TT 30: Superconductivity: Poster Session

By tradiiton the poster sessions in the Low Temperature Physics ivision are long (3-4 hours). Since temporal overlap with interesting oral sessions cannot be completely avoided, we suggest the poster presenters to leave a note at their posters indicating when they would be available for discussion.

Time: Thursday 15:00–18:00 Location: P1

TT 30.1 Thu 15:00 P1

Optimization of single-crystal growth of Fe(Se,S) — •Maik Golombiewski, Teslin Rose Thomas, N. S. Sangeetha, Andreas Kreyssig, and Anna E. Böhmer — Lehrstuhl für Experimentalphysik IV, Fakultät für Physik und Astronomie, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

The iron-based superconductor FeSe and its substitution series Fe(Se,S) have been studied intensively for over a decade. Large (mm-sized) homogeneous single crystals are highly desirable for the accurate characterization of this material. An effective technique to grow Fe(Se,S) single crystals is chemical vapor transport with Cl-salts. However, the sulfur substitution makes the growth of large single crystals harder the higher the substitution percentage is.

We examine which parameters have an influence on the size and homogeneity of our Fe(Se,S) single crystals, namely furnace tilt, quartz ampoule dimensions and form, starting material preparation and temperature gradient. The composition of the single crystals is analyzed with a scanning electron microscope and properties are characterized by resistance measurements as well as x-ray diffraction experiments.

We find that we can consistently grow single crystals with masses ranging from 3 mg to more than 10 mg, depending on S-content. Other types of chemical substitution are explored.

TT 30.2 Thu 15:00 P1

Magnetic order in transition-metal doped $CaKFe_4As_4$ and the interplay with superconductivity — •Andreas Kreyssig — Institute for Experimental Physics 4, Ruhr-Universität Bochum, 44801 Bochum, Germany — Ames Laboratory, U.S. DOE, and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

$CaKFe_4As_4$ is an iron arsenide superconductor in which partial substitution of Fe by a transition metal shifts the ground state from superconducting to antiferromagnetically ordered. The magnetic structure is a hedgehog spin-vortex crystal arrangement within the Fe planes. This magnetic order is different from the stripe-type spin density wave observed in other iron arsenide superconductor, however, related to the same entangled propagation vectors based on Fermi-surface nesting. In this presentation the determination of the magnetic order will be reviewed and the interplay of the magnetism with superconductivity will be discussed in detail.

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TT 30.3 Thu 15:00 P1

Feedback of non-local d_{xy} nematicity on the magnetic anisotropy in FeSe — •Steffen Bötzel and Ilya Eremin — Institut für theoretische Physik III, Ruhr-Universität Bochum, Bochum, Germany

Details of the nematic state in FeSe and its connection to superconductivity are still a matter of debate. We analyze theoretically the magnetic anisotropy in this state by computing the spin and the orbital susceptibilities from a microscopic multiorbital model. In particular, we consider both the xz/yz and the recently proposed non-local xy nematic ordering. The latter is believed to have a significant impact on the bandstructure and to force a Lifshitz transition. Its inclusion could play a crucial role in reproducing the experimentally measured temperature dependence of the magnetic anisotropy. This provides a direct fingerprint of the different nematic scenarios on the magnetic properties of FeSe.

TT 30.4 Thu 15:00 P1

Microscopic theory of the multi-orbital FFLO phase in the iron-based superconductors — •Luka Jibuti and Ilya Eremin — Institute für Theoretische Physik III, Ruhr-Universität Bochum, D-44801 Bochum, Deutschland

We study the superconducting Frude-Ferrel-Larnik-Ovchinnikov (FFLO) phase, a superconducting phase, where Cooper pairs having non-zero center-of-mass momentum $\vec{q}$, in iron-based superconductors. We develop a microscopic theory model considering two Γ-centered hole pockets created by xz and yz orbitals. We write the low energy effective Hamiltonian of the form $\hat{H} = \hat{H}_0 + \hat{H}_{int}$, where the first term includes the kinetic therm, the $\vec{k}$-independent spin orbit coupling and the Zeeman field. We introduce the superconducting pairing between fermions in xz and yz orbitals and we restrict ourselves with the interactions which lead to the inter-band pairing of Cooper pairs. Writing the system Hamiltonian initially in orbital basis allowes us to observe the changes of the orbital weights at the Fermi energy when making the transition from Normal to FFLO phase and pinpoint the direction and value of the center-of-mass momentum $\vec{q}$ that connects particles within the same orbital. From the mean field calculations for magnetic field just above the Pauli limit and for temperatures close to absolute zero, we are able to observe that $\pm\vec{q}$ vectors connect particles within yz and xz orbitals respectively. We also observe that $\vec{q}$ is highly dependent on the magnetic field and temperature, and the increase of the SOC constant destroys the FFLO phase.

