Field evolution of the FFLO state studied by the microscopic Eilenberger method

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We study magnetic field dependencies of the Fulde-Ferrell-Larkin-Ovchinnikov(FFLO) state and its physical quantities by solving the quasi-classical Eilenberger equations. The FFLO state seems to be realized in a heavy fermion compound $CeCoIn_5$[1]. It is necessary to study the behavior of the physical quantities from the theoretical viewpoints. In the FFLO state superconducting order parameter oscillates, changing its sign in the real space. Since the FFLO state are stabilized in high-fields low-temperature region, vortex effects need to be considered on the same footing.
By solving Eilenberger equations self-consistently, we evaluate two free energies for the vortex state with and without the FFLO state in various fields, and compare the free energy for these two states at each field. We find the region in which the FFLO state becomes stable and magnetic field dependencies of the state. A transition from the vortex state to the vortex and FFLO coexisting state is the second-order transition from the **q**-vector behavior. We calculate that paramagnetic moments, diamagnetic magnetization, and form factor changes as a function of applied field. Based on our numerical results, we analyze these quantities in terms of the nodal planes of the superconducting order parameter and the quasi-particles bounded state.

[1]Kenta M. Suzuki, Masanori Ichioka, and Kazushige Machida, Phys. Rev. B 83, 140503(R) (2011)