TT 3: Superconductivity: Properties and Electronic Structure

Time: Monday 9:30–13:00 Location: HSZ 103

TT 3.1 Mon 9:30 HSZ 103

Band-selective quasiparticle scatterers in a two-band superconductor — •Thomas Gozlinski[1], Qili Li[1], Nola Warwick[1], Janic Beck[1], and Wulf Wulfhekel[1,2] — [1]Physikalisches Institut (PHI), Karlsruher Institut für Technologie (KIT) — [2]Institute for Quantum Materials and Technologies (IQMT), Karlsruher Institut für Technologie (KIT)

We study stacking fault tetrahedra (SFTs) in a bulk Pb crystal by mK scanning tunnelling microscopy and spectroscopy and find that the Bogoliubons of the two superconducting bands produce different quasiparticle interference patterns owed to the respective Fermi surface anisotropy. We believe that such extended crystal defects provide a platform to experimentally study interband couplings and scattering rates in a multiband superconductor.

TT 3.2 Mon 9:45 HSZ 103

Symmetry breaking and emergent phases in a noncentrosymmetric superconductor — •Feifan Wang[1], Xianghan Xu[2], Sang-Wook Cheong[2], and Manfred Fiebig[1] — [1]Dept. of Materials, ETH Zurich, Switzerland — [2]Dept. of Physics and Astronomy, Rutgers University, USA

Symmetry breaking raises rich physics in condensed matters, such as Rashba splitting, Weyl fermions, unconventional superconducting, multiferroic ordering, etc. Nonlinear optical processes, being extremely sensitive to material symmetries, offer a direct access to the observation of subtly broken or even hidden symmetries. Here we discover emergant phases in a noncentrosymmetric superconductor, Mo_3Al_2C, and resolve the symmetry lowering using second harmonic generation measurements. Together with temperature-dependent electronic conductivity measurements, the phase transition from a normal metal at high temperatures to a charge-density-wave state is proposed. In the former, all mirror symmetries are broken bringing in the structural chirality. The correlation between superconductivity/charge-density-wave transition and noncentrosymmetry/chirality will then be discussed. Exotic properties in a low-symmetry system such as Mo_3Al_2C may add new ingredients to the strong-correlation physics.

TT 3.3 Mon 10:00 HSZ 103

Hunt for FFLO superconductivity in transition metal dichalcogenides — •Jiawei Zhang[1], Dennis Huang[1], Yosuke Matsumoto[1], Masahiko Isobe[1], Thomas Palstra[1,2], and Hidenori Takagi[1,3,4] — [1]Max Planck Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany — [2]University of Twente, Drienerlolaan 5, 7522 NB Enschede, The Netherlands — [3]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [4]Department of Physics, University of Tokyo, 113-0033 Tokyo, Japan

The Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state was proposed almost half a century ago. In contrast to the Bardeen-Cooper-Schrieffer state, the FFLO state hosts Cooper pairs with finite center-of-mass momentum, giving rise to a modulation of the superconducting gap in real space. Two-dimensionality plays an essential role in the materialization of the FFLO state. With 1T buffer layers that reduce the interlayer coupling between successive 1H superconducting layers, $4H_b$-TaS_2 is a promising FFLO candidate. I will talk about the two-dimensional nature of superconductivity in this system as revealed by the Berezinskii-Kosterlitz-Thouless transition. Electrical transport measurements with in-plane magnetic field show that the superconductivity survives above the Pauli limit, providing a high-field regime in the phase diagram to host a possible FFLO state.

TT 3.4 Mon 10:15 HSZ 103

Tuning metal/superconductor to insulator/superconductor coupling via control of proximity enhancement between $NbSe_2$ monolayers — •O. Chiatti[1], K. Mihov[1], T. Griffin[1], C. Grosse[1], L. Grote[1], K. Hite[2], D. Hamann[2], M. B. Alemayehu[2], A. Mogilatenko[3], D. C. Johnson[2], and S. F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Solid State Chemistry, University of Oregon, Eugene OR 97403-1253, U.S.A. — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, 12489 Berlin, Germany

The interplay between charge transfer and electronic disorder in transition-metal dichalcogenide multilayers [1] gives rise to superconductive coupling driven by proximity enhancement, tunneling and superconducting fluctuations. Artificial spacer layers introduced with atomic precision change the density of states by charge transfer. Here, we tune the superconductive coupling between $NbSe_2$ monolayers from proximity-enhanced to tunneling-dominated and correlate normal and superconducting properties in $[(SnSe)_{1+\delta})]_m[NbSe_2]_1$ tailored multilayers with varying SnSe layer thickness (m=1-15). We show crossovers between three regimes: metallic with proximity-enhanced coupling, disordered-metallic with intermediate coupling and insulating with Josephson tunneling. [1] A. Devarakonda *et al.*, Science **370**, 231 (2020) [2] M. Trahms *et al.*, Supercond. Sci. Technol. **31**, 065006 (2018)

