Experimental report

19/02/2020

Proposal: **5-42-513** **Council:** 4/2019

Title: Study of the vortex lattice in thenoncentrosymmetric superconductor PbTaSe2

Research area: Physics

This proposal is a new proposal

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Samples: PbTaSe2

Instrument	Requested days	Allocated days	From	To
D33	4	4	30/01/2020	03/02/2020

Abstract:

We propose to investigate the vortex lattice in the noncentrosymmetric superconductor PbTaSe2. This material is a topological superconductor, with ARPES measurements indicating Dirac surface sates and topological nodal lines in the bulk electronic structure, and as a noncentrosymmetric superconductor it is a candidate for an exotic superconducting order parameter which consists of a superposition of s-wave and p-wave states. This may lead to highly anisotropic vortex lattice structures close to the upper critical field, and previously we have observed a hysteretic orientation of the vortex lattice in another noncentrosymmetric superconductor, Ru7B3, a behaviour which was not predicted in theory. We propose to investigate the vortex lattice as a function of applied magnetic field in PbTaSe2, in order to determine its structure and search for any unconventional behaviour.

Experimental Report: Study of the vortex lattice in the noncentrosymmetric superconductor $PbTaSe_2$

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Using the small angle scattering instrument D33, we performed measurements of the magnetic vortex lattice (VL) in the non-centrosymmetric superconductor PbTaSe2. The sample was mounted in a dilution refrigerator and placed within a cryomagnet such that the magnetic field was parallel to the incoming neutron beam, and neutron wavelength of 10 Å was used. The crystal was oriented such that the magnetic field could be applied at any angle within the **ac** plane through rotation of the sample stick. Magnetic field was applied at base temperature, and the VL was imaged by rocking the sample, with magnetic field, around the angles corresponding to the Bragg conditions of the first order VL reflections.

The purpose of this experiment was to investigate the field dependence of the vortex lattice structure, both to search for the distorted vortex lattice structures predicted for noncentrosymmetric superconductors and also to investigate for a possible field-history dependence. The distorted vortex lattice structures have been predicted to emerge close to H_{c2} as a result of a modulated order parameter similar to the FFLO phase, while the field-history dependence of the vortex lattice orientation has been uniquely observed in the noncentrosymmetric superconductor Ru_7B_3.

Unfortunately, no signal from the vortex lattice was observed during this experiment. We performed wide rocks for applied magnetic fields between 0.1 and 0.6 T, larger than was required from the expected theta angle for the vortex lattice, and for fields applied both parallel to and at a slight angle to the **c** axis of the material. The cryostat magnetic field was aligned using the vortex lattice in a sample of niobium, so we can be confident of the rocking angle accuracy. A range of fields were tested as in the case of a disordered vortex lattice increasing the field can overcome the pinning forces, ordering the vortex lattice and causing the formation of Bragg peaks. We tested field orientations of 0, 5 and 10 degrees to the **c** axis, as if there are defects along the **c** axis applying the field at a slight angle to this can also overcome these pinning forces. Unfortunately, no signal was observed. An example of a typical background-subtracted diffraction pattern is shown in Fig. 1(a), with the corresponding intensity as a function of q shown in Fig. 1(b). The expected q of the vortex lattice at this field is indicated in the diffraction pattern by the circle.

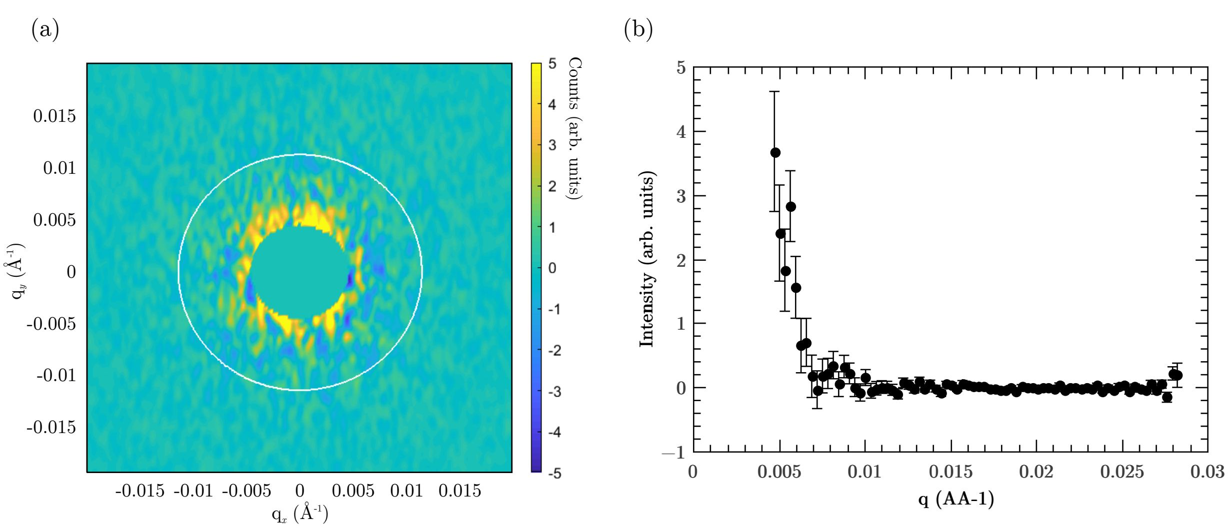

Figure 1: (a) Diffraction pattern at 0.6 T. (b) Intensity as a function of q.