TT 53: Superconductivity: Fe-based Superconductors - 122

Time: Wednesday 9:30–13:15 Location: HSZ 201

TT 53.1 Wed 9:30 HSZ 201

The Pauli-limited multiband superconductor $RbFe_2As_2$ — •Felix Eilers, Diego A. Zocco, Thomas Wolf, Peter Schweiss, Kai Grube, and Hilbert v. Löhneysen — Karlsruher Institut für Technologie, Institut für Festkörperphysik, Karlsruhe, Germany

The compounds AFe_2As_2 - where A denotes an alkali metal element like K or Rb - offer the possibility to probe the unconventional superconductivity in iron pnictides. The upper critical magnetic fields H_{c2} are easily accessible and no additional chemical disorder is introduced by substitutional atoms. We measured the thermal expansion and magnetostriction of a $RbFe_2As_2$ single crystal at temperatures T between 50 mK and 4 K and magnetic fields $\mu_0 H$ up to 14 T. The quantum oscillations observed in our magnetostriction measurements indicate a strongly correlated electron system in accordance with the enhanced Sommerfeld coefficient and Pauli susceptibility of KFe_2As_2 [1]. In addition, they reveal, together with the thermal expansion, the multiband character of the electronic structure and superconductivity. The T-H phase diagram constructed from our field-dependent measurements shows the typical behavior of an orbitally limited superconductor for H parallel to the c-axis, while for H within the ab-plane the superconducting phase transition becomes discontinuous below $T = 1.2$ K. For this field direction the orbital limit strongly exceeds $H_{c2}(T = 0)$, thus pointing to a Pauli-limited upper critical field like in KFe_2As_2 [2].

[1] F. Hardy et al., PRL 111, 027002 (2013)
[2] D. A. Zocco et al., PRL 111, 057007 (2013)

TT 53.2 Wed 9:45 HSZ 201

Single 20-meV boson mode in KFe_2As_2 as seen by point-contact spectroscopy — Y. Naidyuk[1], O.E. Kvitnitskaya[1], N.V. Gamayunova[1], L. Boeri[2], S. Aswartham[3], G. Fuchs[3], S. Wurmehl[3], •D.V. Efremov[3], and S.-L. Drechsler[3] — [1]B. Verkin Institute for Low Temperature Physics and Engineering, National Academy of Sciences of Ukraine, 61103, Kharkiv, Ukraine — [2]Technische Universität Graz, 5150 Institut für Theoretische Physik-Computational Physics, 8010 Graz, Austria — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden e.V.,P.O. Box 270116, D-01171 Dresden, Germany

We investigate the electron-boson interaction in KFe_2As_2 by point-contact spectroscopy. The point-contact spectrum or the derivative of the differential resistance dR/dV exhibits a pronounced maximum at about 20 meV and surprisingly a featureless behavior at lower and higher energies in our point-contact spectra. We discuss phonon and nonphonon (excitonic) mechanisms for the origin of this peak, which may be important for the understanding of serious puzzles of superconductivity in this type of compounds.

TT 53.3 Wed 10:00 HSZ 201

Superconducting specific heat jump $\Delta C \propto T_c^\beta$ ($\beta \sim 2$) and gapless Fermi surfaces in $K_{1-x}Na_xFe_2As_2$ — •V. Grinenko[1], D.V. Efremov[1], S.-L. Drechsler[1], S. Aswartham[1], D. Gruner[1], M. Roslova[1], I. Morozov[1], K. Nenkov[1], S. Wurmehl[1,2], A.U.B. Wolter[1], B. Holzapfel[1,3], and B. Büchner[1,2] — [1]Leibniz-Institute for Solid State and Materials Research, IFW-Dresden, D-01171 Dresden, Germany — [2]Institut für Festkörperphysik, TU Dresden, Germany — [3]Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