TT 3.5 Mon 10:30 HSZ 103

Higgs-CDW hybrid mode in coherently-driven 2H-$NbSe_2$ and $La_{2-x}Sr_xCuO_4$ — •Liwen Feng[1,2,3,4], Jiayuan Cao[2], Tim Priessnitz[1], Gennady Logvenov[1], Bernhard Keimer[1], Yuan Huang[7], Jan-Christoph Deinert[5], Sergey Kovalev[5], Tao Dong[6], Stefan Kaiser[1,3,4], and Hao Chu[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Shanghai Jiaotong University, Shanghai, China — [3]University of Stuttgart, Stuttgart, Germany — [4]Technical University Dresden, Dresden, Germany — [5]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [6]Peking University, Beijing, China — [7]Beijing Institute of Technology, Beijing, China

Superconductivity and a charge-density-wave (CDW) are often found as close neighbors in the thermodynamic phase diagram of many materials at low temperatures. A prototypical system showing the coexistence of the two orders is 2H-$NbSe_2$. Here, we coherently drive collective oscillations by terahertz radiation and report on third harmonic generation (THG) from both CDW amplitude oscillations and Higgs oscillations. We find the interaction between two orders leads to a Fano interference of THG signals, which displays as an out-of-phase interference in the time-domain. This we characterize as Higgs-CDW hybrid that can be controlled by the THz driving field. Additionally, a similar phenomenon manifestes in the underdoped cuprate $La_{2-x}Sr_xCuO_4$ ($x \sim 0.12$) under non-perturbative drive. As such non-linear THz drives of order parameter oscillations opening up possibilities of investigating intertwined orders in the future.

TT 3.6 Mon 10:45 HSZ 103

Clean-limit superconductivity at 197 K in high-pressure sulfur hydride — •Sam Cross[1], Israel Osmond[1], Owen Moulding[1], Takaki Muramatsu[1], Annabelle Brooks[1], Oliver Lord[2], Timofey Fedotenko[3], Jonathan Buhot[1], and Sven Friedemann[1] — [1]HH Wills Physics Laboratory, University of Bristol, UK — [2]School of Earth Sciences, University of Bristol, UK — [3]Photon Science, DESY, Germany

The search for room temperature superconductivity in hydrogen rich compounds has accelerated since the discovery of superconductivity in sulfur hydride, H_3S, in 2015 [1]. Controlled synthesis of hydrides remains a challenge, and further work on the formation pathways will prove vital in the search for room temperature superconductivity in such compounds. Here we confirm the synthesis of cubic $Im\bar{3}m$ H_3S by laser heating elemental sulfur and hydrogen donor ammonia borane, NH_3BH_3. Superconductivity is characterised using electrical transport measurements in a diamond anvil cell, confirming a transition temperature T_c = 197 K at 153 GPa, in agreement with previous studies. The coherence length extracted from measurements of the critical field H_{c2} together with estimations of the carrier mean free path from the normal state resistance suggest that H_3S follows clean-limit behaviour. The work further highlights the potential for in-situ synthesis of clean hydrides using ammonia borane, a more accessible synthesis alternative to pure hydrogen.

[1] A.P. Drozdov et al., Nature 525, 73 (2015)

TT 3.7 Mon 11:00 HSZ 103

Unraveling charge transfer to understand superconductivity in MgB_2 — •Simon Marotzke[1,2], Jan Oliver Schunck[1,3], Amina Alic[4], Octave Duros[4], Moritz Hoesch[1], Alessandro Nicolaou[5], Gheorghe Sorin Chiuzbaian[4], and Martin Beye[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [3]Universität Hamburg, Hamburg, Germany — [4]Sorbonne Université, Paris, France — [5]Synchrotron SOLEIL, Saint-Aubin, France

Magnesium diboride (MgB_2) holds the world-record for the highest transition temperature ($T_C = 39$ K) in a conventional Bardeen-Cooper-Schrieffer (BCS)-type, i.e., phonon-mediated, superconductor. The undoped electron configuration of MgB_2 is still disputed as contradicting results on the appearance of charge transfer upon crossing T_C have been reported. To settle this question, we conducted high-resolution resonant X-ray emission spectroscopy (XES) as well as X-ray absorption spectroscopy (XAS) measurements around the boron K-edge at the SEXTANTS beamline at the synchrotron SOLEIL. In order to investigate the charge transfer between in-plane and out-of-plane states, we varied the polarization of the incoming photons as well as the incidence and emission angle. We report on differences in the spectral intensity for both the absorption and emission spectra upon crossing T_C to be first indications of changes in the density of the boron $2p$ states. Complementary density of states calculations showing good agreement with the experimental data were performed.

