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EXPERIMENTAL STUDY OF INDUCED STAGGERED MAGNETIC FIELDS IN DYSPROSIUM GALLIUM GARNET (DGG)*

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MASTER

Abstract

Neutron diffraction techniques have been used to study induced staggered magnetic field effects in DGG. We find that the application of a uniform magnetic field at temperatures much greater than the Néel temperature induces a significant amount of antiferromagnetic order. The temperature and field dependences of this effect are in good agreement with recent theoretical predictions.

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Running Title: Induced Staggered Magnetic Fields in DGG.

Recent experimental and theoretical work[1] has shown that in certain magnetic systems antiferromagnetic order can be induced by a uniform magnetic field. Since in most systems only a staggered magnetic field can induce antiferromagnetic order, this effect can be thought of as being due to a staggered field which is induced by the uniform field. Microscopic calculations have demonstrated that there are several different mechanisms which can give rise to an induced staggered field.[2] In dysprosium aluminum garnet which is the system in which these effects were first recognized,[1] one mechanism, the so-called staggered interaction mechanism is dominant in the range of field and temperature studied to date.[2,3] In DGG, on the other hand, it has been predicted[2] that the staggered interaction mechanism will be negligible for T > 1 K, and that a different mechanism, the g-value mechanism, will dominate in this case. We have performed a neutron diffraction study of DGG in order to test these predictions.

The experiments were performed at the High Flux Beam Reactor at Brookhaven National Laboratory. The sample was a 2 mm diameter sphere and the magnetic field was applied along the [111] direction. The temperature was varied between 1.5 and 4.2 K and was thus always far above the Néel temperature of DGG,[4] which is 0.37 K.

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ere.

Some typical results for the antiferromagnetic order in low fields are given in Fig. 1. The solid lines show the theoretical predictions for the g-value mechanism.[2] Here we have used the g-values determined from resonance experiments[5] on Dy^{3+} in yttrium gallium garnet (YGG), and we have normalized the theoretical values to agree with the experimental value at T = 1.98 K and H = 5 kOe.[6] The agreement between theory and experiment is seen to be good, and we conclude that the g-value mechanism is dominant in this region of field and temperature.

ig. 2 near
ere.

Figure 2 shows results for the intensity of the $(03\bar{3})$ reflection in fields up to 40 kOe. The dashed line shows the theoretical prediction using the g-value mechanism. While this agrees fairly well with the experimental results in low fields, there are clear deviations in high fields. We believe that these deviations are due to another mechanism, the anisotropy of the ionic Van Vleck susceptibility.[1,2] Unfortunately, it is not possible to make any quantitative estimates for this mechanism at this time. However, it is possible to use the measured average Van Vleck susceptibility to obtain an approximate upper limit on the effect.[2] The solid lines in Fig. 2 show the theoretical predictions with both the g-value and Van Vleck mechanisms included. Here the components of the Van Vleck susceptibility were taken to be $\alpha_x = 0.07$, $\alpha_y = 0$, and $\alpha_z = 0.07$, all in units of emu/mole (here x, y, and z refer to local axes[5]), which is consistent with the value $\alpha = \alpha_x + \alpha_y + \alpha_z = 0.14$ emu/mole obtained by Cooke et al.[7] The agreement between theory and experiment is now quite reasonable over the entire range of fields studied. We note that the Van Vleck contribution for H < 10 kOe is relatively small, and this is why the low field results in Fig. 1 could be accounted for by the g-value mechanism alone. Although these results do not prove that the high field behavior is due to the Van Vleck mechanism, they do show that this effect could easily be large enough to account for the experimental observations.

In conclusion, our results indicate that in DGG two different induced staggered field mechanisms are important. The g-factor mechanism is dominant in low fields, while the anisotropy in the Van Vleck susceptibility is important in high fields. While the agreement with the theory is quite reasonable, there are several factors which prevent a complete, quantitative comparison between theory and experiment at this time. First, more accurate values for the microscopic parameters, especially the components of the ionic Van Vleck susceptibility are needed. Second, further work is needed to obtain quantitative estimates of extinction effects, so that the experimental results can be expressed in absolute units without scaling.