We present a systematic study of the electronic specific heat jump ($\Delta C_{\rm el}$) at the superconducting transition temperature T_c of $K_{1-x}Na_xFe_2As_2$. Both T_c and $\Delta C_{\rm el}$ monotonously decrease with increasing x. The jump scales approximately with a novel power-law: $\Delta C_{\rm el} \propto T_c^\beta$ with $\beta \approx 2$ determined by the impurity scattering rate. This finding is in sharp contrast to most of all iron-pnictide superconductors with a cubic Bud'ko-Ni-Canfield (BNC) scaling. Our observations, also, suggests that disorder diminishes the small gaps leading to partial gapless superconductivity which results in a large residual Sommerfeld coefficient in the superconducting state for $x > 0$. Both T-dependence of $C_{\rm el}(T)$ in the superconducting state and the nearly quadratic scaling of $\Delta C_{\rm el}$ at T_c are well described by the Eliashberg-theory for a single-band d-wave superconductor with weak pair-breaking due to nonmagnetic impurities having reduced the density of superconducting quasi-particles.

TT 53.4 Wed 10:15 HSZ 201

Coupled order parameters in $Ca_{1-x}Na_xFe_2As_2$ — •Philipp Materne[1], Sirko Bubel[1], Hemke Maeter[1], Rajib Sarkar[1], Johannes Spehling[1], Luminita Harnagea[2], Sabine Wurmehl[2,1], Bernd Buechner[2,1], Hubertus Luetkens[3], and Hans-Henning Klauss[1] — [1]Institut für Festkörperphysik, Technische Universität Dresden, 01062 Dresden, Germany — [2]IFW Dresden, Postfach 270016, 01171 Dresden, Germany — [3]Paul-Scherrer-Institut, 5232 Villigen, Switzerland

The antiferromagnetic parent compound, $CaFe_2As_2$, shows a supression of the spin density wave and a subsequent superconducting state upon partial substitution of Ca by Na. Along the substitution series, superconducting transition temperatures up to ≈35 K were found. We studied the electronic phase diagram of $Ca_{1-x}Na_xFe_2As_2$ using Mössbauer spectroscopy and muon spin relaxation experiments in terms of order parameter interaction in the coexistence region as well as electronic properties in the pure magnetic and superconducting parts of the phase diagram. The results were compared with recently published data of $Ba_{1-x}Na_xFe_2As_2$ [1].

[1] H. Maeter *et al.*, arXiv:1210.6881

TT 53.5 Wed 10:30 HSZ 201

Specific heat of $Ca_{0.32}Na_{0.68}Fe_2As_2$ single crystals: unconventional $s_\pm$ multi-band superconductivity with intermediate repulsive interband coupling and sizable attractive intraband couplings — •S.-L. Drechsler[1], S. Johnston[1], H. Rosner[2], M. Abdel-Hafiez[1], V. Grinenko[1], L. Harnagea[1], Y. Krupskaya[1], D. Bombor[1], S. Wurmehl[1], C. Hess[1], A. Wolter[1], and B. Buechner[1] — [1]IFW-Dresden, Germany — [2]MPI CPfS-Dresden, Germany

We report a low-temperature specific heat study of single crystals of the heavily hole doped superconductor $Ca_{0.32}Na_{0.68}Fe_2As_2$. This compound exhibits bulk superconductivity with a transition temperature $T_c \approx 34$ K, which is evident from the magnetization, transport, and specific heat measurements. The zero field data manifests a significant electronic specific heat in the normal state with a Sommerfeld coefficient γ ≈53 mJ/mol K^2. Using a multi-band Eliashberg analysis, we demonstrate that the dependence of the zero field specific heat in the superconducting state is well described by a three-band model with an unconventional $s_\pm$ pairing symmetry and gap magnitudes Δ_i of about 2.35, 7.48, and -7.50 meV. Our analysis indicates a non-negligible attractive intraband coupling,which contributes significantly to the relatively high value of T_c. The Fermi surface averaged repulsive and attractive coupling strengths are of comparable size and outside the strong coupling limit frequently adopted for describing high-T_c iron pnictide superconductors. We further infer a total mass renormalization of the order of five, including the effects of correlations and electron-boson interactions.

