Energetics of Half-Quantum Vortices

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Abstract

Half-quantum vortices possessing non-Abelian statistics offer the prospect of new applications in quantum computing (Figure 1). Magnetic cantilever measurements have detected half-flux states (Figure 1) in mesoscopic rings of the layered material strontium ruthinate [2] adding evidence that superconducting strontium ruthinate may posses a p-wave order parameter [3]. The stability region of the half-flux states were seen to grow linearly with applied in-plane field. A proposal accounting for this behavior has been presented [4] involving a model of the superconducting condensate as being composed of two, separate, "spin-up" and "spin-down" condensates; the so-called equal spin pairing (ESP) state. In the half flux state only one of the condensates possesses a vortex causing a mismatch in their velocities and, thus, a mismatch in their densities (Figure 2). This density mismatch between the two spin directions implies a magnetic moment which, when coupled to the in-plane magnetic field, can reduce the free energy of the half flux state relative to the integer flux states. In this paper, I will present COMSOL evaluated numerical analyses of the free energy of the vortex states using a Ginzburg-Landau type model over a range of parameter values and using geometries similar to the experimental setup (Figure 3). Initial results using COMSOL indicate that the proposed mechanism in [4] can, indeed, produce an increased stability of the half-flux state with increased in-plane magnetic field. Figure 4 shows the reduction of the free energy of the half-flux state versus the zero and unit flux states with increased in-plane magnetic field. The diminishing free energy leads to an increase in the stability region of the half-flux state. Besides being of basic scientific interest, the confirmation of the existence of half-quantum vortices may be used as a resource for topological quantum computation.

Reference

1. M. Stone and S. B. Chung, Phys. Rev. B 73, 014505 (2006)
2. Jang et. al., Science, 331, p. 186 (2011)
3. A.P. Mackenzie and Y. Maeno, Rev. Mod. Phys. 75, 657 (2003)
4. V. Vakaryuk and A.J. Leggett, Phys. Rev. Lett. 103, 057003 (2009)

Figures used in the abstract

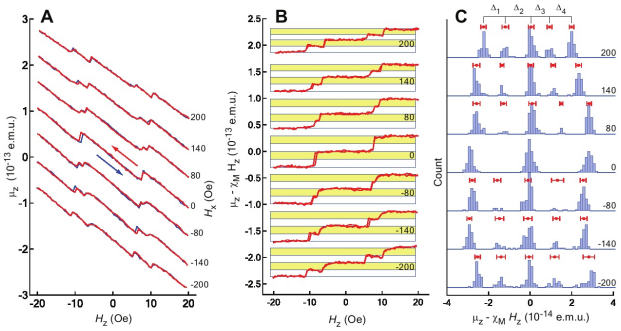

Figure 1: Measurements of the half-flux state.

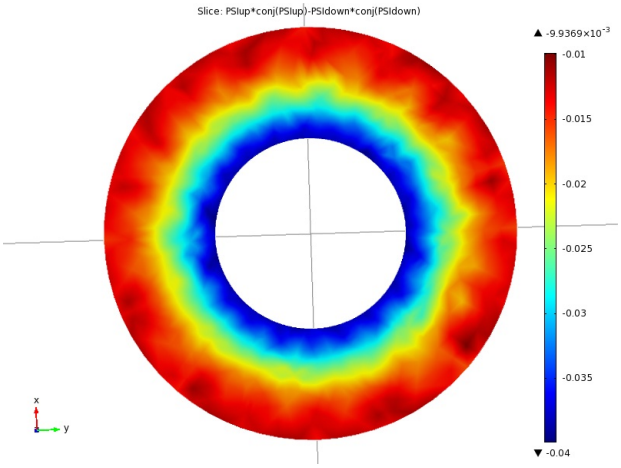

Figure 2: COMSOL simulation showing spin polarization due to kinematic effects.

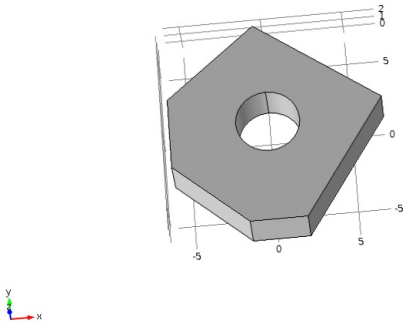

Figure 3: Simulation geometry.

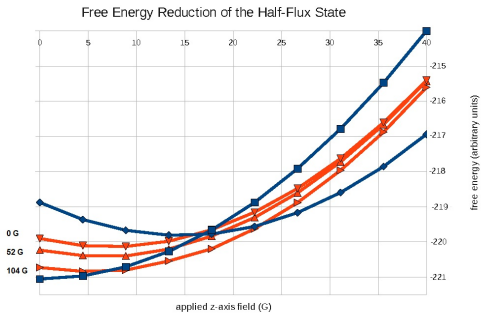

Figure 4: The reduction of the free energy of the half-flux state with increased in-plane field.