Experimental report

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Title: Measurements of spin-wave stiffness in Mn1-xFexGe by SANS

Research area: Physics

This proposal is a new proposal

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Samples: Mn0.1Fe0.9Ge
Mn0.2Fe0.8Ge
Mn0.3Fe0.7Ge

Instrument	Requested days	Allocated days	From	To
D11	8	7	19/09/2016	26/09/2016

Abstract:

The helical magnetic structure of B20-type compounds caused by the hierarchy of
exchange interaction: main ferromagnetic exchange interaction, J, together with the antisymmetric Dzyaloshinskii-Moryia (DM) interaction, D, stabilize the helical (homochiral) structure in these systems below Tc, and the weakest cubic anisotropy direct the spin helix along the main axis of the structure. Mn1-xFexGe compounds undergo the transition from the helical state into the ferromagnetic at the critical concentration xc = 0.75. This fact could be related to the unusual behavior of the spin-wave stiffness of these compounds. Recent studies of the spin wave stiffness in FeGe have shown the applicability of SANS in studying the dynamical properties of helical magnets. Moreover, it is shown that Bak-Jensen model has a restricted application and the energy of cubic anisotropy should be taken into account for pure FeGe. The general aim of the proposed experiment is to measure the spin-wave stiffness of the Mn1−xFexGe and its evolution with the temperature and concentration of substituted element on the Fe-rich side of the phase

Measurements of spin-wave stiffness in $Mn_{1-x}Fe_xGe$ by SANS

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I. INTRODUCTION

The cubic B20 compounds have a noncentrosymmetric crystal structure described by the $P2_13$ space group. The lack of a symmetry center of the crystal structure produces the chiral spin-spin Dzyaloshinskii-Moriya (DM) interaction [1, 2]. According to the model suggested by Bak and Jensen [3] and independently by Kataoka [4], the major ferromagnetic exchange interaction J, together with the DM interaction D produces a (homochiral) structure in these systems below T_C. The energy landscape in these systems is given by J and D, which are balanced via the helix wave vector $k_s = D/J$. The anisotropic exchange interaction has been added to the model, changing slightly the value and fixing the direction of the wave vector k_s along the principle cubic axes.

As noticed by Kataoka and co-workers [4] and Maleyev and co-workers [5], the cubic anisotropy can play an important role in the case of relatively small values of the helix wave vector k_s. If the anisotropic energy gets comparable to the DM interaction, it can destabilize the entire helix structure and stabilizes the ferromagnetic state instead. This situation does occur in the $Fe_{1-x}Mn_xGe$ compounds at $x = x_C$, where the transformation from the left-handed helix to the right-handed helix appears [6].

The experimental determination of the constants describing the energy landscape of the B20 compounds is not trivial. It was only recently that the spin wave stiffness was measured for the FeGe compound in the high temperature [7]. In this experiment we were able to measure the spin-wave stiffness A and its temperature dependence close to T_C for the solid solution $Fe_{0.8}Mn_{0.2}Ge$ with SANS in order to follow the evolution of the energy landscape that stabilize the helical magnetic structure with increase of Mn concentration.

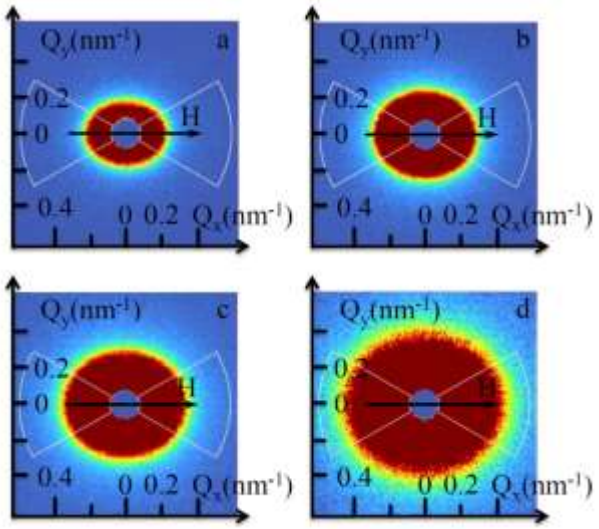

Fig. 1. Maps of the SANS intensities for the $Fe_{0.8}Mn_{0.2}Ge$ taken at the field 0.200 T well above HC2 = 0.06 T at (a) T = 200 K, (b) T = 220 K, (c) T = 230 K, (b) T = 240 K. The arrow shows a direction of the field. The white sectors correspond to the regions where the azimuthal averaging has been performed.