15 min. break

TT 3.8 Mon 11:30 HSZ 103

Emergence of incipient superconductivity in CrB_2 under anisotropic strain — Alexander Regnat[1], •André Deyerling[1], Christoph Resch[1], Jan Spallek[1], Alfonso Chacon[1], Philipp G. Niklowitz[1,2], Andreas Bauer[1], Marc A. Wilde[1], and Christian Pfleiderer[1] — [1]Physik-Department, Technical University of Munich, D-85748 Garching, Germany — [2]Department of Physics, Royal Holloway, University of London, Egham TW20 0EX, UK

Resistivity studies of the hexagonal C32 diborides MoB_2[1], WB_2[2], and CrB_2[3,4] under ultra-high pressures of the order 100 GPa have recently revealed superconducting transitions, where the precise pressure conditions are unknown. We report a study of the electrical resistivity of the itinerant-electron antiferromagnet CrB_2 [5,6] under uniaxial, hydrostatic, and quasi-hydrostatic pressures up to 0.5 GPa, 2.2 GPa and 8 GPa, respectively. Tracking the magnetic transition temperature and the onset of incipient superconductivity we derive a phase diagram as a function of the ratio of lattice constants c/a. Supported by detailed electronic structure calculations, we suggest that the reduction of lattice constant c controls the suppression of magnetic order and concomitant emergence of superconductivity in CrB_2.

[1] C. Pei et al., arXiv:2105.13250 (2021)
[2] J. Lim et al., arXiv:2109.11521 (2021)
[3] C. Pei et al., arXiv:2109.15213 (2021)
[4] S. Biswas et al. arXiv:2211.01054 (2022)
[5] M. Brasse et al., PRB **88**, 155138 (2013)
[6] A. Bauer et al., PRB **90**, 064414 (2014)

TT 3.9 Mon 11:45 HSZ 103

Annealeing microstructured crystals of cuprate superconductor $Tl_2Ba_2CuO_{6-x}$ — •Ayanesh Maiti[1,2,3], Seunghyun Khim[1], Carsten Putzke[2], and Andrew P Mackenzie[1,3] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden — [2]Max Planck Institute for Structure and Dynamics of Matter, Hamburg — [3]University of St Andrews, Scotland

Cuprates exhibit a variety of interesting physics that is not well understood, ranging from unconventional superconductivity to strange metal behaviour. Past experiments have mostly focused on underdoped cuprates that have complex phases due to competing orders. Studies with overdoped samples were limited by the rarity of candidate materials and the difficulty to probe crystals with surface reconstructions. $Tl_2Ba_2CuO_{6-x}$ is a naturally overdoped cuprate that can be grown with high enough purity to show quantum oscillations, and we can suppress the effects of surface reconstructions by using focused ion beam (FIB) microstructuring techniques. However, FIB procedures remove oxygen from the crystal surface and introduces inhomogeneities in samples, making it hard to study their intrinsic behavior. We are developing annealing techniques to re-homogenize our microstructures, using measurements of the doping-dependent high-temperature resistivity to monitor their oxygen content. This will allow us to study the overdoped part of the cuprate phase diagram and hence improve our understanding of unconventional superconductivity. Our techniques will also enable studies with the full range of doping on a single specimen, eliminating sample-to-sample variations from future experiments.

TT 3.10 Mon 12:00 HSZ 103

Vortex matching at 6 T in $YBa_2Cu_3O_{7-\delta}$ by imprinting an ultradense hexagonal pinning array with focused helium ion irradiation — •Bernd Aichner[1], Lucas Backmeister[1], Max Karrer[2], Katja Wurster[2], Christoph Schmid[2], Reinhold Kleiner[2], Edward Goldobin[2], Dieter Koelle[2], and Wolfgang Lang[1] — [1]Fakultät für Physik, Universität Wien, Wien, Österreich — [2]Physikalisches Institut, Center for Quantum Science (CQ) and LISA$^+$, Universität Tübingen, Tübingen, Deutschland

The focused beam of a helium ion microscope (HIM) is used to locally suppress superconductivity in thin films of the prototypical copper-oxide superconductor $YBa_2Cu_3O_{7-\delta}$ (YBCO). In these pillar-shaped regions, the critical temperature T_c is reduced or entirely suppressed due to pair-breaking by point defects.

The narrow spacing of these nanopillars leads to vortex commensurability effects at high magnetic fields, which appear as pronounced maxima of the critical current and corresponding resistance minima. In accordance with the calculation, these effects appear at an unprecedented high magnetic field of 6 T in a hexagonal nanopillar lattice with 20 nm spacing. In contrast to previous observations, matching phenomena persist in the whole accessible temperature range, from the onset of superconductivity down to a temperature of 2 K. At the matching field, we observe a novel behavior in voltage-current isotherms, which we attribute to an ordered Bose glass phase. These results establish the HIM as a versatile platform for creating ultradense vortex pinning landscapes with complex designs in copper-oxide superconductors.