TT 30.5 Thu 15:00 P1

In search of the superconducting symmetries of $CeRh_2As_2$ — •Fabian Jakubczyk[1,2], Julia M. Link[1,2], and Carsten Timm[1,2] — [1]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

Multiphase unconventional superconductivity is a rare phenomenon, which has recently been discovered in the heavy-fermion compound $CeRh_2As_2$. Here, the transition between two distinct superconducting phases occurs as a function of magnetic field applied along the c axis.At $\mu_0 H^* \approx 4\,\mathrm{T}$ the superconductor changes from a low-field to a high-field state with a large critical field of $\mu_0 H_{c2} = 14\,\mathrm{T}$. However, for in-plane fields only the low-field phase appears, with $\mu_0 H_{c2} = 2\,\mathrm{T}$. Furthermore, at $T_0 \approx 0.4\,\mathrm{K}$ a transition to a suggested quadrupole-density-wave state was reported, whilst the low-field superconducting state is reached at $T_c = 0.26\,\mathrm{K}$. Intriguingly, this quadrupole-density-wave state seems to be suppressed by a c axis field of about H^*, such that the low-field phase lies within it, whereas the high-field state does not. It seems reasonable to assume that the change of superconducting properties might be triggered by the disappearing density-wave state. In order to analyze this and other possible scenarios, we first conduct a symmetry analysis of the locally noncentrosymmetric $CeRh_2As_2$. Moreover, we construct a Landau-type energy functional including the superconducting and density-wave order parameters, as well as the applied magnetic field. From this we can give a statement about the potential symmetries of the superconducting phases.

TT 30.6 Thu 15:00 P1

Ising superconductors: the signatures of triplet pairings in the density of states and vanishing of the "mirage" gap — •Sourabh Patil[1], Gaomin Tang[2], and Wolfgang Belzig[1] — [1]Universität Konstanz, Konstanz, Germany — [2]University of Basel, Basel, Switzerland

The conventional 2D superconductors are governed by the critical in-plane magnetic field above which the superconductivity is destroyed. Monolayer transition-metal dichalcogenides lack inversion symmetry and along with a strong spin-orbit coupling, lead to valley-dependent Zeeman-like spin splitting. This is the Ising spin-orbit coupling (ISOC) which then lifts the degeneracy of the two valleys and enhances the in-plane critical magnetic field. The finite energy pairings are thus obtained in such systems. The main superconducting gap-like feature shifted to finite energy is observed and termed a mirage gap.

The triplet pairings are introduced by the applied field. The equal-spin triplet pairing is always coupled to the singlet pairing, reflected in the self-consistent equations. Importantly, as the applied field is increased, we observe that the mirage gap closes (vanishes) and reopens. We obtain a phase diagram for such vanishing of the mirage gap in the 3D parameter space of the applied field, temperature, and the critical triplet temperature, for a fixed ISOC. The role of topology in such a mirage gap closing and any observable physical effects on the superconductivity would be our topic of study.

[1] G. Tang et. al., Phys. Rev. Lett. 126, 237001 (2021)
[2] M. Kuzmanović et. al., arXiv:2104.00328 (2021)

TT 30.7 Thu 15:00 P1

Time-reversal symmetry breaking in the superconducting state of ScS — •Arushi Arushi[1,2], Roshan Kumar Kushwaha[1], Deepak Singh[3], Adrian Hillier[3], Mathias S Scheurer[4], and Ravi Prakash Singh[1] — [1]Indian Institute of Science Education and Research Bhopal, Bhopal, India — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [3]ISIS Facility, STFC Rutherford Appleton Laboratory, Didcot, United Kingdom — [4]Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria

The study of unconventional superconductors, which go beyond the BCS theory, is a crucial pillar of modern condensed-matter research and it is driven by the potential of these superconductors for applications and by fundamental scientific question, such as understanding their pairing mechanism. For the latter, time reversal-symmetry-breaking superconductivity might be particularly interesting since it is rare in nature and the underlying pairing mechanism must involve more than the conventional electron-phonon coupling. In this regard, we studied the superconducting state of ScS(rocksalt structure) using macroscopic and microscopic measurements such as muon spin rotation/relaxation(μSR). All the performed measurements confirmed the bulk superconductivity at 5.1(1) K. Specific heat together with transverse-field μSR measurements indicate a full gap, while our zero-field μSR study reveals the presence of spontaneous static or quasi-static magnetic fields emerging when entering the superconducting state. We discuss various theoretical possibilities of pairing mechanisms, hint towards an unconventional superconducting state in ScS.

