TT 59: Superconductivity: Fe-based Superconductors - FeSe and others

Time: Thursday 9:30–12:15 Location: HSZ 103

TT 59.1 Thu 9:30 HSZ 103

Phonon spectrum of single-crystalline FeSe — •Tobias Engelhardt[1], Khalil Zakeri Lori[1], Thomas Wolf[2], and Matthieu Le Tacon[2] — [1]Heisenberg Spin-dynamics Group, Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, D-76131 Karlsruhe, Germany — [2]Institut für Festkörperphysik, Karlsruhe Institute of Technology, Hermann-v.-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany

Iron selenide is structurally the simplest iron-based superconductor and has been investigated extensively during the past years. Several experimental tools have been used to investigate the collective excitations, e.g. phonons, in this material. However, due to the lack of large single crystals, most of those experiments are performed on polycrystalline or powder samples. We report on the first phonon spectrum probed on the FeSe(001) surface by means of high-resolution electron energy-loss spectroscopy. Single crystals of FeSe are cleaved under ultra-high vacuum conditions and are subsequently measured above and below the nematic transition temperature. We observe five phonon modes and a phonon cutoff energy of about 42 meV at the center of Brillouin zone. These phonon modes disperse rather weakly while changing the momentum from zero up to the zone boundary, indicating that they are mainly of optical nature. We identify the origin of each phonon mode by comparing the experimental results to the ones of *ab initio* density functional calculations. Finally we comment on the role of temperature on the phonon spectrum.

TT 59.2 Thu 9:45 HSZ 103

Temperature evolution of the band structure of FeSe — •Yevhen Kushnirenko[1], Alexander Fedorov[1,2], Erik Haubold[1], Timur Kim[3], Moritz Hoesch[3], Thomas Wolf[4], Bernd Büchner[1], and Sergey Borisenko[1] — [1]IFW-Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Physikalisches Institut, Universit at zu Köln, Zulpicher Strasse 77, 50937 Köln, Germany — [3]Diamond Light Source, Harwell Campus, Didcot, OX11 0DE, United Kingdom — [4]Institut für Festkörperphysik, Karlsruhe Institute for Technology, Karlsruhe 76021, Germany

We have studied an evolution of the band structure of FeSe in a wide temperature range using angle-resolved photoemission spectroscopy (ARPES). We investigated the behavior of the hole-like bands in the center of the Brillouin zone and electron-like bands in its corners. We have shown that all these dispersions move with temperature as a function of binding energy. Remarkably, a direction of these shifts is different for the center and the corners of the Brillouin zone. This band structure behavior is observed for the orthorhombic state of FeSe (T<86K) as well as for the tetragonal state (T>86K).

TT 59.3 Thu 10:00 HSZ 103

Nodeless superconductivity and impurity bound states in FeSe single crystals — •Sahana Roessler[1], Lin Jiao[1], Chien-Lung Huang[1], Cevriye Koz[1], Ulrich K. Roessler[2], Ulrich Schwarz[1], and Steffen Wirth[1] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany — [2]IFW-Dresden, Institute for Solid State Research, D-01171 Dresden, Germany

We present the superconducting gap structure of FeSe single crystals [1,2] investigated by heat capacity and scanning tunneling microscopy/spectroscopy (STM/S). We show evidence for the existence of two superconducting gaps without nodes [3]. Further, the local density of states in the vicinity of a native selenium dumbbell in the superconducting state displays two resonant states inside the superconducting gap, equally spaced with respect to zero energy, but asymmetric in amplitude. The magnitude of the superconducting gap is found to be insensitive to the impurity potential, which confirms its non-magnetic nature. The in-gap bound states emerging from a non-magnetic impurity-induced pair-breaking suggest a sign changing pairing state in this material.

[1] C. Koz et al., Z. Anorg. Allg. Chem. 640, 1600 (2014)
[2] S. Rößler et al., PRB(R) 92, 060505 (2015)
[3] L. Jiao et al., arXiv:1605.01908 (2016)

TT 59.4 Thu 10:15 HSZ 103

Short-range quasi-static correlations in FeSe single crystals probed by μSR — •Vadim Grinenko[1], Rajib Sarkar[1], Philipp Materne[1], Sirko Kamusella[1], Hubertus Luetkens[2], Jean-Christophe Orain[2], Tatsuo Goko[2], Robert Scheuermann[2], Aichi Yamashita[3], Yoshihiko Takano[3], Yue Sun[4], Tsuyoshi Tamegai[4], Dmitriy Efremov[5], Stefan-Ludwig Drechsler[5], and Hans-Henning Klauss[1] — [1]Institute for Solid State Physics, TU Dresden, D-01069, Germany — [2]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute (PSI), CH-5232 Villigen, Switzerland — [3]National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, 305-0047 JAPAN, Japan — [4]Department of Applied Physics, The University of Tokyo, Hongo, Tokyo 113-8656, Japan — [5]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany

