TT 8: Focus Session: Emerging Phenomena in Superconducting Low Dimensional Hybrid Systems II

Time: Tuesday 13:30–16:15 Location: H7

TT 8.1 Tue 13:30 H7

Theory of Shiba-Shiba tunneling at the edge of a Majorana chain — •Ciprian Padurariu[1], Haonan Huang[2], Björn Kubala[1,3], Christian R. Ast[2], and Joachim Ankerhold[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany

The realization of the Majorana chain [1], a 1D-chain of Yu-Shiba-Rusinov (YSR) impurity states on the surface of a superconductor, suggests that Majorana states emerging at the edges can be probed by an STM. Recently, we have developed an ideal tool to probe and manipulate the edge states of a Majorana chain. It consists of a superconducting STM tip functionalized with its own in-gap YSR state created by a magnetic impurity on the tip. With this device we have studied the sharp resonant transport between the YSR state on the tip and another YSR on the sample, and have developed its theory [2].
This presentation will expand on the theory of Shiba-Shiba tunneling and present the possibilities to manipulate edge states of the Majorana chain. In certain parameter regimes theory predicts that the edge state will transfer from the chain to the tip. This may provide a first step towards realizing braiding of edge states using the STM.

[1] S. Nadj-Perge, *et al.*, Science **346**, 602 (2014)
[2] H. Huang, *et al.*, Nat. Phys. **16**, 1227 (2020)

TT 8.2 Tue 13:45 H7

Spin-polarized zero bias peak from a single magnetic impurity at a s-wave superconductor — •Kyungwha Park[1], Bendeguz Nyari[2], Andras Laszloffy[3], Laszlo Szunyogh[2], and Balazs Ujfalussy[3] — [1]Virginia Tech, Blacksburg, United States — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]Wigner RCP, ELKH, Budapest, Hungary

Topological superconductivity has emerged a promising platform for quantum computing using Majorana modes. Since intrinsic topological superconductors are rare, various heterostructures including ferromagnetic atomic chains on s-wave superconductors have been proposed to realize topological superconductivity. So far, most theoretical studies in heterostructures were done using effective models. Here we investigate the Yu-Shiba-Rusinov (YSR) states of a single magnetic impurity at the surface of superconducting Pb using the fully relativistic first-principles simulations including DFT band structure of Pb and 3d orbitals of the impurity in the superconducting state. For the single Fe and Co impurities, we observe strong effects of spin-orbit coupling on the YSR states as the impurity moment rotates. As the rotation angle varies, we show that two symmetric same-spin YSR states of electron character merge and form a zero-bias peak (ZBP) with large spin polarization. According to effective models, whether a ZBP has net spin polarization or not is often used to determine its topological nature. Our results reveal importance of including realistic band structure and multiple 3d orbitals of the impurity in the calculations.

TT 8.3 Tue 14:00 H7

Conductance anomalies in magnetization-controlled superconductor-ferromagnet-superconductor proximity junctions — •Lukas Kammermeier, Elke Scheer, Angelo di Bernardo, and Maik Kerstingskötter — Universität Konstanz, Konstanz, Germany

A key building block in superconducting spintronics is a controllable superconducting spin triplet device. We study superconducting aluminium contacts, the superconducting properties of which are locally modulated by the inverse proximity effect of an adjacent ferromagnet (cobalt in this case). We show that the zero-field current-voltage characteristics of these devices can be in situ controlled by polarizing the magnet in a parallel magnetic field.

The measurements reveal that we can drive the system into different conductance states controlled by the magnetization state of the ferromagnet. One of these states shows a significant differential conductance increase, which even increases more while the magnetic field is applied, possibly indicating a spin-triplet-dominated transport regime.

