Superconductivity and Supercurrent Anomalies in Quasicrystals

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Superconductivity has been observed in systems lacking translational symmetry, such as amorphous metals $Sn_{0.9}Cu_{0.1}$ and $Pb_{0.75}Bi_{0.25}$, which exhibit a strong electron-phonon interaction. However, weak-coupling superconductivity with spatially extended Cooper pairs in aperiodic systems remains a highly nontrivial issue. In 2018, bulk superconductivity was discovered in Al-Mg-Zn quasicrystals[1] where quasicrystal is a solid that shows sharp Bragg peaks dispite exhibiting rotational symmetry incompatible with periodicity [2,3]. The temperature dependence of the electronic specific heat was found to be consistent with BCS theory.

In this talk, we present the results of a theoretical analysis of the attractive Hubbard model [4-7] using Bogoliubov-de Gennes mean-field theory. We show that quasicrystals exhibit weak-coupling superconductivity that differs from BCS superconductivity [4]. The specific heat jump in quasicrystals is also found to be 10-20% smaller than the BCS theoretical value due to the lack of Fermi surface and coherence peaks [5].

We further studied the spatial distributions of the local supercurrent induced by a uniform vector potential [6,7]. The attractive Hubbard model was numerically studied within the Bogoliubov-de Gennes mean field theory. We will show that non-uniform supercurrent distributions can be realized under inhomogeneous superconducting states in quasicrystals. Furthermore, it is clarified that the paramagnetic components of the supercurrents can flow in a direction perpendicular to the applied vector potential and are finite even at zero temperature. Such phenomena can also be expected in the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state [8,9], however, we note that our results make experimental access much easier because proper adjustment of the magnetic field is unnecessary.

References

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