TT 30.8 Thu 15:00 P1

Topological phase transition away from the Fermi surface in multiband superconductors — •Masoud Bahari[1], Song-Bo Zhang[2], Chang-An Li[1], Carsten Timm[3], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany — [2]Department of Physics, University of Zurich, Winterthurerstrasse 190, 8057, Zurich, Switzerland — [3]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

We demonstrate theoretically that odd-parity multiband superconductors with inversion symmetry host dispersive topological surface states induced solely by interband pairing away from the Fermi surface. The normal state requires to have at least a pair of energy bands with different effective masses. In this regard, spin-orbit coupling is a key ingredient. The topological phase transition occurs between electrons with different quantum numbers at finite excitation energies. Such phase transition happens at direction where the inter- and intraband electron pairings are finite and vanishing at the same time. To capture the underlying physics, we develop a generic theory in the interband representation of Bogoliubov-de Gennes Hamiltonian. We apply our theory to j=3/2 systems and we discuss the pairing channels hosting such surface states.

TT 30.9 Thu 15:00 P1

Majorana flat bands at structured surfaces of nodal noncentrosymmetric superconductors — •Clara Johanna Lapp and Carsten Timm — Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

Surfaces of nodal noncentrosymmetric superconductors can host flat bands of Majorana modes, which provide a promising platform for quantum computation if one can find methods for manipulating localized Majorana wave packets. We study the fate of such flat bands when part of the surface is subjected to an exchange field induced by a ferromagnetic insulator. Exact diagonalization is used to find the eigenstates and eigenenergies of the Bogoliubov-de Gennes Hamiltonian of a model system, for which an exchange field is applied along a strip on the surface of a slab. Moreover, we discuss a setup with a small exchange field applied to the previously field-free strip with the goal of introducing a linear dispersion. By switching this dispersion on and off, a wave packet could be moved in a certain direction. We find that in our model system, a linear dispersion can indeed be achieved. The qualitative features of this dispersion can be predicted from the momentum-dependent spin polarization of the field-free surface.

TT 30.10 Thu 15:00 P1

Piezoelectric control of the electrical field-effect in superconductors — •Leon Ruf, Sara Khorshidian, Sohaila Noby, Jennifer Koch, Elke Scheer, and Angelo Di Bernardo — Department of Physics, University of Konstanz, Konstanz, Germany

Superconducting (sc) transistors are promising building blocks for future superconductors by virtue of their low energy consumption. For real applications this requires devices with Complementary metal-oxide-semiconductor (CMOS) compatibility, high switching speed and high scalability. Some realizations of superconductor/semiconductor hybrid systems, such as Nanocryotrons (nTrons) [1] or thermal driven sc-nanowires (hTron) [2] have already been put forward. An alternative promising architecture are gate-controlled sc devices. Reversible switching via gate-controlled sc-transistors (EF-Trons) has been independently seen for various BCS superconductors, such as Ti [3] and V [4]. Still the physical effect of the EF-Trons is not fully understood and is under debate [5]. By coupling epitaxial piezo-/ferroelectrics to the EF-Trons, we investigate the role of strain and amplification of the electric field through these materials on the switching behavior. We present first results of the growth of epitaxial piezo-/ferroelectrics and characterization of EF-Trons coupled with piezo-/ferroelectrics.

