# FM 19: Topology: Majoranas

Time: Monday 16:30–18:30 Location: 1199

**Invited Talk** FM 19.1 Mon 16:30 1199

**Topological superconductivity in full shell proximitized nanowires** — •Roman Lutchyn — Microsoft Quantum, Microsoft Station Q, University of California, Santa Barbara, California 93106-6105 USA

I will discuss a new model system supporting Majorana zero modes based on semiconductor nanowires with a full superconducting shell. I will demonstrate that, in the presence of spin-orbit coupling in the semiconductor induced by a radial electric field, the winding of the superconducting order parameter leads to a topological phase supporting Majorana zero modes. The topological phase persists over a large range of chemical potentials and can be induced by a predictable and weak magnetic field piercing the cylinder. The system can be readily realized in semiconductor nanowires covered by a full superconducting shell, opening a pathway for realizing topological quantum computing proposals.

FM 19.2 Mon 17:00 1199

**Non-Abelian Majorana fermions in topological s-wave Fermi superfluids** — •Lauri Toikka — University of Innsbruck, Austria

By solving the Bogoliubov-de Gennes equations analytically, we derive the fermionic zero-modes satisfying the Majorana property that exist in vortices of a two-dimensional s-wave Fermi superfluid with spin-orbit coupling and Zeeman spin-splitting. The Majorana zero-mode becomes normalisable and exponentially localised to the vicinity of the vortex core when the superfluid is topologically non-trivial. We calculate the energy splitting due to Majorana hybridisation and identify that the s-wave Majorana vortices obey non-Abelian statistics.

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**Parity-to-charge conversion for readout of topological Majorana qubits** — •Gábor Széchenyi[1] and András Pályi[2] — [1]Eötvös University, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest, Hungary

We theoretically study a scheme to distinguish the two ground states of a one-dimensional topological superconductor, which could serve as a basis for the readout of Majorana qubits. The scheme is based on parity-to-charge conversion, i.e., the ground-state parity of the superconductor is converted to the charge occupation on a tunnel-coupled auxiliary quantum dot. We describe how certain error mechanisms, degrade the quality of the parity-to-charge conversion process. We consider (i) leakage due to a strong readout tunnel pulse, (ii) incomplete charge Rabi oscillations due to slow charge noise, and (iii) charge relaxation due to phonon emission and absorption. To describe these effects, we use simple model Hamiltonians based on the ideal Kitaev chain, and draw conclusions to generic one-dimensional topological superconductors wherever possible. In general, the effects of the error mechanisms can be minimized by choosing an optimal strength for the readout tunnel pulse. In a case study based on InAs heterostructure device parameters, we estimate that the parity-to-charge conversion error is mainly due to slow charge noise for weak tunnel pulses and leakage for strong tunnel pulses.

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**Transport signatures of electron-tunneling-assisted non-Abelian braiding** — Sunghun Park[1], Heung-Sun Sim[2], and •Patrik Recher[3] — [1]Departamento de Física Teórica de la Materia Condensada, Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera, Universidad Autónoma de Madrid, Spain — [2]Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon 34141, Korea — [3]Institute for Mathematical Physics, TU Braunschweig, D-38106 Braunschweig, Germany

We present a theory of coherent time-dependent electron tunneling from a metal tip into a Corbino geometry topological Josephson junction where four Majorana bound states (MBSs) rotate. The time averaged tunneling conductance exhibits, as a function of bias voltage between the tip and the Josephson junction, distinctive conductance peaks that are separated by $h/(4T_J)$ (where $T_J$ is the time period of the system Hamiltonian). This separation is a result of interference between processes where electron tunneling between the tip and the junction interrupts the rotation of the MBSs after different number of round trips. The interference effect is shown to be a direct consequence of two non-commuting braiding operations—a rotation of the four MBSs along the Josephson junction and a tunneling assisted rotation—reflecting the non-Abelian nature of MBSs. This mechanism of non-Abelian state evolution actively utilizes electron tunneling that changes the fermion occupation number parity of the system rather than avoiding it while the MBSs are spatially decoupled from each other and hence are not fused physically.

