Experimental Report

Proposal: **5-42-347** **Council:** 10/2012

Title: Vortex lattice study of highly ordered underdoped YBa(2)Cu(3)O(6+x)(x=0.5, 0.7)

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Researh Area: Physics

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Samples: YBa(2)Cu(3)O(6+x)

Instrument	Req. Days	All. Days	From	To
D33	8	5	19/03/2013	24/03/2013

Abstract:

We propose to perform small-angle neutron scattering investigations of the vortex lattice (VL) in underdoped, twinfree, and highly CuO-chain ordered samples of the High-Tc superconductor YBa(2)Cu(3)O(6+x). Our previous studies have been performed on stoichiometric and twinfree YBa2Cu3O7, which is close to optimal doping. This new study aims to examine the VL on two samples of varying underdoping, for doping levels where field-induced charge-density-wave (CDW) order has been reported.

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Small angle neutron scattering (SANS) studies of the vortex lattice in cuprates provide important information about the field dependent anisotropies within the superconducting state. Vortex lattice studies of slightly overdoped stoichiometric $YBa_2Cu_3O_7$ [1] have provided important information regarding the roles of the Fermi surface and superconducting gap anisotropy in $YBa_2Cu_3O_{6+x}$ ($YBCO_{6+x}$). Previous attempts of SANS studies of underdoped $YBCO_{6+x}$ were unsuccessful.

We recently improved our crystal growth procedure and are now able to prepare high purity $YBCO_{6+x}$ single crystals which are fully detwinned, exhibit highly ordered CuO chain superstructures, and which are sufficiently large for neutron scattering experiments. With this experiment we mainly investigated ortho-II ordered $YBCO_{6.55}$ (superconducting T_c=61K, hole doping p=0.11) and took first test measurements on ortho-III ordered $YBCO_{6.75}$ (T_c=75K, p=0.13).

The two studied samples are crystal arrays with a total sample mass of ~260mg for $YBCO_{6.55}$ and ~70mg for $YBCO_{6.75}$, coaligned on a silicon plate. We were using D33 equipped with the University of Birmingham 17T horizontal field cryomagnet. The $YBCO_{6+x}$ samples were mounted with the crystallographic c-axis in the beam direction. The instrument configuration (wavelength, collimation, detector distance) used for the main part of the experiment with magnetic fields between 0.1T and 0.2T was (12Å, 12.8m, 13m).

The vortex lattice in $YBCO_{6.55}$ was studied at T=2K for fields between 0.05T and 0.2T by taking rocking scans through the Bragg peaks. The background was taken at T=2K and H=0T. Hexagonal vortex lattice Bragg spots could be obtained for fields up to 0.15T. For higher fields only a ring pattern indicating a strongly disordered vortex lattice was measured. For H=0.10T we studied the temperature dependence of the vortex lattice Bragg peaks. Some test measurements on $YBCO_{6.55}$ at higher fields up to H=4T and elevated temperatures, trying to suppress pinning effects remained unsuccessful. First measurements on $YBCO_{6.75}$ were taken for H=0.10T.

While we could obtain clear vortex-lattice Bragg spots for $YBCO_{6.55}$, we could only get a ring-like structure for $YBCO_{6.75}$, see Figure 1. This could be in part due to the fact that the ortho-II superstructure ordering is better defined than the ortho-III superstructure. Another reason is likely the smaller sample mass of $YBCO_{6.75}$ compared to $YBCO_{6.55}$. It might be worth trying to increase the sample mass of our $YBCO_{6.75}$ sample for future studies.

While in $YBCO_7$ (T_c=86K, p=0.18) a vortex lattice is observed to the highest fields (>10T) which can be accessed in SANS studies [1], our measurements on $YBCO_{6.55}$ and $YBCO_{6.75}$ indicate that a vortex lattice can be observed only at very low fields below ~1T. From transport measurements it has been argued that the upper critical field H_{c2} has a minimum

around p=1/8 in $YBCO_{6+x}$ [2]. If this was true, one could expect that for $YBCO_{6.50}$ (T_c=50K, p=0.08) a vortex lattice might persist to higher fields than in $YBCO_{6.55}$.

References

[1] J.S. White *et al.*, *PRL* **102**, 097001 (2009).
[2] G. Grissonnanche *et al.*, arXiv: 1303.3856.

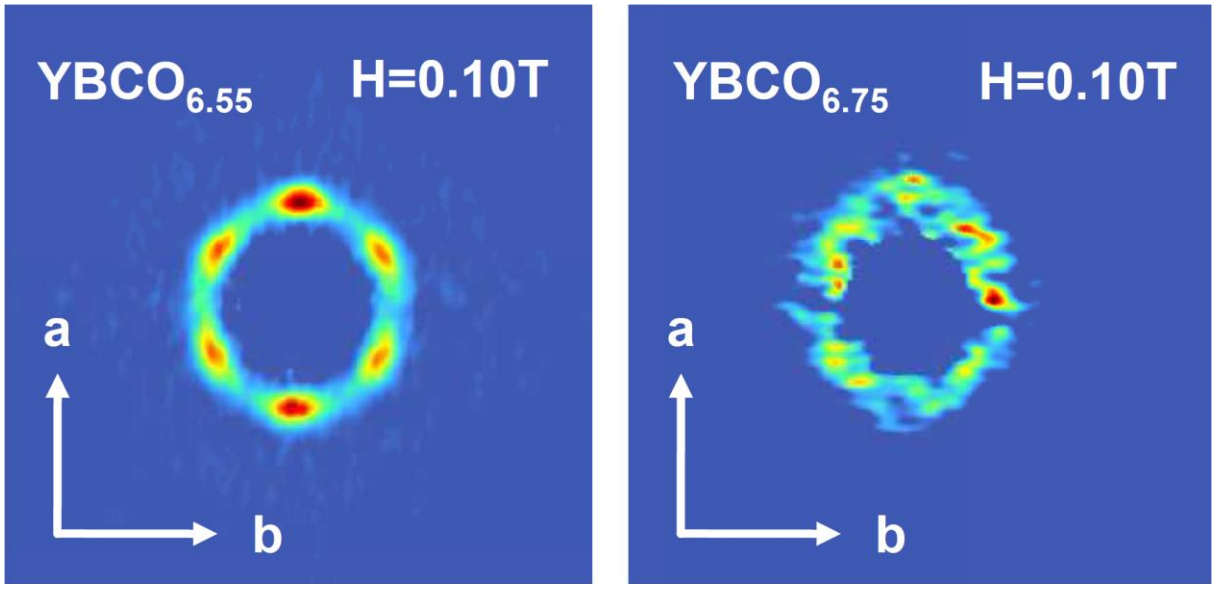

Figure 1 Vortex-lattice diffraction pattern observed in our highly ordered ortho-II phase $YBCO_{6.55}$ and ortho-III phase $YBCO_{6.75}$ crystals for a magnetic field parallel to the crystallographic c-axis of 0.10T.