論　文　の　要　旨

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論 文 題 目　Fermi–surface effect on the Fulde–Ferrell–Larkin–Ovchinnikov state in quasi–one–dimensional superconductors
（準一次元超伝導体におけるＦＦＬＯ状態に対するフェルミ面効果）

The Fulde–Ferrell–Larkin–Ovchinnikov (FFLO) state is the superconducting state in which Cooper pairs have a finite center-of-mass momentum $\boldsymbol{q}$, and stabilized in strongly Pauli-limited clean type-II superconductors. The order parameter of this state exhibits an oscillation in real space with a wave number $\boldsymbol{q}$. The candidate compounds to host the FFLO state are quasi-low-dimensional (QLD) superconductors, such as organic superconductors, high-Tc cuprates, and the QLD heavy fermion superconductors. In the QLD organic superconductors, if the magnetic field is applied in the direction parallel to the most conducting layers, the superconductivity survives up to the Pauli paramagnetic limit H_P because the orbital pair-breaking effect is suppressed. In addition, the anisotropic Fermi-surface structure orients $\boldsymbol{q}$ to the optimum direction, so that the upper critical field is maximized.

In this thesis, the effect of the Fermi-surface anisotropy on the FFLO state is investigated in the quasi-one-dimensional (Q1D) s- and d-wave superconductors, with a brief review of the FFLO state. The equations for Tc, H_{c2}, and H_P are formulated for the Q1D type-II superconductors, and they are numerically solved. The temperature dependence of the upper critical field $H_{c2}(T)$ of the FFLO state is obtained for various ratio of the hopping energies t_b/t_a and the direction of $\boldsymbol{q}$, where t_a and t_b denote the intra- and inter-chain hopping energies, respectively. As a result, a novel dimensional crossover of the FFLO state is discovered both for s- and d-wave pairings, when $t_b/t_a < 0.1$ and $\boldsymbol{q}\ //\ \boldsymbol{a}$, where $\boldsymbol{a}$ is the lattice vector of the most conductive chain. Just below the tricritical temperature T^* of the FFLO, BCS, and normal states, the upper critical field increases steeply as in one-dimensional systems, When the temperature decreases, the rate of increase in $H_{c2}(T)$ diminishes and a shoulder appears. Near $T = 0$, the rate of increase is recovered, which results in an upturn of the $H_{c2}(T)$, but the upturn for s-wave pairing is smaller than that for d-wave pairings. At $T = 0$, the upper critical field converges to a finite value $H_{c2}(0)$. This behavior near $T = 0$ is typical of the FFLO state in two-dimensional systems. On the other hand, for larger t_b/t_a, the behavior of

$H_{c2}(T)$ becomes typical of Q2D systems, both for s- and d-wave pairings. For $t_b/t_a > 0.15$, the upper critical fields exhibit a two-dimensional behavior, except for a slight shoulder in the range of $0.2 > t_b/t_a > 0.15$. For d-wave pairing, when $\phi > \pi/4$, where ϕ is the angle between $\boldsymbol{q}$ and $\boldsymbol{a}$, the upper critical field curve is convex upward at low temperatures, as in three-dimensional isotropic system. This irregular behavior is interpreted by the nesting effect. It is also found that the optimum direction $\boldsymbol{q}$ with which $H_{c2}(T)$ is maximized is parallel to $\boldsymbol{a}$ in the whole temperature range, while $H_{c2}(T)$ is only slightly larger than the Pauli paramagnetic limit for $\boldsymbol{q} \perp \boldsymbol{a}$. We discuss the relevance of the theory to the Q1D organic superconductor $(TMTSF)_2ClO_4$, in which the FFLO state has been suggested from magnetic-field angle-dependence of the superconductive on-set temperature. A shoulder observed in the upper critical field for $\boldsymbol{H} \parallel \boldsymbol{a}$ may be related to the unique temperature dependence of the $H_{c2}(T)$ for $t_b/t_a < 0.1$ and $\phi = 0$. It is also suggested that the orbital pair-breaking effect is extremely weak in this compound, for the theoretical angular dependence of H_{c2} to agree with the experimental result.