Polarisation dependence of the magnetic fluctuations in the weak itinerant ferro-
magnet MnSi below T_c

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The dispersion of the spin-flip and non-spin-flip excitations in the weak itinerant ferromagnet MnSi have been measured in the ferromagnetic phase using inelastic polarised neutron scattering. Because of the steep dispersion curve, the excitations have been determined by means of constant energy scans between 0 and 7 meV. The decrease of the intensity of the spin-flip excitations with increasing energy can be explained by the interaction of the spin waves with the Stoner excitations. The interpretation of the non-spin-flip scattering is a more difficult task because of the low intensity. The non-spin-flip excitations are clearly quasielastic at small E-transfer similar as in a localised ferromagnet. Their spectral weight is significant near T_c .

Keywords: ferromagnet, spin waves, itinerant, polarised neutrons

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I. Introduction

The magnetic moments in itinerant magnets are delocalised, i.e. they cannot be assigned to a particular atom. Hence, the energy scale of the magnetic fluctuations is determined by the energy scale of the conduction electrons and no more by $k_B T_C$, like in a localised system. Here, T_C is the Curie temperature. As a consequence, the spin wave energies extend to $E \gg k_B T_C$. Moreover, single particle excitations between the spin up and spin down bands take place. The loss of long range order can be explained by a decrease of the exchange splitting of the spin polarized 3d bands with increasing temperature [1]. In the following experiment we investigate the interplay of the spin-flip and non-spin-flip excitations near T_C .

II. Experimental

The inelastic polarised neutron experiments with the itinerant ferromagnet MnSi ($T_C=29\text{K}$) were performed on the neutron spectrometers H4m at the HFBR in Brookhaven and IN20 at the Institute Laue-Langevin in Grenoble at several temperatures below T_C . The ferromagnetic order was induced by applying a vertical magnetic field $H=0.7\text{ T}$. In this con-

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figuration, the spin waves give rise to spin-flip scattering and the parallel fluctuations, i.e. the fluctuations along the magnetisation direction, give rise to non-spin-flip scattering [2].

Calculated intensity-contours of quasielastic and spin wave scattering from MnSi are given in Fig. 1. Contours are calculated for neutron energy loss based on the results presented below, assuming a double Lorentzian scattering function :

$$S(q, E) \propto \frac{1}{\kappa_i^2 + q^2} \frac{\Gamma}{(E - E_q)^2 + \Gamma^2} \langle n+1 \rangle, \quad (1)$$

where Γ is the linewidth parametrised by $\Gamma = Aq^{2.5}$ and κ_i are correlation lengths. The Lorentzians are centered at the spin wave energy $E_q = Dq^2$, where D is the stiffness. In the case of quasielastic scattering, D is fixed at zero and κ_i takes a finite value. From the contour maps displayed in Fig. 1, it is clear that for large D , constant energy scans are preferable to measure the spin wave dispersion curve. Also from the contours one sees that constant- E scans yield a peak at finite q for both, spin waves and quasielastic scattering.

The constant- E scan that is displayed in Fig. 2 was measured at $T = 26K$. The data shows that the non-spin-flip scattering and the spin wave scattering are different. The latter is clearly inelastic. With increasing E , the intensity of both types of scattering decreases significantly due to the in-

interaction of the spin waves with the Stoner excitations [3]. A detailed analysis shows that the spin wave renormalisation at 2 meV is stronger than at 5 meV (Fig. 1) in agreement with the fact that the Stoner excitations are only weakly T-dependent.

The dispersion relation for the spin waves in MnSi, as extracted from the measurements, is compared with the calculated contours in Fig.1 and shows a good agreement up to $q=0.36\text{\AA}^{-1}$. Also plotted in Fig.1 is the linewidth Γ of the quasielastic scattering at different momentum transfer q that shows the similarity in energy scale between spin waves and parallel fluctuations.

The interpretation of the non-spin-flip scattering is a difficult task because of the low intensity. At small E , the scattering can be parametrised by means of a quasielastic spectral weight function, i.e. $D = 0$ in Eq. 1. The situation is less clear at large E . Although the scattering seems to extend again over a rather large range of q , the quality of the data does not warrant an unambiguous interpretation in terms of a particular spectral weight function.

III. Conclusions

At small energy transfers the magnetic excitations behave in a weak itinerant ferromagnet similarly as in a localised magnet. The results at large E-transfers indicate that as soon as the spin waves start to interact with the Stoner excitations, they do not renormalize as strongly anymore as at small energies. The non-spin-flip excitations behave in a similar manner. They interact also with the electronic excitations and are therefore strongly reduced in intensity. These effects are clearly related to the itinerant nature of the 3d electrons of MnSi. The experiments prove that parallel fluctuations exist also in itinerant systems and that they must be included in any theory on itinerant magnetism [4].

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Fig. 1 : Intensity-contours of quasielastic scattering (solid lines) and spin wave scattering (dashed lines) of MnSi, according to the scattering func-

tion (1). The squares give the measured linewidth Γ of the parallel fluctuations and the triangles represent the measured dispersion curve of the spin waves.

Fig. 2 : Spin waves and parallel fluctuations as measured near the (110) Bragg peak in MnSi at $E=2\text{meV}$. The peaks with the label LA are acoustic phonons. The solid lines through the data points are fits to Eq. 1 taking into account the resolution function of the spectrometer.

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Fig. 1

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Fig. 2

Momentum Transfer ($1-\zeta \ 1-\zeta \ 0$)