Anisotropy of parametric excitation of magnons in antiferromagnetic $CsMnF_3$

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A strong hexagonal anisotropy of the threshold field of parametric magnon excitation was observed in $CsMnF_3$ at a pump frequency $\nu_p = 18$ GHz along the direction of the static field **H** in the basal plane of the crystal. The experiments performed seem to point to an anisotropic excitation of magnons in **k**-space.

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We have investigated parametric excitation of electronic magnons in the hexagonal easy-plane antiferromagnet $CsMnF_3$. The experiments were performed at a pump frequency $\nu_p = 18$ GHz at $T = 1.2$–3.3 °K. A single-crystal sample of cylindrical shape was placed on the bottom of a cylindrical microwave resonator at the antinode of the magnetic field H of the H_{011} mode in such a way that the static and microwave magnetic fields **H** and **h** were in the basal plane of the crystal. The direction of **H** could be varied by rotating the electromagnet. In addition, a special adaptor made it possible to rotate the sample about the S_6 axis. It was thus possible to vary the directions of **h** and **H** relative to the crystal axis independently.

Our experiments have shown that the threshold field h_c has an anomalous dependence on the direction of the static magnetic field relative to the crystal axes. Figure 1 shows an experimental plot of $h_c(\phi)$, where ϕ is the angle between the direction of the static field and the binary face of the crystal. It is seen that the threshold field has a strong hexagonal anisotropy that leads to the appearance of relatively narrow peaks of width $\sim 10°$ on the $h_c(\phi)$ plot. The experiments were performed on a number of samples prepared at different times, and similar anomalies were observed each time. The ratio $h_{c\,max}/h_{c\,min}$ varied

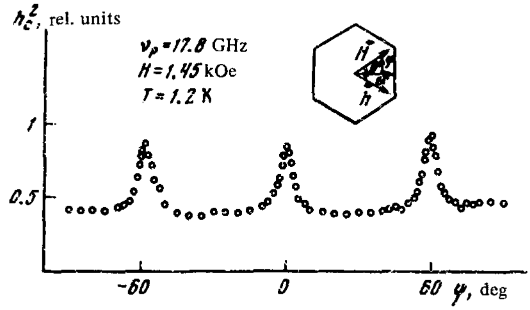

FIG. 1. Dependence of the square of the parametric-excitation threshold field on the direction of **H** in the basal plane of the crystal.

from sample to sample and reached ~3 at $T = 1.2\,°K$. An x-ray investigation of samples has shown that in all cases the **H** direction corresponding to $h_{c\,max}$ coincided, within the limits of experimental accuracy (± 2°), with the direction of the crystallographic binary face.

Figure 2 shows plots of $h_{c\,max}$ and $h_{c\,min}$ against the magnetic field for different temperatures. Within the limits of experimental accuracy, the difference $h_{c\,max} - h_{c\,min}$ does not depend on T, whereas the values themselves change by one order of magnitude.

The theory of parametric magnon excitation[1] yields the following expression for the threshold field:

$$h_c = min(\gamma_{\mathbf{k}} / V_{\mathbf{k}}), \qquad (1)$$

where γ_k is the relaxation of magnons with wave vector **k**, and V_k is the coupling of the parametric magnons with the pump field. Inasmuch as the antiferromagnet was assumed in the theory to be isotropic and the dipole interaction neglected because of the small macroscopic magnetization, the values of γ_k and V_k were found to be independent of the **k** direction, in particular,

$$V_{\mathbf{k}} = \frac{2\gamma H \cos\theta}{\nu_p}, \qquad \theta = \widehat{\mathbf{hH}}. \qquad (2)$$

The observed phenomenon can be explained, in our opinion, in two ways. First, it is possible in principle that $\gamma_{\mathbf{k}}$ depends on the angle ϕ for all **k** (the analogous dependence in the case of V_k can not explain the temperatures de-

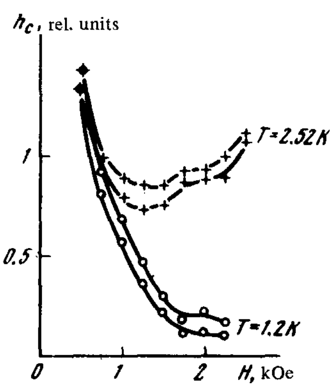

FIG. 2. Plots of $H_{c\,max}$ and $h_{c\,min}$ against the magnetic field.