[1] A. N. McCaughan et al., Nano Lett. 14, 5748 (2014)
[2] A. N. McCaughan et al., Nat. Electron. 2, 451 (2019)
[3] G. De Simoni et al., Nat. Nanotechnol. 13, 802 (2018)
[4] F. Paolucci et al., AVS Quantum Sci. 1, 016501 (2019)
[5] I. Golokolenov et al., Nat. Commun. 12, 2747 (2021)

TT 30.11 Thu 15:00 P1

Gate effect on superconducting metal and metal oxide-based nanodevices — •Sohaila Mohammed, Sara Khorshidian, Angelo di Bernardo, and Elke Scheer — Physics Department, University of Konstanz

Quantum devices based on superconducting materials provide various technological applications, such as e.g. current limiters, electronic filters, routers, digital receivers, and photon detectors. The recent discovery of the reversible modulation of the superconducting critical current (I_c) in nanowires and Dayem bridges under the application of a gate voltage has raised a lot of interest for the possible application of this phenomenon towards the realization of superconducting logic devices. The threshold voltages necessary for the full suppression of I_c, however, remain high and correspond to an electrostatic field of $\sim$ 4 MV/cm. Also, the physical origin of the effect remains controversial. To better understand the mechanism responsible for the suppression of I_c and to determine the physical parameters that can be useful to reduce the high electrostatic fields currently needed for the switching, we have performed a systematic investigation of gate-controlled superconducting devices made of different metal and metal-oxide superconductor materials. We report on our findings and discuss the physical parameters relevant to assess the performance of gate-controlled superconducting devices including their maximum operational temperature, kinetic inductance, leakage currents and switching voltages.

TT 30.12 Thu 15:00 P1

Gate-voltage mediated supercurrent suppression in a superconducting nano-bridge — •Subrata Chakraborty, Danilo Nikolic, and Wolfgang Belzig — Fachbereich Physik, Universität Konstanz, D-78467 Konstanz, Germany

Voltage-gated supercurrent suppression in a superconducting nano-bridge is a hot topic for research in present days. Recent experiments on this effect demonstrate a sudden supercurrent suppression in the bridge with high gate-voltage [1-6]. The microscopic understanding of this is not settled till now. According to the experimental researches, there are three distinct tentative mechanisms, which could be responsible for this event. These mechanisms suggest that at high gate voltage there could be either a direct surface-pair breaking-induced phase transition, superconductivity suppression with induced nonequilibrium phonon distribution due to Joule heating in the gate or supercurrent suppression due to nonequilibrium electronic quasiparticles via a direct small leakage current. In our work, we theoretically investigate the role of gate-voltage induced surface-pair breaking on the supercurrent suppression of superconducting nano-bridge. We speculate this work would present some generic theoretical predictions of this effect allowing to further test it experimentally.

[1] M. Rocci *et al.* *ACS Nano*, **14**, 12621 (2020)
[2] I. Golokolenov *et al*, *Nat. Commun.*, **12**, 2747 (2021)
[3] L.D. Alegria *et al.*, *Nat. Nanotechnol.*, **16**, 404 (2021)

TT 30.13 Thu 15:00 P1

Tunable superconducting single electron transistors: from weak to strong-coupling regime — •Oliver Irtenkauf[1], Laura Sobral-Rey[1], David Ohnmacht[1], Wolfgang Belzig[1], Jens Siewert[2], and Elke Scheer[1] — [1]Univ. Konstanz — [2]Univ. del Pais Basque, Bilbao, Spain

An island coupled to two leads and a gate forms a single electron transistor (SET) that shows Coulomb blockade (CB). All-superconducting SETs have shown to enable a multitude of possible charge transport processes, not all of them are well understood [1], in particular in the strong-coupling regime [2]. The conceptually simpler SSN-SET reduces the number of possible processes. We study a device consisting of a S island coupled to a N lead via an oxide tunnel barrier, and to a S lead with a mechanically controlled break junction (MCBJ). Via the MCBJ, different coupling regimes can be studied from a tunnel contact to a point contact [2]. For weak coupling, our experimental findings in the N state can be understood in terms of the Orthodox Theory of CB [3,4]. For stronger coupling, we observe Andreev and Josephson transport as well as, in the N state, a renormalization of the charging energy [5,6]. We describe our experimental results in the S state with simulations based on a generalized master equation approach [7].

