Experimental report

21/10/2015

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Title: Spin dynamics in the A-Phase of FeCoSi

Research area: Physics

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Samples: Fe1−xCoxSi

Instrument	Requested days	Allocated days	From	To
IN15 Ferromagnetic echo	8	7	08/05/2013	15/05/2013

Abstract:

We propose a spin echo experiment on IN15 to follow the spin dynamics in the A-Phase of FeCoSi, which has been recently identified as a skyrmion lattice state in this non-centrosymmetric cubic semi-conductor.

The pseudo-binary $Fe_{1-x}Co_xSi$, together with the archetype chiral system MnSi, belongs to the family of non-centrosymmetric cubic helimagnets (space group $P2_13$, B20-type structure), the ground state of which can be understood on the basis of a simple Hamiltonian containing three hierarchically ordered interaction terms [1]. The energy scales of these terms are so well separated that it is possible to distinguish between the different contributions: the strongest ferromagnetic exchange interaction fixes the spins at the longest range, the weaker Dzyaloshinskii-Moriya (DM) term, which arises from the lack of inversion symmetry of the B20 lattice structure, rotates the spins at the intermediate scales, whereas the weakest anisotropy term fixes the directions on the spins on the crystallographic lattice. $Fe_{1-x}Co_xSi$ exhibits helical spin order with a relatively long period, much longer than MnSi, in a concentration range $0.05 \leq x \leq 0.8$ and shows all intriguing features found in MnSi [2-5].

We have been studying $Fe_{1-x}Co_xSi$ (x=0.3) under magnetic field applied along [110] direction using SANS and found that at T=40 K, just below Tc, there is a field range around 0.03 T, where one observes distinct diffuse spots, one pair along the field direction and another pair perpendicular to the field at the same time (Fig.1)[3]. This state is known as the A-phase of FeCoSi, which was first observed in MnSi. More recently this A-Phase has been identified as a skyrmion lattice state by Lorentz transmission electron microscopy [5].

To study the slow dynamics of this chiral system, we performed a polarimetric spin echo experiment on $Fe_{1-x}Co_xSi$ in zero field. Looking at the yx and zx chiral terms this experiment clearly demonstrated the chiral nature of the relaxation associated with the long period magnetic helical structure (Fig.2 shows a typical intensity pattern on the multidetector of IN15). To follow the relaxation of the helical signal as a function of temperature we also used the paramagnetic NSE configuration on IN15 with a wavelength of 9 Å. We found a strongly non-exponential behavior (Fig.3), which is reminiscent of spin glass behavior [7] and thus in clear contrast with the relaxation in MnSi [6].

The goal of this experiment was to follow the relaxation as a function of the magnetic field, in the vicinity of the A-phase using IN15 the ferromagnetic NSE mode. The wavelength was 9 Å and a horizontal magnetic field was applied beam with a 7 T cryomagnet. The sample was relatively small and as the scattering appeared at very low Q's the signal over background ratio was poor. For this reason it was possible to analyse the NSE spectra only very close to Tc.

Fig. 1 (a) and (b) show typical scattering patterns at 41 K obtained at zero magnetic field and 500 G respectively. Due to the limited dimensions of the IN15 detector only part of the SANS scattering is seen. Despite this limitation, fig. 1 clearly shows that the almost isotropic scattering at zero magnetic field becomes more visible along the magnetic field $\vec{B}$ at 500 G.

Similarly to zero field, strong deviations from the simple exponential decay have been observed also under field. The spectra at 500 G and at temperatures just above the Skyrmion lattice phase were fitted by a stretched exponential form $\sim\exp(t/\tau_o)^{\beta}$, as shown in fig. 2. The exponent β is ~ 1 at 42.5 K and decreases down to ~ 0.5 at 40 K. The characteristic times τ_o(T) are 3.2 ±0.4, 18 ± 3 and 37 ± 6 ns at 42.5, 41 and 40 K respectively.

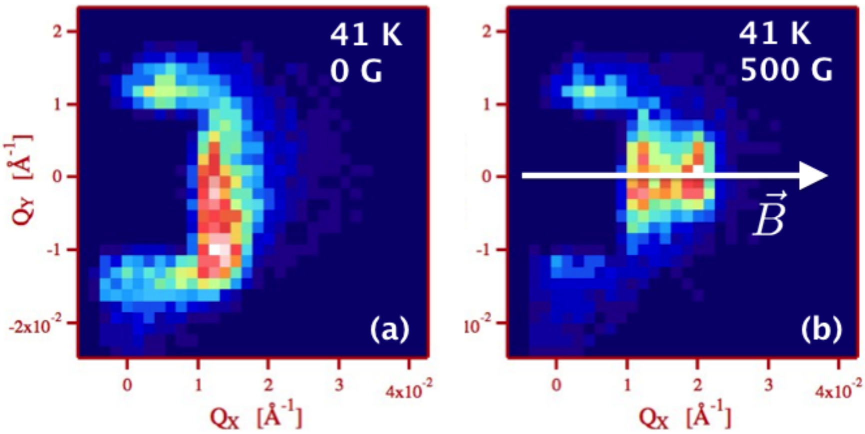

Figure 1:

Typical patterns measured on the detector of IN15 at 41K in (a) zero and (b) 500 G magnetic fields. The field was applied in the detector plane as shown.

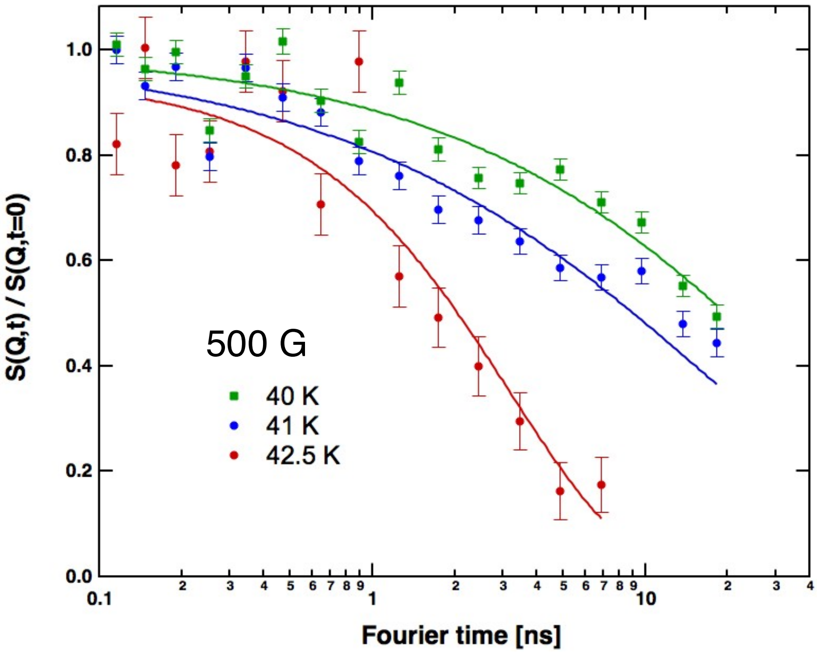

Figure 2:

Intermediate scattering function at 500 G. The solid lines represent the best fit to a stretched exponential decay ~exp$(t/\tau o)^{\beta}$, which is very similar to spin glass behavior.

References

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