TT 29: Superconductivity: Mechanisms, Phase Diagram, Competing Order

Time: Thursday 9:30–13:00 Location: H 3010

TT 29.1 Thu 9:30 H 3010

Evidence for bulk s and d wave superconductivity and important c-axis involvement in cuprates — Rustem Khasanov[1], Alexander Shengelaya[2], •Annette Bussmann-Holder[3], Hugo Keller[1], and K. Alex Müller[1] — [1]Physik-Institut der Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland — [2]Physics Institute of Tbilisi State University, Chavchavadze 3, GE-0128 Tbilisi, Georgia — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

To clarify the order parameter symmetry of cuprates, the magnetic penetration depth was measured along the crystallographic directions a, b, and c in single crystals of $YBa_2Cu_4O_8$ via muon spin rotation. This method is direct, bulk sensitive, and unambiguous. The temperature dependences of the penetration depth along the crystallographic a- and b-directions were found to exhibit an inflection point at low temperatures as is typical and provides evidence for two-gap superconductivity (TGS) with s + d wave character in the planes. In contrast, the penetration depth along the c-axis shows almost pure s wave character which never met the awareness of the community thereby highlighting the important role of c-axis effects. We conclude that TGS is a generic and universal feature in the bulk of cuprates.

TT 29.2 Thu 9:45 H 3010

Optimal lokalisierte Wannier Funktionen bestimmter Symmetrie als Voraussetzung für Supraleitung bzw. Magnetismus — •Ekkehard Krüger — Elfenstraße 107, 70567 Stuttgart

Beobachtungen an den Bandstrukturen elementarer Metalle sowie von Hochtemperatur-Supraleitern lassen stark vermuten, dass sowohl für stabile Cooper-Paare als auch für stabile magnetische Strukturen optimal lokalisierte Wannier Zustände bestimmter Symmetrie im Leitungsband eines Materials verantwortlich sind. Diese Beobachtungen können im Rahmen eines gruppentheoretischen verallgemeinerten Heisenberg-Modells verstanden werden, in dem die Symmetrie atomähnlicher Zustände im Leitungsband durch die Orbitale der Elektronen *und* durch die Mitbewegung der Atomrümpfe bestimmt wird. Die Auswirkungen auf das theoretische Verständnis von (Hoch-T_c-)Supraleitung und Magnetismus werden kurz diskutiert. Ergebnisse für den Antiferromagnet $YBa_2Cu_3O_6$ und den Hochtemperatur-Supraleiter $YBa_2Cu_3O_7$ werden vorgestellt.

TT 29.3 Thu 10:00 H 3010

Charge-carrier dynamics of high-T_c superconductors — •Martin Scheuch, Luca Perfetti, Tobias Kampfrath, Christian Frischkorn, and Martin Wolf — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

By using transient time-resolved THz spectroscopy, we get the full information of the complex conductivity of $Bi_2Sr_2CaCu_2O_{8+\delta}$ in the range from 8 to 30 THz. In addition to static measurements, we also performed femtosecond pump-probe experiments, where a visible pump pulse excites the sample and after variable time delay, the THz pulse measures the pump-induced change in the conductivity. This paves the way to observe the non-equilibrium states. Experiments are performed temperature-dependent from 5 to 300 K. Our results show the breaking of Cooper-pairs and their recovery. This will be discussed including electron cooling and phonon heating.

