TT 33: Transport: Majorana Fermions

Time: Tuesday 14:00–16:00 Location: HSZ 204

TT 33.1 Tue 14:00 HSZ 204

Subband-mixing signatures in Andreev-reflection-enhanced conductance of a quantum point contact — Michal Nowak and •Michael Wimmer — QuTech and Kavli institute of nanoscience, TU Delft, Netherlands

Andreev reflection leads enhancement of the conductance in a quantum point contact, doubling the conductance plateaus [1]. Recent experiments [2, 3] found evidence for this Andreev enhancement, but showed additional, pronounced conductance dips before the transition to the next plateau, at odds with the conductance doubling of [1].

Here, we show that scattering between subbands due to weak disorder can fully explain these observations. This allows to give an estimate for the mean free path in Majorana devices [3].

[1] C.W.J. Beenakker. Phys. Rev. B 46, 12841 (1997)
[2] M. Kjaergaard *et al.*, Nat. Commun. 7, 12841 (2016)
[3] H. Zhang *et al.*, arXiv:1603.01852

TT 33.2 Tue 14:15 HSZ 204

Gapless Andreev Bound States in HgTe based topological Josephson junctions — •Jonas Wiedenmann[1], Erwann Bocquillon[1], Russel Deacon[2], Teun Klapwijk[3], Philipp Leubner[1], Christoph Brüne[1], Seigo Tarucha[2], Koji Ishibashi[2], Hartmut Buhmann[1], and Laurens Molenkamp[1] — [1]Physikalisches Institut 3, Am Hubland, Universität Würzburg — [2]Advanced Device Laboratory, Riken, Japan — [3]Kavli Institute of Nanoscience, Delf, The Netherlands

Due to their inverted bandstructure, HgTe quantum wells of appropriate thickness are a 2D TI and exhibit the Quantum Spin Hall effect. Such a topological insulator in proximity with a conventional superconductor is predicted to lead to the emergence of induced p-wave superconductivity. Majorana bound states occur as zero energy states in vortices or at edges of such a triplet pairing superconductors. In this talk I will focus on detecting two experimental signatures of such zero energy states. We show from the ac Josephson effect that the supercurrent across such a Josephson junction made of a HgTe based topological insulator, varies 4π periodically with the superconducting phase difference. Namely we identify a doubling of the Shapiro steps compared to conventional superconductors [1] and measure Josephson emission at half the Josephson frequency [2]. Furthermore, by applying a magnetic flux to the junction, we are able show that the supercurrent is predominantly carried by states edge states.

[1] Bocquillon et al. Nat. Nano (2016)
[2] Deacon et al. arXiv:1603.09611

TT 33.3 Tue 14:30 HSZ 204

The fermion parity relaxation in the topological Josephson junction — •Oleksiy Kashuba and Björn Trauzettel — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg

The topological Josephson junction is notable for its Andreev level whose energy is 4π periodic in superconducting phase. Being protected by the fermionic parity conservation, the level is supposed to provide the 4π periodic contribution to the supercurrent in addition to the conventional 2π periodicity caused by other levels. In the static experimental setup, however, even a weakest relaxation of the fermionic parity results in the pure 2π supercurrent periodicity. This problem can be in principle eliminated by the dynamically driven phase on the time scales much smaller than relaxation time. In our work we demonstrate that even in the dynamic experiments, the pseudo-equilibrium occupation of the topological level plays a crucial role, and a number of special requirements has to be met in order to obtain a non-zero 4π periodic behavior. For example: The phase should not be driven uniformly, e.g. in the voltage driven Josephson junction the current contribution from the topological Andreev level is zero; the Josephson junction driven by a constant current, i.e. resistively shunted junction (RSJ) model reveals the 4π periodicity only in the case if both 2π and 4π levels are present.

TT 33.4 Tue 14:45 HSZ 204

Josephson effect in topologically confined channels — •Daniel Frombach and Patrik Recher — Institut für Mathematische Physik, TU Braunschweig

In recent times the fractional Josephson effect has been used as a signature of Majorana fermions forming in Josephson junctions mediated by the topologically protected spin helical edge states of a quantum spin Hall insulator [1].

Here we propose a setup based on silicene in which either a single spin helical Kramers pair of edge states [2] or two sets of Kramers pair edge stets can exist at domain walls depending on an externally applied inhomogeneous electrical field. We furthermore investigate a Josephson junction mediated by these edge states through the Bogoliubov de Gennes formalism. We show that the energy phase relation is 4π periodic when the system is in the quantum spin Hall regime but changes to a 2π periodicity due to backscattering effects when two sets of Kramers pair edge states are present.

[1] L. Fu and C.L. Kane, Phys. Rev. B 79, 161408 (2009).
[2] M. Ezawa, New Journal of Physics 14, 033003 (2012).

