TT 48: Topology: Majorana Physics

Time: Thursday 15:00–16:30 Location: H32

Invited Talk TT 48.1 Thu 15:00 H32

Optical Conductivity as a Probe for Chiral Majorana Edge Modes — •Lina Johnsen Kamra[1,2,3], Bo Lu[4], Jacob Linder[1], Yukio Tanaka[5], and Naoto Nagaosa[6] — [1]Norwegian University of Science and Technology, Trondheim, Norway — [2]Universidad Autónoma de Madrid, Madrid, Spain — [3]Massachusetts Institute of Technology, Cambridge, USA — [4]Tianjin University, Tianjin, China — [5]Nagoya University, Nagoya, Japan — [6]RIKEN, Saitama, Japan

Recent years have seen considerable progress towards realizing nonabelian particles for topological quantum devices. A prominent example is the chiral Majorana mode at the edge of topological superconductors. It introduces the possibility of using wave packets propagating at high speed as an alternative to the braiding of zero-dimensional Majorana bound states. However, a weak spot in detecting them lies in reliably capturing quantitative measures such as a quantized conductivity. Recent advances in microwave microscopy [1] have opened a promising new avenue for observing distinct qualitative signatures in their optical conductivity [2,3]. These emerge due to the unique dispersion of the Majorana edge mode that allows photons to break up Cooper pairs into propagating Majorana fermions [2]. As a guide to future experiments, we have shown how the local optical conductivity presents distinct and tunable qualitative features that depend on the symmetry of the superconductivity [3].

[1] K. Lee et al., Sci. Adv. 6, eabd1919 (2020);
[2] J. J. He et al., Phys. Rev. Lett. 126, 237002 (2021);
[3] L. J. Kamra et al., Proc. Natl. Acad. Sci. 121, e2404009121 (2024).

TT 48.2 Thu 15:30 H32

Interedge backscattering in time-reversal symmetric quantum spin Hall Josephson junctions — •Cajetan Heinz[1], Patrik Recher[1,2], and Fernando Dominguez[1,3] — [1]Technische Universität Braunschweig, D-38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, D-38106 Braunschweig, Germany — [3]University of Würzburg, D-97074 Würzburg, Germany

Using standard tight-binding methods, we investigate a novel backscattering mechanism taking place on quantum spin Hall N'SNSN' Josephson junctions in the presence of time-reversal symmetry. This extended geometry allows for the interplay between two types of Andreev bound states (ABS): the usual phase-dependent ABS localized at the edges of the central SNS junction *and* phase-independent ABS localized at the edges of the N'S regions. Crucially, the latter arise at discrete energies E_n and mediate a backscattering process between opposite edges on the SNS junction, yielding gap openings when both types of ABS are at resonance. In this scenario, a 4π-periodic ABS decouples from the rest of the spectrum, and thus, it can be probed preventing the emission to the quasicontinuum. Interestingly, this backscattering mechanism introduces a new length scale, determining the ratio between 4π- and 2π-periodic supercurrent contributions and distorts the superconducting quantum interference (SQI) pattern. Finally, to prove the participation of these ABS, we propose to use a magnetic flux to tune E_n to zero, resulting in the selective lifting of the fractional Josephson effect.

TT 48.3 Thu 15:45 H32

Geometric measure of entanglement in systems with poor man's Majorana modes — •Vimalesh Vimal and Jorge Cayao — Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

The physical realization of minimal Kitaev chains has recently opened an alternative avenue for engineering Majorana physics with interesting applications in quantum computing. Central to these applications is the utilization of the Majorana-like quasiparticles in these systems, known as poor man's Majorana modes, for realizing qubits and highly entangled states. In this work we consider a minimal Kitaev chain hosting poor man's Majorana modes and investigate the generation of maximally entangled quantum states by using an entirely geometric approach [1]. In particular, for pure states, the geometric measure of entanglement is quantified by its distance from the nearest separable state and provides an advantageous approach for quantifying entanglement in multipartite mixed states, in contrast to conventional bipartite measures. We characterize regimes with maximally entangled states, which surprisingly emerge with and without poor man's Majorana modes. We also discuss the generation and control of maximally entangled states by the Josephson effect in a Josephson junction based on minimal Kitaev chains. Our work thus demonstrates the potential of minimal Kitaev chains for applications in quantum information.

[1] V. K. Vimal and J. Cayao, Manuscript in preparation.

TT 48.4 Thu 16:00 H32

Emerging Majorana bound states in superconducting Haldane nanoribbons — •Simone Traverso[1], Niccolò Traverso Ziani[1], Maura Sassetti[1], and Fernando Dominguez[2] — [1]Physics Department, University of Genoa and CNR-SPIN, 16146 Genoa, Italy — [2]Faculty of Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmat, University of Würzburg, 97074 Würzburg, Germany

In the rapidly evolving field of quantum technologies, topological superconductors are promising platforms for topologically protected quantum computation. In this context, manipulating Majorana bound states (MBSs) would be a significant breakthrough.

We introduce a novel approach to designing MBSs, based on the geometric confinement of 2D nodal topological superconductors. We illustrate this mechanism in a superconducting extension of the Haldane model. In 2D, the model displays a nodal topological superconducting phase with chiral Majorana modes. However, by confining one of the dimensions the bulk bands gap out faster than the edge states, allowing for their hybridization and potentially resulting in Majorana zero modes. We assess their emergence by computing the topogical invariant for the quasi-1D setup and inspecting the energy spectrum of open flakes. Their topological nature is confirmed by the zero bias conductance in a normal-superconducting junction, precisely quantized to $2\frac{e^2}{h}$ in presence of an MBS. Our findings indicate quantum confinement as a crucial ingredient for developing quasi-1D topological superconducting phases starting from 2D nodal topological superconductors.

TT 48.5 Thu 16:15 H32

Absence of gapless Majorana edge modes in few-leg bosonic flux ladders — •Felix A. Palm[1,2], Cécile Repellin[3], Nathan Goldman[2,4], and Fabian Grusdt[1] — [1]LMU Munich & MCQST, Munich, Germany — [2]Université Libre de Bruxelles, Brussels, Belgium — [3]Université Grenoble-Alpes, Grenoble, France — [4]Laboratoire Kastler Brossel, Collège de France, Paris, France

Non-Abelian phases of matter, such as certain fractional quantum Hall states, are a promising framework to realize exotic Majorana fermions. Quantum simulators provide unprecedented controllability and versatility to investigate such states, and developing experimentally feasible schemes to realize and identify them is of immediate relevance. Motivated by recent experiments, we consider bosons on coupled chains, subjected to a magnetic flux and experiencing Hubbard repulsion. At magnetic filling factor $\nu = 1$, similar systems on cylinders have been found to host the non-Abelian Moore-Read Pfaffian state in the bulk.

Here, we address the question whether more realistic few-leg ladders can host this exotic state and its chiral Majorana edge states. We perform extensive DMRG simulations and determine the central charge of the ground state. While we do not find any evidence of gapless Majorana edge modes in systems of up to six legs, exact diagonalization of small systems reveals evidence for the Pfaffian state in the entanglement structure. By systematically varying the number of legs and monitoring the appearance and disappearance of this signal, our work highlights the importance of finite-size effects for the realization of exotic states in experimentally realistic systems.