HL 105: Transport: Majorana fermions (TT with DS/HL/MA/O)

Time: Friday 9:30–12:15 Location: H 0104

HL 105.1 Fri 9:30 H 0104

Majorana bound states in a Corbino geometry topological insulator Josephson junction — •Sunghun Park and Patrik Recher — Institute for Mathematical Physics, TU Braunschweig, Germany

An adiabatic exchange of Majorana bound states reveals their exotic anyonic nature. Here we propose an experimental setup consisting of a Corbino-geometry Josephson junction on the surface of a topological insulator, in which Majorana bound states can be created and transported. By solving the Bogoliubov-de Gennes equation, we show that two spatially separated Majorana bound states at zero excitation energy appear in the junction when two flux quanta are introduced, and that their positions can be moved by changing the superconducting phase difference across the junction. These features allow us to perform the exchange operation of the Majorana bound states if we vary the phase difference adiabatically.

HL 105.2 Fri 9:45 H 0104

Topological phases in magnetic adatom-chains on top of a Rashba superconducting surface — •Andreas Heimes, Daniel Mendler, and Panagiotis Kotetes — Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, 76131 Karlsruhe

We investigate a Majorana fermion (MF) platform consisting of a chain of magnetic adatoms placed on top of a conventional superconductor with Rashba spin-orbit coupling. By identifying the classical magnetic ground state of the adatom chain, we extract a phase diagram which exhibits ferromagnetic (FM), antiferromagnetic (AFM) as well as spiral orders. We determine the parameter regime for which the FM or AFM phases dominate over the spiral and perform a topological analysis of the low-energy electronic spectrum. To this end we derive an effective model relying on Shiba bound states. We find that for both magnetic patterns, FM and AFM, the hybrid system behaves as a topological superconductor which can harbor one or even two MFs per edge. We propose directions on how to experimentally access these different MF phases.

HL 105.3 Fri 10:00 H 0104

Localization length and non-adiabaticity - braiding errors in Majorana quantum wires — •Michael Sekania[1,3], Martin Greiter[1], Ronny Thomale[1], and Peter Schmitteckert[2] — [1]Institute for Theoretical Physics and Astrophysics, Julius-Maximilian University of Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Institute of Nanotechnology, Karlsruhe Institute of Technology, D-76344 Eggenstein-Leopoldshafen, Germany — [3]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany

Majorana fermions have been attracting substantial interest in recent years. Several experimental groups have already reported tentative observation of Majorana zero modes in quantum nanowires that are proximity-coupled to a bulk superconductor. The unambiguous detection of Majorana quasi-particles, however, has so far remained elusive. One of the ultimate experimental checks for the existence of Majorana zero modes would be a braiding experiment, that reveals the non-trivial braiding statistics of the Majorana fermions. We present numerical studies of the braiding of Majorana bound states (MBS) in presence of a quasi-particle background, and show braiding errors due to non-adiabaticity – which is a realistic scenario for experiments – and due to system sizes which are comparable to the localization length of the MBS. The latter seems to be the case for certain experimental realizations reported recently. We further address the influence of finite-range interactions on the braiding process.

HL 105.4 Fri 10:15 H 0104

Fractional Josephson Effect in HgTe based Josephson Junctions — •Jonas Wiedenmann[1], Erwann Bocquillon[1], Russel Deacon[2], Simon Hartinger[1], Luis Maier[1], Christopher Ames[1], Koji Ishibashi[2], Tarucha Seigo[3], Teun Klapwijk[4], Hartmut Buhmann[1], and Laurens Molenkamp[1] — [1]EP3, Physikalisches Institut, Universität Würzburg, Würzburg, Germany — [2]Advanced Device Laboratory, RIKEN, Japan — [3]Department of Applied Physics, Univeristy of Tokyo, Tokyo, Japan — [4]Kavli Institute of Technology, Delft University of Technology, Delft, The Netherlands

3D topological insulators are a new class of material in which electronic transport is governed by topological surface states while the bulk remains insulating. Due to the helical spin polarization of the surface states, the coupling to a conventional s-wave superconductor is predicted to lead to the emergence of zero-energy bound states at the S-TI interface. These gapless zero energy states (sometimes referred to as Majorana bound states) are topologically protected against scattering and thus give rise to a 4π periodic Josephson current.

We fabricated Josephson junctions based on the three dimensional topological insulator HgTe and study its response under external rf excitation. An unconventional A.C. Josephson effect is observed which leads us to the conclusion that a 4π contribution in the Josephson current is present. In addition to the observation of an unconventional excess current, this gives robust signatures of the presence of zero-energy states.

HL 105.5 Fri 10:30 H 0104

Josephson current and Majorana bound states through 2DEG with Spin-Orbit Interaction — •Pasquale Marra[1], Roberta Citro[1,2], and Alessandro Braggio[3] — [1]SPIN-CNR, I-84084 Fisciano (Salerno), Italy — [2]Dipartimento di Fisica "E. R. Caianiello", Universitá di Salerno, I-84084 Fisciano (Salerno), Italy — [3]SPIN-CNR, Via Dodecaneso 33, I-16146 Genova, Italy

We investigate the DC Josephson current in a two dimensional electron gas (2DEG) proximized with a s-wave superconductor, in the presence of spin-orbit interaction and magnetic field. Solving the Bogoliubov-De Gennes equations in the framework of a tight-binding Hamiltonian, we calculate the Andreev bound states, the Josephson current, and the Majorana polarization as a function of phase difference between the two superconductors. We therefore investigate the conditions under which Majorana bound states are localized at the system interfaces.

