Interaction between phonons and magnons in multiferroic YMnO3

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We present a study of phonon-magnon coupling in the multiferroic highly-frustrated $YMnO_3$ crystal. We have studied an avoided crossing of the phonon- and magnon-branch below the magnetic transition temperature, $T_N = 72K$, with polarized neutrons, revealing the nature of the different excitation in the coupling region.

The $YMnO_3$ crystal is a highly-frustrated multiferroic system with strong coupling between the magnetic moments, and the ion positions, and also, therefore, between the magnetic excitations and the phonon modes [1]. The signature of this coupling can be seen below T_N in the magnon and phonon excitations, as a gap opens at the crossing point of the two excitations at $q = (0\ 0.185\ 6)$ [2], and in the anomalous temperature dependency of the thermal conductivity [3]. Thermal conductivity is usually slightly suppressed in the region of a magnetic phase transition due to the critical fluctuations of the spins. However, in $YMnO_3$ this suppression effect extends 230 K above the magnetic transition $T_N = 72$ K. It can be understood in terms of phonon scattering by spin fluctuations [3].

In this experiment we aimed to detemine the nature of the exitations by polarization analysis of the inelastic signal. We performed in total four series of constant-q scans: one in the middle of the Brillouin zone and three at the zone boundary. For each scan, both spin-flip and non-spin-flip scattering was measured. The incident polarization was in every case along the scattering vector to let the magnetic scattring be present in the spin-flip scattering signal only. One example of data is shown in Fig. 1

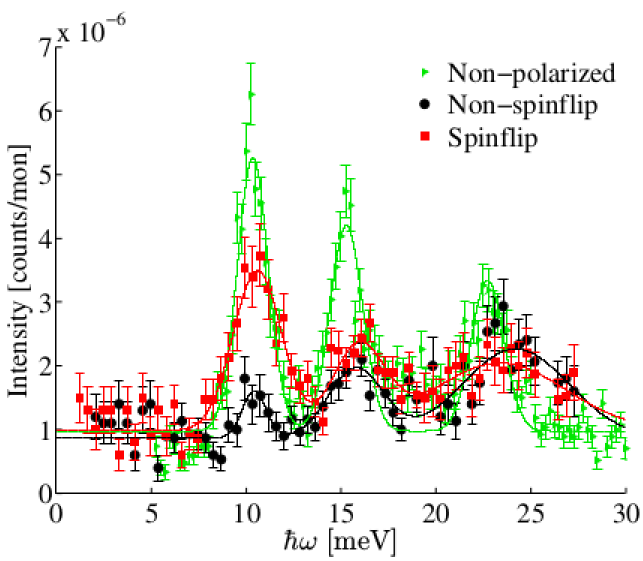

Figure 1: Example of a polarized inelastic scan at C5. The black and red points are non-spin flip and non-spin data, respectively, while green points show earlier data from PSI, measured without polarization analysis.

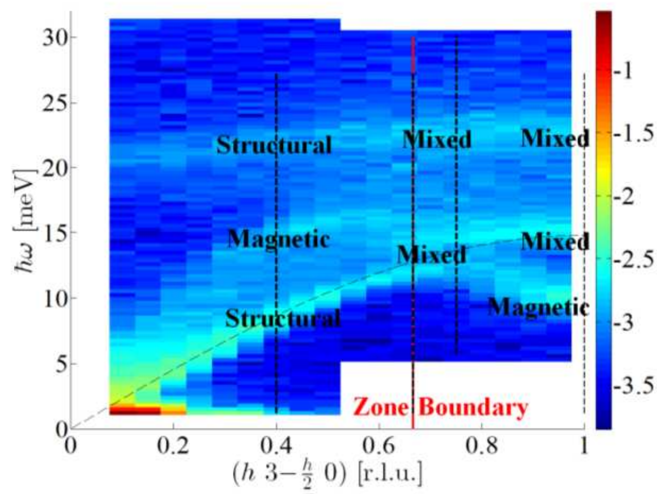

Figure 2: A full map of the magnon and phonon dispersions at 40 K from (3 0 0) to (2.5 1 0) measured at EIGER, PSI. The polarized C5 energy scans are shown with the black lines. From these scans we have detemined the nature of the exitations and labled them accordingly. At (2.66 0.66 0) we reach the zone boundary and from this point and to (2.5 1 0) we scan along the boundary.

Fig. 2 shows the dispersion along the high symmetry directions in the first Brilllouin zone, with data taken at EIGER at PSI. The role of our present experiment was to indicate the nature of the excitations at different places in the zone, labeled in the figure. We find that the magnon and phonon branches observe avoided crossing, and that the nature of the modes close to the avoided crossing at $h = 0.75$, $\hbar\omega = 13\ meV$, is a coupled magnetic-structural excitation. The conclusions for the optical modes above 20 meV is less clear, as several modes may contribute to the observed signal.

[1] S. Lee et al Nature 451, 805 (2008)
[2] S. Petit, et al. PRL 99 266604 (2007)
[3] P. Sharma et al. PRL 93 177202 (2004)