Nonequilibrium phenomena in complex matter: new observations and new theories

BOOK OF ABSTRACTS

Ambroz, Krvavec, December 17th – 19th 2012

Nonequilibrium phenomena in complex matter: new observations and new theories
December 17th – 19th, 2012
Ambrož, Krvavec, Slovenia

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Ambrož, Krvavec, December 2012

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MEDNARODNA
PODIPLOMSKA ŠOLA
JOŽEFA STEFANA

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In search for the pairing glue in cuprates by non-equilibrium optical spectroscopy

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In strongly-correlated electron materials the electronic and optical properties are significantly affected by the coupling of fermionic quasiparticles to different degrees of freedom, such as lattice vibrations and bosonic excitations of electronic origin. Broadband ultrafast spectroscopy [1] is emerging as the premier technique to unravel the subtle interplay between quasiparticles and electronic or phononic collective excitations, by their different characteristic timescales and spectral responses. By investigating the femtosecond dynamics of the optical properties of prototypical copper oxides (Y-Bi2212) over the 0.5-2 eV energy range, we disentangle the electronic and phononic contributions to the generalized electron-boson Eliashberg function [2], showing that the spectral distribution of the electronic excitations, such as spin fluctuations and current loops, and the strength of their interaction with quasiparticles can account for the high critical temperature of the superconducting phase transition [3]. Finally, we discuss how the use of this technique can be extended to the underdoped region of the phase diagram of cuprates, in which a pseudogap in the quasiparticle density of states opens.
The microscopic modeling of the interaction of ultrashort light pulses with unconventional superconductors will be one of the key challenges of the next-years materials science, eventually leading to the full understanding of the role of the electronic correlations in controlling the dynamics on the femtosecond timescale.

[1] C. Giannetti et al. *Nat. Commun.* **2**:353 (2012)
[3] E. van Heumen et al. *Phys. Rev. B* **79** 184512 (2009)
[2] J.P. Carbotte et al. *Rep. Prog. Phys.* **74** 066501 (2011)
[3] S. Dal Conte et al. *Science* **335** 1600 (2012)

Kinetics of hot electrons in metals: Theoretical overview

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In recent years investigations of photo-response functions in advanced materials have gone through a vigorous revival. In particular, laser "pump-probe" techniques, where a second probe pulse is delayed in time with respect to the pump pulse, provide unique information on the strength of electron-electron (e-e) and electron-phonon (e-ph) interactions in metals and doped insula-tors if an adequate theory is in place. I will present overview of models of the relaxation of hot electrons in metals.

Magnetooptical time-resolved study of Eu^{2+} spin dynamics in $EuFe_2(As_{1-x}P_x)_2$ pnictide superconductor

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We investigate the Eu^{2+} dynamics in $EuFe_2(As_{0.7}P_{0.3})_2$ (EFAP) pnictide superconductor and parent nonsuperconducting $EuFe_2As_2$ (EFA) using optical pump-probe femtosecond spectroscopy in magnetic field. In both cases we observe an emergence of a slow anisotropic photoinduced relaxation component concurrent with Eu spin ordering. A remarkable change of the quasiparticle relaxation dynamics at the antiferromagnetic (AFM) spin density wave (SDW) transition temperature 200 K is observed.

The magnetic field dependence of the relaxation in the superconducting EFAP is different than in the nonsuperconducting EFA. In EFA we observe switching of the optical-transients anisotropy with increasing magnetic field attributed to a field-induced antiferromagnetic (AFM) to ferromagnetic (FM) phase transition. In the superconducting EFAP a large coherent magnon oscillation is observed at a similar metamagnetic transition. The oscillation is absent in the transient magneto-optical Kerr effect suggesting an interplay between the Eu^{2+} spin and charge degrees of freedom.

