FM 64: Poster: Topology

Time: Wednesday 16:30–18:30 Location: Tents

FM 64.1 Wed 16:30 Tents

Majorana bound states in hybrid two-dimensional Josephson junctions with ferromagnetic insulators — •Pauli Virtanen — University of Jyväskylä, Finland

We consider a Josephson junction consisting of superconductor/ferromagnetic insulator (S/FI) bilayers as electrodes which proximizes a nearby two-dimensional (2D) electron gas. We address the 2D bound-state problem by a transfer-matrix approach that reduces the problem to an effective 1D Hamiltonian. We consider a narrow channel coupled with multiple ferromagnetic superconducting fingers, and discuss the topological invariants, spectrum, free energy, and multiterminal Josephson currents of the setup.

FM 64.2 Wed 16:30 Tents

Theory of reflectometry-based readout of topological Majorana qubits — •Vahid Derakhshan Maman and Andras Palyi — Budapest University of Technology and Economics, Budapest, Hungary

Qubits based on Majorana zero modes of topological superconductors are thought to be more noise-resilient than conventional qubits. Readout of these qubits is possible only when the topological protection is temporarily lifted, and therefore it is especially important to understand the error mechanisms that affect the readout process. In this work, we theoretically describe errors in a setup where readout is performed using gate reflectometry of an auxiliary quantum dot that is tunnel-coupled to two Majorana zero modes. We use simple tight-binding models (e.g., the few-site Kitaev chain), and we describe readout error caused by low-frequency charge noise. We quantify the readout error as the function of model parameters (proximity-induced gap, strength of charge noise, system size, etc.), and thereby provide guidelines for the design and interpretation of future dynamical experiments aiming at control and readout of topological Majorana qubits.

FM 64.3 Wed 16:30 Tents

Designing transmon qubits to study topological insulator Josephson junctions in a 3D cavity — •Jonas Krause[1,2], Christian Dickel[1], Junya Feng[1], Richard Bounds[1], Shabir Barzanjeh[3], Johannes Fink[3], and Yoichi Ando[1] — [1]University of Cologne — [2]ETH Zurich — [3]IST Austria

Transmon qubits are a leading platform for quantum computing and have also been used to study unconventional Josephson junctions based on proximitized semiconductor nanowires, graphene and carbon nanotubes. We aim to use a transmon to study topological insulator (TI) Josephson junctions. TI-superconductor hybrid devices are predicted to host Majorana bound states that can be used for topological quantum computing. The transmon has in this context been proposed as a readout circuit via charge-parity detection. However, many proposals require considerable magnetic fields. Copper cavities are unaffected by strong magnetic fields and provide a clean microwave environment, making them ideal for the study of the transmon response to magnetic fields. We first study the magnetic-field dependence in conventional aluminum transmons and then move to TI devices. The transmon design for this purpose leads to a few changes from conventional 3D-cavity transmons: Higher charging energies are likely desirable for investigating quasiparticle poisoning dynamics. We will also investigate the effect of vortex traps on coherence and field resilience of the transmons. As opposed to on-chip resonators, the 3D setup requires minimal fabrication steps, thus implementing a fast and easy-to-use microwave probe station for TI junctions.

FM 64.4 Wed 16:30 Tents

Andreev spectroscopy in topological insulating Josephson junctions — •Richard Bounds[1], Christian Dickel[1], Junya Feng[1], Jonas Krause[1,2], Shabir Barzanjeh[3], Johannes Fink[3], and Yoichi Ando[1] — [1]University of Cologne — [2]ETH Zurich — [3]IST Austria

There are currently multiple efforts to realise a new kind of qubit based on topologically protected Majorana zero modes (MBS). One proposed realization resides in topological insulator nanowires proximitized with an s-wave superconductor. Josephson junctions on topological insulator materials would also host Andreev bound states (ABS). We aim to study the ABS spectrum of a topological insulator junction in the RF SQUID configuration coupled to a microwave resonator, in order to better understand the transport in the junction, in particular its dependence of the phase difference across the junction. Such spectroscopy, performed on planar junctions as well as nanowire junctions, will allows us to directly address the possible 4π periodicity of the Andreev levels and quasiparticle poisoning dynamics. The latter would likely also be a limiting factor for MBS physics and is therefore an important prerequisite experiment toward realising MBS qubits.

FM 64.5 Wed 16:30 Tents

Majorana zero modes in skyrmion-vortex pairs — •Jonas Nothhelfer[1], Kjetil Hals[2], Matteo Rizzi[3,4], and Karin Everschor-Sitte[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]University of Agder, Grimstad, Norway — [3]Institute of Complex Systems, Forschungszentrum Jülich, Germany — [4]Institute for Theoretical Physics, Universität zu Köln

Ferromagnet-superconductor heterostructures have been shown to allow for novel topological composite excitations - skyrmion-vortex pairs [1], which support the occurrence of Majorana bound states [2]. Their non-abelian exchange statistics makes Majorana modes suitable for topological quantum computation. Our goal is to study the braiding of Majorana zero modes via the controlled motion of skyrmions. For this we model a magnetic skyrmion imprinted in the ferromagnet and a vortex in the superconductor. We solve the eigensystem of the superconductor in the Bogoliubov-de Gennes formalism self-consistently for the superconducting gap under the influence of the magnetic field generated by the magnetic thin film and spin orbit coupling. As predicted by [1] we reproduce that composite topological excitations can emerge as pairs of superconducting vortices bound to magnetic skyrmions. Exploiting the finite binding energy, we expect that moving the skyrmion via methods from the spintronics toolbox will also induce a motion of the vortex and the Majorana zero mode bound to it. [1] Kjetil M. D. Hals, Michael Schecter and Mark S. Rudner, Physical Review Letters **117**, 017001 (2016) [2] Stefan Rex, Igor V. Gornyi, Alexander D. Mirlin, arXiv:1904.04177 (2019)

FM 64.6 Wed 16:30 Tents

Top-down fabrication of gate-tuneable bulk-insulating TI nanowires and their quantum transport — •Matthias Rössler, Dingxun Fan, Felix Münning, Oliver Breunig, Andrea Bliesener, Gertjan Lippertz, Alexey Taskin, and Yoichi Ando — II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany -

With proximity-induced superconductivity, bulk-insulating topological insulator nanowires (TI NWs) are expected to serve as a robust platform for realizing Majorana bound states. When exploiting their non-Abelian exchange statistics, these states could enable topological quantum computation schemes. Compared to previous experiments on semiconductor nanowires, a TI-based platform for MBS is predicted to have relaxed requirements for the tuning of chemical potential and magnetic field, resulting from the inherent property of spin-momentum locking. We have performed fabrication and optimization of TI NWs based on a scalable approach, namely etching of MBE-grown high quality BST thin films. Using this technique, highly gate-tuneable bulk insulating TI NWs with a diameter of less than 100 nm can be prepared to form arbitrary networks. Signatures of a so-called π-shift in Aharonov-Bohm-like transport oscillations indicate an opening and reclosing of the topologically protected 1D zero-gap mode unique to TI NWs with an axial magnetic flux dependent quantized 1D surface subband dispersion. Making use of this platform, we present first results on proximity-induced superconductivity in such TI nanowires.