15 min. break.

HL 105.6 Fri 11:00 H 0104

Thermal conductance as a probe of the non-local order parameter for a topological superconductor with gauge fluctuations — •Fabian Hassler[1], Bernard van Heck[2], Emilio Cobanera[3], and Jascha Ulrch[1] — [1]JARA Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany — [2]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands — [3]Institute for Theoretical Physics, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands

We investigate the effect of quantum phase slips on a helical quantum wire coupled to a superconductor by proximity. The effective low-energy description of the wire is that of a Majorana chain minimally coupled to a dynamical *2 gauge field. Hence the wire emulates a matter-coupled gauge theory, with fermion parity playing the role of the gauged global symmetry. Quantum phase slips lift the ground state degeneracy associated with unpaired Majorana edge modes at the ends of the chain, a change that can be understood as a transition between the confined and the Higgs-mechanism regimes of the gauge theory. We identify the quantization of thermal conductance at the transition as a robust experimental feature separating the two regimes. We explain this result by establishing a relation between thermal conductance and the Fredenhagen-Marcu string order-parameter for confinement in gauge theories. Our work indicates that thermal transport could serve as a measure of non-local order parameters for emergent or simulated topological quantum order.

HL 105.7 Fri 11:15 H 0104

Topological Kondo Effect in Transport through a Superconducting Wire with Multiple Majorana End States — •Oleksiy Kashuba and Carsten Timm — Institute für Theoretische Physik, Technische Universität Dresden

We investigate a system of multiple Majorana states at the end of a topological superconducting wire coupled to a normal lead. For a minimum of three Majorana fermions at the interface, we find nontrivial renormalization physics. Interface tunneling processes can be classified in terms of spin-1/2 and spin-3/2 irreducible representations of the SU(2) group. We show that the renormalization of the tunneling amplitudes belonging to different representations is completely

different in that one type is suppressed, whereas the other is enhanced, depending on the sign of the interaction coupling. This results in distinct temperature dependencies of the tunneling current through the interface and different spin polarizations of this current.

HL 105.8 Fri 11:30 H 0104

Topological superconductivity in Rashba semiconductors without a Zeeman field — •Panagiotis Kotetes — Karlsruhe Institute of Technology

I propose new hybrid devices based on multichannel Rashba semiconductors, which harbor Majorana fermions (MFs) without a Zeeman field [1]. In contrast, magnetic fluxes, supercurrents or electric fields can be employed, yielding an enhanced device manipulability. The generic topological phase diagram exhibits features of quantum criticality and a rich interplay of phases with 0, 1 or 2 MFs per edge. The most prominent and experimentally feasible implementation, relies on the already existing platforms of InAs-2DEG on top of a Josephson junction. Appropriate design of the latter device, allows phases with 1 or 2 MFs, both detectable in zero-bias anomaly peaks with a single or double unit of conductance. The absence of the Zeeman field in these devices could be assisting for a Kondo-peak-free interpretation of the expected MF signatures.

[1] P. Kotetes, arXiv:1409.5264.

HL 105.9 Fri 11:45 H 0104

Majorana flat bands in anisotropic systems — •Daniel Mendler, Panagiotis Kotetes, and Gerd Schön — Institut für theoretische Festkörperphysik, Karlsruher Institut für Technologie

It has been recently proposed that topologically protected Majorana flat bands (MFBs) emerge in superconductors with nodal energy spectrum. In this work we introduce a new class of gapful superconductors, in which MFBs can occur due to strong anisotropy. The prototype system exhibiting this kind of behavior is the nematic $p_x + p_y$ spinless superconductor, which supports an edge MFB with controllable bandwidth. Our proposal can be for instance experimentally implemented in topological superconductors engineered from i. semiconductors with tunable spin-orbit coupling or ii. topological insulator surfaces with intrinsic magnetic order in proximity to a conventional SC. By investigating the topological properties of both setups, we show that their unique features render them feasible platforms for manipulating the Majorana fermion bandstructure and realizing MFBs.

HL 105.10 Fri 12:00 H 0104

Topological phases of interacting fermions in one-dimensional superconductor - normal metal geometry — Dganit Meidan[1,2], •Alessandro Romito[1], and Piet W. Brouwer[1] — [1]Department of Physics, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel — [2]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

One-dimensional superconductors can be in non-trivial topological phases harboring Majorana end-states, which possess non-abelian statistics. It has been recently established that in the presence of interactions the classification of topological superconducting phases can be significantly altered. Specifically, for one-dimensional superconductors possessing a time reversal symmetry (BDI class), interactions reduce the infinitely many non-interacting phases (Z topological index) to eight distinct ones (Z_8 topological index).

In this talk I will consider multi-mode superconducting wires in such BDI class when probed by an external contact, and discuss their low temperature and voltage bias transport properties. I will first show that the Andreev reflection component of the scattering matrix of the probing lead provides a topological index, r=-4, ..., 4, which distinguish the eight topological phases. The two topologically equivalent phases with r= 4,-4 support emergent many-body end states, which are identified to be a topologically protected Kondo-like resonance. The path in phase space that connects these equivalent phases crosses a non-fermi liquid fixed point where a multiple channel Kondo effect develops.