[1] Zhi Ren et al. Phys. Rev. B 78. 052501 (2008)
[2] S.Zapf et al. Phys.Rev. B 84, 140503(R) (2011)
[3] Z. Guguchia et al. Phys. Rev. B 84, 144506 (2011)

Ultrafast dynamics in correlated materials investigated by time- and angle-resolved photoelectron spectroscopy

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Femtosecond time- and angle-resolved photoelectron spectroscopy (tr-ARPES) is on its way to developed from an experimental tool in surface science to a general method in solid state physics [1,2]. Of particular interest are excited states and relaxation dynamics in correlated materials like high temperature superconductors and Mott insulators. In this talk results on cuprate [3] and Fe-pnictide superconductors [4] obtained by tr-ARPES will be discussed. In addition recent results on the combined Mott insulator and charge density wave compound 1*T*-TaS_2 will be presented.

[1] Dynamics at Solid State Surfaces and Interfaces, U. Bovensiepen, H. Petek, M. Wolf (eds.), Wiley-VCH, Weinheim, 2011.
[2] U. Bovensiepen, P. S. Kirchmann, Laser Photonics Rev. **6**, 589 (2012).
[3] R. Cortés et al., Phys. Rev. Lett. **107**, 097002 (2012).
[4] L. Rettig et al., Phys. Rev. Lett. **108**, 097002 (2011).

High superconducting critical temperatures depend systematically on the electron-phonon relaxation rate

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We report on the systematic study of the electron energy relaxation for pnictides, cuprates, and bismuthates high-temperature superconductors in the normal state. The energy relaxation of photoexcited electrons proceeds by transferring the electrons' excess energy to phonons and possibly other bosonic excitations. We find that the superconducting critical temperature T_c depends systematically on the electron-phonon relaxation rate $1/\tau_{e\text{-}ph}$, which is a direct experimental measure of the strength of the electron-phonon interaction, and is found to correlate with structural parameters, in particular the length of the crystallographic *a*-axis. $T_c(1/\tau_{e\text{-}ph})$ is a non-monotonic function with the maximum at intermediate relaxation rates (~16 ps^{-1}), suggesting that the electron-phonon interaction provides the attractive interaction for the high-T_c pairing mechanism, where the highest T_c occurs in the crossover region between weak and strong electron-phonon interaction.

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Time resolved reflectivity in underdoped LSCO

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We will present measurements of electron relaxation in underdoped $La_{2-x}Sr_xCuO_4$ (x = 0.025, 0.035, 0.06) measured by time resolved optical spectroscopy (pump-probe @ 800 nm). Results will be compared to the data on La_2CuO_4 and discussed in terms of theoretical models.

Ultrafast relaxation dynamics in doped charge-transfer insulators

Simone Peli[1], Stefano Dal Conte[1,2], Daniele Brida[2], Federico Cilento[3], Francesco Banfi[1], Gabriele Ferrini[1], Stefano Lupi[4], Giulio Cerullo[2], Fulvio Parmigiani[3,5] and Claudio Giannetti[1]

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In correlated materials, the femtosecond relaxation dynamics of non-equilibrium excitations is crucially regulated by the electron-electron and electron-phonon scattering processes. Here, we study the relaxation pathways of optically excited single-plane Bi-based copper oxides (Bi2201) over a wide doping range. A high-temporal resolution (10 fs) pump broadband-probe optical technique is used to disentangle the electronic and phononic processes on the basis of their different timescale. The electronic processes are revealed as a transient increase of the electronic scattering rate. On the 50 fs timescale the heating of the lattice, as a consequence of electron-phonon scattering, induces a variation of the high-energy charge-transfer optical transitions.
These results are promising in view of understanding the role of the electronic correlations in the ultrafast relaxation processes of doped charge-transfer insulators.

Non-equilibrium steady states of boundary-driven open quantum chains

T. Prosen

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We will discuss a general non-equilibrium setup by which one can approach the quantum transport problem in one dimension. One considers a strongly interacting quantum chain with fully coherent bulk dynamics and driven out of equilibrium in terms of Lindblad dissipators which only act on degrees of freedom near the boundary, i.e. at the ends of the chain. Non-equilibrium state carrying the physical currents is then approximated as the steady state of the corresponding Markovian master equation.

