Experimental report

14/08/2019

Proposal: **5-14-262** **Council:** 4/2018

Title: Measurement of the Flux Line Lattice in Heavy Fermion Superconductor U6Fe

Research area: Physics

This proposal is a new proposal

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Samples: U6Fe

Instrument	Requested days	Allocated days	From	To
D33	3	2	10/09/2018	12/09/2018

Abstract:

U6Fe becomes superconducting below 4 K and has an exceptionally high critical field (Hc2) of 10 - 13 T (depending on direction). We have recently discovered a charge density wave (CDW) with period 66 Å appears below 10 K and coexists with the superconducting state below 4 K. For U6Fe a CDW may promote a long sought modulated phase of superconductivity known as a Fulde-Ferrell Larkin Ovchinnikov state. Studies of the flux line lattice (FLL) can provide a wealth of information about the detailed nature of the superconducting state in a material. In the case of U6Fe where such a high Hc2 exists, it is possible to have a synchronisation field where the periodicity of the FLL synchronises with the period of the CDW. At fields close to the synchronisation field the geometry of the FLL is expected to deform and its orientation could change. For a perfectly hexagonal FLL a 3:1 synchronisation will occur at a field close to 4.4 T. This would provide direct evidence of a FLL-CDW interaction. Our proposal is to measure the geometry of the FLL in the field range crossing this synchronisation fields to look for such changes.

Experimental Report

The aim of the experiment was to measure the flux line lattice (FLL) in the superconducting state of the heavy fermion material U_6Fe. Previous X-ray diffraction results discovered charge density wave (CDW) order with period 66 Å that co-exists with superconductivity. This makes U_6Fe a prime candidate to investigate interplay between FLL and charge order owing to a high critical field (H_{C2}) of 10 T. It may then be possible to have a synchronisation field where the periodicity of the FLL synchronises with the period of the CDW. At fields close to the synchronisation field the geometry of the FLL is expected to deform and its orientation could change. This would provide direct evidence of a FLL-CDW interaction. Our proposal was to measure the geometry of the FLL in the field range crossing synchronisation ratios of 6:1 and 7:1 to look for any geometrical changes.

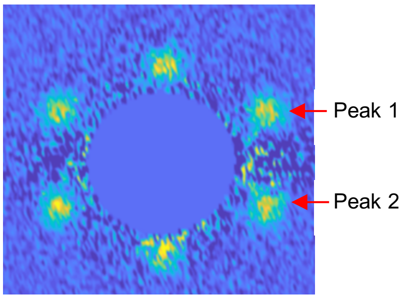

Figure 1: The measured small-angle neutron scattering from the flux-line lattice in U_6Fe at 2 K and an applied field of 1 T.

Two co-aligned crystals of U_6Fe were mounted with the CDW modulation vector perpendicular to the incoming beam and the detector camera placed at a distance of 2 metres. The measured small angle neutron scattering in an applied field of 1 T is shown in Figure 1 displaying a well defined hexagonal FLL. The two peaks labelled 1 and 2 of the FLL in Figure 1 were measured at 2 K as a function of field to look for synchronisation of FLL and CDW periodicity with ratios of 6:1 and 7:1. The azimuthal angle between the two peaks and their full-width half maximum (FWHM) are shown against field and the corresponding FLL periodicity (d-spacing) in Figure 2 (a). Both the azimuthal angle and FWHM show peaks, as indicated by the black arrows, at 0.875 and 1.38 T. The periodicity of the FLL at 0.875 and 1.38 T corresponds to 480 and 385 Å respectively. Comparison with the period of charge order (66 Å) shows synchronisation ratios of approximately 7:1 (480 Å) and 6:1 (385 Å). The integrated intensity of peak 1 against field is shown in Figure 2 (b) where anomalies are also seen at 0.875 and 1.38 T, indicated by the arrows. This provides evidence for a direct interaction between the FLL and CDW. Further analysis is ongoing and a comparison with magnetic ac susceptibility measurements is being carried out. The overall objective of the experiment was to measure the FLL in U_6Fe, which we have clearly observed. The FLL synchronisation with the CDW is a significant finding and will be of interest to the wider scientific community.

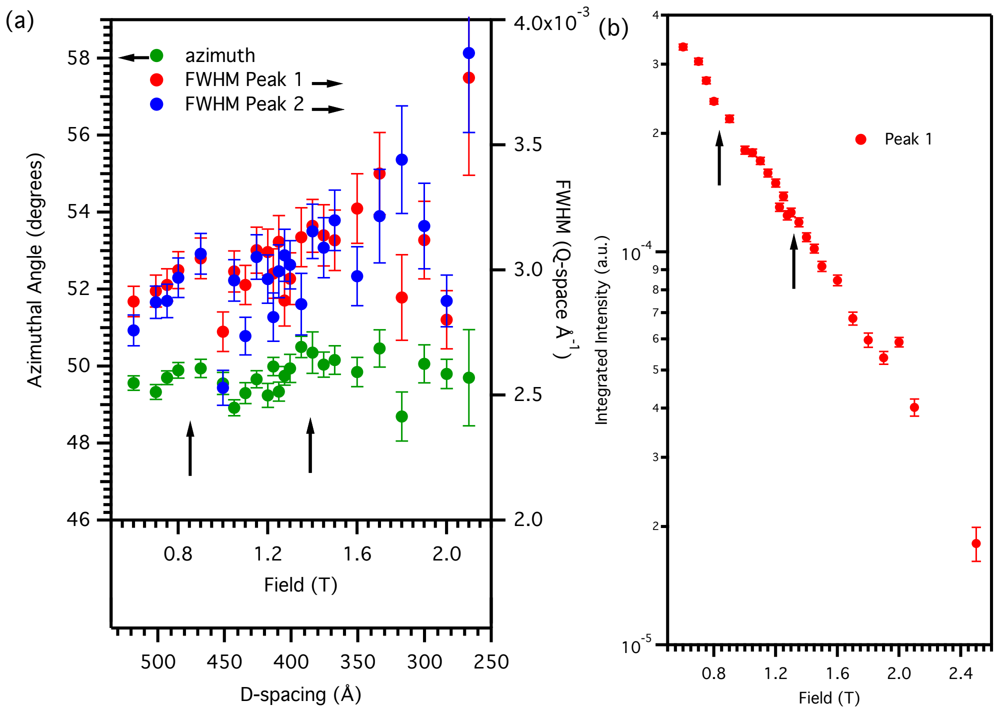

Figure 2: (a) The green markers represent the azimuthal angle in degrees (left axis) between peaks 1 and 2 of the FLL against applied magnetic field. The bottom axis also includes a scale representing the corresponding d-spacing of the FLL. Red and blue markers represent the full width half maximum (right axis) of peaks 1 and 2 respectively. Peaks in the values of both azimuthal angle and FWHM at 0.875 and 1.38 T are indicated by the black arrows. (b) The integrated intensity of peak 1 on a log scale as a function of applied field. Anomalies in intensity are seen at the same fields of 0.875 and 1.38 T and indicated by the black arrows.