FM 19.5 Mon 17:45 1199

**Fully in situ fabricated Josephson devices via the Jülich process** — •Peter Schüffelgen[1], Daniel Rosenbach[1], Chuan Li[2], Tobias W. Schmitt[1], Michael Schleenvoigt[1], Benjamin Bennemann[1], Lidia Kibkalo[1], Martina Luysberg[1], Gregor Mussler[1], Erwin Berenschot[2], Niels Tas[2], Alexander A. Golubov[2], Alexander Brinkman[2], Thomas Schäpers[1], and Detlev Grützmacher[1] — [1]Peter Grünberg Institute, Forschungszentrum Jülich — [2]MESA+ Institute, University of Twente

Networks of topological insulator (TI) nanostructures in proximity to superconductors (S) have been predicted to provide a platform for topologically protected quantum computing. A combination of selective area growth and stencil lithography allowed us to fabricate $Nb-(Bi,Sb)_2Te_3$ S-TI hybrid devices fully under ultra-high vacuum conditions. The so-called Jülich process yields highly transparent S-TI interfaces and provides a protective capping layer to the devices before they are exposed to ambient conditions. Measurements on as-prepared Josephson junctions show signatures of Majorana bound states. By restricting TI growth to selected areas only, it is possible to move from single Josephson junctions towards complex circuitry for future topological quantum computation architectures.

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**Integration of topological Josephson junctions into superconducting quantum circuits** — •Tobias W. Schmitt[1,2], Malcolm R. Connolly[3], Michael Schleenvoigt[2], Abdur R. Jalil[2], Dennis Heffels[2], Chenlu Liu[3], Stefan Trellenkamp[2], Florian Lentz[2], Elmar Neumann[2], Gregor Mussler[2], Peter Schüffelgen[2], Karl D. Petersson[4], and Detlev Grützmacher[2] — [1]JARA-FIT Institute Green IT, RWTH Aachen University — [2]Peter Grünberg Institute, Forschungszentrum Jülich — [3]Imperial College, London — [4]Center for Quantum Devices, Station Q Copenhagen, Niels Bohr Institute, University of Copenhagen

The interface of a 3D topological insulator (3D TI) and an s-wave superconductor (S) is predicted to host elusive Majorana modes. In lateral topological S-TI-S Josephson junctions Majorana bound states (MBS) are assumed to contribute to transport. Due to superimposed conventional Andreev bound states (ABS), observation of unambiguous Majorana signatures in transport measurements is hindered. In order to differentiate MBS from ABS signatures, it has been proposed to integrate S-TI-S junctions into superconducting qubits [1]. A technical challenge in this fabrication process is the protection of the TI surface from degradation at ambient conditions while maintaining a pristine interface to the s-wave superconductor. In this contribution, I will report on recent progress in the integration of in situ fabricated S-TI-S junctions in superconducting quantum circuits and present preliminary results on these devices. [1] arXiv:1902.07229

FM 19.7 Mon 18:15 1199

**Dephasing and relaxation of topological many-body states in quantum Ising models** — •Hannes Weisbrich, Wolfgang Belzig, and Gianluca Rastelli — University of Konstanz

Inspired by recent progress in coupled arrays of qubits, we study the dephasing and relaxation dynamics of topological states in an extended class of quantum Ising chains of finite length [1]. We assume a local dephasing interaction of each spin with a local thermal bath, from which we derive a Lindblad equation. This kind of interaction preserves the parity in the system [2]. We demonstrate a correlation between the decoherence in the ground state subspace manifold and the topology in the spin chain, characterized by a winding number g. In particular, in the topological regime and at low temperature, the decoherence rates can be exponentially suppressed. For the simple case of the transverse Ising model (g=1) this simply corresponds to the exponentially small overlap of the two localized Majorana zero energy modes of the equivalent Kitaev chain. We generalize this result to a chain with a three body, next nearest neighbor interaction (with g=2) in which the ground state subspace is fourfold degenerate with two ground states in each parity sector (even and odd), namely with four Majorana modes.

[1] H. Weisbrich, W. Belzig, G. Rastelli, SciPost Phys. 6, 037 (2019).
[2] H. Weisbrich, C. Saussol, W. Belzig, G. Rastelli, Phys. Rev. A 98, 052109 (2018).