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Vortex structure and flux flow in multi-component superconductors

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Some exotic unconventional superconductors have multiple superconducting phases, indicating multi-component pair potential of the superconductivity. In a superconducting state of $PrOs_4Sb_{12}$, spontaneous moment observed by the muon spin relaxation (μSR) experiment indicates the multi-component pairing function[1]. Thermal conductivity experiment suggests the double transition accompanied with fourfold-twofold symmetry change at H^* [2], also indicating multi-component pairing. In the multi-component superconductors, the combination of multi-components introduces interesting behaviors, such as domain structure, exotic vortex structure, etc. We study the exotic vortex state in multi-component superconductors by a simulation of the time-dependent two-component Ginzburg-Landau theory [3,4].

In two-component superconductors, two superconducting states with different relative phase (for example, 0 and π) are degenerate in free energy. Therefore, domain structure may appear, i.e., some regions in a sample are the domain with relative phase 0, and others are the domain with relative phase π. Between the domains, a domain wall appears as a topological defect, which is not easily destroyed. When magnetic fields are applied to this domain structure, some of vortices are trapped at the domain wall. And these vortices at the domain wall become exotic structure called as "vortex sheet", where conventional vortex splits into two vortices with half flux-quantum, as shown in Fig. 1(a)

We also investigate the flux flow and the pinning of the vortex sheet structure [4]. In the free flux flow case, the vortex sheet with half flux-quantum vortices also flows with the flux flow of the conventional vortices. Therefore, the domain wall moves by the flux flow. In the pinning case, since many vortices are trapped at pinning centers, the line of the vortex sheet also can not easily flow. However, half flux-quantum vortices easily flow along the vortex sheet. After the flow through the vortex sheet, a pair of half flux-quantum vortices is combined at the front corner of the vortex sheet, and changes to a conventional vortex with a flux quantum. This conventional vortex leaves from the vortex sheet.

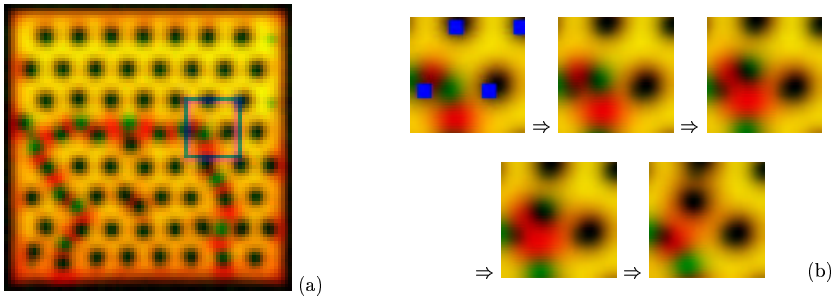

Figure 1: The vortex structure in the flux flow with the pinning centers. (a) The red and green circles are half-flux-quantum vortices at the domain wall. Black circles are conventional vortices. (b) Time evolution for a creation process of a conventional vortex from half flux-quantum vortices within the enclosed area in (a). The positions of the pinning centers are represented by blue squares in the first panel.

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[2] K. Izawa, *et al.*, Phys. Rev. Lett. **90** (2003) 117001.
[3] Y. Matsunaga, M. Ichioka, and K. Machida, Phys. Rev. Lett. **92** (2004) 157001.
[4] Y. Matsunaga, M. Ichioka, and K. Machida, Phys. Rev. B. **70** (2004) 100502.