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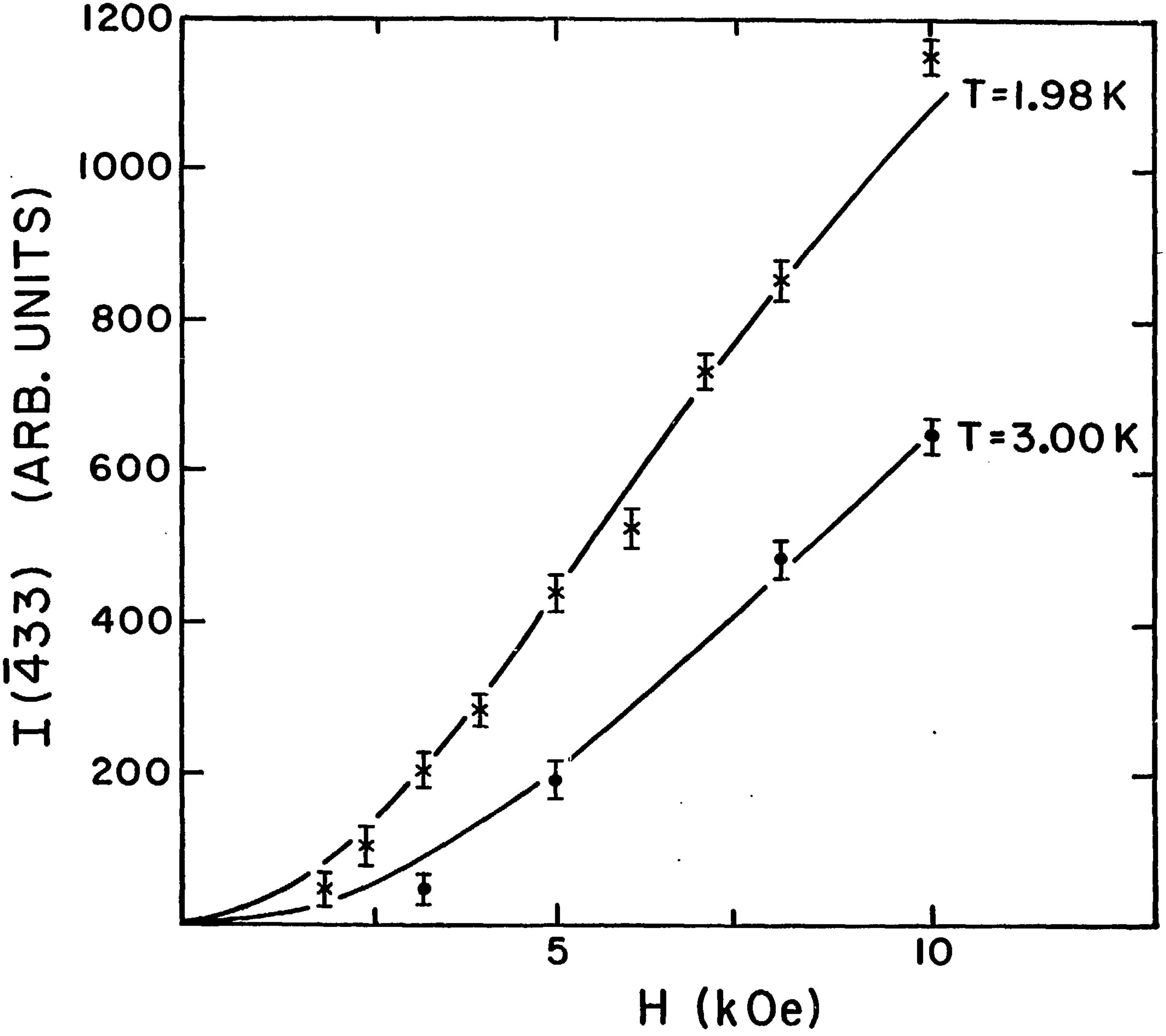
Figure Captions

FIG. 1: Intensity of the $(\bar{4}33)$ reflection as a function of field at two temperatures. The solid lines are the theoretical predictions described in the text.

FIG. 2: Intensity of the $(03\bar{3})$ reflection as a function of field at two temperatures. The dashed line is the theoretical prediction for 1.66 K using the g-value mechanism alone. The solid lines are the theoretical predictions with both the g-value and Van Vleck mechanisms included as described in the text.


