TT 34: Superconductivity: Heterostructures

Time: Tuesday 11:15–13:00 Location: HSZ 201

Invited Talk TT 34.1 Tue 11:15 HSZ 201

Giant Thermopower in the Emerging Field of Super-Spintronics — •Matthias Eschrig — Department of Physics, Royal Holloway, University of London, Egham, Surrey TW20 0EX, United Kingdom

Thermoelectric effects in metals and superconductors are usually negligibly small as they require a strongly asymmetric density of states. Thus, relatively little attention has been paid to these effects so far in the new emerging field of super-spintronics. This field combines the advantages of control of spin as basic principle in spintronics with that of macroscopic quantum interference, a hallmark of superconductivity. At the same time, non-local transport has been studied during the past decade in connection with so-called crossed Andreev reflection in a number of pivotal experiments. I will discuss how the idea of non-local transport has been generalised to include thermal currents in superconducting spintronics devices [1]. Surprisingly, it turns out that a dramatic enhancement of thermoelectric effects can be achieved when combining spin-dependent scattering phases with spin-filtering effects in superconductor-ferromagnet heterostructures. Thermopowers of the order of 100 μV/K can be achieved. We study a non-local setup with three terminals (two ferromagnetic, one superconducing), and show that a nonlocal version of the Onsager symmetry relations holds. We calculate all thermodynamic coefficients in diffusive as well as ballistic structures, and include non-equilibrium distribution functions as well as singlet-triplet mixing in the superconducting region.

[1] P. Machon, M. Eschrig, W. Belzig, PRL **110**, 047002 (2013).

TT 34.2 Tue 11:45 HSZ 201

Giant thermoelectric effects in proximity-coupled superconductor-ferromagnet devices — •Peter Machon[1], Matthias Eschrig[2], and Wolfgang Belzig[1] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]SEPnet and Hubbard Theory Consortium, Department of Physics, Royal Holloway,
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The usually negligibly small thermoelectric effects in superconducting heterostructures can be boosted dramatically due to the simultaneous effect of spin-dependent scattering and spin-filtering [Phys. Rev. Lett. **110**, 047002 (2013)]. Using that principle, we propose realistic setups to measure the local thermoelectric effects combining superconducting and ferromagnetic elements. We find that a thermopower $\sim 100\mu V/K$ can be achieved if the setup allows to drain the thermal current. For applications in nano-cooling we show that the figure of merit can exceed one for realistic parameters at low temperatures.

Due to crossed Andreev reflections and coherent electron transfer, three terminal structures also provide nonlocal thermoelectricity, here discussed in clean and in disordered structures. Our results show that a nonlocal version of the Onsager's reciprocity relation holds in a three terminal quantum coherent device.

TT 34.3 Tue 12:00 HSZ 201

Features and functionalities of superconducting hybrids with mixed singlet and triplet states — •Pablo Burset[1], Felix Keidel[1], Yukio Tanaka[2], Naoto Nagaosa[3], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany — [2]Department of Applied Physics, Nagoya University, Nagoya, 464-8603, Japan — [3]Department of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan

We propose a model for a superconductor where both spin-singlet and triplet pairing amplitudes can coexist. By solving the Bogoliubov-de Gennes equations with a general pair potential that accounts for both spin states we study experimental signatures of normal metal and superconductor hybrids. The interplay between the spin-singlet and triplet correlations manifests in the appearance of two effective gaps. This double gap structure can be detected in the conductance of an isolated normal-superconductor junction. Interestingly, depending on which spin state is dominant, the conductance presents a conventional gap structure or an unconventional zero-bias peak. The form of the Andreev bound states formed at a short ballistic Josephson junction strongly depends on the spin state of the pairing amplitude at each superconductor. The periodicity of the current flowing through the junction changes for a dominant singlet or triplet pairing. Remarkably, for an arbitrary mix of the spin states, the Josephson current can be spin polarized for a certain range of the phase difference between the superconductors.

