MAR12-2011-006370
Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Majorana fermions in semiconductor nanowires with realistic physical parameters

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Semiconductor nanowires proximity coupled to s-wave superconductors represent a unique solid state platform for realizing and observing the elusive Majorana fermion. The existence and stability of the Majorana bound states localized at the ends of the wire depend on a set of parameters that includes the chemical potential, the external magnetic field, the spin-orbit coupling, the strength of the semiconductor-superconductor coupling, and the strengths of various types of disorder. It is critical to determine whether or not the parameter regimes that ensure the stability of the Majoranas are consistent with realistic experimental conditions. In this talk I will summarize the results of a theoretical study of multiband semiconductor nanowires that focuses on understanding the key experimental conditions required for the realization and detection of Majorana fermions. I will show that multiband occupancy not only lifts the stringent constraint of one-dimensionality, but also allows having higher carrier density in the nanowire. This significantly enhances the stability of the topologically nontrivial phase against various types of disorder, such as short-range impurities in the bulk superconductor, disorder at the semiconductor-superconductor interface, and disorder in the semiconductor nanowire. The detailed study of the parameter space for multiband semiconductor nanowires establishes the realistic likelihood of the existence of zero-energy Majorana modes within laboratory conditions.