Experimental report

16/09/2019

Proposal: 5-31-2639 **Council:** 10/2018

Title: Study of the multiferroic to superconductor transition of the Fe-based spin ladder BaFe2Se3

Research area: Physics

This proposal is a new proposal

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Samples: BaFe2Se3

Instrument	Requested days	Allocated days	From	To
D1B	5	5	29/08/2019	03/09/2019

Abstract:

The Iron-based spin ladder BaFe2Se3 with multiferroic properties at high temperature becomes superconducting under pressure. In order to study the physical parameters involved in this transition, we plane to perform a neutron powder experiment under pressure. The determination of the magnetic structure as a function of pressure will help to understand the stabilization of the superconducting phase

Report for the experiment 31 2639 :

"Study of the competition between magnetism and superconductivity in $BaFe_2Se_3$"

According to previous researches, BaFe2Se3 becomes superconducting between 10 and 15 GPa at low temperature [1,3]. In addition, the local magnetic moment is still present in the superconducting phase. The coexistence of magnetism and superconductivity is a very important issue as it has never been observed previously in any other superconducting materials. The aim of the experiment was to investigate the magnetic structure of BaFe2Se3 under pressure to uncover the relationship between magnetism and superconductivity.

$BaFe_2Se_3$ forms a quasi-one-dimensional structure consisting of two ladders (A and B) along the b axis formed by edge-sharing $FeSe_4$ tetrahedron [Fig. 1(a)]. Under ambient pressure, $BaFe_2Se_3$ presents a Block-type magnetic order in which the magnetic moments along **a**-axis form blocks of 4 Fe spins ferromagnetically ordered, which stack antiferromagnetically along the direction of the ladder [2].

At the end of august 2019, we have performed 5 days' measurements in D1B and got very interesting results. By measuring the powder neutron diffraction under 3.5, 6 and 10.2 GPa at 3 K, we found that the magnetic peak shift from 16.8° at low pressure to 29.2° at high pressure [Figure 1(a)]. This corresponds to a modification of the magnetic structure which now order with a propagation wave vector (1/2 0 ½). By refining the data, we obtained the magnetic structure of 6 and 10.2 GPa is CX-type. The difference between Block-type and CX-type magnetic structures is shown in Fig. 1(b).

Fig. 1(c) shows the pressure dependence of the moment per Fe in BaFe2Se3. Between 0 and 3.5 GPa when the magnetic structure is Block-type, the moment decreases rapidly while the moment increases from 6 to 10.2 GPa in the C-X phase. According to previous researches, $BaFe_2Se_3$ becomes superconducting between 10 and 15 GPa at low temperature. [2, 3] In addition, the local magnetic moment is still present in the superconductive phase. The coexistence of magnetism and superconductivity is a very important issue as it has never been observed previously in any other superconducting materials.

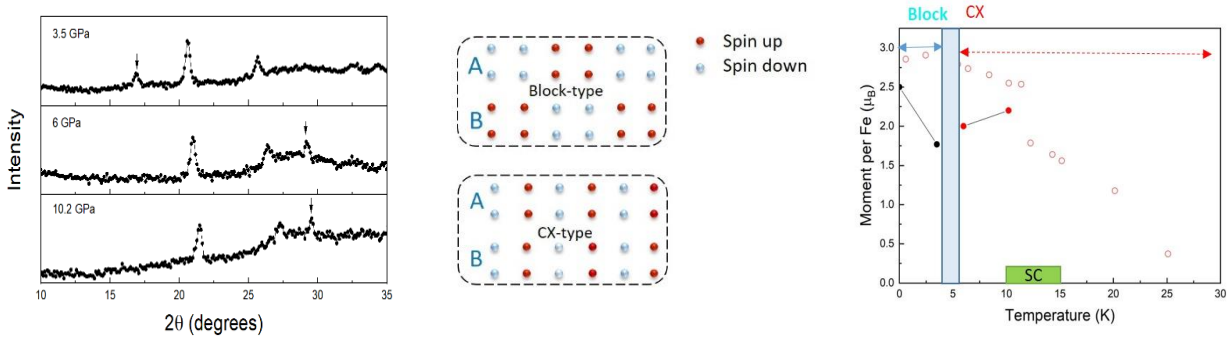

Figure 1: (a) The neutron diffraction at 3.5, 6 and 10.2 GPa at 3 K. (b) Block-type and CX-type magnetic structure in BaFe2Se3. The A and B ladders are corresponding to the A and B ladders in Fig. 1(a). (c) The pressure dependence of the moment per Fe in $BaFe_2Se_3$. The solid symbols are experimental data and open symbols are DFT data from Ref. 5.

During this experiment, we have lost 2 days of measurement due to instrumental problems.

Indeed, the cell blew up already at 6 GPa while it was designed for 12 GPa. Thus, we only reached 10.2 GPa, which is not enough to determine the presence of magnetism in the superconducting phase. We thus would like to ask for 2 more days in order to perform the two last pressures.

References

[1] J.M. Caron et all, PHYSICAL REVIEW B 84, 180409(R) (2011)
[2] J. Ying et al, PHYSICAL REVIEW B 95, 241109(R) (2017)
[3] Y. Zhang, PHYSICAL REVIEW B, 97, 045119 (2018)