I will describe several interesting results which have recently been obtained in our group along these lines. Firstly, using numerical methods inspired by the density matrix renormalization group, one can – quite remarkably - find examples of diffusive transport in clean, and even Bethe-ansatz integrable, strongly interacting systems (at high-temperature near-equilibrium conditions), such as the Heisenberg XXZ spin 1/2 chain and the one-dimensional Hubbard model.

Secondly, under far from equilibrium conditions, one can find several exact analytical solutions which describe steady states with anomalous transport properties. For example, in the Heisenberg XXZ chain under extreme boundary driving we show that the steady-state density operator of a finite system of size n is -- apart from a normalization constant – a polynomial of degree 2n-2 in the coupling constant. The perturbative (weak coupling) version of our ansatz is used to derive a novel quasi-local conservation law of the anisotropic Heisenberg model, by means of which we rigorously estimate the spin Drude weight (the ballistic transport coefficient) in the easy-plane regime.

Nonequilibrium dynamics of doped antiferromagnetic Mott insulators in two dimensions

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Out-of-equilibrium dynamics of two-dimensional antiferromagnetic Mott insulators driven by a constant or time-dependent external force represents an exciting and widely unexplored field of both theoretical as well as experimental research. We study by means of numerical calculations how doped holes (charge carriers) described within the t-J model and the t-J-Holstein model behave under highly nonequilibrium conditions. In particular, we are interested how the accumulated energy (e.g., in the steady state if the electric field is constant, or during the relaxation process if a short laser excitation is introduced) is transferred from charge carriers to quantum spin and phonon degrees of freedom contained within the model.

I will first present two examples revealing peculiarities of nonequilibrium dynamics in two dimensions [1,2]. The first example concerns the steady state of a single hole driven by a constant electric field, where at large electric fields the propagation of hole in direction transverse to the field represents an efficient channel to emit its excess energy [1]. In the second example, I will show that the bound state of two holes decays with the onset of a finite steady current if both the mechanism for binding and the dissipation mechanism are due to the same origin. Interestingly, we observe that the short-time dynamics on the square lattice is governed by the decay in the direction transverse to the electric field, leading to much shorter decay times than on a quasi one-dimensional ladder system [2].

Then I will address the steady state properties of a driven hole within the t-J-Holstein model, where the energy gained by the propagation along the field can flow to both spin and phonon degrees of freedom [3]. Such an investigation of a multi-component system under nonequilibrium conditions is motivated by recent developments of pump-probe experiments, and addresses a highly nontrivial question about the main relaxation mechanism of two-dimensional strongly correlated materials. Our results indicate that for values of model parameters as relevant for materials like cuprates, the energy in the steady state flows predominantly to the spin subsystem.

Finally, I will discuss relaxation dynamics of doped systems after a short laser irradiation, relevant for comparison to ultrafast experiments [4].

[1] M. Mierzejewski, L. Vidmar, J. Bonča and P. Prelovšek, Phys. Rev. Lett. 106, 196401 (2011).
[2] J. Bonča, M. Mierzejewski and L. Vidmar, Phys. Rev. Lett. 109, 156404 (2012).
[3] L. Vidmar, J. Bonča, T. Tohyama and S. Maekawa, Phys. Rev. Lett. 107, 246404 (2011).
[4] D. Golež, J. Bonča, L. Vidmar and S. A. Trugman, arXiv:1209.2586 (accepted to Phys. Rev. Lett.).

