Theoretical Study for Vortices and The FFLO State of Type II Superconductors

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When the Pauli-paramagnetic effect strongly acts the pair-breaking for Cooper pairs, in an applied-field the phase-transition between the normal and superconducting state can be the first order transition. Under the temperature of this first order transition the order-parameter can have the spatial modulation. This is called as Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state[1, 2]. Recently, in the superconductor $CeCoIn_5$ the existence of this FFLO state is suggested by experimental studies[3].

There are earlier studies for the Pauli-paramagnetic effect. Some of them focus on the superconducting phase-diagram for the temperature and applied field. Because $CeCoIn_5$ is type II superconductor, we have to consider the Pauli-paramagnetic effect associated with the FFLO state on the same footing with vortices of the mixed state. However, there are a few studies which consider those vortices[4, 5].

We study the free energy of the FFLO state in the vortex-lattice state by using the numerical calculation, which is based on the quasiclassical theory. By comparing free energies we aim to understand the phase-diagram of a superconductor in which there is the Pauli-paramagnetic effect. In the presentation we will report field and periodic-length dependence of the free energy, which is obtained by the self-consistent calculation study.

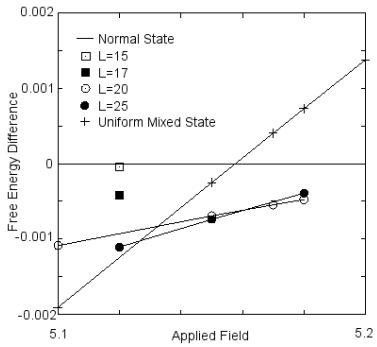

Fig. 1: Field dependence of the free energy difference. L is periodic-length of the order-parameter modulation. Data are for the uniform mixed state, L=25, 20, 17, 15, and normal state from bottom to top at the lower field.

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