TT 1: Tutorial: Topological Insulators and Majorana-Fermion Physics

Topological insulators form a new class of quantum matter, with a bulk gap and exotic conducting surface states. When coupled to superconductors, so-called Majorana bound states are expected to exist under certain conditions. In this Tutorial, an introduction into the basic theoretical ideas is given, and the relevant experimental signatures and results are discussed.

Time: Sunday 16:00–18:25 Location: H20

Tutorial TT 1.1 Sun 16:00 H20

Topological Insulators and Superconductors — •Andreas Schnyder — Max Planck Institut für Festkörperforschung, D-70569 Stuttgart, Germany

The recent discovery of new topological electronic phases in insulating materials with strong spin-orbit coupling has lead to a renewed interest in topological states of matter. These topological materials have a full insulating gap in the bulk and support exotic metallic surface states, which are a consequence of bulk topological invariants. Topological insulating states have been observed in HgTe/(Hg,Ce)Te semiconductor quantum wells, in BiSb alloys, in Bi_2Se_3, and in other Bi-based compounds. Topological superconductor are fully gapped superconductors that exhibit zero-energy Majorana surface states. Here we review the theoretical foundations for topological insulators and superconductors, discuss topological band theory, and survey recent experimental findings on three-dimensional topological insulators and superconductors.

5 min. break

Tutorial TT 1.2 Sun 16:50 H20

Proximity Induced Superconductivity in Topological Insulators — •Hartmut Buhmann — Physikalisches Institut, EP3, University Würzburg, Würzburg, Germany

The discovery of Dirac-like surface states on a topological insulator (TI) and their qualitative relation to Cooper-pairs in superconducters inspired the exploration of interactions between those two states. In 2008 L. Fu and C.L. Kane [1] showed that so-called Majorana bound states are expected to exists under certain conditions in the proximity of those interfaces. Since then many ideas for experimental investigations have been published but unfortunately none of those has been realized so far.

In this presentation I will summarize the important signature for the search for Majorana bound states in connection with topological insulators and I will report on recent results on proximity induced superconductivity in TI surface states.

[1] Liang Fu and C. L. Kane, Phys. Rev. Lett. **100**, 096407 (2012)

5 min. break

Tutorial TT 1.3 Sun 17:40 H20

Majorana Fermions in Hybrid Nanosystems — •Michael Wimmer — Instituut-Lorentz, Universiteit Leiden, The Netherlands

Majorana fermions are particles that are their own anti-particle. To our current knowledge, they do not exist as elementary particles in nature. In the recent years it was however realized that quasi-particle excitations in solid state systems can mimic Majorana fermions. In particular, they appear in topological superconductors.

In the tutorial, I will show the basic properties of these "solid state Majoranas", and discuss how topological superconductors can be engineered in hybrid nanosystems consisting of ordinary superconductors and semiconductors. I will also briefly review the recent experiments that have found strong hints for the evidence of Majorana fermions in such hybrid systems. Finally, I will discuss some of the more exotic properties of Majorana fermions and how they are related to topological quantum computing.