Relaxation dynamics of the Holstein polaron

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Polaron is a quasi-particle, which is formed by a charged particle and accompanied polarisation field. As electron is moving throught the crystal its interacting with the lattice creates deformation. This deformation acts as a effective potential well, which lowers the mobility of the quasiparticle. In previous years theoretical research was limited on the equilibrium properties of the systems. However, as experiments starts probing physical properties far beyond the linear response regime, the interest on the correlated phenomena out of the equilibrium rapidly starts to grow in fields like the transport in nanosystems, ultra-cold atomic gasses and time resolved optical spectroscopy (pump and probe experiments). I will represent the nonequillibrium dynamics of the Holstein polaron problem driven by a constant or pulse modulated electric field. In the case of constant electric field the crucial condition for emergence of the quasi-stationary current in the system driven by constant electric field is the existence of the bath, which can absorb energy, while for pulse modulated field we can analyse the relaxation dynamics.

Ultrafast charge recombination in photoexcited Mott-Hubbard insulator

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Recent femtosecond pump-probe experiments on Mott-Hubbard insulators reveal charge recombination and thermalization which is in picosecond range, much faster than in clean band-gap semiconductors although the excitation gaps in Mott-Hubbard insulators are larger. We present a calculation of the recombination rate of the excited holon-doublon pairs based on the model relevant for undoped cuprates which shows that such fast pro- cesses can be explained even quantitatively with the multi-magnon emission. The precon- dition is the existence of the Mott-Hubbard bound exciton of the s-type. We find that its decay is exponentially dependent on the Mott-Hubbard gap and on the magnon energy, with a small prefactor which can be traced back to strong correlations and consequently large exciton-magnon coupling.

[1] Z. Lenarčič and P. Prelovšek, arXiv:1211.3236 (2012)
[2] H. Okamoto et al., Phys. Rev. B 83, 125102 (2011)

Hubbard exciton revealed by time-domain optical spectroscopy

Daniele Fausti

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This contribution will focus on our recent results in Pump&Probe broadband spectroscopy in insulating transition metal oxides. We use broadband ultrafast pump-probe spectroscopy in the visible range to study low-energy transitions across the Mott-Hubbard gap in the orbitally ordered insulator YVO_3. The pump-induced transfer of spectral weight between the two peaks reveals that the low-energy one is a Hubbard exciton, i.e., a resonance or a nearly bound state between a doublon and a holon. Finally, we speculate that the pump-driven spin disorder can be used to quantify the kinetic energy gain of the excitons in a ferromagnetic environment.

Coherent topological defect dynamics on the femtosecond timescale in superconductors and electronic crystals.

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The control of condensed matter systems out of equilibrium by laser pulses allows us to investigate the system trajectories through symmetry-breaking phase transitions. Thus the evolution of both collective modes and single particle excitations can be followed through different transitions with femtosecond resolution. Generally, two types of transitions are of immediate interest: the normal-to-superconductor transition and the charge-density wave ordering transition. Connected with these transitions, of particular interest is the coherent evolution of topological defects forming during the transition via the Kibble-Zurek mechanism, which appears to be measurable in optical pump probe experiments.

The formation of the superconducting condensate after a laser-induced quench enables us to distinguish the dynamics of the order parameter ψ from the quasiparticle (QP) dynamics for the first time on a Ginzburg-Landau (G-L) timescale $<10^{-13}$ s. Time-dependent GL theory and thermal diffusion processes are used to predict the trajectory of the $\psi(t)$ after the quench. Under fast quench conditions where the quench time is comparable or shorter than the GL time, vortices according to the Kibble-Zurek scenario are predicted to appear on a time-scale of 3-5 ps, just before the crossover from non-thermal to thermal dynamics. Experimentally, by tuning the quench rate, we investigate the crossover from fast to slow quench. Evidence for vortex formation in the Kibble-Zurek scenario will be critically examined in LaSrCuO, as well as departures from behaviour beyond TDGL theory close to the critical time. In CDW systems, the topological excitations – domain walls – are created by the Kibble-Zurek mechanism. The coherent annihilation of topological defects can be observed as distortions of the AM lineshape appearing when order-parameter waves emitted after topological defect annihilation events reach the surface of the crystal. Such behavior is found to be common in some rare-earth telluride and some transition metal selenide CDW systems. Higgs-like excitations are spontaneously created, and interaction with "dark matter" analogue excitations can be discussed. Finally the possibility of reaching hidden states of matter by ultrafast quench will be introduced. (The details will be presented by Igor Vaskivskyi.)

