Magnon Broadening Effects in Double Layered Manganite $La_{1.2}Sr_{1.8}Mn₂O₇$

Nobuo Furukawa^a, Kazuma Hirota b

^a Department of Physics, Aoyama Gakuin University, Setagaya, Tokyo 157-8572, Japan ^b CREST,Department of Physics, Tohoku University, Sendai 980-8578, Japan

Abstract:

Magnon linewidth of $La_{1.2}Sr_{1.8}Mn₂O₇$ near the Brillouin zone boundary is investigated from both theoretical and experimental points of view. Abrupt magnon broadening is ascribed to a strong magnon-phonon coupling. Magnon broadening observed in cubic perovskite manganites is also discussed.

1 Introduction

Magnetic excitation spectra of colossal magnetoresistance (CMR) manganites in the ferromagnetic metal phase attract our attention in the point whether they can be understood by the conventional double-exchange (DE) mechanism. For $(La, Sr)MnO_3$ and $(La, Pb)MnO_3$ where T_c is relatively high, a cosine-band type magnon dispersion is observed[[1, 2](#page-2-0), [3](#page-2-0)]. At low temperature, Magnon linewidth Γ is narrow enough throughout the Brillouin zone, which makes it possible to observe well-defined magnon branches, and it becomes broad at finite temperature. The DE model explains the cosine-band dispersion[[4\]](#page-2-0) as well as the temperature dependence of the linewidth in the form $\Gamma \propto (1-M^2) \omega_q$, where M is the magnetization normalized by the saturationvalue and ω_q is the magnon dispersion [[5\]](#page-3-0). The origin of the magnon broadening is the Stoner absorption, which disappears at $T \to 0$ (or $M \to 1$) due to the half-metallic nature of the system.

For compounds with lower T_c , Doloc *et al.* [[6\]](#page-3-0) observed broadening of magnon dispersion. They claimed that the abrupt increase of linewidth near the zone boundary can not be explained by DE mechanism alone. One of the possible explanations is that the broadening is caused by the magnon-phonon interaction [\[7](#page-3-0)]. A strong coupling between magnons and phonons are through the modulation of the exchange coupling by the lattice displacement.

Anomalous broadening of magnon linewidth is also observed in the doublelayered manganite $\text{La}_{1.2}\text{Sr}_{1.8}\text{Mn}_2\text{O}_7$ $\text{La}_{1.2}\text{Sr}_{1.8}\text{Mn}_2\text{O}_7$ $\text{La}_{1.2}\text{Sr}_{1.8}\text{Mn}_2\text{O}_7$ [8]. Intra double-layer coupling creates optical and acoustic branches of magnons. Two-dimensional dispersion of both branches indicates that the inter double-layer coupling is sufficiently weak. Magnon broadening near the zone boundary is also observed in this compound. In this paper we investigate the possibility of this broadening caused by the magnon-phonon interaction.

2 Comparison between theory and experiment

As for dispersionless optical phonon with frequency Ω_0 , the magnon linewidth due to magnon-phonon interaction is given by $\Gamma(q) \propto D(\omega_q - \Omega_0)$, where $D(\omega)$ is the magnon density of states [\[7\]](#page-3-0). In a two dimensional system, we have step-function like behavior

$$
\Gamma(q) = \begin{cases} \Gamma_0 & \omega_q > \Omega_0 \\ 0 & \omega_q < \Omega_0 \end{cases} . \tag{1}
$$

When a magnon with momentum q has energy $\omega_q > \Omega_0$, it is possible to find an elastic channel to decay into a magnon-phonon pair with momentum q' and $q - q'$, respectively, which satisfies $\omega_q = \omega_{q'} + \Omega_0$. This is the reason why magnon linewidth abruptly becomes broad as magnon branch crosses that of the phonon.

Let us now compare the theoretical results with experimental data. We show inelastic neutron scattering intensities for $La_{1.2}Sr_{1.8}Mn₂O₇$ in Fig. 1, where a contour map is plotted in the ω -q plane. Scattering vector is taken as $(1 + q, 0, 5)$ in the reciprocal lattice units. Details of experimental are given in ref. [\[8\]](#page-3-0). A well-defined acoustic magnon branch is observed near the zone center. We also see optical phonon which is nearly dispersionless at $\omega \sim 20$ meV. Above $q \sim 0.3$ where magnon branch and phonon branch crosses, we see an abrupt increase of the magnon linewidth. A weak trace of the dispersion is observed above the crossing point.

The data is consistently explained as follows. Magnon dispersion is cosineband like with the zone boundary energy ~ 40 meV, which crosses with the optical phonon with $\Omega_0 \sim 20$ meV. A strong coupling between magnons and phonons creates abrupt magnon broadening above the crossing point.

3 Discussion

Magnon dispersions so far observed in the ferromagnetic metal phase of manganites are well defined near the zone center regardless of compounds and dimensionalities. Zone boundary broadening is, however, strongly compound dependent. The present result suggests that the zone-boundary magnon broadening is influenced by the strength of the magnon-phonon interactions. Although magnon-phonon dispersion crossing is also reported in threedimensional manganites [3, [9\]](#page-3-0), zone-boundary broadening is observed only in low T_c compounds. This implies a relation between T_c and spin-lattice interaction strength. Strong damping of the zone-boundary magnons might also explainthe "zone-boundary softening" of magnons in low T_c manganites [[10](#page-3-0)], if we assume that the zone-boundary flat dispersion observed by neutron inelastic scattering is allocated as an optical phonon branch, while the real zone-boundary magnon branch at higher frequency is wiped out above the magnon-phonon crossing point.

Further detailed studies of the relations between the magnon linewidth broadening above the magnon-phonon crossing point and the other magnetoelastic behaviors will clarify the role of the spin-lattice interactions to various physical properties.

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Figure captions.

Figure 1:

The dispersion relation of acoustic branch of spin wave of $La_{1.2}Sr_{1.8}Mn₂O₇$ at 10 K ($I4/mmm$: $a = 3.87 \text{ Å}, c = 20.1 \text{ Å}$). Measurements were carried out on the triple-axis spectrometer TOPAN located in the JRR-3M reactor of JAERI. PG (002) reflection of pyrolytic graphite was use to monochromate and analyze neutrons. Data were taken at every 1 meV and 0.05 rlu (reciprocal lattic unit) along $(1 + q 0 5)$ and accumulated for 7 min. Contours are drawn every 20 counts between 0 and 400. Nearly dispersionless optical phonon branch is also observed at $\omega \sim 20$ meV.

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