[1] J.M. Hergenrother et al., PRL 72, 1742 (1994)
[2] T. Lorenz et al., JLTP 191, 301 (2017)
[3] D. V. Averin, K. K. Likharev, JLTP 62, 345 (1986)
[4] H. Grabert, M. H. Devoret, NATO Sci. Ser. B, 294 (1992)
[5] P. Joyez et al., PRL 79, 1349 (1997)
[6] S. Jezouin et al., Nature 536, 58 (2016)
[7] J. Siewert, G. Schön, PRB 54, 7421 (1996)

TT 30.14 Thu 15:00 P1

Interplay between charging effects and superconducting transport in a tunable SET — •David Christian Ohnmacht[1], Laura Sobral Rey[1], Jens Siewert[2], Wolfgang Belzig[1], and Elke Scheer[1] — [1]Universität Konstanz, Konstanz, Deutschland — [2]University of the Basque Country, Bilbao, Spain

All-superconducting single electron transistors (SSS-SETs) have shown to enable a multitude of possible charge transport processes which are not well understood, in particular in the strong-coupling regime [1]. To disentangle these processes, the conceptually simpler (SSN)-SET, which has never been investigated experimentally before is considered [2]. Electron tunneling, Cooper pair tunneling and (multiple) Andreev reflection ((M)AR) are possible in the S-S mechanically controlled break junction (MCBJ) which can be adjusted to cover all coupling regimes: from a tunnel contact to a point contact with a small number of highly transmissive transport channels. The experimental data is compared to theoretical results obtained by using a master equation approach, including the rates of different transport mechanisms [3]. In order to account for MAR, we include the rates for the individual processes which are obtained from the theory of full counting statistics into the master equation framework [4]. The rates for MAR are computed using transmission probabilities according to the experimental data taking into account the presence of multiple transport channels. The limits of this master equation approach for a SSN-SET with a MCBJ are discussed in detail. Finally, it is shown that the charging energy decreases as the coupling of the MCBJ increases.

TT 30.15 Thu 15:00 P1

Preparation of Nb/MnSi heterostructures — •Julius Grefe[1], Rodrigo de Vasconcellos Lourenço[2], Markus Etzkorn[2,3], Stefan Süllow[1], and Dirk Menzel[1,3] — [1]IPKM, TU Braunschweig, Germany — [2]IAP, TU Braunschweig, Germany — [3]LENA, TU Braunschweig, Germany

Motivated from theoretical predictions [1], the preparation of Nb/MnSi heterostructures, which are candidates for the usage as superconducting spin valves, is introduced. The substrates are obtained by cutting oriented Triarc-Czochralski grown MnSi single crystals into thin disc-shaped wafers. The surfaces of these substrates are prepared by various polishing steps, wet chemical etching, Ar sputtering and thermal annealing. After these processes the surfaces have been investigated by AFM and TEM and show surface roughnesses in the order of 1 nm. In order to investigate proximity effects between the chiral magnet MnSi and a superconductor we have deposited onto the substrates thin Nb films using molecular beam epitaxy. These heterostructures have been investigated in terms of magnetoresistivity measurements.

[1] N. G. Pugach et al., Appl. Phys. Lett. **111**, 162601 (2017)

TT 30.16 Thu 15:00 P1

Orientation-dependent magnetoresistance of Nb/MnSi heterostructures — •Philip Schröder[1], Julius Grefe[1], Stefan Süllow[1], and Dirk Menzel[1,2] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, TU Braunschweig, Germany

During high-resolution four probe (magneto-)resistivity measurements the reliability of the data strongly depends on the contacts' characteristics. If a vector magnet is not available the change of the sample orientation with respect to the field always requires demounting, reorientation and recontacting of the sample. We have measured the resistivity of a superconducting Nb thin film deposited on a helimagnetic MnSi substrate as function of the angle between the surface and the external magnetic field. In order to maintain the same four-probe configuration without recontacting an experimental setup has been developed allowing 720° sample rotation in a homogeneous field up to 1.1 T. The setup is used to accurately investigate the shift due to the proximity effect of the critical temperature T_c of the Nb film in contact to a magnetic system exhibiting a non-collinear spin structure. We show that the spin-helix orientation of the MnSi substrate is able to tune the T_c of Nb so that this heterostructure can be used as a two-component superconducting spin valve.

TT 30.17 Thu 15:00 P1

Decoupling of $NbSe_2$ monolayers in tailored SnSe-based multilayers — •O. Chiatti[1], K. Mihov[1], T. Griffin[1], C. Grosse[1], M. B. Alemayehu[2], K. Hite[2], D. Hamann[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

Van-der-Waals superlattices with two-dimensional (2D) superconducting layers of a transition-metal dichalchogenide (TMD) embedded between other materials have received a lot of attention [1]. Here, we examine the coupling between the $NbSe_2$ monolayers in $[(SnSe)_{1+\delta}]_m[NbSe_2]$ ferecrystals [2]. m is an adjustable parameter to control the spacing between $NbSe_2$ layers and tune the inter-layer coupling, with a crossover from 3D to 2D superconductivity. The electric transport shows three regions: I. for $m = 1 - 4$ the films resemble "good" metals and 3D anisotropic superconductors, with inter-layer coupling enhanced by proximity effect in the SnSe layers and charge transfer from $NbSe_2$ to SnSe; II. for $m = 5 - 9$ the films are "dirty" metals and 3D anisotropic superconductors, with inter-layer coupling reduced by disorder and smaller charge transfer; III. for $m > 9$ they are "bad" insulators and a stack of disordered quasi-2D superconductors, with Josephson coupling between $NbSe_2$ monolayers.

