Van der Waals interaction between flux lines in High-T_c Superconductors

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Abstract

In anisotropic or layered superconductors thermal fluctuations as well as impurities induce a van der Waals (vdW) attraction between flux lines, as has recently been shown by Blatter and Geshkenbein in the thermal case [Phys. Rev. Lett. 77, 4958 (1996)] and by Mukherji and Nattermann in the disorder dominated case [Phys. Rev. Lett. 79, 139 (1997)]. This attraction together with the entropic or disorder induced repulsion has interesting consequences for the low field phase diagram. We present two derivations of the vdW attraction, one of which is based on an intuitive picture, the other one following from a systematic expansion of the free energy of two interacting flux lines. Both the thermal and the disorder dominated case are considered. In the thermal case in the absence of disorder, we use scaling arguments as well as a functional renormalization of the vortex-vortex interaction energy to calculate the effective Gibbs free energy on the scale of the mean flux line distance. We discuss the resulting low field phase diagram and make quantitative predictions for pure BiSCCO ($Bi_2Sr_2CaCu_2O_8$). In the case with impurities, the Gibbs free energy is calculated on the basis of scaling arguments, allowing for a semi-quantitative discussion of the low-field, low-temperature phase diagram in the presence of impurities.