1200
1000
800
600
400
200
I ($\bar{4}$33) (ARB. UNITS)
5
10
H (kOe)
T=1.98 K
T=3.00 K

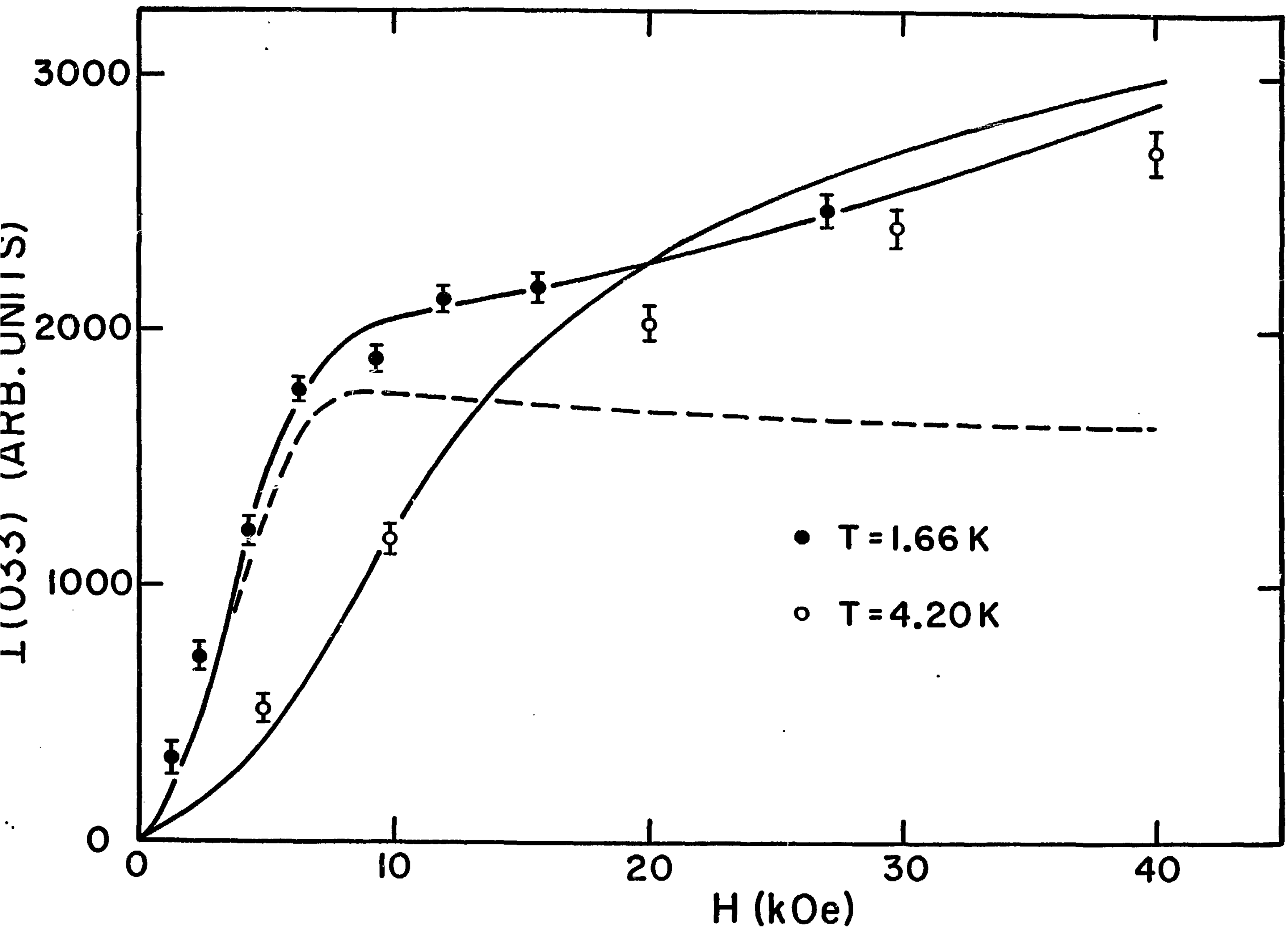


FIG. 2