TT 29.4 Thu 10:15 H 3010

Variational cluster calculation of the magnetic resonance mode in high-T_c superconductors — •Sascha Brehm[1], Enrico Arrigoni[2], Michael Potthoff[3], Markus Aichhorn[1], and Werner Hanke[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany — [2]Institut für Theoretische Physik, Technische Universität Graz, Austria — [3]Institut für Theoretische Physik, Universität Hamburg, Germany

We present a new quantum-cluster scheme for calculating two-particle correlation functions within symmetry-broken, e.g. antiferromagnetic (AF) and d-wave superconducting (dSC) phases. This scheme, which we apply to the 2-D Hubbard model, is based on the variational cluster approach (VCA) from which we obtain the normal and anomalous one-particle Green's functions in the thermodynamic limit from variationally optimized self-energies computed on finite clusters. In the spirit of this embedded cluster calculation, we also obtain the frequency and momentum dependent two-particle vertex from a calculation on an isolated cluster. It is specifically demonstrated that the new approach reproduces the magnetic resonance mode, which has been found in inelastic neutron scattering experiments in various underdoped high-T_c superconductors. Confirming a general belief, this resonance is indeed intimately related to the microscopic mechanism of superconductivity, i.e. it is a (S=1) magnetic exciton lying in the SC gap. In contrast to previous calculations, which are weak-coupling schemes (e.g. RPA), our scheme takes into account the strongly correlated physics of the high-T_c superconductors.

TT 29.5 Thu 10:30 H 3010

Single-particle vs. two-particle properties in LSCO — •Wolfgang Prestel, Bernhard Muschler, Leonardo Tassini, Michael Lambacher, Andreas Erb, and Rudi Hackl — Walther-Meißner-Institute, Garching

On the overdoped side, high-T_c superconductors can be described as normal, though strongly correlated, metals. In order to explore the doping range in which the correlations become dominant, we compare single-particle properties as seen by ARPES and two-particle properties as measured by, e.g., Raman, dc and optical transport. To this end, we implement a phenomenological model for the electronic spectral function resembling ARPES data and calculate two-particle quantities using a generalized Kubo formula. On the overdoped side, the results of the model calculations agree to within 20 % with the experimental data including spectral and temperature dependences. Towards optimal doping the experimental B_{1g} Raman response is strongly suppressed in an energy range below 1000 cm^{-1} in comparison to the spectra obtained from the model. This suppression is belived to originate from strong electronic correlations since it precedes the loss of spectral weight in the anti-nodal region found in ARPES experiments.

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TT 29.6 Thu 10:45 H 3010

Phonon anomalies in detwinned $YBa_2Cu_3O_{6+x}$: Evidence for in-plane anisotropy in the electronic system — •Mohammed Bakr, Clemens Ulrich, Chengtian Lin, Manuel Cardona, and Bernhard Keimer — Max Planck Institute, Stuttgart, Germany

The pairing symmetry of high T_c superconductors is predominantly of d-wave character with a probable small s-wave component. In detwinned YBCO, this results in an ***ab***-anisotropy of the 2Δ gaps. Different experiments have revealed controversial ***ab***- discrepancies in the 2Δ gaps and therefore the s-wave contribution. Raman light scattering (RLS) allows us to probe the electronic signals directly and also anisotropies in the phonon lineshapes. We have performed RLS experiments on detwinned $YBa_2Cu_3O_{6.95}$ single crystals using different laser lights. Within the experimental error of 4 meV, the electronic gaps along ***a***- and ***b***- axes show no differences. Phonons are quite sensitive to changes in the electronic system. Therefore, some phonons show a pronounced Fano-type line shape which implies a strong electron-phonon coupling. In the normal state, the Fano asymmetry parameter q^{-1} shows a sizable ***ab***-anisotropy which can be understood by basic band structure calculations. Below T_c, q^{-1} changes drastically and in a distinguishable behavior for the ***a***- and ***b***-axes. For instance the B_{1g}-like mode at 340 cm^{-1} shows a substantial ***ab***-dissimilarity whereas the apical oxygen phonon at 501 cm^{-1} shows the largest anisotropy. Furthermore, we have found that the anisotropy in the q^{-1} is highly dependent on the exciting laser energy. Our results shed more light on the strong electronic correlations in high-T_c superconductors.