TT 8.4 Tue 14:15 H7

Heat-charge separation and nonlocal response in superconductor-InAs nanowire hybrid devices — Artem Denisov[1], Gregor Koblmueller[2], and •Vadim Khrapai[3] — [1]Department of Physics, Princeton University, Princeton — [2]Walter Schottky Institut, Physik Department, and Center for Nanotechnology and Nanomaterials, TU Muenchen — [3]Osipyan Institute of Solid State Physics of the Russian Academy of Sciences

Nonlocal quasiparticle transport in normal-superconductor-normal (NSN) hybrid structures probes sub-gap states in the proximity region. Here we show that a non-local shot noise is a complementary to conductance measurement in superconducting proximity devices. Using NSN InAs nanowire based devices we demonstrate that quasiparticle response is practically charge-neutral. This is qualitatively explained by numerous Andreev reflections of a diffusing quasiparticle, that makes its charge completely uncertain. As a result, the sub-gap response is dominated by the heat transport component with a thermal conductance being on the order of the conductance quantum. By contrast, strong fluctuations and sign reversal are observed in the nonlocal conductance, including occasional Andreev rectification signals. Our results evidence effective heat-charge separaion at the central S-terminal.

We are grateful to our colleagues A. Bubis, S. Piatrusha, N. Titova, A. Nasibulin, J. Becker, J. Treu, D. Ruhstorfer and E. Tikhonov for their contribution to the preprint arXiv:2101.02128 on which this presentation is based.

15 min. break

TT 8.5 Tue 14:45 H7

Supercurrent-enabled Andreev reflection in a chiral quantum Hall edge state — •Andreas Bock Michelsen[1,2], Patrik Recher[3], Bernd Braunecker[1], and Thomas Schmidt[2] — [1]SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK — [2]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [3]Institut für Mathematische Physik, Technische Universität Braunschweig, 38106 Braunschweig, Germany

A chiral, spinless quantum Hall edge state placed in proximity to an s-wave superconductor experiences induced superconducting correlations. This effect provides a promising pathway to the realization of Majorana zero-modes and their parafermionic generalizations as non-Abelian anyons. Recent experiments have observed the phenomenon through conductance signatures of the mediating process of Andreev reflection, where electrons tunnel in pairs. We develop a tunneling model of the system and demonstrate that this process is enabled by the superconductor surface hosting spin-orbit coupling and a supercurrent induced by the strong magnetic field. By integrating out the superconductor we develop an effective model of the proximitized edge state, and derive an expression for the probability of an electron being transported as a hole through the edge state. This lets us analytically predict the outcome of conductance measurements given external experimental parameters.

TT 8.6 Tue 15:00 H7

Majorana zero modes in one- and two-dimensional magnet-superconductor hybrid systems — •Stephan Rachel — School of Physics, University of Melbourne, Parkville, VIC 3010, Australia

Majorana zero modes, exotic quasiparticles in topological superconductors, are considered as the fundamental building blocks of future fault-tolerant quantum computers. The list of candidate materials is, however, short. Magnet-superconductor hybrid (MSH) systems represent one of the most promising platforms for topological superconductivity: magnetic atoms are placed on the surface of a conventional superconductor with spin-orbit coupling, leading to a topologically nontrivial system. Here we report recent theoretical progress on one- and two-dimensional MSH systems, and discuss them in the light of the latest experiments. By combining ab initio modeling and toy-model calculations on the theoretical side with atom-manipulation techniques via STM on the experimental side, we are getting closer to a complete understanding of Majorana zero modes in MSH systems.

TT 8.7 Tue 15:15 H7

Josephson and Andreev transport in a superconducting single electron transistor with a normal lead (SSN-SET) — •Laura Sobral Rey[1,2] and Elke Scheer[1,2] — [1]Physics department, University of Konstanz, 78464, Konstanz, Germany — [2]QuESTech consortium

An island coupled via a tunnel barrier to two leads and a gate forms a single electron transistor (SET) that shows Coulomb blockade. All-superconducting SETs (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, we study here the conceptually simpler SSN-SET, which has never been investigated experimentally before.

The SSN-SETs studied here consist of an S island coupled to an N lead via an oxide tunnel barrier, and to an S lead with a mechanically controlled break junction (MCBJ). Via the MCBJ, different coupling regimes can be studied: from a tunnel contact when the MCBJ is broken to a point contact when it is closed. In that limit the MCBJ has a small number of highly transmissive transport channels.

