TT 50: Superconductivity: (General) Theory

Time: Friday 9:30–12:15 Location: H 3010

TT 50.1 Fri 9:30 H 3010

State of the art and new developments in superconducting density functional theory — •Antonio Sanna and Eberhard K. U. Gross — Max Planck Institute Halle

We will present the theoretical framework of superconducting density functional theory (SCDFT), a fully parameter-free approach to superconductivity. The advantages and disadvantages of this method will be presented, as well as more recent extensions and perspectives. First I will present the connection of the theory to Eliashberg's method, and discuss some exact limits. Then I will report on how this connection is used to improve the existing phononic functionals. Applications to several materials will be shown. The purely electronic part of the coupling in SCDFT will also be analyzed properties and limits of the static random phase approximation will be discussed. Finally I will report on recent extensions which include dynamical effects in the screened interaction.

TT 50.2 Fri 9:45 H 3010

Reliability study of the Migdal-Eliashberg theory for strong coupling superconductors — Johannes Bauer[1], Jong E Han[1,2], and •Olle Gunnarsson[1] — [1]Max-Planck Institute for Solid State Research, Heisenbergstr.1, 70569 Stuttgart, Germany — [2]Department of Physics, SUNY at Buffalo, Buffalo, New York 14260, USA

The Migdal-Eliashberg (ME) theory for strong electron-phonon coupling and retardation effects of the Morel-Anderson type form the basis for the quantitative understanding of conventional superconductors. In recent years, the validity of the ME theory for values of the electron-phonon coupling strength $\lambda > 1$ has been questioned by model studies. By distinguishing bare and effective parameters, and by comparing the ME theory with the dynamical mean field theory (DMFT), we clarify the range of applicability of the ME theory. Specifically, we show that ME theory is very accurate as long as the product of effective parameters, $\lambda\omega_{\rm ph}/D$, where $\omega_{\rm ph}$ is an appropriate phonon scale and D an electronic scale, is small enough [1]. The effectiveness of retardation effects for the competing Coulomb interaction is usually considered based on the lowest order diagram in the perturbation theory. We analyze these effects to higher order and find modifications to the usual result for the Coulomb pseudo-potential μ^*. Retardation effects are weakened due to a reduced effective bandwidth appearing in the expressions. Comparsion with the non-perturbative DMFT corroborates our findings [2].

[1] J Bauer, J E Han, and O Gunnarsson, Phys. Rev. B. 84, 184531 (2011).
[2] J Bauer, J E Han, and O Gunnarsson, in preparation (2011).

TT 50.3 Fri 10:00 H 3010

A Green function approach to superconductivity in nanofilms — •Rolando Saniz, Bart Partoens, and François Peeters — Universiteit Antwerpen, Antwerpen, Belgium

We reformulate the BCS theory of superconductivity in the Green function framework in such a way that it is readily applied to inhomogeneous systems. We study here nanofilms and go beyond previous models in that we take into account the effects of confinement on electron-phonon coupling, as well as on the electron and phonon fields. We show that, contrary to what has been advanced in recent years, the increases of the density of states as the film thickness increases will tend to suppress the critical temperature, and not enhance it. Instead, it is the increase of the phonon modes with increasing film thickness that can lead to increases of the critical temperature above the bulk value. Further, we show that the multigap character of superconductivity in nanofilms will result in general in a condensate composed of subcondensates with different coherence lengths. This is in analogy with the very recent suggestion that different coherence lengths exist in two-gap superconductors such as MgB_2.

TT 50.4 Fri 10:15 H 3010

Phase Diagram of Electron Systems near the Superconductor-Insulator Transition — •Thomas Nattermann[1], Valery Pokrovsky[2,3], and Gianmaria Falco[1] — [1]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany — [2]Department of Physics, Texas A&M University, College Station, Texas 77843-424 — [3]Landau Institute for Theoretical Physics, Chernogolovka, Moscow District, 142432, Russia

The zero temperature phase diagram of Cooper pairs exposed to disorder and magnetic field is determined theoretically from a variational approach. Four distinct phases are found: a Bose and a Fermi insulating, a metallic and a superconducting phase, respectively. The results explain the giant negative magneto-resistance found experimentally in In-O, TiN, Bi and high-T_c materials.

TT 50.5 Fri 10:30 H 3010

Is the $t-J$ model sufficient to describe magnetic excitations in cuprates? — •Wei Chen[1] and Oleg Sushkov[2] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]University of New South Wales, Sydney 2052, Australia

We adopt theself-consistent Born approximation to study the renormalization of magnetic excitations in a two-dimensional antiferromagnetic state due to finite hole doping. We found that the incoherent motion of holes strongly influences high energy magnons, which causes a significant reduction of magnon bandwidth at large doping. However, by comparing with recent resonant inelastic x-ray scattering data, we conclude that the strongly correlated holes, as described by the $t-J$ model, are not sufficient to determine the magnetic excitations in underdoped cuprates.