TT 34.4 Tue 12:15 HSZ 201

Proximity effect in superconductor/conical magnet/ferromagnet heterostructures — •Daniel Fritsch and James F. Annett — H. H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, United Kingdom

At the interface between a superconductor and a ferromagnetic metal spin-singlet Cooper pairs can penetrate into the ferromagnetic part of the heterostructure with an oscillating and decaying spin-singlet Cooper pair density. However, if the interface allows for a spin-mixing effect, equal-spin spin-triplet Cooper pairs can be generated that can penetrate much further into the ferromagnetic part of the heterostructure, known as the long-range proximity effect [1]. Here, we present results of spin-mixing based on self-consistent solutions of the microscopic Bogoliubov-de Gennes equations incorporating a tight-binding model. In particular, we include a conical magnet into our model heterostructure to generate the spin-triplet Cooper pairs and analyse the influence of conical and ferromagnetic layer thickness on the unequal-spin and equal-spin spin-triplet pairing correlations. It will be shown that, in agreement with experimental observations, a minimum thickness of the conical magnet is necessary to generate a sufficient amount of equal-spin spin-triplet Cooper pairs allowing for the long-range proximity effect [2].

[1] J. W. A. Robinson, J. D. S. Witt, and M. G. Blamire, Science **329**, 59 (2010).
[2] D. Fritsch and J. F. Annett, arXiv:1311.3278 (2013).

TT 34.5 Tue 12:30 HSZ 201

Multiply gapped density of states in a chaotic normal metal in contact with superconductors — •Johannes Reutlinger[1], Wolfgang Belzig[1], Yuli Nazarov[2], and Leonid Glazman[3] — [1]University of Konstanz, Department of Physics, 78457 Konstanz, Germany — [2]Kavli Institute of Nanoscience Delft, Delft University of Technology, 2628 CJ Delft, Netherlands — [3]Department of Physics, Yale University, New Haven CT 06511-8499, USA

The spectral properties of a normal metal adjacent to a superconductor are strongly dependent on the characteristic mesoscopic energy scale - the Thouless energy E_{Th} - and the strength of the connection. We predict that the local density of states (LDOS), besides the well known minigap $\sim E_{\mathrm{Th}}$, can exhibit a multiple gap structure. For ballistic contacts we calculate these secondary gaps analytically in the framework of the quantum circuit theory of mesoscopic transport. For a cavity coupled to two superconductors with phase difference φ the secondary gap $\sim \Delta^3/E_{\mathrm{Th}}^2$ for $E_{\mathrm{Th}} \gg \Delta$ with maximum width at $\varphi = 0$ disappears at a critical phase $\pm\Delta/E_{\mathrm{Th}}$. The existence of a critical ratio E_{Th}/Δ calls for a reconsideration of the level statistics in chaotic Andreev dynamics, which has previously only been addressed thoroughly for $E_{\mathrm{Th}} \ll \Delta$. For generic contacts, like diffusive connectors or dirty interfaces no gap exists, but the density of states is still suppressed around Δ. Analytical calculations relate the secondary gap to the transmission eigenvalue distribution at small transmissions.

[1] J. Reutlinger, L. Glazman, Yu. V. Nazarov, W. Belzig, arXiv:1308.2529 (2013)

TT 34.6 Tue 12:45 HSZ 201

Measuring local magnetic fields in superconductors via XMCD — •Claudia Stahl[1], Stephen Ruoss[1,2], Patrick Audehm[1], Markus Weigand[1], Gisela Schütz[1], and Joachim Albrecht[2] — [1]Max-Planck-Institut für Intelligente Systeme, Heisenbergstraße 3, 70569 Stuttgart, Germany — [2]Aalen University, Beethovenstraße 1, 73430 Aalen

We use soft ferromagnetic thin films in order to map the magnetic flux line distribution in superconductors. For that purpose amorphous CoFeB is directly deposited on top of high-T_c superconducting YBCO structures. The magnetic stray fields of supercurrents lead to a local reorientation of the magnetic moments in the ferromagnet.

Using polarized x-rays it is possible to measure the local magnetization via the XMCD effect. With XMCD spectroscopy we find a temperature-dependent signal in the CoFeB layer which can be attributed to the currents flowing in the superconductor. This signal can be additionally measured with high spatial resolution paving the way to x-ray microscopy of magnetic structures in superconductors. The measurements are carried out at our scanning x-ray microscope MAXYMUS and our own dedicated reflectometry endstation at Bessy II of the HZB in Berlin.