhombic-SDW transition temperature. Panels a) and b) correspond to different in-plane probe polarizations.

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Perturbation study of the critical voltage in non-equilibrium stationary superconductor.

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We study a simplified model for the bulk properties of stationary superconductor. The system is driven out-of-equilibrium by a voltage bias, imposed as an imbalance of chemical potential at the interface. We solve the dynamical mean-field equations using iterative second-order perturbation theory in the Nambu-Keldysh formalism. We follow the progressive destruction of the superconducting state formed by the left- (L) and right- (R) moving electrons as effect of a bias of the order of the energy gap. We demonstrate that at intermediate-to-strong coupling the transition to the normal state occurs through an *bad superconducting* state, which is characterized by a smaller value of the order paramater and incoherent excitations. We discuss the physical origin of this novel phase in terms of energetic gain.

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Decay of topologically protected state in $1T\text{-}TaS_2$

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Here we report on relaxation of hidden photoinduced state in $1T\text{-}TaS_2$. As was shown earlier, it is possible to switch $1T\text{-}TaS_2$ from insulating commensurate CDW-ordered state to a stable metallic topologically protected state at low temperatures [1].
Recent experiments show that at intermediate temperatures in the range 40-80 K lifetime of the hidden state is relatively short (1-10^3 s) that makes it possible to directly measure resistance as the thermal state recovers. The relaxation process does not fit well to usual for glassy relaxation stretched exponential law that is a consequence of scaling theory [2].
Absolute value of the resistance immediately after the excitation is independent on switching pulse energy. However with increase of the pulse energy, relaxation time increases at constant temperature. With increasing of temperature, relaxation time decreases at constant pulse energy.
Few different substrates were tested. Results show that strain effects play important role in stabilization of the hidden state.

References

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Pseudogap photodestruction and recovery, measurements on $Bi_2Sr_2CaCu_2O_{8+d}$

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In copper oxide high temperature superconductors electronic density of states at the Fermi level is characterized not only by the superconducting (SC) gap but also by the pseudogap(PG). PG is present both in superconducting region and above the critical temperature up to the temperature T* which monotonically decreases with doping. There is still no convergence on the nature of the gap as well as no clear understanding whether the gap is collective or not[1]. We perform photodestruction experiments to find similarities and differences with the superconducting gap behavior.
In standard two pulse pump-probe reflectivity traces three components are present in general case. They are associated with 1) hot carriers (HC) relaxation, relaxation across the pseudogap and the superconducting gap (SC). HC component is constant with temperature and linear with excitation pulse energy. Superconducting component shows saturation with excitation energy attributed to the photodestruction of the superconducting state [2]. Pseudogap component also shows saturation behavior with threshold value dependent on T*.
We report the measurements of excitation energy dependencies of the pseudogap component in slightly under- and overdoped as well as nearly optimally doped $Bi_2Sr_2CaCu_2O_{8+d}$.
We investigate the recovery of this component by three pulse technique [3] as a function of excitation energy and temperature for the underdoped sample. Using symmetry analysis we separate different components of the signal and measure the superconducting fluctuations in the vicinity of T_c

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Normal state bottleneck and nematic fluctuations from femtosecond quasiparticle relaxation dynamics in Sm(Fe,Co)AsO

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By means of the femtosecond laser spectroscopy we studied the temperature and fluence dependence of the relaxation dynamics in the superconducting $Sm(Fe_{0.93}Co_{0.07})AsO$ single crystal [1]. Similarly as previously observed in Ba-122 system [2], the reflectivity relaxation transients in nominally tetragonal phase show a two-fold rotational anisotropy with respect to the probe polarization at temperatures below ∼200 K. Above T_c the transient reflectivity amplitude decreases with increasing temperature which is associated with a bottleneck in the relaxation. The bottleneck is a fingerprint of the presence of a pseudogap in the quasiparticles density of states. Both, the normal states and the superconducting components show a similar anisotropy, which indicates that the superconductivity is coexisting with nematicity and the pseudogap. To estimate the electron phonon coupling constant λ we analyze the reflectivity transients at high T and find a moderate electron phonon coupling constant $\lambda \sim 0.2$ consistent with previous studies.

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The transient state of photo-perturbated $1T$-TaS_2

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$1T$-TaS_2 is a layered material that exhibits a manifold of electronic and structural phases [1], giving rise to a complex interplay between electronic correlation effects and structural modifications. Of particular interest is the photo-induced melting of the low-temperature (T< 180 K) Mott-phase that drives the system into a "cross-over state" substantially different from the high temperature metallic state [2,3].
To investigate this phase, we performed time-resolved photoemission spectroscopy experiments for various sample temperatures (30-300 K) and different excitation fluences < 1 mJ/cm^2. After excitation we find a depletion of the lower Hubbard band (LHB), the excitation of hot carriers and oscillations of the spectral weight at the Fermi level that can be attributed to the excitation of coherent optical phonon modes. The population dynamics within the LHB and of excited hot electrons are analyzed and compared to characteristic time-scales in the system. Energy dependent dynamics of hot electrons with relaxation times below 300 fs are found above the Fermi level, while the re-establishment of the Mott signature occurs on longer time-scales > 1 ps. We will discuss a possible scenario considering a localized, partial quenching of the insulating state.
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Strain-induced enhancement of the electron energy relaxation in strongly correlated superconductors

