Topological entanglement entropy and gapless Majorana edge modes in the three-dimensional Kitaev model

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Abstract

In this thesis, we have studied two different topological aspects of the three-dimensional Kitaev model on hyperhoneycomb lattice, a generalization of Kitaev's honeycomb lattice spin model. In the first part we have calculated the topological entanglement entropy (TEE). We find that for this model TEE is not directly determined by the total quantum dimension of the system. This is in contrast to general two dimensional systems and many three dimensional models, where TEE is related to the total quantum dimension. Our calculation also provides TEE for a three-dimensional toric-code-type Hamiltonian that emerges as the effective low-energy theory for the Kitaev model in a particular limit.

In the second part we have obtained analytical solutions for the zero-energy Majorana edge modes. We have considered three types of edges—zigzag, bearded and armchair—and found the regions in parameter space where each type of edge mode exists. In the gapless phase, we obtain edge state solutions which are the drumhead surface states associated with nodal-line semimetals. We have also found a correspondence between noninteracting complex fermions and Majorana fermions on bipartite lattices, which explains the equivalence of energy spectrum and eigenmodes of Kitaev model and a corresponding tight-binding model for complex fermions on the same lattice.