TT 71: Ultrafast Phenomena

Time: Thursday 9:30–11:15 Location: HSZ/0103

TT 71.1 Thu 9:30 HSZ/0103

Ultrafast control of competing FM and CDW orders in $SmNiC_2$ — •Chandra V Kotyada[1], Bhageerath Swaraj[1], Amon. P Lanz[1], Priyanka Yogi[1], Amir.A Haghighirad[2], Sofia. M Souliou[2], Matthieu Le Tacon[2], and Jure Demsar[1] — [1]JGU Mainz — [2]KIT

$SmNiC_2$ belongs to the rare-earth (R) transition-metal carbide family $RNiC_2$, a unique class of intermetallic compounds that crystallize in the non-centrosymmetric orthorhombic $CeNiC_2$-type structure and exhibit pronounced quasi-one-dimensional characteristics. Diffraction studies on $SmNiC_2$ reveal an incommensurate charge-density-wave (CDW) modulation with wavevector $(0.5,\ 0.5+\delta,\ 0)$ below $T_{\mathrm{CDW}} \approx 148$ K. Upon lowering the temperature, a first-order phase transition into a ferromagnetic (FM) state occurs at $T_{\mathrm{M}} \approx 18$ K, accompanied by a complete suppression of the CDW order.

Here, we apply optical pump-probe spectroscopy to investigate collective response in both symmetry-broken phases. Using CDW amplitude mode as a fingerprint of the CDW order, we then use the quench-pump-probe approach to track the dynamics of the photoinduced FM-to-CDW phase transition. We show that the buildup of the CDW after quenching the FM order is limited by the demagnetization time of 10 ps.

TT 71.2 Thu 9:45 HSZ/0103

Experimental signature of transient symmetry breaking in a cavity superconductor — •Siyu Duan[1,2], Jingbo Wu[1], Xiaoqing Jia[1], Huabing Wang[1], Ilya M. Eremin[3], Götz S. Uhrig[2], Biaobing Jin[1], and Zhe Wang[2] — [1]Research Institute of Superconductor Electronics (RISE) & Key Laboratory of Optoelectronic Devices and Systems with Extreme Performances of MOE, School of Electronic Science and Engineering, Nanjing University, Nanjing 210023, China — [2]Department of Physics, TU Dortmund University, 44227 Dortmund, Germany — [3]Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44801 Bochum, Germany

Transient states of matter far from equilibrium may exhibit physical properties beyond those allowed by the equilibrium-state crystalline symmetries. We explore ultrafast and direct electronic excitations of transient states in a cavity superconductor by using time-resolved terahertz-pump terahertz-probe spectroscopy. Our results show that the strong terahertz field can transiently modify the symmetries of the electronic subsystems via the injection of a transient supercurrent, leading to high-order nonlinear dynamical responses that are not compatible with the equilibrium-state symmetries, which evidences for transient symmetry breaking on the picosecond time scale. Our study also finds that the strong coupling of the superconductor to the designed microcavities enables the sensitive detection of the nonlinear responses associated to the transient symmetry breaking.

TT 71.3 Thu 10:00 HSZ/0103

Giant Dynamical Paramagnetism in the driven fluctuating superconductors — •Marios Michael[1], Duilio De Santis[2], Eugene Demler[2], and Patrick Lee[3] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38 01187 Dresden Germany — [2]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland — [3]Department of Physics, MIT, 77 Massachusetts Avenue, 02139 Cambridge, MA, USA

In the past decade, photo-induced superconducting-like behaviors have been reported in a number of materials driven by intense pump fields. Of particular interest is the high-Tc cuprate Y Ba2 Cu2 O(6+x) (YBCO), where such effect has been reported up to the so-called pseudogap temperature T* ~ 300-400 K. In a recent tour-de-force experiment, a transient magnetic field which is proportional to and in the same direction of an applied field has been observed outside the sample, suggestive of flux exclusion due to the Meissner effect. In this talk I will present a different explanation of these experiments, based on the model of preformed Cooper pairs in the pseudogap phase. I will demonstrate that a combination of external magnetic field and strong terahertz drive used in experiments by Fava et al. Nature 2024, results in a novel Floquet instability in the model. This instability results in currents at the edges of the bilayer formed by defects or grain boundaries, with the current flowing in the opposite direction of the equilibrium screening current, producing a giant paramagnetic magnetization in the same direction as the applied field. We show how this scenario can fit most of the available data.

TT 71.4 Thu 10:15 HSZ/0103

Two-dimensional coherent spectroscopy of multiband superconductor — •Silvia Neri — Max Planck for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart

An intriguing question in superconductivity is how to efficiently detect signatures of the collective excitations associated with the superconducting order parameter. The features associated with collective modes can indeed provide insight into various aspects of the superconducting state. We address this question by theoretically modeling a 2D THz pump probe spectroscopy experiment for a two-band superconductor. Two-dimensional spectroscopy is a powerful method with wide applications, from rovibronic excitations in biomolecular systems to magnons in antiferromagnets, and it has been recently applied to superconducting collective modes [1]. To numerically compute the dynamics of our model, we adopt a pseudospin description and choose realistic parameters for both the pulses and the superconducting state, reflective of MgB_2. The numerically evaluated 2D spectrum shows, in addition to the first- and third-harmonic signals, the presence of sidebands associated with the Leggett-mode frequency of the system. We then derive an analytical expression for the nonlinear current to identify the process responsible for this numerical finding. Our results suggest that applying 2D techniques to superconductors offers a promising route for exploring their collective dynamics.