[1] A. Devarakonda *et al.*, Science **370**, 231 (2020)
[2] M. Trahms *et al.*, Supercond. Sci. Technol. **31**, 065006 (2018)

TT 30.18 Thu 15:00 P1

Spin-orbit effects in the vortex inductance of Al/InAs heterostructures — •Jaydean Schmidt, Lorenz Fuchs, Denis Kochan, Maximillian Ufer, Simon Reinhardt, Michael Prager, Matthias Kronseder, Dominique Bougeard, Nicola Paradiso, and Christoph Strunk — University of Regensburg (Germany)

In this work, we demonstrate the interplay of spin-orbit interaction and in-plane magnetic field in synthetic Rashba superconductors. We investigate the vortex inductance of epitaxially grown Al/InAs heterostructures containing an high-mobility surface-near InAs quantum well covered with a epitaxial layer of aluminum. An AC-current drives vortex oscillations around pinning centers which can be probed via inductance. The vortex inductance was found to be orders of magnitude larger than the kinetic inductance. When applying an in-plane field, the vortex inductance drops in particular for $B_{\|} \perp I_{AC}$ signaling an increase of the pinning force. With respect to the angle between magnetic field and ac-current, a prominent two-fold anisotropy is observed. The unusual behavior of the vortex inductance signals a deformation of the vortex cores and can be theoretically explained by introducing an additional term in the Ginzburg-Landau free energy of a superconductor, resulting from the Rashba spin-orbit interaction [1].

[1]L. Fuchs et al., arXiv: 2201.02512

TT 30.19 Thu 15:00 P1

Generalising Beenakker equation to take into account evanescent modes — •Daniel Kruti and Roman-Pascal Riwar — Institute for Theoretical Nanoelectronics (PGI-2), Jülich Research Centre and Institute for Theoretical Physics, University of Cologne

Superconductor–normal-metal–superconductor Josephson junctions have been examined extensively in past years. In particular, the case where the normal region is modelled by an ideal normal conductor with an intermittent scattering region can be well described by the celebrated Beenakker equation. Strictly speaking however, this equation is applicable only in the asymptotic plain wave limit, neglecting evanescent modes. However, the situation is changing by recent experimental advances. First, conductor regions are now fabricated with significantly decreased impurity scattering, leading to situations where scattering is dominated by the junction geometry. Second, miniaturisation is advancing such that evanescent modes should no longer be neglected. While this regime has already been captured by numerical methods, we here strive for an explicit analytical treatment, and generalise the Beenakker equation to short junctions with geometric scattering.

TT 30.20 Thu 15:00 P1

Controlling the Critical Current in Ferromagnetic Josephson-Junctions by Magnetization and Microwave Irradiation — •Lukas Kammermeier, Andreas Bloch, Oliver Irtenkauf, and Elke Scheer — Universität Konstanz, Konstanz, Germany

A key building block in superconducting spintronics is a controllable superconducting device that accomodates long-ranged triplet currents [1]. It has been suggested to create long range triplets with the help of ferromagnetic resonance in superconductor-ferromagnet-superconductor (SFS) structures made of conventional s-wave superconductors [2]. Here we explore this possibility by studying the electronic transport in SFS junctions in different geometries and realizations of the F spacer, subject to microwave irradiation, with spin injection and as function of the magnetization state of the ferromagnet. We show that we can manipulate the critical current of overdamped S-S/F-S proximity junctions by several percent by flipping a single domain in the ferromagnet. First results on spin injection will be presented.

