Topological states in low-dimensional systems

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Topological phases in quantum condensed matter systems have been at the center of attention over the past decade and have become one of the most rapidly developing subjects. I will review recent progress on topological states in low-dimensional system with the main focus on Majorana fermions and parafermions. Both are non-Abelian particles useful for topological quantum computation, with the parafermions possessing a much more powerful braiding statistics. To generate parafermions, proximity-induced superconductivity is needed to be induced in semiconductor spin-orbit materials [1-3].

In my talk, I am going to discuss proximity effect both for 1D and 2D both analytically and numerically. Semiconducting quantum wires defined within two-dimensional electron gases and strongly coupled to thin superconducting layers have been extensively explored in recent experiments as promising platforms to host Majorana bound states. We have studied numerically such a geometry, consisting of a quasi-1D wire coupled to a disordered three-dimensional superconducting layer [4-7]. In the strong-coupling limit of a sizable proximity-induced superconducting gap, all transverse subbands of the wire are significantly shifted in energy relative to the chemical potential of the wire. For the lowest subband, this band shift is comparable in magnitude to the spacing between quantized levels that arise due to the finite thickness of the superconductor (which typically is ~500 meV for a 10-nmthick layer of Aluminum); in higher subbands, the band shift is much larger. Additionally, the width of the system, which is usually much larger than the thickness, and moderate disorder within the superconductor have almost no impact on the induced gap or band shift. As a result, a huge band shift and significant renormalization of semiconducting material parameters in the strong-coupling limit make it challenging to realize a topological phase in such a setup, as the strong coupling to the superconductor essentially metallizes the semiconductor. This metallization of the semiconductor can be tested experimentally through the measurement of the band shift.

If time allow, I will also switch to two- and three-dimensional topological system. I will discuss several setups in which topological phases can be engineered both is static [8,9] and driven (Floquet) [10,11] regimes.

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