The FeSe system is an exception among the Fe based superconductors since it has a nematic transition at $T_s \sim 90$ K without long-range magnetic order down to lowest temperatures. The understanding of this phenomenon is a big challenge for a microscopic theory. We investigated high-quality single crystals of FeSe using zero field and high field muon spin rotation/relaxation (μSR) measurements. We observed that weak quasi-static local magnetic fields appear below 200 K in the entire sample volume. The static field inhomogeneity increases with the reduction of the temperature down to $T^* \sim 75$ K, where the transition to another magnetic state is observed. The evidence for the short-range quasi-static magnetic correlations well above T_s in FeSe provides a strong constraint for future microscopic theories.

TT 59.5 Thu 10:30 HSZ 103

Spatial variation of the two-fold anisotropic superconducting gap in a monolayer of $FeSe_{0.5}Te_{0.5}$ on a topological insulator — •Anand Kamlapure[1], Sujit Manna[1], Lasse Cornils[1], Torben Hänke[1], Martin Bremholm[2], Philip Hofmann[3], Jens Wiebe[1], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, Hamburg, Germany — [2]Department of Chemistry and Center for Materials Crystallography, Aarhus University, Denmark — [3]Department of Physics and Astronomy, and Interdisciplinary Nanoscience Center iNANO, Aarhus University, Denmark

We present a low temperature scanning tunneling spectroscopy (STS) study of the superconducting properties of monolayers of $FeSe_{0.5}Te_{0.5}$ grown on the 3D topological insulator $Bi_2Se_{1.2}Te_{1.8}$. While the morphology and the overall transition temperature resemble those of similarly doped bulk crystals, the spectroscopic data shows a much larger spatial inhomogeneity in the superconducting energy gaps. Despite the gap inhomogeneity all the spectra can be described with a two-fold anisotropic s-wave gap function. The two-fold nature of the gap symmetry is evident from the Bogoliubov quasiparticle interference (QPI) pattern which shows distinct C_2 symmetric scattering intensities. We argue that the gap inhomogeneity emerges as a result of intrinsic disorder in our system similar to disordered conventional superconductors. Our system thus provides an ideal platform to study unconventional superconductivity in Fe chalcogenides in a single layer and in close proximity to a topological insulator.

TT 59.6 Thu 10:45 HSZ 103

Ultrathin FeSe films on Bi_2Se_3(0001) studied by STM and STS — •Jonas Warmuth, Udai Raj Singh, Verena Markmann, Jens Wiebe, and Roland Wiesendanger — Dept. of Physics, Hamburg University, Hamburg, Germany

Thin film iron chalcogenide superconductors have recently attracted interest due to an increase in transition temperatures as compared to the bulk material [1]. We report on the structural and electronic properties of ultrathin FeSe films grown on Bi_2Se_3(0001) [2]. Scanning tunnelling microscopy (STM) reveals FeSe thin films in the tetragonal phase with heights of one and two unit cells (UC) in respect to the Bi_2Se_3 surface. We observe striped moiré patterns and dumb-bell shaped defects on the FeSe films. Scanning tunnelling spectroscopy (STS) does not show any signature of a superconducting gap in the tunnelling spectra on the one and two UC thick FeSe islands down to 6.5 K [3]. These spectra rather show an asymmetric behaviour and a finite density of states at the Fermi level similar to spectra on bulk FeSe.

[1] I. Bozovic *et al* **2014** *Nature Physics* 10 892
[2] Y. Wang *et al* **2012** *J. Phys: Condensed Matter* 24 47
[3] U. Singh *et al* **2016** *J. Phys: Condensed Matter* 29 2

15 min. break.

TT 59.7 Thu 11:15 HSZ 103

Resonant scattering in the quasiparticle interference in superconducting LiFeAs — •Steffen Sykora[1], Zhixiang Sun[1], Pranab Kumar Nag[1], Jose Maria Guevara Parra[1], Danny Baumann[1], Rhea Kappenberger[1], Robert Beck[1], Sabine Wurmehl[1,2], Sergey Borisenko[1], Bernd Büchner[1,2,3], and Christian Hess[1,3] — [1]IFW Dresden — [2]Institute for Solid State Physics, TU Dresden — [3]Center for Transport and Devices, TU Dresden

Probing the quasiparticle interference (QPI) by scanning tunneling microscopy/spectroscopy (STM) is an important tool to investigate the character of the superconducting state. We develop a theoretical model for the QPI in LiFeAs and compare the results with recent STM measurements of the Fourier transformed local density of states. Our selfconsistent t-matrix calculation goes beyond the standard Born approximation and is based on realistic band structure data. We find dominant QPI intensity at small transfer momentum in excellent agreement with the experiment. An unusual measured in-gap intensity is explained within the same theoretical framework by higher-order Andreev-scattering processes. The theoretical analysis reveals an important role of specific multiple scattering processes that lead to a resonant scattering mode at the energy scale of the superconducting gap. We discuss our results in the context of the pairing mechanism in LiFeAs.