II. PERFORMED EXPERIMENT

For the investigation of the dynamical properties of the magnetic system of the $Fe_{0.8}Mn_{0.2}Ge$ compound an unpolarized beam with a mean wavelength of λ = 0.6 nm was used with a sample-detector distance equal to 8 m. A magnetic field (0.08 - 1.0 T) was applied perpendicular to the incident beam. Figure 1 shows a typical SANS maps for the $Fe_{0.8}Mn_{0.2}Ge$

compound, which are taken above H_{C2}. As the field reaches H_{C2} the elastic scattering disappears and only the inelastic scattering centered at $\boldsymbol{Q} = \pm\boldsymbol{k}_s$ remains.

In order to define the cut-off angle θ_C, the background intensity was measured at $H \gg H_{C2}$ was subtracted from the other scattering maps. To improve the statistics, the scattering intensity was azimuthally-averaged over the angular sector of 90 degrees around the direction of the external magnetic field (Fig.1). The expected step-like intensity profile appears to be smeared around the value of the cut-off angle due to the spin-wave dumping. The position of the cut-off angle θ_C was determined as the center of the atan-function which was used to fit the data and captures the main features of the scattering. Its width δ is related to the spin-wave dumping $\boldsymbol{\Gamma}$ and can roughly be estimated as $\boldsymbol{\Gamma} = E_n\delta$, where E_n is the energy of the incident neutrons.

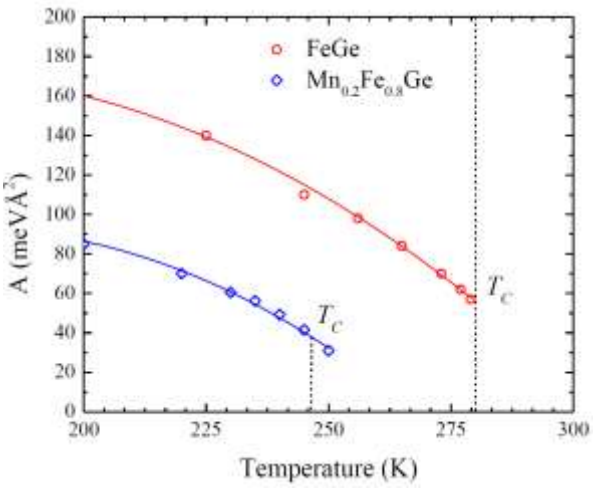

Fig. 2. Temperature dependence of the spinwave stiffness: open red circles measured from the cut-off angle with the corresponding fit for the FeGe compound, blue diamonds measured by the cut-off angle with the corresponding fit for the $Fe_{0.8}Mn_{0.2}Ge$ compound.

The spin-wave stiffness, obtained from the cut-off angle for different temperatures is shown in Fig. 2. The measured temperature dependence was fitted by the power law: $A(T) = a(1 - c(T/T_C)^z)$. Parameters are found to be equal to $a = 0.10 \pm 0{:}01$ eVÅ^2, $c = 0.63 \pm 0.02$ and $z = 6.2 \pm 0.8$. The similarly determined dependence of the spin-wave stiffness for FeGe is added to the same Fig.2 [7]. The measured temperature dependence was fitted by the same power law, with the parameters: a = 0.19 ± 0.01 eVÅ^2, $c = 0.70 \pm 0.01$ and $z = 4.2 \pm 0.5$.

III. RESULTS

Comparison of the two compounds shows that although the critical temperatures T_C differ for 10 percent only, while the values of the spin wave stiffness are different by factor of two close to T_C. This is probably related to the large (4-5 times) difference in the helix wave vector value k_s for the two compounds. If one suggests that the Dzyaloshinskii-Moriya interaction is the destabilizing factor for the ferromagnetic order, then it is much stronger for the pure FeGe as compared to the doped $Fe_{0.8}Mn_{0.2}Ge$ compound. Thus Mn-doping results in the both: decrease of the ferromagnetic exchange interaction (the spin-wave stiffness decreases by factor of 2) and in remarkable weakening of the DM interaction. Altogether, both these changes provide relatively small decrease of the critical temperature T_C.

In conclusion, we have experimentally determined the spin-wave stiffness and the spin-wave dumping in the high temperature phase of the $Fe_{0.8}Mn_{0.2}Ge$ compound. We have found large difference in values of the spin wave stiffness but similar temperature dependence. We classify the magnetic phase transition in both compounds as being the first order since the spin wave stiffness does not drop to zero at the critical temperature T_C.

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