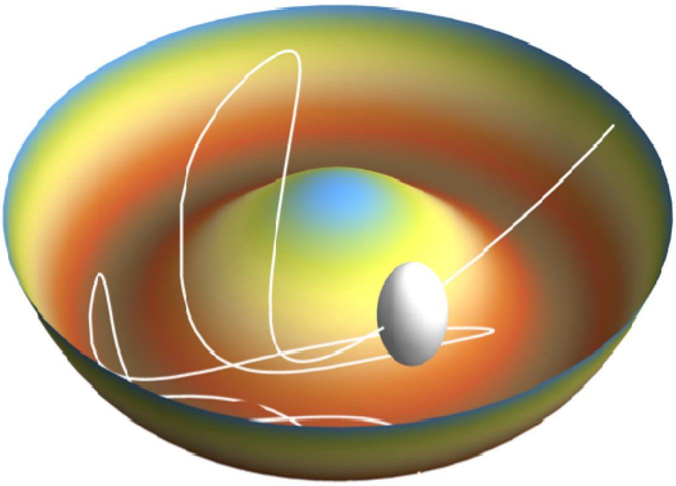

Figure 1: A predicted trajectory of a superconductor undergoing a normal-to-superconductor transition in real time under rapid quench conditions.

Non-equilibrium phase transition in cuprates. Measurements by three pulse pump-probe technique.

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In the present presentation we report about the application of the three pulse technique (3PT) to investigation of strongly non-equilibrium phase transitions in cuprates. The technique is a modification of the standard pump probe experiment - the additional strong pulse, we call it destruction (D) pulse is applied prior to the pump (P) and probe (pr) pulses. The P-pr response is recorded at a set of time delays after the D pulse thus tracking the evolution of the system.
We report the results of measurements on the underdoped $Bi_2Sr_2CaCu_2O_{8+d}$. Two regimes in power of the D pulse reveal different phenomena.

a) for strong D pulses the pseudogap state (PG) is destroyed. The recovery time shows fluence dependence at least at the temperature where the signal is strong enough, thus pointing that the PG is not a single particle constant gap.
b) for weak D pulses the PG is unimpaired but the superconducting (SC) state is partially destroyed. In this regime by characteristic footprint of the SC responce we detected the presence of the superconducting fluctuations up to 20 K above the critical temperature. We have measured the quasiparticle relaxation and the recovery of this state.

Real time obesrvations of quasi-particle relaxation dynamics in undoped iron-based pnictides by means of femtosecond laser spectroscopy

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We investigate the photoexcited quasipartcile relaxation in undoped SmFeAsO and $Ba(Fe,Co)_2As_2$ single crystals. Below T_{SDW} the $\Delta R/R$ transients are dominated by the initial single exponential relaxation. The temperature dependence of the relaxation at $T<T_{SDW}$ indicates appearance of a QP relaxation bottleneck. The bottleneck is attributed to the partial charge gap opening with a BCS-like temperature dependence due to the band- structure reconstruction below T_{SDW}. In $Ba(Fe,Co)_2As_2$ samples the relative charge gap magnitude $2\Delta(0)=k_B T_{SDW}$ decreases with Co-doping, consistent with a decrease of the stability of the orthorombic/SDW state.
Moreover, we observe a 2-fold symmetry breaking instability in $Ba(Fe,Co)_2As_2$ in all undoped samples up to 200 K. We associate it with fluctuations or ordering of Fe *d* orbitals.

