TT 14: Superconductivity: (General) Theory

Time: Monday 15:00–18:00 Location: H19

TT 14.1 Mon 15:00 H19

SCDFT, review and applications — •Antonio Sanna[1], Jose Flores-Livas[2], Arkady Daviydov[1], Andy Linscheid[3], and E.K.U. Gross[1] — [1]Max Planck Institute of Microstructure Physics, Halle(Saale), Germany — [2]Department of Physics, Universität Basel, Switzerland — [3]Department of Physics, University of Florida, USA

We review the theoretical framework of Density Functional Theory for SuperConductors (SCDFT) and present recent applications and extensions as the calculation of the superconducting order parameter in real space[1]. SCDFT unlike conventional McMillan-Eliashberg theory, leads to reliable critical temperatures in a completely parameter free fashion. We discuss a formal connection between these approaches, the relative advantages and disadvantages, and how Eliashberg theory is used as ground for functional construction and to help extracting all the relevant physical properties from the solution of the SCDFT Kohn-Sham equations.

[1] A. Linscheid, A. Sanna, A. Floris, E.K.U. Gross, PRL **115**, 097002 (2015).

TT 14.2 Mon 15:15 H19

A novel approach in Eliashberg theory of superconductivity with ab-initio static and dynamic Coulomb interaction applicable for real materials — •Arkadiy Davydov, Antonio Sanna, Sangeeta Sharma, John Kay Dewhurst, and E. K. U. Gross — Max Planck Institute of Microstructure Physics, Halle (Saale), Germany

In standard Eliashberg methods the Coulomb interaction is usually restricted to the use of a single phenomenological parameter μ^* adjusted to give the right superconducting critical temperature (T_c). In this work we present a parameter-free Eliashberg approach, in which we treat the screened Coulomb interaction within the random phase approximation (RPA) in its static and full dynamic limit. The full energy range of the Coulomb interaction is taken into account, which becomes computationally affordable with the introduction of a suitable isotropic approximation. We have tested the method on a set of conventional superconductors. We will discuss the reliability of the predicted T_c both by using a static and a dynamic Coulomb interaction.

TT 14.3 Mon 15:30 H19

The role of Coulomb interaction for fluctuation corrections to the BCS theory of superconductivity — •Sonja Fischer and Jörg Schmalian — Institut für Theorie der Kondensierten Materie, KIT, Germany

We study fluctuation corrections to the gap equation of the BCS theory of superconductivity, taking into account the role of long ranged Coulomb interactions that is known to transfer superconducting phase fluctuations to the electron plasma frequency. Particular attention is paid to the previously discussed [1] cancellation of amplitude and phase fluctuation corrections in neutral superconductors.

[1] S. Kos A. J. Millis, and A. I. Larkin, PRB **70**, 214531 (2004)

TT 14.4 Mon 15:45 H19

Utilizing atomic force spectroscopy to test an alternative electrodynamic theory of superconductors — •Angelo Peronio and Franz J. Giessibl — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany

In the traditional theoretical description of superconductivity, a static electric field cannot penetrate a superconductor, since screening occurs like in a normal metal. This can be traced back to the fact that the London equations [1], the phenomenological equations describing the electrodynamics of superconductors, are derived within the Coulomb gauge. J. E. Hirsch proposes to use the Lorenz gauge instead [2], deriving a consistent solution where the electric field penetrates the superconductor up to the London penetration depth.

We report on initial experiments to test Hirsch's hypothesis, performed with a combined STM/AFM qPlus sensor equipped with a superconducting tip. If a superconductor screens electric fields differently from a normal metal, the electrostatic interaction between tip and sample should change when the tip becomes superconductive.

[1] F. London, Superfluids Vol. I, Wiley (1950)
[2] J. E. Hirsch, Physica C **508**, 21 (2015)

TT 14.5 Mon 16:00 H19

First-principles approach for superconducting slabs and heterostructures — •Gabor Csire — Wigner Research Centre for Physics, Budapest, Hungary

We present a fully ab-initio method to calculate the transition temperature for superconducting slabs and heterostuctures.

In the case of thin superconductor layers the electron-phonon interaction may change significantly. Therefore we calculate the layer dependent phonon spectrum to determine the layer dependence of the electron-phonon coupling for such systems. The phonon spectrum is than coupled to the Kohn-Sham-Bogoliubov-de Gennes equation via the McMillan-Hopfield parameter, and it is solved self-consistently.

The theory is applied to niobium slabs and niobium-gold heterostructures. Based on these calculations we investigate both the dependence of the superconducting transition temperature on the thickness of superconducting slabs and the inverse proximity effect observed in thin superconducting heterostructures.

TT 14.6 Mon 16:15 H19

Multiple scattering theory for superconducting heterostructures — •Balazs Ujfalussy — Wigner Research Centre for Physics, Budapest, Hungary

We generalize the screened Korringa-Kohn-Rostoker method for solving the corresponding Kohn-Sham-Bogoliubov-de Gennes equations for surfaces and interfaces.

