TT 19: Topological Superconductors

Time: Wednesday 11:45–13:00 Location: H23

TT 19.1 Wed 11:45 H23

Periodic supercurrent oscillations in topological insulator nanowire Josephson junctions in an axial magnetic field — •Michael Barth[1], Jacob Fuchs[1], Cosimo Gorini[1,2], and Klaus Richter[1] — [1]Institute of Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]Université Paris-Saclay, CEA, CNRS, SPEC, 91191, Gif-sur-Yvette, France

Helical surface states of 3-dimensional topological insulator (TI) nanowires are expected to have very promising physical properties like forbidden backscattering [1]. Moreover it is predicted that a topological superconducting state which could possibly host Majorana fermions can be realized by bringing a normal s-wave superconductor in close proximity to a TI [2]. We theoretically study the influence of an axial magnetic field on the supercurrent flow in TI nanowire Josephson junctions. The wire is modeled by an effective 2 dimensional setup and we take into account the special surface geometry by incorporating the partial superconducting coverage of the wire circumference. By employing numerical tight-binding simulations [3] and a semiclassical analytical approach [4], we show that the critical current can exhibit periodic oscillations, where the period corresponds to half of the superconducting flux quantum.

[1] X.-L. Qi and S.-C. Zhang, Rev. Mod. Phys. 83, 1057 (2011)
[2] A. Cook and M. Franz, Phys. Rev. B 84, 201105(R) (2011)
[3] Kun Zuoet et al., Phys. Rev. Lett. 119, 187704 (2017)
[4] V. P. Ostroukh et al., Phys. Rev. B 94, 094514 (2016)

TT 19.2 Wed 12:00 H23

Superconductivity in HgTe based quantum point contacts — •Johannes Baumann, Martin Stehno, Hartmut Buhmann, and Laurens Molenkamp — Institute for Topological Insulators and Physikalisches Institut, Experimentelle Physik 3, Universität Würzburg, 97074 Würzburg, Germany

Quantum point contacts have been suggested as tunable transmission elements in topological quantum circuits. We etched narrow constrictions into the weak links of topological Josephson junctions prepared from high-mobility, band-inverted HgTe quantum wells (2D topological insulator). In such devices, the conductance and supercurrent transmission decrease step-wise as we deplete the carriers in the constriction electrostatically with a gate. In the entire gating range, the supercurrent diffraction pattern in a perpendicular magnetic field exhibits a slow decay indicative of a small number of Andreev bound states funnelling through the constriction. Under microwave irradiation, odd Shapiro steps are suppressed in the current-voltage characteristic of the open constriction. This observation has been linked to the appearance of a 4pi-periodic contribution to the supercurrent of topological Josephson devices. Surprisingly, we recover all steps as we reduce the transmission to a small number of channels. We discuss possible origins of the effect and implications for topological quantum devices.

TT 19.3 Wed 12:15 H23

Tunable 4π-periodic supercurrent in HgTe-based topological nanowires — •Ralf Fischer[1], Jordi Picó-Cortés[2,3], Wolfgang Himmler[1], Gloria Platero[2], Milena Grifoni[3], Dimitry Kozlov[4], Nikolay Mikhailov[4], Sergey Dvoretsky[4], Christoph Strunk[1], and Dieter Weiss[1] — [1]Experimental and Applied Physics, University of Regensburg — [2]Instituto de Ciencia de Materiales de Madrid — [3]Institute of Theoretical Physics, University of Regensburg — [4]Novosibirsk, Russia

Topological insulator nanowires in proximity to conventional superconductors have been proposed as a tunable platform to realize topological superconductivity. The tuning is done using an axial magnetic flux Φ which allows transforming the system from trivial at $\Phi = 0$ to topologically nontrivial when half a magnetic flux quantum $\Phi = \Phi_0/2$ threads the cross-sectional area of the wire.

In our work, we investigate Josephson junctions based on HgTe nanowires and probe the Shapiro step spectrum. From the suppression of odd Shapiro steps, we extract the 4π- and 2π-periodic portion of the supercurrent $I_{4\pi}$ and $I_{2\pi}$ using a resistively and capacitively shunted junction model. The ratio $I_{4\pi}/I_{2\pi}$ changes from a small value of few percent at $\Phi = 0$ up to a maximum at $\Phi = \Phi_0/2$. The presence of $I_{4\pi}$ at $\Phi = 0$ and small magnetic fields indicate that in this regime Landau-Zener transitions cause the 4π-periodic current. By disentangling the 4π-periodic supercurrent of trivial an topological origin, our data suggest that topological 4π-periodic supercurrents dominate at axial magnetic fields above $\Phi_0/4$.

TT 19.4 Wed 12:30 H23

Complex magnetic ground states and topological electronic phases of atomic spin chains on superconductors — •Jannis Neuhaus-Steinmetz[1], Elena Vedmedenko[1], Thore Posske[2], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, 20355 Hamburg, Germany — [2]I. Institute for Theoretical Physics, University of Hamburg, D-20355 Hamburg, Germany

Understanding the magnetic properties of atomic chains and nanoscopic wires on superconductors is an essential cornerstone on the road towards controlling and constructing topological matter. Yet, even in the simplest models of suspended chains, the classes of available magnetic ground states remain debated. Ferromagnetic (FM), antiferromagnetic (AFM), and spiral configurations have been suggested and experimentally detected, while additionally non-coplanar and complex collinear phases have been conjectured. Here, we resolve a recent controversy by determining the magnetic ground states of chains of magnetic atoms in proximity to a superconductor with Monte-Carlo methods, which employ the initial tight-binding model directly without further simplifications. We confirm the existence of FM, AFM and spiral ground states, and identify additional more complex ground states. We topologically classify the electronic structures, and investigate the stability of the magnetic states against increasing superconductivity. In addition, we introduce a computationally efficient alternative for approximating the magnetic ground state with an effective Heisenberg model, which we demonstrate by using our previous results as a benchmark for this new method.

TT 19.5 Wed 12:45 H23

Density functional Bogoliubov - de Gennes calculations for a topological superconductor — •Philipp Rüssmann[1,2] and Stefan Blügel[2] — [1]Institute of Theoretical Physics and Astrophysics, University of Würzburg, Würzburg, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany

The possibility to combine topological electronic band structures and superconductivity (SC) opens new pathways towards engineering exotic quantum matter. Proximity induced superconductivity in the topological surface state of topological insulators (TIs) offers the possibility to realize a chiral *p*-wave superconductor. Such a superconductor is an exotic state of matter which supports non-Abelian anyons and is of great interest for Majorana-based quantum computing applications. Material-specific insights into the microscopic details of such SC/TI interfaces are of great interest and an indispensable ingredient in the challenging materials optimization problem.

Here we first introduce the recent Bogoliubov de-Gennes (BdG) extension to the all electron full potential relativistic Korringa-Kohn-Rostoker (KKR) Green function code JuKKR [1]. We apply the KKR-BdG method to the s-wave superconductor Nb [2] and investigate the proximity induced superconductivity in the topological surface state of a SC/TI heterostructure.

[1] https://jukkr.fz-juelich.de
[2] PRB **105**, 125143 (2022)