TT 51: Topological Superconductors

Time: Thursday 16:45–18:15 Location: H32

TT 51.1 Thu 16:45 H32

Disentangling the Individual Junctions in Multi-Terminal Devices — •Josua Thieme[1,2], Nisha Shahi[1], Abdur Rehman Jalil[1], Benedikt Frohn[1], Detlev Grützmacher[1,2], and Peter Schüffelgen[1] — [1]Forschungszentrum Jülich, Germany — [2]RWTH Aachen, Germany

One avenue towards building a topological qubit, is by creating and manipulating Majorana zero modes in a hybrid device made from s-wave superconductors and 3D topological insulators (TIs). Such hybrid multi-terminal devices possess an increased number of interfaces and the coupling between all electrodes needs to be assured. We present low-temperature measurements of a TI-based three-terminal Josephson device fabricated by a combination of selective-are growth of $(BiSb)_2Te_3$ and shadow evaporation of Nb. This approach allows for the in-situ fabrication of Josephson devices with an exceptional interface quality, which is important for obtaining a strong proximity effect. In our measurements, we find quartet resonances, formed by two entangled Cooper pairs. Additionally, we present a method on how to disentangle the contributions of individual junctions in a multi-terminal device.

TT 51.2 Thu 17:00 H32

Non-Hermitian Topology in Multi-Terminal Superconducting Junctions — •Valentin Wilhelm, David Christian Ohnmacht, Hannes Weisbrich, and Wolfgang Belzig — Universität Konstanz, Konstanz, Germany

Recent experimental advancements in dissipation control have yielded significant insights into nonhermitian Hamiltonians for open quantum systems. Of particular interest are the topological characteristics exhibited by these non-hermitian systems, that arise from exceptional points–distinct degeneracies unique to such systems. In this study, we focus on Andreev bound states in multiterminal Josephson junctions with non-hermiticity induced by normal metal or ferromagnetic leads [1]. By investigating several systems of different synthetic dimensions and symmetries, we predict fragile and stable non-hermitian topological phases in these engineered superconducting systems.

[1] D.C. Ohnmacht, V. Wilhelm, H. Weisbrich, W. Belzig, arXiv:2408.01289 (2024).

TT 51.3 Thu 17:15 H32

Localized Edge States in Antiferromagnet-Superconductor Hybrid Structures — •Ignacio Sardinero[1,2], Yuriko Baba[1,2], Rubén Seoane-Souto[3], and Pablo Burset[1,2,4] — [1]Department of Theoretical Condensed Matter Physics, Universidad Autónoma de Madrid, 28049 Madrid, Spain — [2]Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain — [3]Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), Sor Juana Inés de la Cruz, 3, 28049 Madrid, Spain — [4]Instituto Nicolás Cabrera, Universidad Autónoma de Madrid, 28049 Madrid, Spain

Topological superconductors (TSCs) are promising building blocks for robust and reliable quantum information processing [1]. Most approaches to implement TSCs focus on materials with intrinsic spin-orbit coupling (SOC). However, a recent alternative strategy relies on synthetically engineering spin orbit using spatially varying magnetic fields [2]. Such proximitized structures need to be carefully designed so that the magnetic and superconducting orders coexist, avoiding stray fields detrimental for superconductivity. Here, we circumvent this challenge by investigating the role of antiferromagnetic (AF) textures in proximity to 2-dimensional superconducting surfaces. Our results reveal that the interplay between AF order and the SC coherence length impacts the density of states at the Fermi level. We show that lattice symmetry plays a crucial role for emerging topological phases, with higher-order phases arising when interlayer SOC is considered.

[1] S. Das Sarma et al., npj Quantum Inf. 1, 15001 (2015);
[2] I. Sardinero, R. Seoane-Souto, P. Burset, PRB 110, L060505 (2024).

TT 51.4 Thu 17:30 H32

Proximity-Induced Superconductivity into Thin Films of Magnetic Topological Insulators — •Daniele Di Miceli[1,2], Eduárd Zsurka[1,3], and Thomas Schmidt[1] — [1]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [2]Department of Physics, University of the Balearic Islands, E-07122 Palma, Spain — [3]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, D-52425 Jülich, Germany

Inducing superconducting (SC) correlations into magnetic topological insulators (MTIs) is becoming a promising route toward topological superconductivity and the realization of topologically protected Majorana bound states. However, a detailed understanding of the proximity effect in such MTI-SC heterostructures is still missing.

To address this question, we have developed a theory for the SC pairing induced by a conventional BCS superconductor on top of a 3D MTI thin film. By performing a perturbation series expansion in the electron tunneling between the SC and the MTI, we computed the corrections to the normal and anomalous Green's functions in the MTI in terms of the unperturbed propagators in the two isolated materials. Since the latter can be obtained exactly as a solution to the Gor'kov equations, this makes it possible to evaluate the Green's functions in the full MTI-SC heterostructures.

Our results provide a detailed description of the induced pairing, in particular showing the existence of p-wave correlations in the MTI.

TT 51.5 Thu 17:45 H32

Topological Classification of Chiral Symmetric One Dimensional Interfaces — •Harry MullineauxSanders and Bernd Braunecker — University of St. Andrews, St. Andrews, United Kingdom

Low dimensional topological phases can be engineered by placing a scattering interface into a higher dimensional bulk where the in-gap bands of quasi low dimensional interface modes can be tuned to a topologically non-trivial phase. However the classification of such modes cannot be done through low-dimensional conventional methods due to the dimensional mismatch and local nature of the topological bands. We demonstrate that there exists a simple and efficient classification method through the local Green's function at the interface, that sidesteps numerically heavy real space computations. We show that the Green's function maintains the protecting symmetries of the Hamiltonian and produces the correct phase diagram, together with a formula disentangling the contributions to the topological invariant from the substrate and the interface. For illustration we apply our method to a model of a spiral magnetic interface in an s-wave superconductor. Furthermore we compare with an alternative classification scheme derived from the spatially reduced ground state projector and show that it can produce an erroneous topological classification due to gap closures driven by the strong entanglement between the internal and spatial degrees of freedom which are naturally contained in the local Green's function. [arXiv:2407.01223]

TT 51.6 Thu 18:00 H32

Role of Spin-Orbit Coupling on Topological Superconductivity from First Principles — •András Lászlóffy[1], Bendegúz Nyári[2], Levente Rózsa[1], László Szunyogh[2], and Balázs Újfalussy[1] — [1]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest, Hungary

Recent developments on magnetic structures on superconductors paved the way to explore topological phases in real materials [1,2]. This was achieved by solving the Kohn-Sham-Dirac Bogoliubov-de Gennes equations within the Korringa-Kohn-Rostoker multiple scattering theory. By investigating 1D magnetic chains on superconductors we demonstrate that the spin-orbit coupling plays a key role in the formation of a topological phase, however, it is challenging to scale it up, because SOC is implicitly included in the Dirac equation. To circumvent this, we calculate the superconducting order parameter and the Shiba band structure of magnetic chains on a Ta overlayer on Nb. Ta has a very similar crystal structure and lattice constant to Nb. It is also a superconductor with a much smaller gap size and a considerably larger SOC. With varying the Ta layer thickness SOC can be tuned in a way which is in principle reproducible in experiments. We show that a few layers of Ta has tiny effects on the energy of the Yu-Shiba-Rusinov states of single adatoms, however, varying the SOC can tune the chains into a topologically non-trivial domain.

[1] Nyári et. al., PRB 108, 134512 (2023);
[2] Lászlóffy et. al., PRB 108, 134513 (2023).