Vortex core structure in s-wave and d-wave superconductors

K. Machida, M. Ichioka, N. Hayashi and T. Isoshima

Department of Physics, Okayama University, Okayama 700-8530, Japan

Abstract

Microscopic theories on vortex core structures in both s- and d-wave clean superconductors are presented. Our study is based on either quasi-classical Eilenberger theory or Bogoliubov-de Gennes (BdG) theory. The former framework is quite versatile in extracting spatially resolved quasi-particle excitations around a vortex not only in s-wave but also in d-wave superconductors. The STM experiments on $NbSe_2$ by Hess et al. are analyzed by this method, revealing rich internal excitation structures around a core. By solving the Eilenberger equation for a vortex lattice case, we now able to understand the interrelation among the nodal structure of the energy gap, quasi-particle excitations in vortex cores and vortex overlapping effect in the lattice.

The BdG equation is solved numerically for an isolated s-wave vortex case. Upon approaching the extreme quantum limit: $k_F\xi_0 \sim O(1)$ (k_F:the Fermi wave number and ξ_0:the coherent length), which is not covered by the quasi-classical theory, we find further new features of the vortex core, such as charge accumulation at a core associated with broken particle-hole symmetry, Friedel oscillation in the spatial variation of the pair potential and saturation of the Kramer-Pesch effect. Some of these features are being revealed by recent experiments.