[1] J. Linder, W. A. Robinson, Nat. Phys. 11, 307 (2015)
2] S. Takahashi, S. Hikino, M. Mori, J. Martinek, S. Meakawa, Phys. Rev. Lett. 99, 057003 (2007)

TT 30.21 Thu 15:00 P1

A Ballistic Graphene Cooper Pair Splitter — Preeti Pandey[1], Romain Danneau[2], and •Detlef Beckmann[2] — [1]Institute of Nanotechnology, Karlsruhe Institute of Technology, D-76021 Karlsruhe, Germany — [2]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, D-76021 Karlsruhe, Germany

We report an experimental study of a Cooper pair splitter based on ballistic graphene multiterminal junctions. In a two transverse junction geometry, namely the superconductor-graphene-superconductor and the normal metal-graphene-normal metal, we observe clear signatures of Cooper pair splitting in the local as well as nonlocal electronic transport measurements. Our experimental data can be very well described by our beam splitter model. These results open up possibilities to design new entangled state detection experiments using ballistic Cooper pair splitters.

[1] Phys. Rev. Lett. 126, 147701 (2021)

TT 30.22 Thu 15:00 P1

Coupling of supercurrent and quasiparticle excitations in superconductor nanostructures — •Paul Maier and Detlef Beckmann — Institut für Quantenmaterialien und Technologien, Karlsruher Institut für Technologie

We report on the experimental observation of coupling between nonequilibrium modes of the quasiparticle excitations in thin superconducting films in the presence of supercurrent and high parallel magnetic fields. The coupling is due to a difference in the number of available quasiparticle states, depending on their relative propagation direction to the supercurrent. Recently the occurrence of a spin-energy (spin-antisymmetric charge imbalance) current in the presence of energy imbalance was predicted [1]. Here the resulting spin-energy imbalance for a spatial gradient in the energy imbalance was probed in nonlocal conductance measurements with spectral resolution. The measurements show excellent agreement with numerical models and provide proof of the coupling of energy and spin-energy modes.

[1] F.Aikebaier et al., Phys. Rev. B 98, 024516 (2018)

TT 30.23 Thu 15:00 P1

Bloch oscillation effects in ultrasmall Josephson junctions embedded in high-inductance environment — •Fabian Kaap and Sergey Lotkhov — Physikalisch-Technische Bundesanstalt, Bundesallee 100 38116, Deutschland Braunschweig

The adiabatic transport of Cooper pairs, also known as Bloch oscillations(BO), can be of high interest in future applications for metrology, due to the fundamental current-to-frequency relation, $I_\mathrm{B} = 2e \times f_\mathrm{B}$. In order for the BO in ultrasmall Josephson junctions to be observed, one has to suppress the quantum fluctuations of charge by means of embedding the junctions into a high impedance environment.

For this purpose, we elaborated a dedicated inductively-resistive planar biasing circuit, which includes high-kinetic-inductance meanders made from granulated aluminium and high-ohmic microstrips of partially oxidized titanium. Using this approach, we were able to measure the characteristic back-bending in an IV-curve of a dc-biased SQUID with Josephson junction of sub-100nm-sizes. By varying the ratio of the Josephson energy E_J and the charging energy E_C, using an external magnetic field, we were able to manipulate the shape of the IV-curves back-bending, which can be explained by a modification of the lowest Bloch energy band of Cooper pairs. With this biasing technique the way is paved to circumvent the microwave coupling issues hindering the realization of dual Shapiro step experiments.

TT 30.24 Thu 15:00 P1

Superconductor-insulator transition in ultra-thin granular aluminum films — •Thomas Huber[1], Aviv Moshe[2], Guy Deutscher[2], and Christoph Strunk[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, Regensburg, Germany — [2]Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

The relation between homogenously disordered and granular superconductors is so far not clearly understood. In particular, the existence of highly insulating states in grAl has yet not been demonstrated. Here we investigate ultra-thin grAl films in the truely 2D limit and find a superconducting transition for sample S with $R_\square(4K) \approx 3k\Omega$ and insulating behavior for sample I with $R_\square(4K) \approx 7.75k\Omega$ (d-SIT). By increasing the perpendicular magnetic field we drive both samples (deeper) into the insulating regime (B-SIT), where we find activated behavior in a temperature range $T^*(B) < T < \approx 800mK$. For $T < T^*$ and $B < \approx 1T$, the R(T) curves saturate, indicating an intermediate anomalous metallic state [1] on both sides of the SIT [2]. The resistance $R_\square$, the activation energy E_A and the threshold voltage V_T depend on magnetic field and show strong similarities to the behavior of both regular Josephson junction arrays [3] and homogenously disordered films [4].

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