Experimental report

24/10/2017

Proposal: 4-03-1726 **Council:** 4/2016

Title: Intrinsic instability of the helixspin structure in Fe diluted MnGe and quantum phase transition.

Research area: Physics

This proposal is a continuation of 4-02-444

Main proposer: Evgeniy ALTYNBAEV

Experimental team: Evgeniy ALTYNBAEV
Evgeny MOSKVIN
Konstantin PAVLOV
Sven-Arne SIEGFRIED

Local contacts: Peter FOUQUET

Samples: MnGe
Mn0.75Fe0.25Ge
Mn0.6Fe0.4Ge

Instrument	Requested days	Allocated days	From	To
IN15	13	4	17/11/2016	23/11/2016
IN11	13	0		

Abstract:

The proposal aims to investigate the critical dynamics of the helix structure in Fe-diluted MnGe by neutron spin echo technique. The MnGe compound has a cubic B20 structure with the lattice constant a=0.4806 nm. Its magnetic system orders below TC = 130 K in a helical structure. The scattering patterns show dramatic changes in the temperature evolution of the magnetic structure. Doping influence the magnetic system of MnGe the same as the temperature. That means that higher the Fe concentration in the compound less stable the magnetic system is. We assume that the knowledge about the main dynamical properties of Fe-diluted MnGe is the key for understanding of both critical phenomena: temperature phase transition of Ge-based compounds, and the quantum phase transition with Fe-replacement. We propose to measure the temperature and Fe-concentration dependence of the relaxation rate of the spin fluctuations. We expect to observe two characteristic timescales of the magnetic dynamics of Fe-diluted MnGe.

Intrinsic instability of the helix spin structure in Fe diluted MnGe and quantum phase transition

E. Altynbaev[1,2], E. Moskvin[1,2], S.-A. Siegfried[3],
P. Fouquet[4], P. Falus[4], S. Grigoriev[1,2]

[1]*Petersburg Nuclear Physics Institute, Gatchina, 188300 St-Petersburg, Russia*
[2]*Faculty of Physics, Saint-Petersburg State University, 198504 Saint Petersburg, Russia*
[3]*Helmholtz Zentrum Geesthacht, 21502 Geesthacht, Germany*
[4]*Institute Laue Langevin, Grenoble, 38042 Grenoble, Cedex 9, France*
[5]*Institute for High Pressure Physics, 142190, Troitsk, Moscow Region, Russia.*

I. INTRODUCTION

The magnetic system of MnGe compound has a cubic B20 structure and orders in a helical spin structure with a wavevector k ~ 2.2 nm^{-1} at low temperatures. The helicity is realized by an antisymmetric Dzyaloshinskii-Moriya (DM) interaction caused by the lack of a center of symmetry in Mn atomic arrangement. This DM interaction is isotropic itself but another weak anisotropic exchange (AE) interaction fixes a direction of the magnetic spiral along one of the cube diagonals [1, 2]. The temperature evolution of pure MnGe compound has already been investigated carefully [3]. Previous measurements show that the temperature evolution for $Mn_{1-x}Fe_xGe$ compounds with $x < 0.5$ is similar to a pure MnGe compound [4]. Nevertheless doping influence magnetic system the same as the temperature. That means that higher the Fe concentration in the compound less stable the magnetic system is.

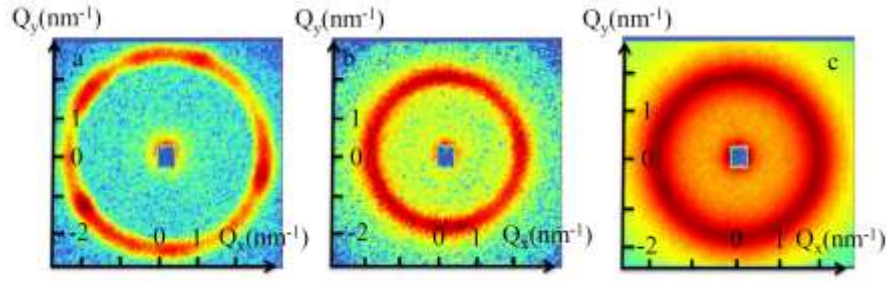

Figure 1: SANS intensity maps for x = 0.0 (a) [1], x=0.25 (b) and x=0.4 (c).

The temperature evolution of the magnetic structure of MnGe has been studied by small-angle neutron scattering and the scattering profile function was carefully analyzed in the whole temperature range [3]. SANS experiments with Fe diluted MnGe have been done using D33 instrument at ILL reactor. The scattering maps in figure 1 show typical powder-like patterns for $Mn_{1-x}Fe_xGe$ compounds with x = 0.0, 0.25 and 0.4.

In work [3] we split the whole temperature range for four parts. The low temperature part showing the coexistence of the Stable Helix and Fluctuating Helix below T_C = 130 K for pure MnGe compound. Existence of the fluctuating helix below ordering temperature shows the intrinsic instability of the helix structure. The contribution to the scattering which ascribed to the helical fluctuations is accompanied by and correlated to the strong abnormal scattering ascribed to the spin excitations. In the temperatures between 130 K and 150 K, the spin helix fluctuations and strong spin excitations result in the partially ordered fluctuating spin helix state. The high temperature part showing the existence of the ferromagnetic nano-regions above T_{SR} = 175 K for compound with $x = 0.0$.

