Physics of Majorana fermions

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The goal of this tutorial talk is to provide an introduction to the subject of Majorana fermions. Majorana fermions are quasiparticles, which are their own antiparticle. To build such a state one has to combine an electron and hole excitation. One needs a superconductor to allow for the charge non-conservation, and a topological (Berry) phase to tune the excitation energy to zero. The natural candidate systems, which may host Majorana fermions, are hybrid structures of a topological insulator in the proximity of a superconductor. We review experimental progress and some recent theoretical proposals to realize, tune, and detect the Majorana quasiparticle in a working device.

Much of theoretical excitement surrounding (possible) realization of Majorana fermions results from the intrinsically non-local nature of such quasiparticles. We will explain how a non-Abelian statistics arises upon exchange of two bound Majorana fermions. The qubit can be encoded with two such pairs of bound Majoranas and is expected to be robust against decoherence. We discuss also prospects of experimentally realizing the theoretically simple exchange manipulation in actual multi-terminal setups.