TT 33.5 Tue 15:00 HSZ 204

Fano resonances in transport through Majorana networks — •Alexander Schuray, Luzie Weithofer, and Patrik Recher — TU Braunschweig, Institute of Mathematical Physics

Electronic transport experiments with nanowires in proximity to a superconductor [1] suggest the existence of exotic emergent particles namely Majorana bound states (MBS), which are promising candidates for topological quantum computation [2].

Transport experiments using quantum dots (QDs) coupled to MBS have been proposed [3] as the parameters of the dot may be a handle to find unique signatures of the MBS. In contrast to these previous works, we study a system in which a one dimensional topological superconductor is contacted with a normal conducting lead at one end and a QD at its other end. To obtain the transport properties of such a setup we use a Keldysh Green's function method [4]. We show that in this setup two Fano resonances which are symmetric with respect to the energy level of the QD arise. Moreover, this symmetry is only destroyed by long range tunneling terms and so is a unique signature of the topologically protected MBS. Furthermore, we verify our effective model calculations with numerical results for a Kitaev chain.

[1] V. Mourik et al., Science 336, 1003 (2012)
[2] T. Karzig et al., arXiv:1610.05289 (2016)
[3] M. Leijnse, and K. Flensberg, Phys. Rev. B 84, 1400501 (2011)
[4] L. Weithofer, P. Recher, and T. L. Schmidt, Phys. Rev. B 90, 205416 (2014)

TT 33.6 Tue 15:15 HSZ 204

Non-equilibrium Andreev States Population in Short Conventional and Topological Superconducting Junctions — •Raffael Klees, Wolfgang Belzig, and Gianluca Rastelli — Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany

Recent experiments reported the observation of the non-equilibrium dynamics of the Andreev bound states (ABS) in superconducting atomic contacts (SAC) [1] and in proximized semiconductor nanowires [2]. Motivated by these reports, we study a short superconducting junction of length $L \ll \xi$ (coherence length) inserted in a dc-SQUID and coupled to an LC-resonator [2]. We calculate the non-equilibrium occupation of the ABS by taking into account the phase fluctuations in the dc-SQUID and by assuming that the junction is irradiated with photons. We analyse the role of the non-equilibrium distribution of the quasiparticles of the continuum in different regimes. We systematically compare the cases of a SAC and a topological junction [3] in order to point out the peculiar features of the latter. Finally, we discuss how to measure such a non-equilibrium occupation in experiments similar to [1].

[1] C. Janvier *et al.*, Science **349**, 1199 (2015); L. Bretheau *et al.*, Nature **499**, 312 (2013)
[2] A. P. Higginbotham *et al.*, Nat. Phys. **11**, 1017 (2015)
[3] J. I. Väyrynen *et al.*, Phys. Rev. B **92**, 134508 (2015)

TT 33.7 Tue 15:30 HSZ 204

Helical gaps in interacting Rashba wires at low electron densities — •Thomas Schmidt and Christopher Pedder — Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg

Rashba spin-orbit coupling and a magnetic field perpendicular to the Rashba axis have been predicted to open a partial gap ("helical gap") in the energy spectrum of noninteracting or weakly interacting one-dimensional quantum wires. By comparing kinetic energy and Coulomb energy we show that this gap opening typically occurs at low electron densities where the Coulomb energy dominates. To address this strongly correlated limit, we investigate 1D and quasi-1D Rashba wires using Wigner crystal theory. We find that in the 1D case, the helical gap exists even in the limit of strong interactions but its dependence on electron density differs significantly from the weakly interacting case. In the quasi-1D case, we find that a helical gap can open even without applied magnetic field.

TT 33.8 Tue 15:45 HSZ 204

Evolution of the transmission phase through a Coulomb-blockaded proximitised wire — •Casper Drukier[1], Bernd Rosenow[1], and Yuval Oreg[2] — [1]University of Leipzig, Leipzig, Germany — [2]Weizmann Institute of Science, Rehovot, Israel

We present a study of the transmission of electrons through a semiconductor quantum wire with strong spin-orbit coupling in proximity to an s-wave superconductor, which is Coulomb-blockaded. Such a system supports Majorana bound states in the presence of an external magnetic field, and is of interest due to recent experimental progress and the prospect of quantum information processing.

Without superconductivity, phase lapses are expected to occur in the transmission phase. We find that they disappear when a topological superconducting phase is stabilised. We derive a model, based on an expansion in terms of Bogoliubov quasi-particles, which allows us to express tunneling through the nanowire with the help of effective matrix elements, which depend on both the fermion parity of the wire and the overlap with Bogoliubov-de-Gennes wave-functions. Using the scattering matrix formalism this allows us to study the transmission phase in different regimes.