TT 59.8 Thu 11:30 HSZ 103

Tunneling spectroscopy and long wavelength quasiparticle interference in LiFeAs — •Z. Sun[1], P. K. Nag[1], S. Sykora[1], S. Borensiko[1], D. Bauman[1], R. Kappenburger[1], R. Beck[1], S. Wurmehl[1], B. Büchner[1,2,3], and C. Hess[1,3] — [1]Leibniz-Institute for Solid State and Materials Research, IFW-Dresden, 01069 Dresden — [2]Institute for Solid State Physics, TU Dresden, 01069 Dresden — [3]Center for Transport and Devices, TU Dresden, 01069 Dresden

We want present large-scale scanning tunneling spectroscopic map results on LiFeAs, especially focusing on the small momentum quasiparticle scatterings, where not much attention have been paid to previously. At the superconducting state, two particle-hole symmetric features are observed in the quasiparticle interference pattern: i) a large gap with a size of about 10 meV at 6.7 K; ii) ingap scatterings with small momentum transfer q close to zero. The evolution of the large gap size with temperature shows a mean field order parameter-like behavior with a critical temperature at T_c. For the large gap, we think that it reflects multiple scattering effects. And for the ingap particle-hole symmetric scatterings, we argue that they are due to the local variation of the superconducting order parameter caused by the defects and are related to Andreev reflection.

TT 59.9 Thu 11:45 HSZ 103

The quest for LaFeAsO single crystals — •Rhea Kappenberger[1,2], Saicharan Aswartham[1], Sebastian Selter[1], Francesco Scavaraggi[1,2], Federico Caglieris[1], A. U. B. Wolter[1], Christian Hess[1,3], Hans-Joachim Grafe[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2,3] — [1]Leibniz Institute for Solid State and Materials Research Dresden IFW, Dresden, Germany — [2]Institut für Festkörperphysik, TU Dresden, 01069 Dresden, Germany — [3]Center for Transport and Devices, TU Dresden, 01069 Dresden, Germany

Since the discovery of Fe-based superconductors in 2008, a lot of progress in crystal growth has been made in the 11, 111 and 122 systems. However, in the 1111 systems large crystals of high quality are very difficult to obtain, which renders investigations which crucially rely on single crystals, e.g. investigations of nematicity, practically impossible.

In this work, we present a novel approach of obtaining large La(Fe,Co)AsO and LaFeAs(O,F) single crystals using solid state synthesis and flux growth under ambient pressure. We were able to map out a new electronic phase diagram using single crystals of La(Fe,Co)AsO by several techniques such as structural, magnetic and resistivity measurements.

TT 59.10 Thu 12:00 HSZ 103

Lattice-assisted nematic order in $Ca_{10}Pt_3As_8(Fe_{1-x}Pt_xAs)_{10}$ — •Felix Brückner, Vadim Grinenko, Rajib Sarkar, Maksym Surmach, Dmytro Inosov, and Hans-Henning Klauss — Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany

A broken 4-fold rotational symmetry, caused by electronic correlation effects, known as nematicity, is a well established fact in many iron-based superconductors. Slanted stacking of crystallographic layers can influence the formation of nematic order. This is investigated at the example of the triclinic system $Ca_{10}Pt_3As_8(Fe_{1-x}Pt_xAs)_{10}$. We present a joint study including magnetostriction, anisotropic resistivity, NMR and inelastic neutron scattering.

A phase transition at $T^* \approx 40$ K, far above the superconducting $T_c = 13$ K, manifests itself in a change in magnetic dynamic properties and a weak nematic lattice transition as well. NMR studies show a drastic decrease of low-energy magnetic fluctuations and a slight static broadening, interpreted as the opening of a pseudo spin-gap. A peak in the INS spectrum at the antiferromagnetic peak is found below the transition temperature. Since the nematic transition is twinned, we can observe the inequivalence of (1,1,0) and (1,-1,0) directions by applying magnetic field that detwins the sample and by measuring magnetostriction and resistivity. Beside the phase transition at T^* we found a second magnetic phase transition at ≈ 4 K.