TT 3.11 Mon 12:15 HSZ 103

Quantum interference in a finite-width mesoscopic ring with superconducting vortices — Gian Paolo Papari[1,2,3] and •Vladimir M. Fomin[4,5] — [1]Dipartimento di Fisica, Università di Napoli “Federico II”, I-80126 Napoli, Italy — [2]CNR-SPIN, UOS Napoli, I-80126 Napoli, Italy — [3]Istituto Nazionale di Fisica Nucleare (INFN), Naples Unit, I-80126 Napoli, Italy — [4]Institute for Integrative Nanosciences (IIN), Leibniz IFW Dresden, D-01069 Dresden, Germany — [5]Moldova State University, MD-2009, Chişinău, Republic of Moldova

We analyze the origin of the parabolic background of magnetoresistance oscillations measured in finite-width superconducting mesoscopic rings with input and output stubs and in patterned films. The transmission model [1] explaining the sinusoidal oscillation of magnetoresistance is extended to address the background as a function of the magnetic field. Apart from the interference mechanism activated by the ring, pinned superconducting vortices as topological defects introduce a further interference-based distribution of supercurrents that affects, in turn, the voltmeter-sensed quasiparticles. The onset of vortices changes the topology of the superconducting state in a mesoscopic ring in a such a way that the full magnetoresistance dynamics can be interpreted owing to the interference of the constituents of the order parameter induced by both the ring itself and the vortex lattice in it.

[1] G. P. Papari and V. M. Fomin, Phys. Rev. B 105, 144511 (2022)

TT 3.12 Mon 12:30 HSZ 103

Frequency-locking effect in Nb open nanotubes — Igor Bogush[1,2], Oleksandr V. Dobrovolskiy[3], and •Vladimir M. Fomin[1,2] — [1]Institute for Integrative Nanosciences (IIN), Leibniz IFW Dresden, D-01069 Dresden, Germany — [2]Department of Theoretical Physics, Moldova State University, MD-2009 Chişinău, Republic of Moldova — [3]University of Vienna, Faculty of Physics, Nanomagnetism and Magnonics, Superconductivity and Spintronics Laboratory, 1090 Vienna, Austria

We study alternating voltage generation in Nb open nanotubes under weakly modulated transport current and magnetic field by numerically solving the time-dependent Ginzburg-Landau equation [1]. Under stationary currents and fields, as a rule, an alternating voltage with a fixed frequency is generated in the nanotube. The frequency is associated with the period of the vortex nucleation at the nanotube edges. If the transport current is modulated by a weak ac component with a frequency close to the nucleation frequency, we reveal the effect of frequency-locking of the vortex nucleation, i.e., the nucleation frequency becomes equal to the external frequency of the modulated transport current. The frequency-locking width is discussed as a function of the modulation depth. Its sensitivity to the magnetic field variation opens up opportunities for the experimental examination of the effect.

[1] I. Bogush and V. M. Fomin, Phys. Rev. B 105, 094511 (2022)

TT 3.13 Mon 12:45 HSZ 103

Superconductivity in curved 3D nanoarchitectures —
•Vladimir M. Fomin[1,2] and Oleksandr V. Dobrovolskiy[3] — [1]Institute for Integrative Nanosciences (IIN), Leibniz IFW Dresden, D-01069 Dresden, Germany — [2]Laboratory of Physics and Engineering of Nanomaterials, Department of Theoretical Physics, Moldova State University, MD-2009 Chişinău, Republic of Moldova — [3]University of Vienna, Faculty of Physics, Nanomagnetism and Magnonics, Superconductivity and Spintronics Laboratory, 1090 Vienna, Austria

In recent years, superconductivity and vortex matter in curved 3D nanoarchitectures have turned into a vibrant research avenue because of the rich physics of the emerging geometry- and topology-induced phenomena and their prospects for applications in (electro)magnetic field sensing and information technology. We outline the experimental techniques capable of the fabrication of curved 3D nanostructures and present a selection of own results on the intertwined dynamics of screening superconducting currents, Abrikosov vortices and slips of the phase of the superconducting order parameter therein. We share our vision regarding the prospect directions and current challenges in this research domain, arguing that curved 3D nanoarchitectures open a new dimension in superconductors research and possess great potential for magnetic field sensing, bolometry, and fluxonic devices [1].

[1] V. M. Fomin, O. V. Dobrovolskiy, Appl. Phys. Lett. 120, 090501 (2022)