VORTEX LATTICE STRUCTURES IN YNi_2B_2C.

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ABSTRACT

We observe a flux lattice with square symmetry in the superconductor YNi_2B_2C when the applied field is parallel to the c-axis of the crystal. A square lattice observed previously in the isostructural magnetic analog $ErNi_2B_2C$ was attributed to the interaction between magnetic order in that system and the flux lattice. Since the Y-based compound does not order magnetically, it is clear that the structure of the flux lattice is unrelated to magnetic order. In fact, we show that the flux lines have a square cross-section when the applied field is parallel to the c-axis of the crystal, since the measured penetration depth along the 110 crystal direction is smaller than the penetration depth along the 100 by approximately 30%. This causes the square symmetry of the lattice. Although we find considerable disorder in the arrangement of the flux lines at 2.5T, no melting of the vortex lattice was observed.

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Shortly after rare earth nickel borocarbides of the type RNi_2B_2C (R=rare-earth) were found[1] to be superconducting in 1994, it was found that some of these compounds containing a magnetic rare earth ion exhibited coexistence[2,3] of magnetic order with superconductivity. The interplay between superconductivity and magnetism is a topic of considerable interest. In order to separate out those effects that are due to magnetic order, we have studied the compound YNi_2B_2C, which does not order magnetically.

The neutron scattering measurements were carried out on the 30-m SANS facility at Oak Ridge National Laboratory. The sample was a single crystal of YNi_2B_2C which was grown by a high temperature flux method using Ni_2B flux with isotopic ^{11}B to reduce neutron absorption. The crystal (of dimensions 3.4mm×3.7mm×0.6mm thick) had a mosaic, determined by neutron diffraction, of less than 0.2°. The crystal had a T_c (onset) of 15.7K.

With the field parallel to the c-axis (long axis of the nuclear tetragonal cell) of the crystal, four-fold symmetry was observed for the flux lattice diffraction pattern (Fig. 1) for an applied field was 0.4Tesla. The first order (10 and 01) spots were aligned along the 110 crystallographic axes. The lattice had reasonably long range translational order so that second order (11) peaks were also detectable. In this respect, it resembles the square flux lattice observed in Pb[4]. A square lattice is also seen in Nb[5] under certain conditions, when the field is parallel to the 110 direction. The square lattice existed[6] in the field range from $0.4T$-$2.5T$ but a hexagonal lattice was seen below[7] about $.012T$. studied. Clearly, the fll structure is completely unrelated to the magnetic order, contrary to the suggestion of Yaron et al[8] based on data for the magnetic Er analog.

Rocking curves (about the vertical axis) perpendicular to the incident neutron and applied field directions gave a width for the flux line crystal of 0.45°±0.05°. Our measured rocking curve width translates to a minimum length, l, of 9.2μm over which the flux lines scatter coherently. From the temperature dependence of the intensity for an applied field of 1T, it is seen that the temperature (T) dependence of the second-order peak is identical to that of the first order reflection, evidence that the mosaic does not change with T.

The London penetration depth, λ_L, is obtained[9] from the Bragg intensity from the relation:

$$\frac{I}{I_0 V} = \frac{2\pi}{q}\left[\frac{\gamma}{2}\right]^2 \lambda_n^2 \left(\frac{1}{\varphi_0}\right)^2 \left(\frac{B}{(1+q^2\lambda_L^2)}\, e^{-(2\pi^2 B\xi^2/\varphi_0)}\right)^2$$

where V is the sample volume, γ is the neutron gyromagnetic ratio, B the applied field, ξ is the coherence length and λ_n is the neutron wavelength. At 0.4T, the London depth is 1180±80Å, which is considerably larger than that for $ErNi_2B_2C$ from SANS measurements. This measure represents an upper limit on the penetration depth.

We see[10] that the penetration depth along the 110 is 30% smaller than that along the 100, using the c-axis London depth as a gauge. This results in the cross-section of a single flux line being square, when the applied field is parallel to the c-axis. Consequently, the stacking is square when the vortices begin to overlap, which occurs at approximately 0.1 *T* in this geometry. This agrees well with the field where the change in symmetry[7] is observed.

