Experimental report

12/09/2016

Proposal: **5-32-800** **Council:** 4/2014

Title: Investigation of vortex structuresin the intermediate mixed state ofMgB2: comparison with Niobium

Research area: Physics

This proposal is a new proposal

Main proposer: **Alain PAUTRAT**

Experimental team: Annie BRULET
Alain PAUTRAT

Local contacts: Robert CUBITT

Samples: MgB2 extremely dense ceramics
MgB2 crystals

Instrument	Requested days	Allocated days	From	To
D33	5	0		
D22	5	0		
D11	5	5	06/05/2015	11/05/2015

Abstract:

Recently, vortex clusters have been observed at low magnetic field in MgB2 using magnetic decorations imaging. It was explained as the existence of of new state of superconductivity, called "1.5 superconductivity". However, this has been debated since it is known that the intermediate mixed state observed in more conventional low Tc materials exhibit similar effects. Based on our recent experiments of very small angle neutron scattering in Pure Nb (TPA, LLB, submitted), we propose to measure the low field vortex structures in MgB2, both in single crystals and in dense polycristals as function of magnetic field and temperature. Comparison with detailed scattering data obtained in Nb will allow to clarify the situation and the mechanism of vortex attraction which stabilizes the clusters. It would also provide the first bulk probe of the reportex vortex clusters in MgB2, which were only seen by surface techniques.

EXPERIMENTAL REPORT FOR 5-32-800

Investigation of vortex structures in the intermediate mixed state of MgB2:

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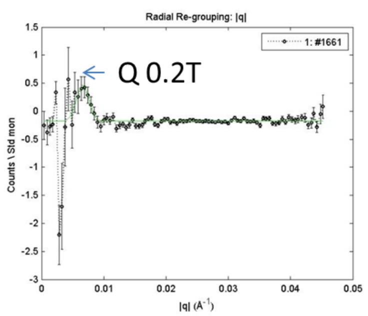
The aim of the experiment was to measure the vortex structure in the two gap superconductor MgB2 in the very low field limit so as to eventually reveal unconventional behavior in the so called "type 1.5" regime. Comparison with a more conventional, still 2 gaps superconductor NbSe2 was also proposed. Indeed, coexistence of Meissner zones and of Vortex clusters due to attractive interactions are expected, and SANS measurements are highly requested to clarify both the genuine existence and formation mechanism of these unconventional states. There are to major concerns, one is the low Q vector where the measurements have to be made. Typically Q<10^{-3} Å (i.e. $B_{applied}$ <50 G) is feasible on the long D11 spectrometer (fig.1). Single crystals of MgB_2 are of very small size (typ <0.2 mg), then a strongly densified ceramic was preferred. The last difficulty is the presence of 10B (about 20%) which is a strong neutron absorber. Then our samples were in principle enriched with 11B for limiting this absorption. Despite this, from the beginning of the experiment, we note avery strong absorption, and we estimate from the experimentally measured transmission an amount, of 18% of 10B, which corresponds only to a very small 11B enrichment.
We have passed some times to try to measure the vortex lattice, after a radial regrouping, some signal at the expected QBragg vector of the vortex lattice emerges (see fig1). However, this signal is too weak and to close to the background value to analyze seriously any small effect such as the one expected in the Type 1.5 scenario. We then decided to stop the measurements which were too time consuming (typ. 10H/scan) for having only data of weak significance.



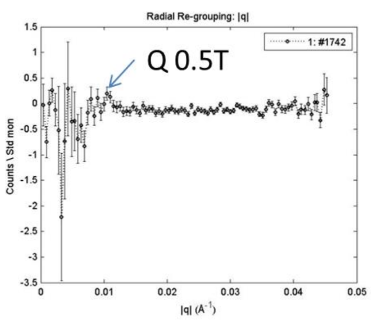


Fig.1: Radial regrouping of the scattered intensity from the vortex lattice (raw data at 4K and normal state background substracted). Note the small Bragg peaks that are observed,

Then, we change the sample for a high quality $NbSe_2$ single crystal, so as to see the vortex lattice in the very low field limit. This part of experiment was very successful. It was possible to measure the lattice as function of a reasonable extent of fields (Fig.2) and temperatures. We have data corresponding to a vortex lattice created by a field so low that the remanent field of the coil B=13G, i.e, was measured by the center of the Bragg peaks Q=5.2 10^{-4} $Å^{-1}$.

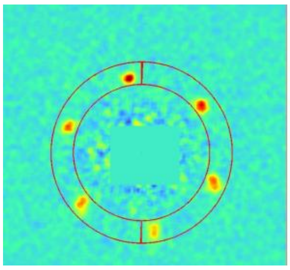


Fig.2: 2D image of the scattered intensity from the vortex lattice in NbSe2 , 4K, 500G

We have observed an ordering/disordering transition at low field, that can be discussed in the light of the physical properties (i.e. critical current and phase diagram) measured in our lab. Quite interestingly, due to the very low field used here, we have, thanks a collaboration with Bariloche (Argentina), performed decoration imaging (direct space technique) of the vortices at the sample surface, in the same sample and at equivalent fields. This allows us to have a full understanding of the surface/bulk behavior of the lattice with two very complementary experiments. We are currently writing an article with these all these new results.

N.B: We would like to specially thank the ILL staff and our local contact for the implication and precious help all along the experiment.