Experimental report

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Title: RKKY to DMI: Study of spin-wave dynamics of Fe-doped MnGe by SANS

Research area: Physics

This proposal is a new proposal

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Samples: $Mn_{0.1}Fe_{0.9}Ge$
$Mn_{0.2}Fe_{0.8}Ge$
$Mn_{0.3}Fe_{0.7}Ge$
$Mn_{0.4}Fe_{0.6}Ge$
$Mn_{0.5}Fe_{0.5}Ge$

Instrument	Requested days	Allocated days	From	To
D33	9	2	10/10/2018	12/10/2018

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. The presence of the DM chiral interaction leads to the chirality of the spin-waves in the field-polarized state of the helimagnets. Contrary to the ordinary DM helical magnets, the MnGe compound possess a short period spin helix, reminiscent more the RKKY type of the spirals. In case of symmetrical exchange interaction the dispersion relation of the magnons should give an isotropic scattering pattern. Taking into account that the magnetic system of FeGe is based on DMI while MnGe shows the RKKY-like magnetic structure, the transition from one type of the magnetic structure to another should appear with Fe-replacement of the Mn. The general aim of the proposed experiment is to follow the evolution of the ratio between two main interactions, which determine the helical magnetic order in Mn1−xFexGe.

RKKY to DMI: Study of spin-wave dynamics of Fe-doped MnGe 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]. Contrary to the ordinary DM helical magnets, the MnGe compound possess a short period spin helix, reminiscent more the RKKY type of the spirals. The small angle neutron scattering [3] and Mossbauer spectroscopy [4] studies show that the stable helical structure at T = 0 K becomes intrinsically unstable upon temperature increase. Assuming the strong effective RKKY interaction as a constituting interaction for the magnetic structure in the MnGe, while DM interaction plays only a secondary role in this helimagnet, one can explain the most of the experimental puzzles of the MnGe compound. For example, the amplification by the temperature of the competition between RKKY interaction and DM interaction, leads to the rise of the excitations of the magnetic structure and to the complex transition to the disordered spin state. The assumption on the presence and active role of RKKY interaction in B20 helimagnets was recently approved by study of the quantum phase transition in $Mn_{1-x}Fe_xSi$ [5].

The experimental determination of the constants describing the energy landscape of the B20 compounds is not trivial. However the technique to measure the spin wave stiffness (SWS) was developed and the SWS for the FeGe and Mn-doped compounds was already measured at high temperature [6, 7]. In this experiment we tried to measure the spin-wave stiffness A and its temperature dependence close to T_C for the solid solution of $Mn_{0.8}Fe_{0.2}Ge$ with SANS in order to follow the evolution of the energy landscape that stabilize the short periodic helical magnetic structure with increase of Fe concentration.

II. PERFORMED EXPERIMENT

For the investigation of the dynamical properties of the magnetic system of the $Mn_{0.8}Fe_{0.2}Ge$ compound an unpolarized beam with a mean wavelength of λ = 0.6 nm was used with a sample-detector distance equal to 2 m. A magnetic field (0.08 - 5.0 T) was applied perpendicular to the incident beam. 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. 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.

The spin-wave stiffness, obtained from the cut-off angle for different temperatures is shown in Fig. 2 together with the dependence of the square of the critical angle θ_C versus external magnetic field. Accordingly to the case of DMI helimagnet the dependence of the square of the cut-off angle should linearly depend on the value of the external magnetic field.

However one can see that this rule is not fulfilled for most of the temperatures in case of $Mn_{0.8}Fe_{0.2}Ge$ compound (Fig. 1 left). As a result it gives a distribution of possible values of the SWS for each temperature (Fig. 1 right).

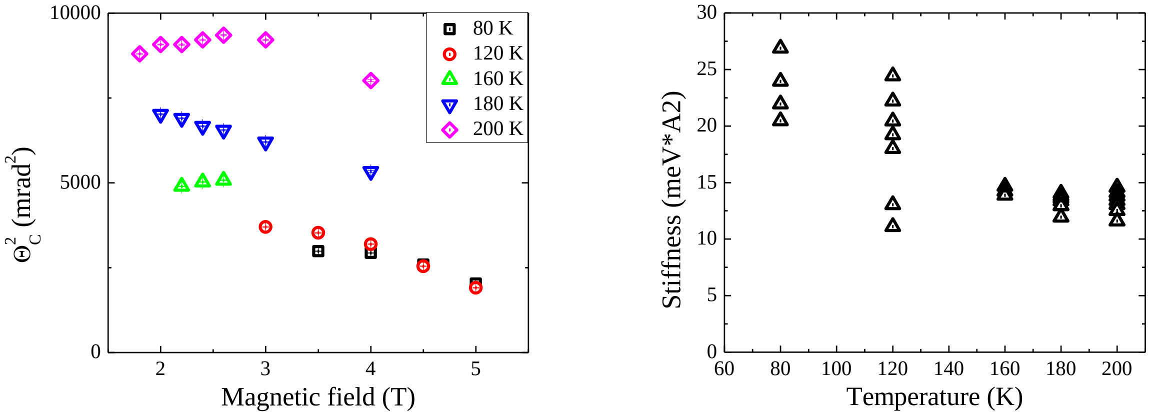

Fig. 1. Field dependence of the square of the cut-off angle for different temperatures measured (left); temperature dependence of the spin-wave stiffness (right) for the $Fe_{0.8}Mn_{0.2}Ge$ compound.

III. RESULTS

The analysis of the obtained results shows that the SWS value is not zero at T_C. The deviation of the field dependence of the cut-off angle from the DMI model is an indirect evidence of the additional component on the energy landscape of the MnGe-based compounds. Therefore in order to correctly estimate the stiffness value for studied compound the additional theoretical and experimental investigations are needed.

In conclusion, we have experimentally measured the quasielastic scattering from the $Mn_{0.8}Fe_{0.2}Ge$ compound at the wide temperature range at fields above H_{C2}. We have found large difference in values of the spin wave stiffness at different field values and constant temperature that points out the necessity to implement the RKKY-like interaction into developed model in order to evaluate the obtained results.

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