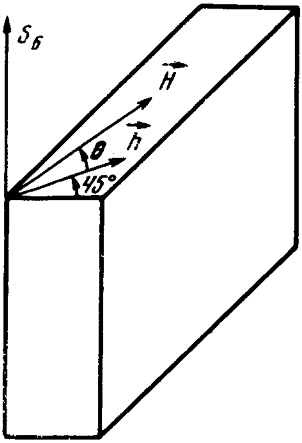

FIG. 3. Geometry of experiment with thin plate.

pendence of the effect, since V_k does not depend on temperature). Although such a possibility was not considered in the theory, the $\gamma_k(\phi)$ dependence may be the result, for example, of the hexagonal magnetic anisotropy in the basal plane, which is permitted by the symmetry of the crystal. There are, however, two considerations that contradict this explanation: First, an investigation of the angular dependence of the AFMR of the same samples at 9 GHz, has shown that within the limits of experimental accuracy (~1%) the resonant field $H_R(\phi)$ is constant, so that the anisotropy in the plane is small ($H_{a2} < 0.1$ Oe). Second, the presence of hexagonal anisotropy H_{a2} should apparently lead to a smooth $h_c(\phi)$ dependence in the form $h_c \propto \sin 6\phi$, whereas experiment reveals sharp peaks.

The observed phenomenon can be explained in a different way by assuming that the parametric magnons are excited in **k**-space not isotropically, but in the same direction as **H**, and that there exists an hexagonal anisotropy of the magnon relaxation along the direction of **k**. This relaxation anisotropy can be due to sample defects which, as is well known, can align themselves in the crystal in definite directions. This agrees with the observed variation of the effect from sample to sample. The anisotropy of the magnon excitation in **k**-space may be due to dipole interaction. This question was considered theoretically in[1], from which it follows that the magnons excited in $CsMnF_3$ should primarily have **k** ∥ **H**.

To investigate the anisotropy of the excitation of the magnons in **k**-space and to determine the "easy" direction, we performed an experiment based on the fact that at $T = 1.2$ °K the proper relaxation of the magnons is so small that an appreciable contribution to the relaxation is made by scattering from the crystal boundaries.[2] A $CsMnF_3$ plate measuring $2.5 \times 2.5 \times 0.5$ mm was cut in such a way that its plane was perpendicular to the basal plane. The sample was fastened to the resonator in such a way that the plane of the plate made an angle 45° with the direction of **h** (see Fig. 3). We measured the ratio $\sigma = h^2(\theta = -45°)/h_c^2(\theta = 45°)$.

Assume that the magnons are excited anisotropically (more readily, they should be produced with **k** ∥ h or **k** ⊥ H). Then they will be excited in this experiment either along or across the plate, and σ should differ from unity at temperatures at which scattering from the boundaries is appreciable. The measurements were performed in the temperature interval 1.2—1.7 °K. At $T = 1.7$ °K we have $\sigma = 1$, increasing to 1.4 at $T = 1.2$ °K as the temperature is lowered. Thus, our experiments seem to offer evidence of an isotropic distribution of the parametric magnons in k-space ($\mathbf{k} \parallel H$) near the excitation threshold.

In addition, from the fact that $h_{c\,\max} - h_{c\,\min}$ does not vary with temperature it follows that the relaxation due to the scattering of the magnons by the defects enters additively in the magnon relaxation.

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