Exchange Field Splitting in Ytterbium Iron Garnet

H. WATANABE* AND B. N. BROCKHOUSE
Neutron Physics Branch, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada
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The exchange-field splitting of a single Yb^{3+} ion in ytterbium iron garnet was measured by observing the energy distribution of neutrons scattered by the specimen at room temperature and at liquid nitrogen temperature. The results are consistent with those of other experiments and also with Tinkham's spin-wave model.

THE exchange coupling between the rare-earth ions and iron ions in rare-earth iron garnets has been measured by means of a number of methods.[1-3] The experiments measure an energy splitting which is assumed to correspond to the flipping of spins of a single rare-earth ion in the presence of the effective field from the above coupling. Here we present a method in which neutrons are magnetically scattered by the rare-earth ions, and this splitting can be observed in the energy distribution of the scattered neutrons. The technique is similar to that used for the study of crystal field splitting of the ground levels in rare-earth oxides.[4,5]

We have observed the exchange-field splitting in a sample of powdered YbIG on the rotating crystal spectrometer[6] at NRU reactor. With the incident neutron wavelength of 4.059 Å, and with the specimen in the symmetrical position (the transmission of the specimen was 73%), the scattered neutrons were measured at a scattering angle ϕ of 32°, an angle which lies well away from any of the Debye-Scherrer lines. Measurements were made at room temperature and at liquid nitrogen temperature, and the results are shown in Fig. 1.

Peaks can be seen which correspond to mean energy transfers of about 2.4 meV at room temperature and of 3.0 meV at liquid nitrogen temperature. These energy values can be compared with similar values from other measurements.[1-3] Our value at liquid nitrogen temperature is very close to the value of 25 cm^{-1} obtained by Sievers and Tinkham[3] using infra red. Since the infra red measurements are of "spin waves" of wave vector $q \simeq 0$, while the neutron measurements give an average energy for "spin waves" over a large range of $\mathbf{q}$ space, the results suggest that the flat dispersion relation (energy vs wave vector) proposed by Tinkham[7] may be correct.

The change of the peak position with temperature is approximately consistent with the temperature variation of the saturation magnetization of the iron sublattice deduced from Pauthenet's magnetic measurement.[8] Also, the line broadening ($\sim$1.3 meV) at room temperature is about what might be expected.

We have also studied the crystal-field splitting with the beryllium detector method.[9] Care was taken to distinguish proper peaks from Debye-Scherrer reflections[5] also present. Although a good measurement could not be obtained there was evidence for a peak at $\sim$0.07 eV, a value crudely consistent with the value 610 cm^{-1}, obtained from optical absorption measurements[10] for the Γ_8-Γ_7 separation in this material.

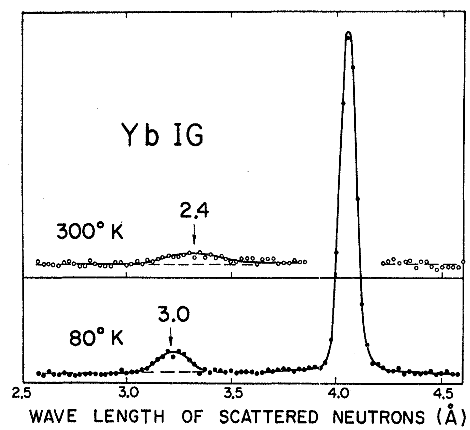

FIG. 1. Spectrum of neutrons (4.059 Å) scattered from YbIG as measured with the rotating crystal spectrometer, with no corrections applied. (The corrections do not greatly change the patterns.) Energy transfers in units of meV are indicated.

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* International Atomic Energy Agency Fellow from the Research Institute for Iron, Steel and other Metals, Tohoku University, Sendai, Japan, now returned.

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