Inelastic Neutron Scattering Measurements on a Quadrupolar Ordering in Yb monopnictides

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The compound YbSb is well-known as a mixing-type quadrupolar ordering occurs at 5 K. One of the most anomalous properties of Yb monopnictides (YbN, YbP, YbAs and YbSb) is the unexpected splitting of the first excited states (Γ 8) of the crystal field splitting. Keller et al. proposed that the unexpected splitting is explained by the occurrence of a quadrupolar ordering around 80 K in YbN, YbP and YbAs.[1] In order to study the quadrupolar ordering in Yb monopnictides, inelastic neutron scattering experiments on the powder samples of YbSb and a single crystal of YbAs were measured.

The Γ 6 - Γ 8 excitation was observed around 17 meV using the triple axis spectrometer 6G(TOPAN) with a fixed kf. The energy spectra were measured down to 0.7 K including the quadrupolar ordering state. The energy spectra has almost no change at 5 K, that is consistent with the results of the molecular field calculation assuming O20-type ordering. The energy spectra between 0 and 3.5 meV were also measured by the triple axis spectrometer C1-1(HER). A strong q-dependence of the intensity at 0.4 meV was observed below 5 K. The q-dependence is enhanced with lowering the temperature. The q-dependence is probably ascribed to the dispersion of the excitation in the quadrupolar ordering state. Further studies at lower energy are required.

Now we turn to the experimental results on a single crystal of YbAs.
Figure 1 shows the q-dependence of the energy spectra of YbAs at 3.3 K. The measurements were carried out on the triple axis spectrometer 6G(TOPAN) with a fixed kf. The structure in the figure shows the transition between Γ 6 ground states and Γ 8 excited states.
The intensity at (2, 0, 0) is smaller than that at (3, 0, 0). This means the intensity of the zone center is smaller than that of the zone boundary. This situation is similar to PrOs4Sb12 that has a quadrupolar ordering. In the case of YbAs, the quadrupolar ordering around 80 K is still controversial. If there is no quadrupolar ordering around 80 K, our results indicate the importance of the quadrupolar interactions between 4f electrons. Further studies using the single crystal of YbAs is promising.

The observed q-dependence suggests that the theoretical approach beyond the molecular field approximation is required in order to understand the magnetic properties of Yb monopnictides.

[1] L. Keller et al.: Europhys. Lett. 26 (1994) 353.

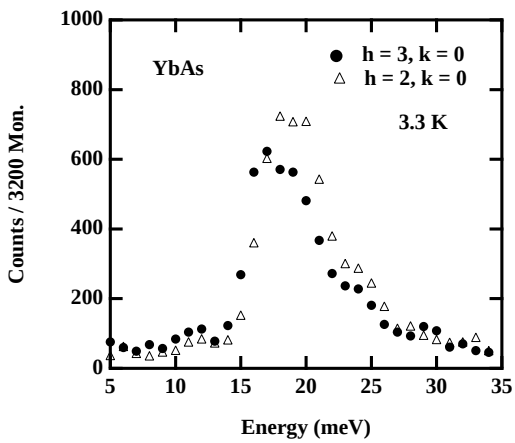

Fig. 1. Energy spectra at Q = (3, 0, 0) and (2, 0, 0).