TT 29.7 Thu 11:00 H 3010

Modelling the normal-state properties of the heavily overdoped cuprate $La_{1.7}Sr_{0.3}CuO_4$ — •Alessandro Narduzzo[1,2], Guillaume Albert[1], Matthew M.J. French[1], Nikorn Mangkorntong[3], Makoto Nohara[3], Hidenori Takagi[3], and Nigel E. Hussey[1] — [1]University of Bristol, UK; — [2]IFW Dresden, Germany; — [3]University of Tokyo, Japan.

The metallic properties of high-T_c superconductors still represent a major unresolved issue. Fermi-liquid based interpretative approaches require the existence of a single quasiparticle scattering rate with an in-plane anisotropy that is temperature dependent. Here we model

the temperature dependence of resistivity ρ, Hall coefficient $R_{\rm H}$ and magnetoresistance MR in the heavily overdoped non-superconducting cuprate $La_{1.7}Sr_{0.3}CuO_4$. Empirically, $\rho \sim T^2$ up to 50K, $MR \sim T^{-4}$ while $R_{\rm H}$ shows a strong temperature dependence, changing sign and becoming negative above $T \approx 170$K. The positive Hall coefficient at low temperatures appears inconsistent with the electron-like Fermi surface reported by ARPES measurements at this doping. By introducing a Fermi surface with large regions of negative curvature centred on the zone-diagonals and an anisotropic and temperature dependent scattering path length we manage to achieve a satisfactory explanation and fitting of the experimental results. Our analysis implies a striking breakdown of the isotropic-ℓ approximation at low temperatures in this heavily overdoped cuprate, a result that may have important implications for our understanding of the low-T Hall coefficient across the entire phase diagram [1]. [1] http://arxiv.org/abs/0707.4601.

15 min. break

Invited Talk TT 29.8 Thu 11:30 H 3010

Charge redistribution at YBCO-metal interfaces — •Udo Schwingenschlögl and Cosima Schuster — Institut für Physik, Universität Augsburg, D-86135 Augsburg

Charge redistribution at YBCO-metal interfaces is crucial for technological applications of YBCO superconductors, since the band structure is modified on a local scale. In particular, the superconducting CuO_2 planes are intrinsically electron doped (underdoped) due to the metallic contact. In order to obtain quantitative insight into this intrinsic doping mechanism, the normal-state YBCO electronic structure close to YBCO-metal interfaces is studied by means of first-principles band calculations, based on density functional theory. Because of a strong lattice relaxation, it is essential to carry out a detailed structure optimization, which is done for prototypical interface geometries. Additional defects or substitution of the cations may support or compensate the charge transfer. Oxygen vacancies, for instance, tend to locally underdope the superconductor. Intentional overdoping by substituting Y by Ca, on the other hand, compensates this effect and therefore can be used to enhance the critical current density. In addition, effects of electronegative impurities, like F or Cl, are of interest, particularly as concerns the re-extraction of charge from an underdoped YBCO-metal interface.

TT 29.9 Thu 12:00 H 3010

Dynamical magnetic susceptibility in the lamellar cobaltate superconductor $Na_xCoO_2{\cdot}yH_2O$ — •Maxim Korshunov[1,2] and Ilya Eremin[1,3] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]L.V. Kirensky Institute of Physics, Siberian Branch of RAS, Krasnoyarsk, Russia — [3]Institute für Math. und Theor. Physik, TU Braunschweig, Braunschweig, Germany