[1] Mertelj et al. Physical Review B 81, 224504 (2010).
[2] Stojchevska et al. Physical Review B 86, 024519 (2012).

Time- and angle-resolved photoemission spectroscopy of the CDW material RTe_3

Laurenz Rettig[1], R. Cortés[2], J.-H. Chu[3], I.R. Fisher[3], F. Schmitt[3], P.S. Kirchmann[4], R.G. Moore[3], Z.-X. Shen[3,4], M. Wolf[2], and U. Bovensiepen[1]

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Abstract:

We present femtosecond (fs) time-and angle-resolved photoemission spectroscopy (trARPES) experiments on the family of prototypical charge-density wave (CDW) compounds RTe_3 (R=rare-earth). In $DyTe_3$, the time-resolved Fermi surface mapping using a novel position-sensitive time-of-flight spectrometer [1] reveals the collapse of the CDW energy gap on an ultrafast timescale. Furthermore, the momentum- dependent analysis of the transient occupied and unoccupied band dispersion allows for a direct measure of the time-dependent order parameter and facilitates a detailed analysis of the CDW nesting condition on a fs time scale.

In addition, at low excitation, we observe the coherent excitation of the CDW amplitude mode oscillations [2], which modulate the CDW order parameter magnitude. We analyze its temperature dependence in $HoTe_3$, $DyTe_3$ and $TbTe_3$ and demonstrate its coherent control in a pump-pump-probe experiment.

[1] P. S. Kirchmann, L. Rettig, D. Nandi, et al., Appl. Phys. A 91, 211 (2008).
[2] F. Schmitt, P.S. Kirchmann, U. Bovensiepen, et al., Science 321, 1649 (2008).

Multi-pulse time resolved optical spectroscopy in strongly driven CDW

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Ultrashort laser pulses are a convenient tool for coherent excitation of phonons and collective electronic-lattice modes in CDW systems. Due to the availability of strong laser pulses the phonons can be driven far from equilibrium, exposing nonlinear effects. These effects are often difficult to track by the standard pump-probe optical spectroscopy due to the presence of large first-order signals. Trying to overcome this problem we devised a differential multi-pump-pulse technique[1] that enables us to detect small differences between highly excited trajectories of a system.
Using this technique we were able to investigate a hitherto unexplored aspect of the CDW amplitude mode behavior under strongly driven nonequilibrium conditions in the ordered phase below the CDW photoinduced destruction threshold. We first use a strong pump pulse (P_1) to excite large-amplitude coherent oscillations of the amplitude mode (AM) and other phonon modes and then a standard pump-probe (P_2-p) pulse sequence to interrogate the system. By means of this approach we are able to directly investigate the anharmonicity of the effective AM potential, as well as detect the anharmonic coupling of the collective bosonic mode (the AM) of the CDW to other lattice modes in 1T-TaS_2 and $TbTe_3$.[2]
Apart from the coherent response we use the same technique to study the incoherent recombination of topological defects after a quench of the system by an intense laser pulse. We follow the evolution of the system on a wide range of timescales. Following initial coherent amplitude mode coherent modulation on a few picosecond timescale, that has been already discussed in detail recently,[2] the evolution of the AM is found to follow a slower recovery due to incoherent annihilation of the topological defects on a timescale up to ~30 ps and is fairly consistent with the thermal diffusion on longer timescales.

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Current-carrying superconducting channels: bifurcation phenomena

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The properties of the resistive state of the narrow superconducting channels of different lengths are investigated by direct numerical integration of the time-dependent Ginzburg-Landau equations (TDGLEs) [1]. We have demonstrated that singularities of the current-voltage characteristics (CVCs) correspond to a number of different bifurcation points of the TDGLEs. We have revealed the types of the bifurcations which induced the singularities in the CVCs.

