Quasicrystalline Topological Superconducting States in Ammann-Beenker Lattice

M. Hori[1,2], R. Ghadimi[3], T. Sugimoto[1], T. Tohyama[1], K. Tanaka[2]

[1] *Dept. of Applied Physics, Tokyo University of Science, Tokyo, Japan*
[2] *Dept. of Physics & Engineering Physics, and Centre for Quantum Topology and Its Applications (quanTA), University of Saskatchewan, Saskatoon, SK, Canada*
[3] *Center for Correlated Electron Systems, Institute for Basic Science, Korea*

Topological superconductivity (TSC) results in a non-trivial superconducting state characterized by a nonzero topological invariant in the bulk. The bulk-edge correspondence implies the existence of edge modes, which are zero-energy Majorana fermions appearing along the edges of the system in the case of TSC. There has been an experimental report on detecting Majorana fermions along the surfaces of a two-dimensional (2D) topological superconductor [1]. Theoretically, self-consistent studies of TSC have only been made for periodic crystals such as square lattice systems [2]. In such systems with translational symmetry, wavenumber is a good quantum number and Bloch's theorem can be utilized.

Recently, superconductivity has been experimentally realized in a quasicrystal [3]. We investigate TSC in 2D quasicrystals, Ammann-Beenker lattice (Fig. 1). The Ammann-Beenker lattice consists of a square and a rhombus, colored by red and blue, respectively, in Fig. 1. It has local eight-fold rotational symmetry and self-similarity. Due to the long-range order of the Ammann-Beenker lattice, there are Bragg peaks in pseudo-wavenumber space. Whether a stable TSC phase can exist in quasicrystals is not obvious, because of their aperiodic and self-similar structure.

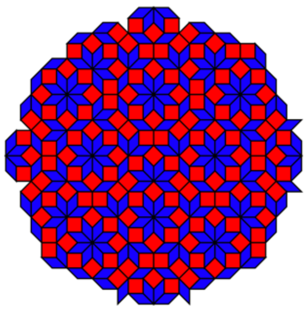

Fig. 1: *Ammann-Beenker lattice*

We solve the Bogoliubov-de Gennes equations on the tight-binding model for 2D TSC [4] generalized for quasicrystals self-consistently [2]. This model [4] describes 2D TSC with broken time-reversal symmetry as experimentally realized [1], whose topological nature is governed by the first Chern number. For quasicrystals, we calculate the Bott index as the topological invariant of the system, which is equivalent to the first Chern number in the absence of translational symmetry [5].

By solving for the superconducting order parameter self-consistently, we have found topological phase transitions in the Ammann-Beenker lattice for various electron density including half filling. There is a certain pseudo-wavenumber that is associated with the topological phase transition at half filling. Furthermore, the value of the pseudo-wavenumber is characterized by the self-similarity, local eight-fold rotational symmetry, and mirror symmetry of the Ammann-Beenker lattice.

References

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