As an application of the theory, we study the quasiparticle spectrum of Au overlayers on a Nb(100) host. We find that within the superconducting gap region, the quasiparticle spectrum consists of Andreev bound states with a dispersion which is closely connected to the underlying electronic structure of the overlayer. We also find that the spectrum has a strongly k-dependent induced gap. The properties of the gap are discussed in relation to the thickness of the overlayer, and it is shown that certain states do not participate in the Andreev scattering process.

From the thickness dependence of the gap size we calculate the superconducting critical temperature of Au/Nb(100) heterostructures what we compare with with experiments. Moreover, predictions are made for similar heterostructures of other compounds.

15 min. break

Invited Talk TT 14.7 Mon 16:45 H19

Spectroscopic signatures of collective modes in superconductors — •Lara Benfatto — ISC-CNR and Department of Physics, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185, Rome, Italy

The technological progresses made in the last few years in the spectroscopic techniques require a critical revision of our understanding of the interactions of the light with the matter. In the case of superconducting systems light can in principle couple both to fermionic single-particle excitations and to bosonic superconducting collective modes, i.e. amplitude (Higgs) or phase fluctuations of the superconducting order parameter. At low temperature single-particle excitations are suppressed at energies below twice the gap value, leaving a window to the potential spectroscopic detection of the collective excitations in disordered superconductors. In this talk I will review some recent theoretical progresses in our understanding of the role of superconducting modes in linear and non-linear optical spectroscopy.

TT 14.8 Mon 17:15 H19

The Higgs-mode in charged superconductors without particle-hole symmetry — •Matthias Hecker — KIT, Karlsruhe

In a charged BCS superconductor there are two collective modes, namely the amplitude or Higgs mode and the plasmon mode reflecting the fact that due to long range Coulomb interactions phase fluctuations are shifted to the plasmon energy. Usually, the experimental determination of the Higgs mode is challenging as its energy sits right at the edge of the quasi-particle continuum. Using a field integral approach we investigate the possibility of detecting the Higgs mode by measuring density-density correlations. Without the assumption of particle-hole symmetry there is a finite coupling between the two excitation modes which is usually suppressed by the small factor $\frac{\Delta_0}{E_F}$.

However, in doped $SrTiO_3$ the latter ratio is of the order $\frac{\Delta_0}{E_F} \approx 10^{-1}$. We explore whether this coupling is sufficient to exploit the experimentally easy access to charge excitations in order to detect a Higgs mode signal.

TT 14.9 Mon 17:30 H19

Induced Superconductivity in the Hubbard model — •Nikolaj Bittner[1], Takami Tohyama[2], and Dirk Manske[1] — [1]Max–Planck–Institut für Festkörperforschung, D–70569 Stuttgart, Germany — [2]Department of Applied Physics, Tokyo University of Science, Tokyo 125–8585, Japan

New insights into the properties of the strongly correlated electron system can be gained by studying it in nonequilibrium. For instance, under the action of a strong laser pulse the system can undergo a phase transition and even the induced superconductivity may occur [1,2].

In this contribution we present a theoretical study of the nonequilibrium dynamics in the one-dimensional extended Hubbard model. Particular emphasis is on the possibility to induce superconductivity in this system driven out of equilibrium. Within the framework of the time-dependent Lanczos algorithm we investigate the time evolution of our model for two different nonequilibrium scenarios, which occur by (i) an interaction quench and by (ii) action of a light pulse. For both cases we calculate the time dependent optical conductivity and the superconducting correlation functions. In particular, we observe from our calculations appearance of a transient Meissner effect, which is a fingerprint of the induced superconductivity. This is in agreement with the obtained correlation functions and opens a new way to induce superconductivity in an experiment.

[1] S. Kaiser et al., PRB **89**, 184516 (2014)
[2] D. Fausti et al., Science **331**, 189 (2011)

TT 14.10 Mon 17:45 H19

Unconventional superconductivity and interaction induced Fermi surface reconstruction in the two-dimensional Edwards model — •Dai-Ning Cho[1], Jeroen van den Brink[1], Holger Fehske[2], Klaus W. Becker[3], and Steffen Sykora[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, D-17487 Greifswald, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany

We study the competition between unconventional superconducting pairing and charge density wave (CDW) formation for the two-dimensional Edwards Hamiltonian at half filling, a very general two-dimensional transport model in which fermionic charge carriers couple to a correlated background medium. Using the projective renormalization method we find that a strong renormalization of the original fermionic band causes a new hole-like Fermi surface to emerge nearby the center of the Brillouin zone, before it eventually gives rise to the formation of a charge density wave. On the new, disconnected parts of the Fermi surface superconductivity is induced with a sign-changing order parameter. We discuss these findings in the light of recent experiments on iron-based oxypnictide superconductors.