Experimental Report

22/08/2014

Proposal: **5-53-236** **Council:** 10/2012

Title: Spin fluctuations close to the quantum critical point of MnFeSi

This proposal is a new proposal

Researh Area: Physics

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Samples: Mn_(1-x)Fe_(x)Si

Instrument	Req. Days	All. Days	From	To
D22	4	3	04/06/2013	07/06/2013

Abstract:

The cubic B20-type (space group P213) compound Mn_(1-y)Fe_(y)Si with y = [0; 0.15] order in a spin helix structure with a small propagation vector $0.36 < k < 0.70$ nm^-1. The critical temperature of the compounds T_C decreases with the Fe doping and approaches zero, discovering the quantum phase transition (QPT) at y_C ≈ 0.15. Mn_(1-y)Fe_(y)Si undergoes a transition from a paramagnetic phase (P) passing a partially chiral fluctuating state (PCF), followed by a highly chiral fluctuating (HCF) state resulting in a stable spiral (S) state at T_C. The magnetic properties at the transition from P to PCF are clearly related and perhaps determined by the value of the correlation length of critical fluctuations and the value of the spiral wave vector, which increases significantly upon doping from 0.36 nm-1 to 1.00 nm^-1. The proposal is aimed to study in details the character and changes of the thermal phase transition upon its way to the quantum critical point at y_C ≈ 0.15 – 0.17 by means of polarized small angle neutron diffraction (SANS). The measurements would be crucial for revealing the true nature of the QPT.

Spin Fluctuations close to the quantum critical point of $Mn_{1-y}Fe_ySi$

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The cubic B20-type (space group $P2_13$) compounds $Mn_{1-y}Fe_ySi$ with y = [0; 0.15] order in a spin helix structure with a small propagation vector $0.36 < k < 0.70$ nm^{-1} [1]. The spin helix structure is well interpreted within the Bak-Jensen (B-J) hierarchical model, which implies the competition between the ferromagnetic spin exchange and the antisymmetric Dzyaloshinskii-Moriya interaction (DMI), in its turn, caused by a lack of inverse symmetry in the atom arrangement. The critical temperature of the compounds T_C decreases with the Fe doping and approaches zero, discovering the quantum phase transition at $y_C \approx 0.15$.

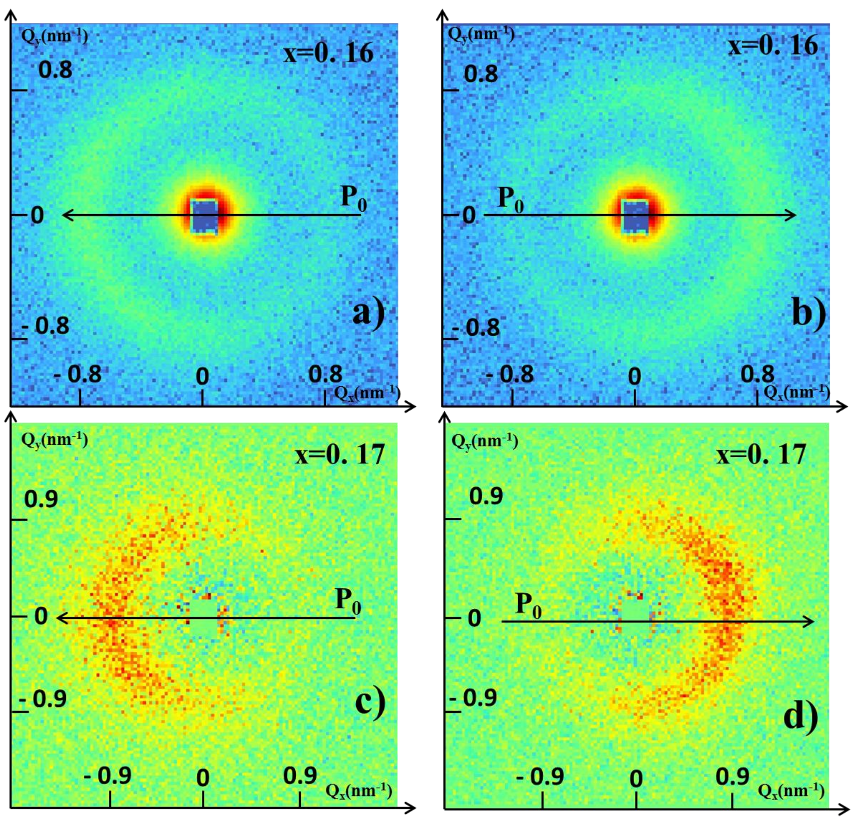

Fig. 1. Maps of the polarized SANS intensities for the polarization P_0 along the guide field (left) and opposite to it (right) at T = 2 K for of compounds $Mn_{1-y}Fe_ySi$ with y = 0.16 (a,b) and y = 0.17 (c,d).

