TT 85: Superconductivity: Higgs Modes in Condensed Matter and Quantum Gases (jointly with DY, MA, O)

Time: Thursday 9:30–11:15 Location: H 2053

Invited Talk TT 85.1 Thu 9:30 H 2053

A Brisk Walk through Phase Transitions in Time: Oscillating Order and the Dynamics of Topological Defects — •Dragan Mihailovic — Jozef Stefan Institute, Ljubljana, Slovenia

New techniques in time-resolved optical spectroscopy allow us to investigate phase transitions under controlled, yet highly non-ergodic conditions. The measurement of the temporal evolution of not only single particle and collective excitations, but also topological excitations through the transition lead to a new insight into the emergence of functional properties under non-equilibrium conditions. Experiments on well-known rare earth and transition metal chalcogenides which I will discuss reveal some unexpected phenomena. For example, femtosecond coherent oscillations of the order parameter and the subsequent coherent creation and annihilation of topological defects leads to a transient domain structure which decays through the emission of dispersive Higgs-like amplitude waves [1,2]. Remarkably, if the conditions are right (defined by the material), the topological defects may form an ordered metastable state, which is topologically protected, opening a route to the creation of hidden states [3]. Such switching between states with different charge order occurs at unprecedented speeds and is of potential interest for ultrafast non-volatile memory technology, with either optical or electrical control.

[1] R. Yusupov et al., Nature Phys. **6**, 681 (2010)
[2] D. Mihailovic et al., J. Phys.: Condens. Matter **25**, 404206 (2013)
[3] L. Stojchevska et al., Science **344**, 177 (2014)

TT 85.2 Thu 10:00 H 2053

Nonadiabatic dynamics and coherent control of nonequilibrium superconductors — •Andreas Schnyder[1], Holger Krull[2], Dirk Manske[1], and Götz Uhrig[2] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany — [2]Lehrstuhl für Theoretische Physik I, Technische Univerität Dortmund, Otto-Hahn Straße 4, 44221 Dortmund, Germany

Inspired by recent THz pump-THz probe experiments on NbN films [1], we theoretically study the pump-probe response of nonequilibrium superconductors coupled to optical phonons. For ultrashort pump pulses a nonadiabatic regime emerges, which is characterized by amplitude oscillations of the superconducting gap [2] and by the generation of coherent phonons [3]. Using density-matrix theory as well as analytical methods, we compute the pump-probe response of the superconductor in the nonadiabatic regime and determine the signatures of the order parameter and of the phonon oscillations in the pump-probe conductivity. We find that the nonadiabatic dynamics of the superconductor reflects itself in oscillations of the pump-probe response as a function of delay time between pump and probe pulses [4]. We also consider two-band superconductors and study the interplay of the two amplitude oscillations of the two gaps.

[1] R. Matsunaga et al., PRL 111, 057002 (2013)
[2] E. A. Yuzbashyan et al., PRL 96, 097005 (2006)
[3] A. P. Schnyder, D. Manske, and A. Avella, PRB 84, 214513 (2011)
[4] H. Krull, D. Manske, G. S. Uhrig, and A. P. Schnyder, PRB 90, 014515 (2014)

TT 85.3 Thu 10:15 H 2053

THz Investigations of the Higgs Amplitude Mode in Superconducting Thin Films — •Martin Dressel[1], Uwe S. Pracht[1], Daniel Sherman[2], Aviad Frydman[2], Boris Gorshunov[1,3,4], Pratap Raychaudhuri[5], Nandini Trivedi[6], and Assa Auerbach[7] — [1]1. Phys. Inst., Universtät Stuttgart — [2]Phys. Dept., Bar Ilan University, Ramat Gan, Israel — [3]General Physics Inst, RUS, Moscow, Russia — [4]Moscow Inst. Phys. and Techn., Dolgoprudny, Russia — [5]Tata Inst. Fund. Res., Mumbai, India — [6]Phys. Dept., Ohio State University, Columbus, U.S.A. — [7]Phys. Dept., Technion, Haifa, Israel

We have measured thin superconducting films of various degrees of disorder by THz spectroscopy in order to investigate the optical conductivity at low temperatures. While the properties of weakly disordered superconductors, such as NbN or InO, can be well described by the BCS theory, significant deviations are observed as disorder increases towards the superconductor-insulator transition. On both sides of the transition, tunneling spectroscopy determines a finite pairing gap 2Δ. In contrast, the threshold frequency for the dynamical conductivity, which in BCS theory is associated with the gap, vanishes critically toward the superconductor insulator transition. Here we can identify an excess optical spectral weight below 2Δ as the first unambiguous evidence of a well-defined Higgs amplitude mode observed in a superconductor.

TT 85.4 Thu 10:30 H 2053

Magnon-Interactions and Higgs Mode in 2D Quantum Antiferromagnets from Raman Scattering — •Simon Weidinger and Wilhelm Zwerger — Physik-Department, Technische Universität München, 85747 Garching, Deutschland

We present a theory for Raman scattering on 2D quantum antiferromagnets. The microscopic Fleury-Loudon Hamiltonian is expressed in terms of an effective O(3)- model. Well within the Neel ordered phase, the Raman spectrum contains both a two-magnon and two-Higgs contribution which are calculated diagrammatically. The spectrum is dominated by a broad two-magnon peak but it is hardly affected by the Higgs-mode of the 2D Neel ordered state. This is a consequence of the momentum dependence of the Raman vertex in the relevant B_{1g} symmetry. The resulting nontrivial spectrum, which has the antiferromagnetic exchange coupling as a single parameter, is in very good agreement with experiments on undoped cuprates.

TT 85.5 Thu 10:45 H 2053

Higgs Mechanism in Three-Dimensional Topological Superconductors and Anomalous Hall Effect in Zero Magnetic Field — •Flavio Nogueira and Ilya Eremin — Theoretische Physik III, Ruhr-Universität Bochum

We discuss the peculiar nature of Higgs mechanism in an effective field theory for three-dimensional topological superconductors. The effective theory features two order parameters associated to the two chiral fermion species in the system. The resulting electrodynamics of such a topological superconductor exhibits a topological magnetoelectric effect with an axion field given by the phase difference of the order parameters. As consequence, the London regime is highly non-linear and anomalous Hall effect in the absence of an external magnetic field occurs. In this anomalous Hall effect the generated current transverse to an applied electric field changes sign with the temperature. We also discuss the scaling behavior of the penetration depth near the transition temperature, which is also shown to exhibit a scaling exponent that is crucially influenced by the axion term, varying continuously as function of the average phase difference.

TT 85.6 Thu 11:00 H 2053

Nonequlibrium dynamics of s- and d-wave superconductors — •Holger Krull[2], Götz S. Uhrig[1], Andreas P. Schnyder[2], and Dirk Manske[2] — [1]TU Dortmund, Dortmund, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany

We study the nonequilibrium dynamics of s- and d-wave superconductors, which are induced by a ultra-short pump pulse or a quench, respectively. The dynamics is studied by use of the density matrix formalism as well as by analytical calculation. We focus on the temporal evolution of the order parameter. For s-wave superconductors the nonadiabatic evolution of the order parameter is well established in the collisionless regime. It shows a $1/\sqrt{t}$ decaying oscillation, which can be interpreted as Higgs mode in a superconductor. Here, we consider the evolution of a d-wave order parameter and compare it with the s-wave case.