With increase of the Fe concentration in the compound the critical temperature T_C decreases to 0 K for $Mn_{1-x}Fe_xGe$ compound with $x_{cl} = 0.35$ [4]. The scattering contribution ascribed to the helical fluctuations prevails over the contribution ascribed to the stable spin structure at low temperatures for all compounds with $x > 0.25$.

II. PERFORMED EXPERIMENT

In order to investigate magnetic dynamic of Fe diluted MnGe compound at the whole temperature range, the IN15 instrument was used. Two different samples of $Mn_{1-x}Fe_xGe$ compound with x = 0.0 and 0.25 were measured at different temperatures above and below T_N, using 6 Å and 10 Å wavelengths and Fourier times from 0.004 ns to 600 ns. The intermidiate scattering function obtained at two Q-values, namely $Q = 0.73$ nm^{-1} and 1.3 nm^{-1}, at different temperatures is presented in Fig.2a and b. It is clearly seen in Fig.1a that the average the lifetime of the ferromagnetic fluctuations increases with temperature up to 180 K and decreases with further increase of the temperature. As it seen in Fig.2b, the decay of the intermediate scattering function appears on the same timescales as for the smaller Q-values showing the influence of ferromagnetic nano-regions on the magnetic signal at $Q = k_s$. As long as the ferromagnetic correlations and helical fluctuations coexist at temperatures 130 K < T < 175 K [3], the further decrease of the intermediate scattering function at $Q \sim k_s$ is to be expected with the characteristic timescale $\tau_h > 300$ ns, which corresponds to the average time of the helical fluctuations.

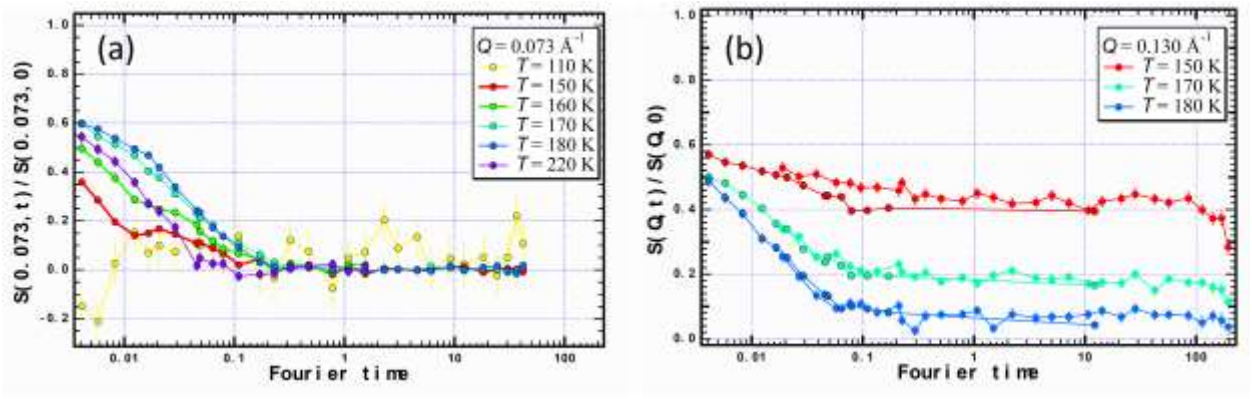

Figure 2: The temperature evolution of the intermediate scattering function *S(Q, t)*, obtained for MnGe at $Q = 0.73$ nm^{-1} (a) and 1.3 nm^{-1} (b). Spectra were collected at different temperatures. Lines are the guide for the eyes.

III. RESULTS

As a result of the experiment, the dynamical properties of the ferromagnetic nano-regions have been investigated and its temperature evolution has been followed. At T < 170 K the intermediate scattering function coming from the scattering on short-order ferromagnetic fluctuations could be fitted with two different exponential decay functions (Fig.2a). The average lifetime of these ferromagnetic nano-regions increases with temperature reaching maximum value at T ~ 175 K and decreases again with further increase of temperature. The decay of the intermediate scattering function at higher Q value observed at the same timescale as for the smaller Q ($\tau < 0.1$ ns) could be fitted with the stretched exponential law (Fig. 2b). The nature of such evolution of the intermediate scattering function with Q requires additional theoretical and experimental studies.

References

[1] I.E. Dzyaloshinsky, Nonmetals. Sov. Phys. JETP, 19:960, 1964 [Zh. EKSP. Teor. Fiz 46,1420 (1964)];

[2] P. Bak and M.H. Jensen, J. Phys. C: Solid St. Phys.,13(31):L881-L885, 1980;

[3] E. Altynbaev, S.-A. Siegfried, V. Dyadkin, E. Moskvin, D. Menzel, A. Heinemann, C. Dewhurst, L. Fomicheva, A. Tsvyashchenko, and S. Grigoriev, Physical Review B 90, 174420 (2014);

[4] E. Altynbaev, S.-A.. Siegfried, E. Moskvin, D. Menzel, C. Dewhurst, A. Heinemann, A. Feoktystov, L. Fomicheva, A. Tsvyashchenko, S. Grigoriev, Phys. Rev. B 94, 174403 (2016).