O 50: Focussed Session: Majorana Fermions in Condensed Matter (jointly with DS, HL, MA, and TT)

Majorana fermions arise as quasi-particle excitations in condensed matter systems which exhibit non-Abelian exchange statistics. This property makes them a fundamentally new type of particles, and possibly allows topological quantum computing in this system. In the last few years, the study of Majorana fermions has rapidly evolved from being a mere theoretical concept to a practical realization: Following theoretical proposals involving hybrid nanosystems consisting of conventional superconductors and semiconducting nanowires, experiments have now found signatures of Majorana fermions. This Focused Session will discuss various aspects of Majorana fermions and the hybrid systems hosting them, including both theoretical and experimental contributions.

Organizers: Fabian Hassler (RWTH Aachen), Michael Wimmer (Leiden University)

Time: Wednesday 15:00–18:00 Location: H20

Invited Talk O 50.1 Wed 15:00 H20

Subgap States in Majorana Wires — •Piet Brouwer — Freie Universität Berlin

A one-dimensional spin-orbit coupled nanowire with proximity-induced pairing from a nearby s-wave superconductor may be in a topological nontrivial state, in which it has a zero energy Majorana bound state at each end. In this talk, I will discuss how non-idealities in this proposal, such as potential disorder, deviations from a strict one-dimensional limit, or details concerning the termination of the wire, affect the topological phase and its signatures in a current-voltage measurement. In particular, I'll argue that the topological phase can persist at weak disorder or for multichannel wires, although some of the signatures of the presence of Majorana fermions are obscured.

Invited Talk O 50.2 Wed 15:30 H20

New Measurements on Nanowire Majorana Systems — •Charles Marcus[1,3], Hugh Churchill[2,3], Mintang Deng[4], and Hongqi Xu[4] — [1]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Copenhagen, DK — [2]Department of Physics, MIT, Cambridge, MA USA — [3]Department of Physics, Harvard University, Cambridge, MA USA — [4]Division of Solid State Physics, Lund University, Lund, Sweden

This talk will present recent measurements on gated InSb nanowires coupled to a superconducting film. This set-up is one designed to detect Majorana end states. We show data similar to that seen in other groups recently, and also extend measurements in a number of directions, including higher field and higher conductance. Oscillatory structure suggesting interacting end-state Majoranas is found. We also identify transport regimes where even-odd Kondo-like features are evident, combined with Andreev bound states.

This research is sponsored by Microsoft Project Q, the Danish National Research Foundation, and Harvard University.

Topical Talk O 50.3 Wed 16:00 H20

Adaptive Tuning of Majorana Fermions in a Quantum Dot Chain — •Anton Akhmerov — Harvard University, USA

I will explain how to overcome the obstacles that disorder and high density of states pose to the creation of unpaired Majorana fermions in one-dimensional systems. This is achieved by splitting the system into a chain of quantum dots, which are then tuned such that the chain can be viewed as an effective Kitaev chain with maximally localized Majorana fermions. Resonant Andreev spectroscopy allows us to make this tuning adaptive, so that each pair of dots may be tuned independently of the other. Our numerical simulations show that already in three quantum dots it is possible to have almost completely decoupled Majorana fermions.

15 min. break

Topical Talk O 50.4 Wed 16:45 H20

Majorana Fermions in Disordered Quantum Wires — •Alexander Altland — Institute for Theoretical Physics, Zülpicher Str. 77, 50937 Köln

Proximity coupled spin-orbit quantum wires have recently been shown to support midgap Majorana states at critical points. We show that in the presence of disorder these systems are prone to the buildup of a second bandcenter anomaly, which is of different physical origin but shares key characteristics with the Majorana state: it is narrow in width, insensitive to magnetic fields, carries unit spectral weight, and is rigidly tied to the band center. Depending on the parity of the number of subgap quasiparticle states, a Majorana mode does or does not coexist with the impurity generated peak. The strong 'entanglement' between the two phenomena may hinder an unambiguous detection of the Majorana by spectroscopic techniques.

Topical Talk O 50.5 Wed 17:15 H20

Parity Effects and Crossed Andreev Noise in Transport through Majorana Wires — •Bernd Rosenow[1], Björn Zocher[1,2], and Mats Horsdal[1] — [1]Institut für Theoretische Physik, Universität Leipzig, D-04009 Leipzig, Germany — [2]Max-Planck-Institute for Mathematics in the Sciences, D-04103 Leipzig, Germany

One of the defining properties of a topologically ordered state is the ground state degeneracy on surfaces with nonzero genus. In semiconductor-superconductor hybrid structures, a phase transition between regular and topologically nontrivial superconductivity is expected as a function of chemical potential or magnetic field strength. The difference in ground state degeneracies of the two phases is reflected in the parity and magnetic flux dependence of nonlinear Coulomb blockade transport through a ring shaped structure.

In nanowires of finite length, topologically non-trivial superconductivity is expected to give rise to Majorana bound states at the ends of the wire. The non-locality of Majorana bound states opens the possibility of crossed Andreev reflection with nonlocal shot noise, due to the injection of an electron into one end of the superconductor followed by the emission of a hole at the other end. When coupling the end states to leads via quantum dots with resonant levels, in the space of energies of the two resonant quantum dot levels we find a four peaked clover-like pattern for the strength of noise due to crossed Andreev reflection, distinct from the single ellipsoidal peak found in the absence of Majorana bound states.

O 50.6 Wed 17:45 H20

Majorana qubit rotations in microwave cavities — •Thomas L. Schmidt, Andreas Nunnenkamp, and Christoph Bruder — Department of Physics, University of Basel, CH-4056 Basel, Switzerland

Majorana bound states have been proposed as building blocks for qubits on which certain operations can be performed in a topologically protected way using braiding. However, the set of these protected operations is not sufficient to realize universal quantum computing. We show that the electric field in a microwave cavity can induce Rabi oscillations between adjacent Majorana bound states. These oscillations can be used to implement an additional single-qubit gate. Supplemented with one braiding operation, this gate allows to perform arbitrary single-qubit operations.