TT 53.6 Wed 10:45 HSZ 201

ARPES of iron-based superconductors: from low- to high-energy edge of 3d band — •Daniil Evtushinsky, Volodymyr Zabolotnyy, Janek Maletz, Bernd Büchner, and Sergei Borisenko — Institute for Solid State Research, IFW Dresden, P. O. Box 270116, D-01171 Dresden, Germany

An overview of the available angle-resolved photoemission spectroscopy (ARPES) measurements of iron-based superconductors will be given. Large variety of Fermi surface shapes and topologies as well as superconducting gap momentum distributions was observed. At the same time one can point out several common tendencies for iron high temperature superconductors - band renormalization, often a two-gap behavior, presence of an electronic coupling to the low-energy bosonic modes. A correlation between the superconducting gap magnitude and orbital origin of the electronic states was found; further analysis of the electronic structures of different iron arsenides consistently points to the significance of $3d_{xy,yz}$ bands for superconductivity in these materials. The recently revealed high-energy anomalies in the electronic spectra of iron superconductors are very reminiscent of the corresponding structures for cuprates. This implies that physical processes with energy scales of the whole 3d band might be important for the emergence of superconductivity with highest transition temperatures.

TT 53.7 Wed 11:00 HSZ 201

Electronic structure and quantum criticality in $Ba(Fe_{1-x-y}Co_xMn_y)_2As_2$, an ARPES study. — •J. Fink[1], E.D.L. Rienks[2], T. Wolf[3], K. Koepernik[1], I. Avigo[4], P. Hlawenka[2], C. Lupulescu[5], T. Arion[6], F. Roth[7], W. Eberhardt[7], and U. Bovensiepen[4] — [1]Leibniz-Institute for Solid State and Materials Research, Dresden, Germany — [2]Helmholtz-Zentrum, Berlin, Germany — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Universität Duisburg-Essen, Duisburg, Germany — [5]Technische Universität Berlin, Berlin, Germany — [6]Universität Hamburg, Hamburg, Germany — [7]Center for Free-Electron Laser Science, Hamburg, Germany

We used angle-resolved photoemission spectroscopy (ARPES) and density functional theory calculations to study the electronic structure of $Ba(Fe_{1-x-y}Co_xMn_y)_2As_2$ for x=0.06 and $0 \leq y \leq 0.07$. From ARPES we derive that the substitution of Fe by Mn does not lead to hole doping, indicating a localization of the induced holes. An evaluation of the measured spectral function does not indicate a diverging effective mass or scattering rate near optimal doping. Thus the present ARPES results indicate a continuous evolution of the quasiparticle interaction and therefore question previous quantum critical scenarios.

15 min. break.

TT 53.8 Wed 11:30 HSZ 201

Spin Fluctuations in doped Ba122 probed by NMR Spin Lattice Relaxation Rate — •Uwe Gräfe[1], Hannes Kühne[2,3], Saicharan Aswartham[1], Philip Kuhns[2], Arneil Reyes[2], Sabine Wurmehl[1,4], Bernd Büchner[1,4], and Hans-Joachim Grafe[1] — [1]IFW Dresden, Institute for Solid State Research, P.O. Box 270116, D-01171 Dresden, Germany — [2]National High Magnetic Field Laboratory, Florida State University, Tallahassee, Florida 32310, USA — [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden High Magnetic Field Laboratory, P.O. Box 510119, D-01314 Dresden, Germany — [4]TU-Dresden, Institute for Solid State Physics, D-01062 Dresden, Germany

In this talk we take a closer look on Co doped Ba122 by the local probe technique of NMR. Like many other iron pnictides Co doped Ba122 shows an increased spin lattice relaxation rate (SLR) above the superconducting transition temperature which hints at enhanced antiferromagnetic spin fluctuations (SF). These fluctuations are debated to play a crucial role for the pairing mechanism of superconductivity (SC). However, evidence for progressive slowing of SF in F doped La1111 (PRB 88, 104503) as well as evidence for cluster spin glass behavior in underdoped Ba122 (PRL 111, 207201) points at a competition of SC and antiferromagnetic order. We investigated the field dependence of the SLR in optimally Co doped Ba122 in detail to gain insights into the nature of spin fluctuations and their relevance for SC.