For weak coupling, our experimental findings can be understood in terms of the orthodox theory [2]. For stronger coupling, we observe Andreev and Josephson transport, as well as a renormalization of the charging energy and dynamical Coulomb blockade, which are also observed in the N state.

[1] T. Lorenz, J. Low Temp. Phys. 191, 301 (2017)
[2] T.A. Fulton, Phys. Rev. Lett. 59, 109 (1987)

TT 8.8 Tue 15:30 H7

Unconventional Meissner screening induced by chiral molecules in a conventional superconductor — Hen Alpern[1], Morten Amundsen[2], •Roman Hartmann[3], Nir Sukenik[1], Alfredo Spuri[3], Shira Yochelis[1], Thomas Prokscha[4], Vitaly Gutkin[1], Yonathan Anahory[1], Elke Scheer[3], Jacob Linder[2], Zaher Salman[4], Oded Milo[1], Yossi Paltiel[1], and Angelo Di Bernardo[3] — [1]The Hebrew University of Jerusalem — [2]Norwegian University of Science and Technology — [3]Universität Konstanz — [4]Paul Scherrer Institut

Superconducting spintronics is emerging as an alternative technology that can overcome the main limitation of conventional spintronic devices, their high current dissipation. It has developed after the discovery that Cooper pairs with parallel-aligned spins (spin-triplets) can be generated at the interface between a conventional superconductor (S) and a magnetically inhomogeneous ferromagnet (F). More recently, by performing low-temperature scanning tunneling spectroscopy measurements of chiral molecules (ChMs) adsorbed on the surface of a Nb (S) thin film, we have observed subgap features due to spin-triplet states. Motivated by these results, we have performed low-energy muon spectroscopy on ChMs/Nb which shows evidence for an unconventional Meissner screening effect. Our experimental data and theoretical analysis show that the unconventional Meissner screening is due to the generation of spin-triplet pairs, as a result of the ChMs acting as a spin active interface. These results pave the way for the realisation of novel devices based on ChMs/S hybrids for superconducting spintronics.

TT 8.9 Tue 15:45 H7

Magic angles and current-induced topology in twisted nodal superconductors — •Pavel Volkov, Justin Wilson, and Jed Pixley — Rutgers University

We propose twisted bilayers of two-dimensional nodal superconductors as a new platform to realize topological and correlated superconducting phases. We show that the Fermi velocity of the Dirac excitations in the Bogoliubov-De Gennes quasiparticle dispersion is strongly renormalized by the interlayer hopping, vanishing at a "magic angle", where time-reversal breaking superconductivity is induced. We demonstrate that magnetic field, electric gating, and current bias can be used for versatile control of the system. In particular, an interlayer current bias opens a topological gap, with the system being characterized by a non-zero Chern number.

TT 8.10 Tue 16:00 H7

Vortex inductance as a probe of symmetry breaking in Rashba superconductors — •Lorenz Fuchs[1], Denis Kochan[1], Simon Reinhardt[1], Christian Baumgartner[1], Sergei Gronin[2], Geoffrey Gardner[2], Tyler Lindemann[2], Michael Manfra[2], Christoph Strunk[1], and Nicola Paradiso[1] — [1]University of Regensburg (Germany) — [2]Purdue University (USA)

In this work, we demonstrate the use of vortices as directional probes of the superconducting condensate symmetry via vortex inductance measurements. We investigate Al/InAs heterostructures containing a high-mobility InAs quantum well that is proximitized by the epitaxially grown Al top layer. In out-of-plane magnetic field, ac-current-driven oscillations of vortices around pinning centers give rise to an additional inductance, which is orders of magnitude larger than the bare kinetic inductance of the superfluid. We find that the application of an additional in-plane magnetic field induces a surprising increase of the pinning potential and demonstrate that such increase obeys a characteristic two-fold anisotropy when changing the angle between the in-plane field and the ac-current. The observed counter-intuitive behavior can be theoretically explained by introducing Lifshitz-invariant terms (resulting from the Rashba interaction and the in-plane field) in the Ginzburg-Landau free energy.