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Short Range Magnetic Correlation in DyB_4 with Geometrical Frustration

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Introduction

Multiple magnetic phase transitions in tetragonal rare-earth RB_4 compounds has been attracting interest where both the quadrupolar and magnetic degrees of freedom are active. In addition, the R-ions form a geometrically frustrated lattice of Shastry-Sutherland-type. In Ref. 1, we reported on the short-ranged magnetic correlation in DyB_4, in which two phase transitons occur at T_{N1}=20.3 K and at T_{N2}=12.7 K. The signal of resonant x-ray scattering for the (100) reflection exhibits different temperature dependence for the azimuthal angles of Ψ=0° and 90°, where incident polarization is perpendicular and parallel, respectively, to the c-axis. In the intermediate phase, where the quadrupolar moments are considered to be fluctuating, the peak profile for the signal at Ψ=90° is broadened, while that at Ψ=0° is sharp. From an analysis

$$F^{(E1)}_{\sigma-\pi'} = 2k_1 b\cos\theta\left(\sqrt{2}\langle J_z\rangle\cos\Psi - \langle J_x\rangle\sin\Psi\right)$$
$$\mp 2k_2 a\cos\theta\left(\sqrt{2}\langle O_{22}\rangle\cos\Psi + \langle O_{zx}\rangle\sin\Psi\right) .$$

assuming a model structure of magnetic and quadrupolar moments, we have the structure factor as follows,
This shows that the signal at Ψ=90° represents the in-plane magnetic moment or the Ozx-type quadrupolar moment. The broadened peak profile shows that they are short-range ordered. However, unfortunately, it was not clear which order paremeter is reflected in the resonant signal. In order to clarify this ambiguity, we compared the intensity among (1 0 0), (3 0 0) and (5 0 0) reflections. Through the factors a= cos(2π*hx*) and b=sin(2π*hx*), *x* the position parameter of Dy, we can deduce whether the resonance reflects <J> or <O>.

Results, Analysis, and Discussion

Resonant x-ray scattering experiment has been performed at BL16A2 using a liquid He cryostat. Polarization analysis was carried out using a PG(006) analyzer.

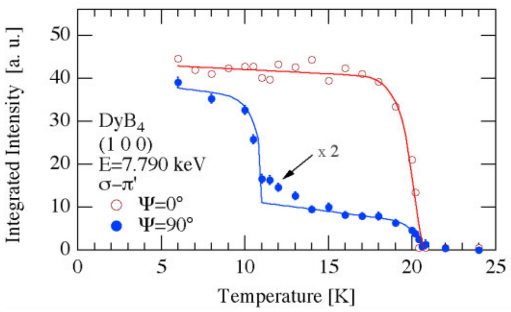

Figure 1: Temperature dependences of the resonant scattering intensity for the (1 0 0) reflection of DyB_4 at two azimuthal angles near 0° and 90°.

Figure 2 shows the observed intensity of the (*h* 0 0) reflection for *h*=1, 3, and 5 as compared with the b=sin(2π*hx*) curve, which reflects the magnetic part of the structure factor. Apparently the observed intensity can be well explained only by the magnetic term in the structure factor both at T=15 K in the intermediate phase and at T=7 K in the low-temperature pha1e. This result shows that the resonant x-ray scattering experiment in DyB_4 detects the magnetic moment.

Since the magnetic susceptibility and elastic constant measurements show that the Jx and Oyz are not ordered in the intermediate phase, the resonant x-ray signal at Ψ=90° may indicate that the in-plane moments are fluctuating dynamically with short-range correlation; the finite intensity reflects the snapshot of the short-range order in the time-scale of resonant x-ray diffraction.

It is now clear that we observe the short-range order of the magnetic moment. Therefore, it is interesting to compare the signal of neutron diffraction, which has about 1000 times longer time-scale of observation. We performed neutron diffraction experiment on DyB_4 and confirmed that the ratio <*Jx*>/<*Jz*> is less than 1/10, while the ratio in resonant x-ray diffraction is about 1/3. This is a strong evidence for the above scenario that the in-plane moment are dynamically fluctuating with short-range correlation.

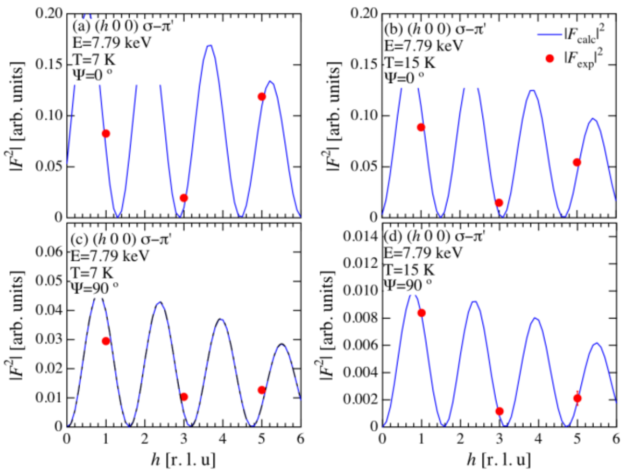

Figure 2: Comparison of the observed intensity and the b=sin(2π*hx*) curve.

References

[1] D. Okuyama et al., J. Phys. Soc. Jpn., **74**, 2434 (2005).

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