Physikalisches Kolloquium der TU Berlin Chair: Ralph Ernstorfer

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Majorana bound states in topological insulators without a vortex

In my talk, I will discuss a three-dimensional topological insulator (TI) wire with a nonuniform chemical potential induced by gating across the cross section [1-3]. This inhomogeneity in chemical potential lifts the degeneracy between two one-dimensional surface state subbands. A magnetic field applied along the wire, due to orbital effects, breaks time-reversal symmetry and lifts the Kramers degeneracy at zero momentum. If placed in proximity to an s-wave superconductor, the system can be brought into a topological phase at relatively weak magnetic fields. Majorana bound states (MBSs), localized at the ends of the TI wire, emerge and are present for an exceptionally large region of parameter space in realistic systems. Unlike in previous proposals, these MBSs occur without the requirement of a vortex in the superconducting pairing potential, which represents a significant simplification for experiments. In my talk, I will also discuss metallization effects caused by a coupling between a thin layer of an s-wave superconductor and a TI nanowire [3-5]. In the strong coupling limit, required to induce a large superconducting pairing potential, we find that metallization results in a shift of the TI nanowire subbands (∼20 meV) as well as it leads to a small reduction in the size of the subband gap opened by a magnetic field applied parallel to the nanowire axis. Surprisingly, we find that metallization effects in TI nanowires can also be beneficial. Most notably, coupling to the superconductor induces a potential in the portion of the TI nanowire close to the interface with the superconductor, this breaks inversion symmetry and at finite momentum lifts the spin degeneracy of states within a subband. As such coupling to a superconductor can create or enhance the subband splitting that is key to achieving topological superconductivity. This is in stark contrast to semiconductors, where it has been shown that metallization effects always reduce the equivalent subband-splitting caused by spin-orbit coupling. We conclude that, unlike in semiconductors, the metallization effects that occur in TI nanowires can be relatively easily mitigated, for instance by modifying the geometry of the attached superconductor or by compensation of the TI material.

References

[1] Henry F. Legg, Daniel Loss, and Jelena Klinovaja, Phys. Rev. B 104, 165405 (2021).

[2] Henry F. Legg, Matthias Rößler, Felix Münning, Dingxun Fan, Oliver Breunig, Andrea Bliesener, Gertjan Lippertz, Anjana Uday, A. A. Taskin, Daniel Loss, Jelena Klinovaja, and Yoichi Ando, arXiv:2109.05188.

[3] Henry F. Legg, Daniel Loss, and Jelena Klinovaja, arXiv:2201.02918.

[4] Christopher Reeg, Daniel Loss, and Jelena Klinovaja, Phys. Rev. B 97, 165425 (2018).

[5] Christopher Reeg, Jelena Klinovaja, and Daniel Loss, Phys. Rev. B 96, 081301(R) (2017).

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