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The deformation potential theorem has been very successful in rationalizing and quantifying the strength of the electron-phonon interaction (EPI) in relation to charge carrier scattering and mobility in semiconductors. Subsequently, it has been shown that the formalism is not limited to semiconductors, but can be extrapolated both to metals and insulators. Strain on the structure caused by external pressure or by doping may result in significant changes of the EPI, leading to changes in functional properties. In both the cuprate and pnictide families of superconductors, the inter-atomic distance has been discussed as a parameter besides the doping level x that is systematically correlated with the superconducting critical temperature T_c. However, it was not understood how this parameter is related to an interaction that is involved in the superconducting pairing mechanism. Here we present systematic measurements of electron energy relaxation in the normal state of different hi gh T_c superconductors to show that in both cuprate and pnictide superconductors the primary electron energy relaxation rate k_1 is directly correlated with the length a of the crystallographic a-axis. The dependence of the deformation potential on the lattice constant rationalizes how the EPI strength increases with increasing negative strain in the a-axis. Using established models which relate k_1 to the EPI, we make the direct experimental connection between the EPI strength and T_c

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Time resolved measurements on Pb and K doped $BaBiO_3$ superconductor

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We present measurements on $BaPb_{1-x}Bi_xO_3$ ($x = 0.2, 0.25$) and $Ba_{1-x}K_xBi_{1.09}O_3$ ($x = 0.28, 0.3$) all superconductors with critical temperatures from 9 K to 30 K. $BaBiO_3$ is a charge-density-wave insulator/ semiconductor. With doping it undergoes a semiconductor to metal transition and is superconductive in parts of its phase diagram. We observe two component relaxation with some phonon oscillation over temperature. Probably due to experimental limitations we were unable to observe superconducting transition, but pseudogap like behavior is present for one component in BPBO. Most of the oscillating amplitude is at 1.7 THz and only weakly varies over measured temperature range.

Transient optical reflectivity in SDW iron-based pnictides: a supercontinuum-probe study

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Employing a broadband ultrafast transient optical spectroscopy we investigate quasiparticle relaxation in normal and spin density wave (SDW) states of $BaFe_2As_2$, $EuFe_2As_2$ and $SrFe_2As_2$ iron-based-pnictide parent compounds in a 1.6-2.6 eV spectral region. With decreasing temperature all samples start to show a twofold inplane rotational symmetry already in the tetragonal phase, significantly above the SDW/structural transition temperature, suggesting the presence of nematic fluctuations. In the SDW state the reflectivity transients across the full spectral range can be described by just two distinct relaxation components consistent with previous optical results at 1.55 eV probe energy [1]. One of the components is absent at high temperature and shows a critical-like slowing down near the SDW transition temperature. Two different possible assignments of this component related either to a single-particle relaxation bottleneck or the collective mode dynamics will be presented and discussed.

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Dynamics of resistive state in narrow superconducting channels

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Previously, it was demonstrated that when parameter u, characterizing the penetration depth of the electric field in the nonequilibrium superconductors, is less than the critical value u_{c1}, which does not depend on L, the phase slip centers appear simultaneously at different spots of the channel [1, 2]. Herewith, for $u > u_{c1}$ these centers arise consecutively at the same place [2]. In our work we demonstrate on the basis of direct numerical integration of the time-dependent Ginzburg-Landau equations [3] that there is another critical value for u [4]. Actually, if u does not exceed a certain value u_{c2}, which depends on L, the current-voltage characteristic exhibits the step-like behaviour. However, for $u > u_{c2}$ it becomes hysteretic. In this case, with increase of j the steady state, which corresponds to the time independent distribution of the order parameter along the channel, losses its stability at switching current value j_{sw}, and time periodic oscillations of both the order parameter and electric field occur in the channel. As j sweeps down, the periodic dynamics ceases at certain retrapping current value $j_r < j_{sw}$. Shunting the channel by a resistor increases the value of j_r, while j_{sw} remains unchanged. Thus, for some high enough conductivity of the shunt j_r and j_{sw} eventually coincide, and the hysteretic loop disappears. We reveal dynamical regimes involved in the hysteresis, and discuss the bifurcation transitions between them.

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Charge carriers photogeneration in few-layers of MoS_2

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The primary photoexcitations in MoS_2 are excitons [1] with a binding energy close to 0.5 eV or even higher in single flakes. Their relaxation behavior has been described as the interplay of trapping, phonon-assisted interband transitions and radiative recombination [2]. On the other hand, the observation of photocurrents and a photovoltaic effect suggests that photoexcitation of MoS_2 also generate charge carriers [3].
Using method of ultrafast spectroscopy we show the photogeneration of long-lived charge carriers few-layers flakes of MoS_2 dispersed in an inert PMMA matrix. Charges are formed from both the A and B excitons with a time constant of approximately 1 ps during the fastest observed exciton relaxation process.

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Conference schedule

9^{00} - 9^{30}		Philipp Werner	Manuel Ligges
9^{30} - 10^{00}		Daniele Fausti	Christoph Gadermaier
10^{00} - 10^{30}	Opening remarks Ulrich Schollwöck	Dragan Mihailović	Primož Kušar
10^{30} - 11^{00}	Götz Uhrig	Coffee break	Coffee break
11^{00} - 11^{30}	Coffee break	Takami Tohyama	Anna Pogrebna Vladimir Baranov Tetiana Borzda
11^{30} - 12^{00}	Martin Eckstein	Naoto Tsuji	

16^{30} - 17^{00}	Claudio Giannetti	Marcus Kollar
17^{00} - 17^{30}	Massimo Capone	Tomaž Prosen
17^{30} - 18^{00}	Coffee break	Coffee break
18^{00} - 18^{30}	Marcin Mierzejewski	Viktor Kabanov
18^{30} - 19^{30}	Lev Vidmar	Tomaž Mertelj

20^{30} - 20^{45}	Zala Lenarčič	Adriano Amaricci
20^{45} - 21^{00}	Jan Kogoj	Igor Vaskivskyi
21^{00} - 21^{15}	Enej Ilievski	Ivan Madan
21^{15} - 21^{30}		Ljupka Stojchevska