Exotic pairing state in quasiperiodic superconductors under magnetic field

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We theoretically study a superconducting state in quasicrystals under magnetic field, partly motivated by the recent discovery of a superconducting quasicrystal [1]. We first introduce an attractive Hubbard model on Penrose-tiling structure as a simple model to discuss the issue [2]. We then solve the model within the Bogoliubov-de Gennes theory, and find an exotic superconducting state at high magnetic field just below the critical field [3]. In that state, the superconducting order parameter changes its sign in real space, with keeping the five-fold rotational symmetry inherent to the Penrose structure (see figure below). The exotic superconducting state is in part analogous to the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state in periodic systems. However, considering that the FFLO state is unstable against impurities, it is remarkable that such an alternating-sign superconducting state appears under the quasiperiodic potential, which often acts as a random potential: Electron system finds a way to keep the coherence under magnetic field by organizing itself in a spatially sign-changing pattern compatible with the underlying quasiperiodic structure.

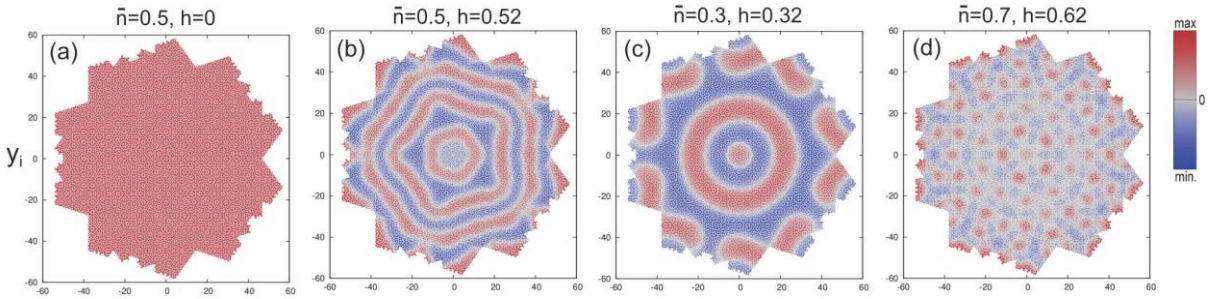

Figure: Color map of the site-dependent superconducting order parameter in the attractive Hubbard model on the Penrose-tiling cluster of 11006 sites. \bar{n} is the average electron density and h is the magnetic field strength. Electron hopping t=1, Hubbard-type interaction U=-3 and temperature T=0.01 are used.

[1] K. Kamiya *et al*., Nature Commun. **9**, 154 (2018).
[2] S. S, N. Takemori, A. Koga, and R. Arita, Phys. Rev. B **95**, 024509 (2017).
[3] S. S and R. Arita, arXiv:1905.01487.