Impact of non-local electrodynamics on vortex matter in clean YNi_2B_2C superconductor: magnetization, irreversibility, and the vortex lattice

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The presence of non-local electrodynamics can strongly affect the properties of clean, high-κ superconductors, when the electronic mean free path is large compared with the coherence length ξ. The borocarbides, especially the nonmagnetic compoundsYNi_2B_2C and $LuNi_2B_2C$, are a particularly good system for observing these effects. Non-locality modifies the vortex-vortex interaction and makes it anisotropic, even in square symmetry (with the magnetic field directed perpendicular to the square basal plane of tetragonal borocarbide crystals) and in cubic materials such as V_3Si.

Thus, nonlocal effects produce the observed hexagonal-to-square phase transitions in the vortex lattice, as observed previously by neutron scattering and STM. The same anisotropic vortex interaction modifies the equilibrium magnetization and changes its dependence on magnetic field from the simple local London relation $M \sim \ln(H)$ to a more complex dependence. The experimental results are well described by Kogan's generalized London theory that introduces a third length scale, the non-locality radius, in addition to the usual coherence length and penetration depth. In studies with the magnetic field directed within the square basal plane, we observe a four-fold oscillation of the magnetization. This cannot be explained by the usual mass anisotropy (a second rank tensor); however, the four-fold periodicity is neatly accounted for by a symmetry-breaking fourth rank tensor that naturally arises in the generalized London theory. Further analysis of basal plane data reveals well-behaved values for all superconductive parameters. In addition to these non-local effects, a further consequence of a long mean free path should be a distinct temperature dependence in the Ginzburg-Landau parameters κ_i, which we indeed observe in studies based both on the heat capacity and magnetization.

Very interestingly, the *irreversible* magnetization also exhibits features directly correlated with non-locality-induced changes in the vortex lattice. In particular, the pinning force density $F_p(H)$ (with field H perpendicular to the basal plane) has a distinct "knee" near the hex-to-square vortex lattice transformation at ~ 1 kOe. With H parallel to the basal plane, F_p is much larger and it exhibits a four-fold angular variation, which again cannot be explained by a mass anisotropy. Finally, all of these non-local phenomena, both reversible and irreversible, become "washed-out" at higher temperatures, as qualitatively expected when the coherence length increases and becomes comparable with the mean free path.

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