[1] A. Dutta et al., J. Phys.: Condens. Matter 37, 203002 (2025)

TT 71.5 Thu 10:30 HSZ/0103

Ultrafast coherent dynamics in open quantum systems: Auger-Meitner decay and controlled stearing of interactions in SF_6 — •Sina Shokri[1], Patrick Rupprecht[2,3], Thomas Pfeifer[3], and Maurits W. Haverkort[1] — [1]ITP, Universität Heidelberg, 69120 Heidelberg, Germany — [2]UC Berkeley Dept. of Chemistry and LBNL Chemical Sciences Division, Berkeley, CA 94720, USA — [3]MPI für Kernphysik, 69117 Heidelberg, Germany

Ultrafast x-ray pump-probe spectroscopy provides a powerful tool to study and steer quantum materials on their intrinsic time and length scales. In correlated molecules and solids, theoretical understanding remains challenging due to the interplay of competing interactions. In small molecules, quantitative modeling of the coupled electronic and vibrational dynamics is possible.

The coupling to many continuous degrees of freedom can lead to rapid loss of coherence. This results in long-time dynamics that are determined by classical equations of motion. Descriptions on the intermediate time scale that show how one goes from coherent quantum dynamics to classical equations of motion are highly non-trivial.

In this work, we employ nonlinear response theory to predict the transient dynamics and Auger-Meitner-induced lifetimes of electronic excitations in x-ray absorption spectroscopy of SF_6, following excitation by an intense infrared laser field. Based on first-principles density functional theory calculations, we show how the intense laser field can modify the Auger-Meitner decay channels and, with that, the coherent lifetimes of excitations.

TT 71.6 Thu 10:45 HSZ/0103

Charged three-particle bound states at the L_{23}-edge in $SrTiO_3$ — •Sarah L. Görlitz[1], Widad Louafi[2], Sina Shokri[1], Martin Brass[1], Marc Merstorf[1], Jonas Hoecht[1], Kevin Ackermann[1], and Maurits W. Haverkort[1] — [1]Institut for Theoretical Physics, Heidelberg University, 69120 Heidelberg — [2]Laboratory of Theoretical Physics, Faculty of Exact Sciences, University of Bejaia, 06000 Bejaia, Algeria

Few-body bound states underpin phenomena across physics-from hadronic three-body systems to excitons and trions in semiconductors-yet their formation and decay remain poorly understood.

We report analogous physics in bulk $SrTiO_3$ in Ti 2p $\rightarrow$ 3d core excitations. The XAS spectrum shows seven sharp peaks, understood from atomic physics as a Ti 2p hole interacting with a local Ti 3d electron in a cubic point group. Fluorescence and Auger-Meitner decay calculations explain the linewidth of the first four peaks but predict much sharper excitations than observed for the last two. Because these highest excited states are degenerate with the continuum, their broadening may arise if they are continuum excitations or resonances rather than bound excitons. To test this, we performed ab initio GW+BSE calculations, which agree with parameter-based atomic multiplet theory and reveal seven infinitely sharp excitons. In contrast, an Anderson-impurity model yields a finite linewidth for the highest excitons. We show that these are three-particle bound states composed of two locally bound Ti 3d electrons, one Ti 2p hole, and an additional free hole in the O 2p valence band.

TT 71.7 Thu 11:00 HSZ/0103

Study of light-induced band inversion in SnTe via Ab Initio Calculations — •Asier Ribechini[1], Álvaro R. Puente-Uriona[1], and Julen Ibañez-Azpiroz[1,2,3] — [1]Centro de Física de Materiales (CSIC-EHU), 20018, Donostia, Spain — [2]IKERBASQUE, Basque Foundation for Science, 48009 Bilbao, Spain — [3]Donostia International Physics Center (DIPC), 20018 Donostia, Spain

Modern technology enables precise control of matter through light-matter interactions. Periodically driven quantum systems, described by Floquet theory, offer a powerful framework for predicting light-induced phenomena, including topological phases and quantum phase transitions [1], though their experimental detection remains challenging.

We evaluate the method of our group [2] for computing the Floquet quasienergy spectrum of SnTe using the velocity gauge in a truncated Hilbert space to build the ab initio time-periodic Hamiltonian. From it, we construct the effective Floquet Hamiltonian and obtain the quasienergy spectrum. Our results reveal a light-induced gap opening between conduction and valence band Floquet replicas near resonant driving, as well as a band-character inversion indicative of a possible light-induced topological phase transition. We further compute the corresponding topological invariants to characterize this transition and discuss our findings in relation to recent time-resolved ARPES evidence for light-induced topological behavior[3].

[1] J. I. Inoue et al., Phys. Rev. Lett. 105, 017401 (2010)
[2] Á. R. Puente-Uriona et al., Phys Rev. B 110, 125203 (2024)
[3] F. Chassot et al., arXiv:2502.11967v1