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Magnetic-field-induced 4f octupole in CeB_6 probed by resonant x-ray diffraction

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Introduction

CeB_6 is a typical Γ_8-quartet system with a simple cubic structure, possessing 15 degrees of freedom in total, 3 dipoles, 5 quadrupoles, and 7 octupoles. The anomalous increase of the antiferroquadrupole (AFQ) transition temperature from T_Q=3.3 K at zero field to 8.3 K at 15 T has been ascribed to an antiferro-type interaction between field-induced octupoles of T_{xyz}-type. Splitting of the Boron-NMR line offers a strong evidence for this interpretation [1]. However, to be exact, we have to mention that direct evdicence of octupole is still lacking. It is worth verifying whether the Txyz-octupole is induced in the Ce 4f-orbital itself.

Experimental Results and Analysis

Experiment

Resonant x-ray diffraction (RXD) experiment has been performed at BL-3A of the Photon Factory. We used a vertical field superconducting magnet placed on a two-axis diffractometer. The incident photon was π-polarized and the energy was tuned to the Ce L_{III}-absorption edge.

Results

Figure 1 shows the results of energy dependences. We immediately notice that the peaks at 5.724 keV (E1) and at 5.718 keV ((E2) become stronger and well resolved for fields in the plus direction, whereas for fields in the minus direction the E2 peak becomes obscure. From this result,

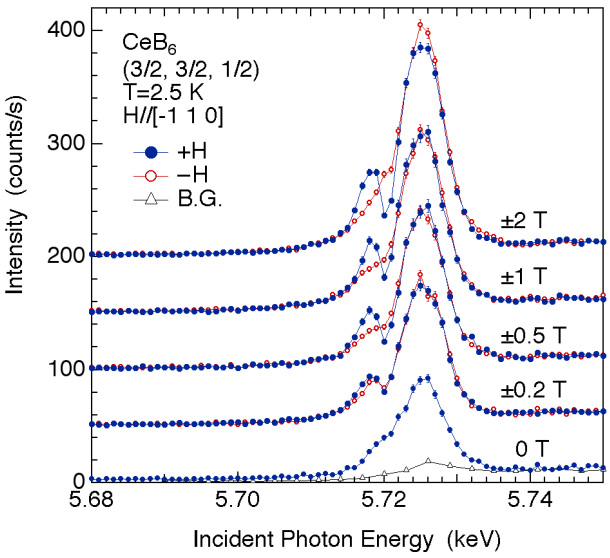

Fig. 1: X-ray energy spectra of the (3/2, 3/2, 1/2) superlattice reflection in magnetic fields with reversed directions. T=2.5 K is is in the AFQ phase.

we can extract the field dependence of the quadrupole and octupole moments.

Analysis

The asymmetric behavior with respect to the field reversal is caused by (1) the interference between the E1 and E2 resonances, and also by the fact that (2) the odd rank tensor (dipole and octupole) changes its sign by the field reversal but the even rank tensor (quadrupole) does not. By using these relationships, we have deduced the field-dependences of the AFQ and AFO moments as shown in Fig. 2. It is noted that the obtained AFO moments agree well with the transferred hyperfine field (THF) as deduced from NMR, which has been interpreted as reflecting the octupole moment.

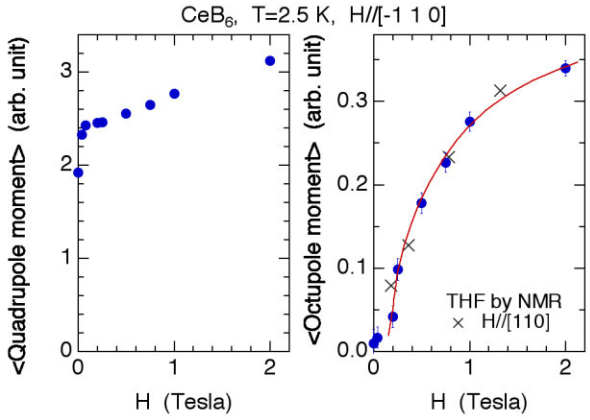

Fig. 2: Magnetic-field dependences of the AFQ and AFO moments deduced from the symmetric E1 and asymmetric E2 intensities. The solid line is a guide for the eye. Crosses represent the transferred hyperfine field as deduced from NMR.

Importance of the present experiment lies in the fact that RXD directly probes the multipole moments of the 4f-orbital itself, whereas NMR indirectly probes the THF of the anisotropic spin distribution of Ce via the 2p and 2s conduction electrons. We expect that the field-reversal method used in the present study can widely be applied to other multipole ordering systems in f-electron compounds. Next subject in CeB_6 is to study the field-induced multipoles in other field directions and compare with the theoretical predictions.

References

[1] O. Sakai et al., J. Phys. Soc. Jpn. **66**, 3005 (1997).

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