The CVCs of the channels of all investigated lengths possess some universal features. The voltage appearance in the system corresponds to the saddle-node homoclinic bifurcation. It leads to the formation of the limit cycle with a diverging period when $j \rightarrow j_c$, where j_c is the critical current. In addition, it induces the formation of the phase slip center (PSC) in the middle of the channel in agreement with the experimental results [2]. The voltage in the vicinity of this bifurcation is proportional to the square root of $j-j_c$ [3]. We have also analytically estimated the period of oscillations in this region of currents.

The second singularity corresponds to the period-doubling bifurcation. In that case two adjacent PSCs are shifted in opposite directions with respect to the center of the wire in striking similarity with the experimental results [2]. As a result of this bifurcation, a new frequency appears in the spectrum of the electromagnetic radiation generated by the current. This frequency is equal exactly to the half of the frequency before the bifurcation point.

The next bifurcation is the destruction of the limit cycle. It does not generate any clear singularity on the CVC for longer wires. However, it causes the voltage discontinuity for the shorter ones. It is also accompanied by the appearance of the third PSC in the center of the channel. However, in the case of the longer wires the third PSC appears inside the range of currents corresponding to the chaotic behavior of the system or after destruction of the chaos. The appearance of the new extra PSC is also confirmed by the experimental results [2].

In addition we have found a few ranges of the current where other limit cycles coexist with the main periodic solution. Therefore, at the same value of the current we have observed different stable periodic solutions with their own attracting phase spaces.

References
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Light induced switching to a hidden state in thin-film 1T-TaS_2

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It was shown that at low temperatures (<100 K) light induced phase transition from commensurate charge density wave (CCDW) state to another, hidden, metastable state in 1T-TaS_2 occurs. Switching was observed in collective mode spectrum measured by means of the coherent phonon spectroscopy.
The possibilities of photoinduced switching in thin-film 1T-TaS_2 were studied on flakes of thicknesses from 10 nm to 100 nm. Traces of switching are detected in collective modes spectra only for samples thicker than 80 nm while for thinner samples no changes were observed. Instead of the distinctive CCDW-state mode at 2.45 THz we observed a mode at lower frequency even in the virgin state of thinner samples.
In contrast to the bulk crystals, thin flakes show drop in the DC resistivity when switched. Such behavior is observed already for 15-nm films, that do not show any changes in phonon spectra. Switching occurs after a single 50-fs pulse.
Flakes of any thickness return to the initial CCDW state after warming to 100 K.

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Programme: Nonequilibrium phenomena in complex matter: new observations and new theories, 2012

Monday, Dec. 17th	
9:25:00	Registration
9:40:00	**Opening** (15')
9:55:00	**Relaxation in superconductors I** DL: Bovensiepen (15’)
10:10:00	Giannetti (40')
10:50:00	Kabanov (40')
11:30:00	Pogrebna (30')
12:00:00	Free activities
18:30:00	**Relaxation in superconductors II** DL: Giannetti (15’)
18:45:00	Bovensiepen (40')
19:25:00	Gadermaier (40’)
20:05:00	Break
20:15:00	Kusar (30')
20:45:00	Peli (30')

Tuesday, Dec. 18th	
9:00:00	**Quantum relaxation** DL: Prelovsek (15')
9:15:00	Prosen (40’)
9:55:00	Vidmar (40’)
10:35:00	Break
10:45:00	Golež (30')
11:15:00	Lenarčič (30’)
11:45:00	Free activities
18:30:00	**Phase transition and order parameter dynamics I** DL: Bonča (15')
18:45:00	Fausti (40')
19:25:00	Mihailovic (40')
20:05:00	Break
20:15:00	Madan (30’)
20:45:00	Stojčevska (30')

Wednesday, Dec. 19th	
9:00:00	**Phase transition and order parameter dynamics II** DL: Mihailovic (15')
9:15:00	Rettig (40')
9:55:00	Mertelj(40’)
10:35:00	Break
10:45:00	Baranov (30')
11:15:00	Vaskivskyi (30’)
11:45:00	**Closing** (15')