A monotonic increase in disorder is observed with applied field possibly prefaces a change in structure of the lattice as the effect of the cores becomes more significant. The drop in intensity that we observe here is continuous. We can identify no sharp changes in behaviour (expected for a solid-liquid transition); the relative intensities of first order to second order peaks at 0.4Tesla imply little or no (0.4%±3%) disorder. We have a well formed lattice at 0.4 Tesla and this lattice becomes progressively more disordered as the field is increased. Detailed analyses indicate that **no** glassy transition is implied by the data in contrast to previous interpretations of magnetic data.

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Figure Captions

Fig. 1 A lattice with square symmetry is observed when the applied field (0.4T) is parallel to the c-axis of the crystal.

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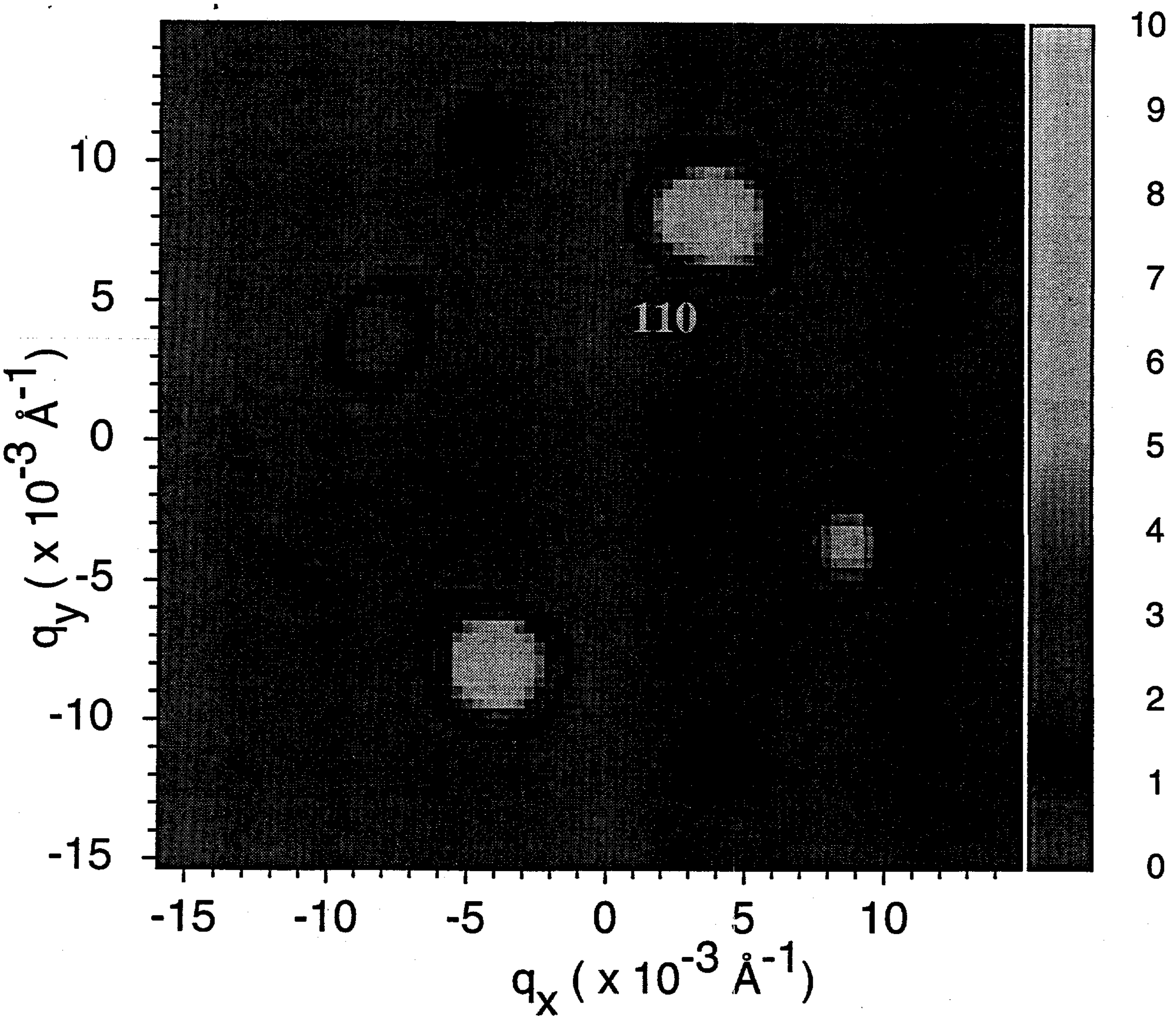

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