TT 53.9 Wed 11:45 HSZ 201

Effects of transition metal doping on the electronic structure of $BaFe_2As_2$ — •Jan Trinckauf[1], Klaus Koepernik[1], Sai Aswartham[1], Vladimir Strocov[2], Sabine Wurmehl[1], Bernd Büchner[1], and Jochen Geck[1] — [1]IFW Dresden, Germany — [2]Paul-Scherrer Institute, Villigen, Switzerland

We have performed resonant soft X-ray ARPES measurements on Co and Ni doped $BaFe_2As_2$ on the $L_{2,3}$ absorption edge of the dopant. We find that the 3*d* contribution of the TM dopant is shifted towards higher binding energies compared to the Fe bands and this shift increases with increasing atomic number. No considerable dispersion can be detected in the resonance features. We compared our data to DFT supercell calculations and see a similar trend in the 3*d* bandweights and the local DOS of the dopant. Most importantly, we observe in the calculations a shift of the Fermi level by the amount expected from the additional electrons on the TM sites, while simultaneously the total Fe 3*d* DOS stays constant. The additional electrons are counted solely towards the dopant. Referring to a model of local scatterers in a one-dimensional metallic chain and a two dimensional square lattice, we find that, while the electronic structure of the model as a function of the impurity potential behaves similar to what is observed in $BaFe_2As_2$, the effective doping behaves very different. This suggests that the almost rigid band like shift of the chimcal potential with doping, even in case of Cu, that is observed both theoretically and experimentally is a peculiarity of the compound, which has strong implications for the developement of superconductivity.

TT 53.10 Wed 12:00 HSZ 201

Analysis of the sub-dominant *d*-wave pairing channel in iron-based superconductors — •Thomas Böhm[1], Florian Kretzschmar[1], Rudi Hackl[1], Thomas P. Devereaux[2], and Alexander F. Kemper[3] — [1]Walther Meissner Institute, Bavarian Academy of Sciences and Humanities, 85748 Garching, Germany — [2]SLAC National Accelerator Laboratory, Stanford Institute for Materials and Energy Sciences, 2575 Sand Hill Road, Menlo Park, California 94025, USA — [3]Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA

An analysis of the light scattering spectra of optimally doped $Ba_{0.6}K_{0.4}Fe_2As_2$ is presented. On the basis of a realistic band structure as derived from LDA calculations it is shown that the narrow feature found experimentally in the B_{1g} ($d_{x^2-y^2}$) Raman spectra can be reproduced quantitatively and be identified as a Bardasis-Schrieffer exciton. The theoretical description of the spectra shows that the coupling strength in the subdominant $d_{x^2-y^2}$ channel is as strong as 60% of that of the dominant s_{+-} channel.

TT 53.11 Wed 12:15 HSZ 201

Raman study of SDW order and band-folding in twin-free $BaFe_2As_2$ — •Florian Kretzschmar[1], Thomas Böhm[1], Bernhard Muschler[1], Andreas Baum[1], Rudi Hackl[1], Alexander F. Kemper[2,3], Thomas P. Devereaux[3,4], James G. Analytis[5], Jiun-Haw Chu[5,6], and Ian R. Fisher[3,4] — [1]Walther Meissner Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Computational Research Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA — [3]Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA — [4]Geballe Laboratory for Advanced Materials, Stanford University, Stanford, California 94305, USA — [5]Department of Physics, University of California, Berkeley, California 94720, USA — [6]Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

We present results of electronic Raman scattering experiments on detwinned $BaFe_2As_2$ above and below the transition into the spin-density-wave (SDW) state. We observe signatures of the SDW gap in all symmetries. The spectra indicate a strong mixing of the bands due to backfolding along the SDW vector. For analysis we calculated the Raman susceptibility on the basis of a 5 band tight binding model using the effective mass approximation. Prominent features in the Raman response can be traced back to a few interband transitions.

TT 53.12 Wed 12:30 HSZ 201

Tracing the $s_{\pm}$ symmetry in iron pnictides — •Micha Schilling[1], Sina Zapf[1], Boris Gorshunov[1,2,3], Andreas Baumgartner[1], Kazumasa Iida[4], Valery A. Dravin[5], Kirill V. Mitsen[5], Dimitri Efremov[6], Oleg Dolgov[7], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institute of General Physics, RAS, Russia — [3]Moscow Institute of Physics and Technology, Russia — [4]Institut für Metallische Werkstoffe, IFW Dresden, Germany — [5]Lebedev Physical Institute, Moscow, 119991 Russia — [6]Institute for theoretical physics, IFW, Dresden — [7]Max-Planck Institut für Festkörperforschung, Stuttgart, Germany

