POLARIZED NEUTRON STUDIES OF FORBIDDEN MAGNON SCATTERING IN GADOLINIUM

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Abstract. Forbidden magnon scattering from Gd was investigated using polarized neutrons. In contrast to earlier results for itinerant electron ferromagnets, forbidden magnons were not observed for this Heisenberg ferromagnet. This suggests that magnetic short range order is more important in the thermally-induced spin-disordering of the itinerant electron systems.

For a single domain ferromagnet at low temperature and with incident neutrons polarized either parallel or antiparallel to both **Q** and the magnetization, magnon creation occurs for neutrons with antiparallel spin but is forbidden for parallel neutron spins [1]. Sokoloff [2] suggested that this forbidden magnon scattering might occur at elevated temperatures as the spin system disorders and develops regions of magnetic short range order misoriented relative to the net magnetization. Measurement of the evolution of this forbidden scattering in the vicinity of T_c should then provide information about how the spin system disorders. Such forbidden magnon studies have been carried out for the itinerant electron ferromagnets Ni [3], MnSi [4] and Pt_3Mn [5] and also for the quasi 2-dimensional ferromagnet K_2CuF_4 [6]. In all cases, forbidden magnons were reported at temperatures both below and above T_c. In this paper, we report a preliminary study of the forbidden magnon scattering from the Heisenberg ferromagnet, Gd.

Triple-axis data were taken on a single crystal of Gd with the neutron polarization parallel or antiparallel to both **Q** and the sample magnetization. A polarizing monochromator and a Be analyser were used with a neutron spin flipper located between the monochromator and the sample to reverse the neutron polarization. The field and temperature range of the measurements was severely limited by the sample depolarization which remained strongly temperature dependent even at the highest available field. As a compromise between the least possible perturbation of the spin system and an adequate temperature range for the data, we eventually settled on an applied field of 4.8 kOe. At this field, the critical fluctuations at T_c are only partially suppressed and measurements can be made down to 270 K with an acceptable depolarization correction of $\sim$ 28 % . This correction decreases rapidly with increasing temperature.

The general behavior of the constant-E data is illustrated in figure 1 which shows scans along $Q = 0, 0, \xi$ at temperatures near and above T_c ($T_c \simeq 290$ K).

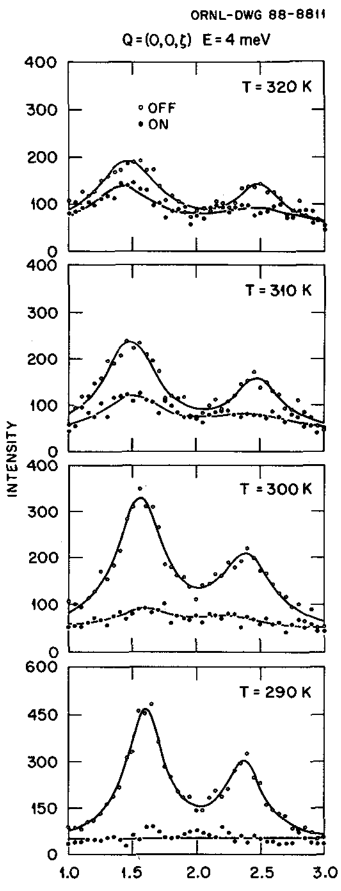

Fig. 1. – Constant-E scans for Gd at temperatures near T_c. These creation peaks are allowed for the flipper-off condition and forbidden for flipper-on.

These are spin wave creation spectra at a constant energy transfer of 4 meV. The 290 K data show clearly the allowed and forbidden character of the flipper-off and flipper-on cross-sections. The forbidden scattering does not occur for $T \leq T_c$ but develops progressively at $T > T_c$. This continuous transfer of intensity from the allowed to the forbidden scattering is quite similar to that previously observed [3-6].

It is well known that peaks in constant-E scans may arise even from diffusive spin fluctuations and do not necessarily correspond to spin wave excitations. Constant-Q measurements are required to determine the presence of underdamped spin waves. We therefore carried out a series of constant-Q measurements and these are illustrated by figure 2. Spin wave creation occurs at positive energy transfers and is clearly allowed for the flipper-off data. Conversely, the annihilation of spin waves is allowed for the flipper-on data. The spin wave peaks become broader and shift to smaller energy transfers with increasing temperature. In addition, there is a small elastic scattering component with an intensity that may be increasing with temperature. The combined effects make it much more difficult to follow the thermal evolution of the scattering above T_c for these constant-Q data than it was for the constant-E data. Nevertheless, it seems clear that peaks do not appear at finite energy transfer in the forbidden scattering above T_c. Therefore, underdamped forbidden magnon scattering is not observed in this region of Q and T.

The existence of forbidden magnons is presumably associated with the presence of magnetically short-range-ordered regions that are misoriented relative to the sample magnetization and which exist over large enough correlation lengths and time scales for the magnons to propagate. In that context, the present results may be reconciled with earlier observations of forbidden magnons in itinerant electron systems since magnetic short range order is expected to be less pronounced in Heisenberg systems such as Gd. In that regard, we note that the clearly resolved spin wave peaks for $T > T_c$ shown in figure 2 are not associated with misoriented clusters but rather with fluctuations from the field-induced magnetization. This is established both by the absence of forbidden magnons and by a comparison of the spin wave spectra below T_c in zero field and above T_c in an applied field. The spectra are the same for equivalent spontaneous and induced magnetization.

The magnetic correlation lengths for Gd are anisotropic and approximately twice as large in the basal plane of the hcp lattice as in the c-axis direction [7]. Future experiments may reveal forbidden magnons in these more highly correlated basal plane directions.

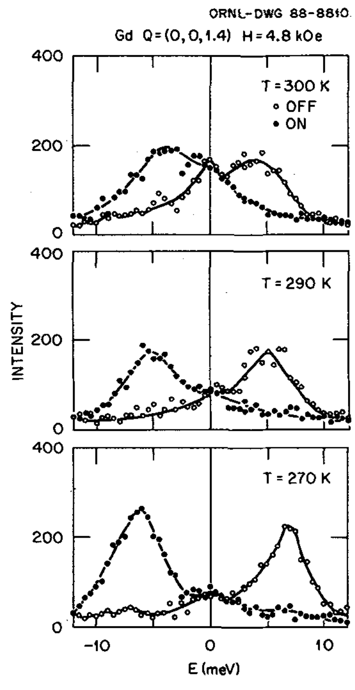

Fig. 2. – Constant-Q scans for Gd at temperatures near T_c. The creation peaks at positive energies are allowed for flipper-off while the annihilation peaks are allowed for flipper-on.

Acknowledgments

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