We systematically analyze the influence of the superconducting gap symmetry and the electronic structure on the dynamical spin susceptibility in superconducting $Na_xCoO_2{\cdot}yH_2O$ within a three different models: the single a_{1g}-band model with nearest-neighbor hoppings, the realistic three-band t_{2g}-model with, and without e'_g pockets present at the Fermi surface. We show that the magnetic response in the normal state is dominated by the incommensurate antiferromagnetic spin density wave fluctuations at large momenta in agreement with experimental temperature dependence of the spin-lattice relaxation rate. Also, we demonstrate that the presence or the absence of the e'_g-pockets at the Fermi surface does not affect significantly this conclusion. In the superconducting state our results for $d_{x^2-y^2}$- or d_{xy}-wave symmetries of the superconducting order parameter are consistent with experimental data and exclude nodeless $d_{x^2-y^2}+id_{xy}$-wave symmetry. We further point out that the spin-resonance peak proposed earlier is improbable for the realistic band structure of $Na_xCoO_2{\cdot}yH_2O$. Moreover, even if present the resonance peak is confined to the antiferromagnetic wave vector and disappears away from it.

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TT 29.10 Thu 12:15 H 3010

Mesoscopic effects in small superconducting grains: a semiclassical approach to BCS theory — Antonio M Garcia-Garcia[2], •Juan Diego Urbina[1], Emil Yuzbashyan[3], Klaus Richter[1], and Boris Altshuler[4] — [1]nstitut für Theoretische Physik, Universität Regensburg, 93053 Regensburg — [2]Physics Department, Princeton University, Princeton, New Jersey 08544, USA — [3]Center for Materials Theory, Rutgers University, Piscataway, New Jersey 08544, USA — [4]Physics Department, Columbia University, 538 West 120th Street, New York, NY 10027, USA

We present a novel approach to mesoscopic superconductivity based on a semiclassical approximation for *both* the density of states and the interaction matrix elements [1] entering the BCS gap equation. In this way, the discretness of the single-particle spectra and the inhomogeneity of the single particle eigenfunctions are included consistenly as mesoscopic fluctuations around the bulk values. We apply the theory to 3D cubic grains, finding good agreement with exact numerical calculations. For grains with irregular shape we predict a novel dependence of the gap with the excitation energy, present in an experimentally relevant region of parameters [2].

[1] J. D. Urbina and K. Richter *Phys. Rev. Lett.* **97**, 214101 (2006).
[2] A. M. Garcia-Garcia, J. D. Urbina, Emil Yuzbashyan, K. Richter and B.L Altshuler cond-mat/0710.2286 (2006).

TT 29.11 Thu 12:30 H 3010

Magnetic Flux Periodicity of h/e in Superconducting Loops — •Florian Loder[1], Thilo Kopp[1], Arno Kampf[1], Jochen Mannhart[1], Christof Schneider[1], and Yuri Barash[2] — [1]EKM, Institut für Physik, Universität Augsburg, 86135 Augsburg — [2]Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Russia

We apply the BCS theory to superconducting rings with unconventional order parameter symmetries. An external magnetic flux changes the character of the states in the condensate; as a consequence the energy of the superconducting ground state varies with a flux period of h/e. This h/e periodicity is caused by the flux-induced reconstruction of the supercurrent carrying condensate.

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TT 29.12 Thu 12:45 H 3010

Surface superconductivity and capacitance of superconductors under electric and magnetic fields — •Klaus Morawetz[1,2], Pavel Lipavsky[3,4], Jan Kolacek[4], Ernst Helmut Brandt[5], and Michael Schreiber[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, 01187 Dresden, Germany — [3]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague 2, Czech Republic — [4]Institute of Physics, Academy of Sciences, Cukrovarnická 10, 16253 Prague 6, Czech Republic — [5]Max Planck Institute for Metals Research, 70506 Stuttgart, Germany

A superconducting layer exposed to a perpendicular electric and parallel magnetic field is considered within the Ginzburg-Landau (GL) approach. The GL equation is solved near the surface and the surface energy is calculated. The nucleation critical field is shown to be changed in dependence on the magnetic and electric field. Special consideration is payed to the induced magnetic-field effect caused by diamagnetic surface currents. The latter effect constitutes the main contribution to the effective inverse capacitance which determines the effective penetration depth. The surface energy becomes strongly dependent on the width of the sample. An experimental realization is suggested for determining the change in the effective capacitance of the layer.