15 min. break.

TT 50.6 Fri 11:00 H 3010

Two-particle self-consistent approach to anisotropic superconductivity — •Junya Otsuki — Department of Physics, Tohoku University, Sendai, Japan — Theoretische Physik III, Zentrum für Elektronische Korrelationen und Magnetismus, Universität Augsburg

A non-perturbative approach to anisotropic superconductivity is developed based on the idea of the two-particle self-consistent (TPSC) theory by Vilk and Tremblay [1]. An exact sum-rule which the momentum-dependent pairing susceptibility satisfies is derived. Effective pairing interactions between quasiparticles are determined so that an approximate susceptibility should fulfill this sum-rule, in which fluctuations belonging to different symmetries mix at finite momentum. The mixing leads to a suppression of the $d_{x^2-y^2}$ pairing close to the half-filling, resulting in a maximum of T_c away from half-filling.

[1] Y. M. Vilk and A.-M. Tremblay, J. Phys. I (Paris) **7** (1997) 1309.

TT 50.7 Fri 11:15 H 3010

Fulde-Ferrel-Larkin-Ovchinnikov phase separation in a one-dimensional superconducting lattice of strongly coupled fermions — •Vivian França and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs Universität, Freiburg, Germany

The exotic coexistence of superconductivity and magnetism, first investigated by Fulde-Ferrell and Larkin-Ovchinnikov (FFLO), is predicted to show a spontaneous breaking of spatial symmetry. In spin-imbalanced fermionic systems, such inhomogeneous superfluidity would take place via a microscale phase separation, with alternating finite-momentum pairs and normal regions, the latter being composed by the excess species. After almost fifty years since the FFLO-phase was predicted, the microscale phase separation has not been observed.

We deduce an expression for the critical polarization below which the FFLO-state emerges in a one-dimensional lattice with spin-imbalanced populations and show that its ground-state is indeed microscale phase separated. For strongly interacting systems, we find that the microscale structure can be observed directly in the density profiles. Our results suggest that clear signatures of exotic superfluidity are accessible for state-of-the-art experiments with single-site resolution, as already achieved for bosons.

TT 50.8 Fri 11:30 H 3010

Competing many-body instabilities and unconventional superconductivity in graphene — •Christian Platt[1], Maximilian Kiesel[1], Dmitry Abanin[2], Werner Hanke[1], and Ronny Thomale[3] — [1]Institute for Theoretical Physics, University of Wuerzburg — [2]Department of Physics, Harvard University — [3]Department of Physics, Stanford University

The band structure of graphene exhibits van Hove singularities (VHS) at doping x = *1/8 away from the Dirac point. Near the VHS, interactions effects, enhanced due to the large density of states, can give rise to various many-body phases at experimentally accessible temperatures. We study the competition between different many-body instabilities in graphene using functional renormalization group (FRG). We predict a rich phase diagram, which, depending on long range hopping as well as screening strength and absolute scale of the Coulomb interaction, contains a d + id-wave superconducting (SC) phase, or a spin density wave phase at the VHS. The d + id state is expected to exhibit quantized charge and spin Hall response, as well as Majorana modes bound to vortices. In the vicinity of the VHS, we find singlet d + id-wave as well as triplet f -wave SC phases. [1] arXiv:1109.2953v1

TT 50.9 Fri 11:45 H 3010

Resonant inelastic x-ray scattering (RIXS) in an unconventional superconductor — •Pasquale Marra, Steffen Sykora, and Jeroen van den Brink — IFW, Dresden, Germany

The investigation of the pairing mechanism in unconventional superconductors has generated enormous interest in spectroscopic techniques which are sensitive with respect to the phase of the superconducting order parameter. We show that resonant inelastic x-ray scattering (RIXS) in combination with an appropriate high energy resolution would be a very promising method in that aspect.

Using a BCS model for unconventional superconductors we calculate the lowest order excitations which are relevant for the RIXS scattering amplitude. We compare different scenarios of pairing and show that the momentum-dependent low energy RIXS spectra are strongly influenced by coherence factors which are known to be phase-sensitive.

TT 50.10 Fri 12:00 H 3010

Supercurrent through cuprate grain boundaries in the presence of strong correlations — •Fabian Alexander Wolf, Siegfried Graser, Florian Loder, and Thilo Kopp — Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Strong correlations are known to severely reduce the mobility of charge carriers near half-filling and thus have an important influence on the current carrying properties of grain boundaries in high-T_c cuprates. We apply a Gutzwiller method to investigate the critical current through microscopically reconstructed grain boundaries for a wide range of misalignment angles. In good agreement with experimental data, we find a reduction of the current by one order of magnitude as compared to an analogous weak coupling evaluation. This reduction emerges from the interplay of charge fluctuations and strong correlations. See Reference arXiv:1106.5759.