Experimental report

09/02/2016

Proposal: 5-32-815

Council: 10/2014

Title: Helical Vortex Structures in Current-Carrying Wires

Research area: Physics

This proposal is a continuation of 5-32-744

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Samples: Nb

Instrument	Requested days	Allocated days	From	To
D33	3	3	19/06/2015	22/06/2015

Abstract:

All useful properties of superconductors derive from zero electrical resistance. In Type-II materials, resistance comes from magnetic flux lines or vortices crossing the applied current. The self-field of a current in a wire circulates around the wire axis, and when this enters the sample and is forced to the wire axis, a voltage is observed that varies as current squared. How this self-field combines with an applied longitudinal field is the subject of fierce theoretical debate: the combination of vortex rings and lines could produce a helical vortex structure or the rings could merely cross the lines via kinks. Previously evidence for rings crossing lines was found by SANS but another experiment with slightly different conditions gave indirect evidence for helicity. Here we propose an experiment to resolve the issue.

Summary of ILL expt Nov 2015 R. Cubitt 5-32-815

Applied field of 0.185T parallel to 0.5 mm diameter Nb wire kept at 4K under liquid He. Self field at surface =8G/A.

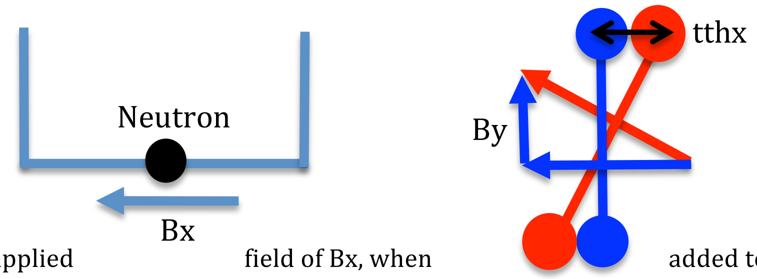

Figure 1. The applied field of Bx, when added to the self-field component, By results in a horizontal spread of the Bragg peak, tthx as an angle measured from the sample.

The applied field is along the direction Bx with the self-field, By being revealed by a transverse component of scattered intensity. With the wire perpendicular to the same value field the critical current was ~0.2A so pinning is very low.
The voltage characteristics are parabolic, consistent with only the self-field component contributing to flux flow.

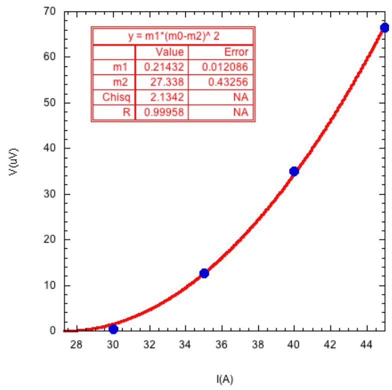

Figure 2. Parabolic voltage with field parallel to wire axis. V=0.21(1)e-6(I-27.3(4)^2 volts.

Previous experiments have shown that with the neutron beam parallel to the wire the range of angles of flux lattice planes was too large to be measured. The solution was to go to a perpendicular geometry. Here only two Bragg peaks are seen, scattered above and below the direct beam. The lattice is very likely to be disordered orientationally meaning these spots are a slice of a ring. The tangential distribution of these Bragg peaks is a direct measure of the vertical (i.e self field) bulk components of the vortex lattice.

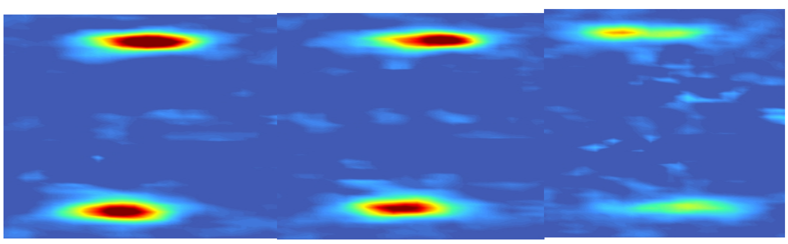

Figure 3. Neutron scattering from 0A (left), 30 A (middle) and 45 A (right).
The field was misaligned to the horizontal by ˜0.5 deg.

With 0 and 30A the scattering is essentially unchanged with a slight angle of the applied field to the horizontal. Only above 30A, where there is a measureable voltage, is there any change in the scattering. At 45A there is a significant change with an asymmetric distribution of angles to the vertical.

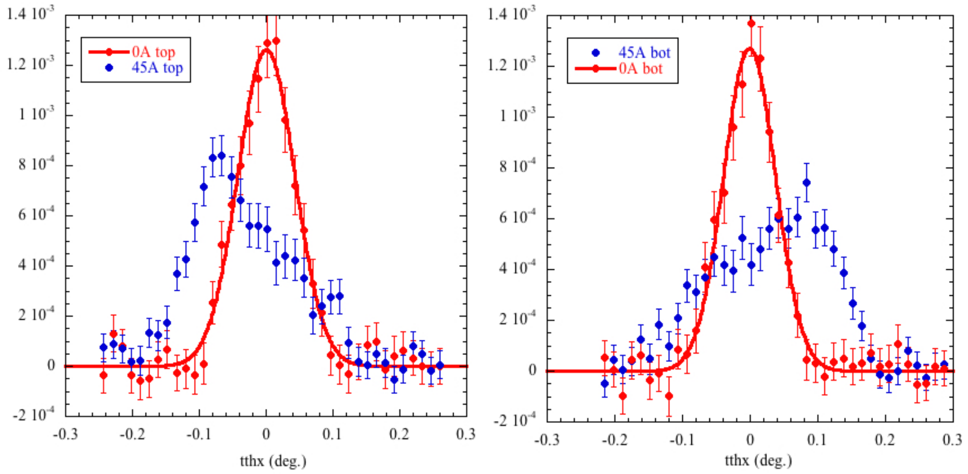

Figure 3. Intensity as a function of the horizontal deflection of the Bragg peak from the sample (tthx) for the top and bottom peaks. The data in red is with no applied current.

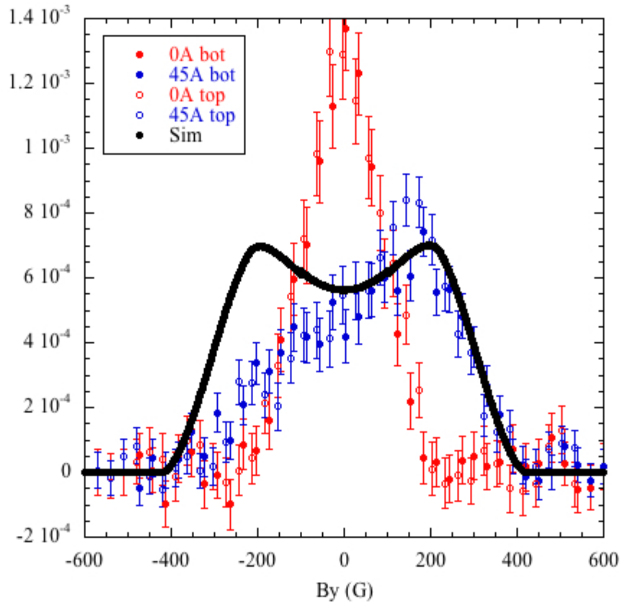

Figure 4. The vertical component (self-field) derived from the horizontal deflection with a simulation of a percet helical state at 40A.

A pure helical state would have a symmetric distribution of By – even with equal anti-helices to helices in Clem cutting model as shown in the simulation in figure 4. The asymmetry could be a sign that the current distribution is not centered on the wire axis but displaced.