The magnetic properties of the doped compounds $Mn_{1-y}Fe_ySi$ were studied by the measurements of magnetization and ac-susceptibility in Ref. [2]. The findings made in [1] confirm the conclusion that the ferromagnetic exchange representing the strongest energy scale of the system leads to the underlining ferromagnetic quantum critical point at y_C. The true identification of this point is impossible without complementary data taken by small angle neutron diffraction. This experiment was aimed to study in details the character and changes of the thermal phase transition upon its way to the quantum critical point at $y_C \approx 0.15 - 0.17$. The polarized SANS measurements are crucial for revealing the true nature of this QP transition.

The high-purity single crystals of $Mn_{1-y}Fe_ySi$ with y = 0.16, 0.17 grown by the Czochralski technique were chosen for this study. The samples were disks with a diameter of 8 mm and a thickness of 1-2 mm. Figure 1 shows the maps of the polarized SANS intensities with the polarization along $+P_0$ and opposite $-P_0$ the magnetic field for two samples of the $Mn_{1-y}Fe_ySi$ system with y = 0.16 (a, b) and y = 0.17 (c, d) at T = 2 K. It is worthwhile to note that the neutron scattering intensity shows a blurred image forming a ring with the radius $|k| = 0.82$ nm^{-1} for the compound with y = 0.16 (Fig. 1 (a,b)), and with radius $|k| = 0.91$ nm^{-1} for y = 0.17 (Fig. 1 (c,d)).

This type of scattering is strongly reminiscent to the critical fluctuations with the random distribution of the orientation of the wavevector **k** above T_C in pure MnSi $|k| = 0.35$ nm^{-1}. The polarization dependent scattering in related to the homochiral nature of the helix magnetic structure under study. We estimate the 100% chirality of the scattering objects at T=2K.

The temperature dependence of the scattering intensity were made for all samples. Figure 2 (a,b) show the Q-dependence of the scattering intensity for $Mn_{1-y}Fe_ySi$ samples with y = 0.16, 0.17. Q-profiles of the scattering intensity is well described by a Lorentsian function.

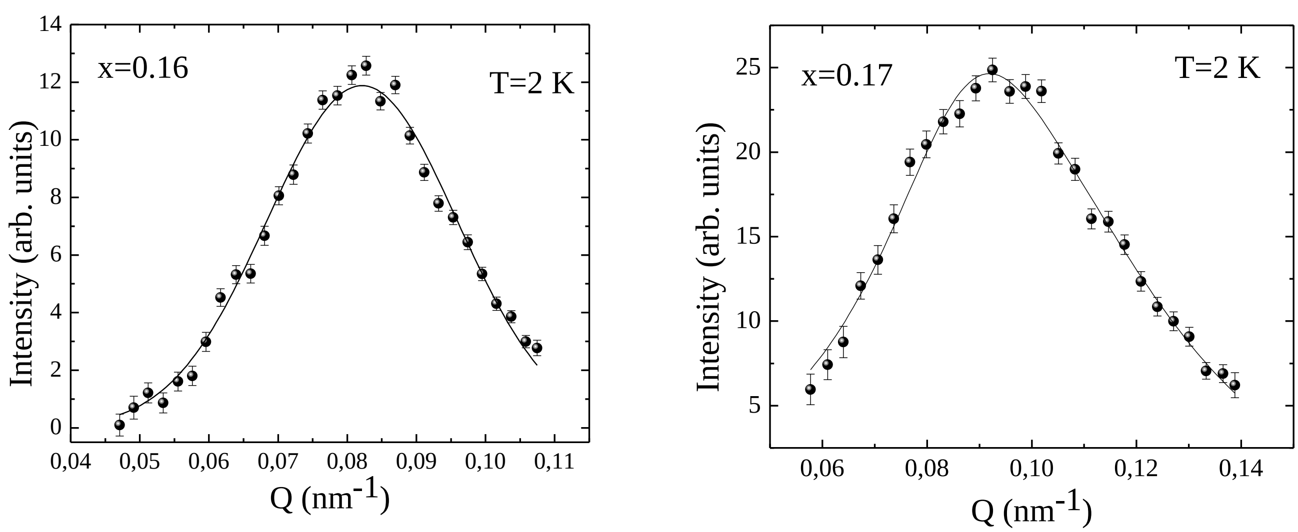

Fig. 2. Q-dependence of the scattering intensity for of compounds $Mn_{1-y}Fe_ySi$ with y = 0.16 and y = 0.17 at T = 2 K.

The magnetic dependence of the scattering intensity was made for all samples too.
We thank the responsible of D22 SANS facility S.Ch. Dewhurst for the allocated time and for the excellent support during the experiment.

References

[1] S. V. Grigoriev, *et al*, Phys.Rev. B, v.79, (2009) 144417
[2] A. Bauer, *et al*, Phys. Rev. B 82, 064404 (2010)
[3] S.V. Grigoriev, *et al*, Phys.Rev.B, 83 (2011) 224411