For multiband iron pnictides, the symmetry of the superconducting order parameter is still under debate. It was suggested [1] that in the case of $s_{\pm}$ symmetry, a disorder-induced crossover from $s_{\pm}$ to s_{++} symmetry could occur, meaning that the smaller superconducting gap Δ_1 first closes and then reopens. To that end, we have step-wise irradiated a $Ba(Fe_{0.9}Co_{0.1})_2As_2$ thin film with protons and measured its complex conductivity in the terahertz frequency range. Our preliminary results show that the irradiation with protons is capable to linearly decrease the critical temperature of the film, while Δ_1 gets suppressed faster. Thus, further irradiation might reveal the reopening of Δ_1 and thus proof the $s_{\pm}$ symmetry of the superconducting order parameter.

[1] D.V. Efremov *et al.*, Phys. Rev. B **84**, 180512 (2011)
[2] B. Gorshunov *et al.*, Phys. Rev. B **81**, 060509 (2010)

TT 53.13 Wed 12:45 HSZ 201

Measuring detwinned $EuFe_2As_2$ without external pressure — •Jannis Maiwald[1], Christian Stingl[1], Sina Zapf[2], Shuai Jiang[2], Nora Bach[1], Kirk Post[3], Hirale S. Jeevan[1], David Neubauer[2], Anja Löhle[2], Conrad Clauss[2], Dimitri Basov[3], Martin Dressel[2], and Philipp Gegenwart[1] — [1]I.Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]1.Physikalisches Institut, Universität Stuttgart, Germany — [3]Department of Physics,

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The formation of twin domains in the low temperature state of high-temperature superconductors is impeding the investigation of the in-plane anisotropy of these materials. Due to the applied pressure, mechanical clamps—commonly used to detwin crystals—induce artificial anisotropy and thus complicate the interpretation of acquired data. In case of the iron pnicides, application of typical laboratory magnetic fields did not lead to a substantial detwinning. In this talk we present a novel way to detwin $EuFe_2As_2$ by brief application of a small magnetic field of ~ 1 Tesla. We will discuss magnetoresistance, magnetostriction/themal expansion and thermopower measurements, revealing that the Eu^{2+} moments support the detwinning not only below, but also above their magnetic ordering at 19K. After removing the field the system remains detwinned up to the structural and electronic phase transition at 190 K, providing a unique possibility to study the in-plane anisotropic properties of this material without the application of any external force.

TT 53.14 Wed 13:00 HSZ 201

Permanent Detwinning of $EuFe_2As_2$ by indirect magnetoelastic coupling — •Sina Zapf[1], Christian Stingl[2], Kirk Post[3], Jannis Maiwald[2], Shuai Jiang[1], Hirale S. Jeevan[2], Nora Bach[2], David Neubauer[1], Anja Löhle[1], Conrad Clauss[1], Dimitri N. Basov[3], Philipp Gegenwart[2], and Martin Dressel[1] — [1]1. Physikalisches Institut, Uni Stuttgart, Germany — [2]I. Physikalisches Institut, Uni Göttingen, Göttingen — [3]Department of Physics, UC San Diego, USA

In order to examine the in-plane anisotropy of high-temperature superconductors, sophisticated methods had to be developed for detwinning single crystals. Unfortunately, in the case of iron pnictides, typical laboratory magnetic fields do not yield an imbalance of twin domains by more than a few percent. Here we present a novel way of permanently detwinning $EuFe_2As_2$ single cystals in magnetic fields of less than 1 Tesla. We will discuss magneto-optical and magnetization measurements, revealing that the Eu^{2+} moments actually support the detwinning not only below, but also above their magnetic ordering at 19 K, probably by an indirect magnetoelastic coupling via the Fe^{2+} spins. Most strikingly, the detwinning remains even when the magnetic field is switched off and the resulting ratio of unbalanced twin domains of about 1:3 is robust against heating to the structural and electronic phase transition at 190 K. This provides a unique possibility to study the low temperature in-plane anisotropy of iron pnictides without the application of any external force, suitable for a wide variety of experimental techniques.