NEAR-INFRARED ROTATION IN GdIG AS A FUNCTION OF TEMPERATURE

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(−140 to 40°C; ferrimagnetic materials; 2.05 and 2.6 μ; E)

Measurements of the Faraday rotation of various ferrimagnetic iron garnets in the visible region of the spectrum have yielded large values of rotation.[1] These have been discussed for the case of YIG by Clogston[2] in terms of possible electric dipole transitions of the ferric ion. Recent experiments of Matthews, Singh and LeCraw[3] indicate that it is the ferric ions on the octahedral sites of the YIG lattice which make the dominant contribution. Krinchik and Tjutneva[4] have shown anomalies in the near-infrared rotation in certain of the rare-earth iron garnets which they ascribe to electronic transitions of the individual rare-earth ions involved. At the same time available infrared data[5] suggest an essentially wavelength-independent contribution to the rotation which has been attributed to the ferrimagnetic resonance absorption. It is the purpose of this Letter to present measurements showing the anamalous variation with temperature of the Faraday effect in GdIG in the near-infrared and to discuss the interpretation of these results in terms of the interplay of these two different mechanisms of rotation.

The GdIG sample employed was a polished single-crystal plate with a thickness d of 0.79 mm. The infrared radiation from a Perkin-Elmer 120 single-beam spectrometer with a bandwidth of 0.2 μ was polarized by a germanium plate polarizer. The polarized radiation entered an axial hole in an electromagnet, passed through the GdIG plate magnetized perpendicular to its surface, and then through a germanium plate analyzer to the detector. The electromagnet is capable of generating fields up to 4000 Oe, sufficient to saturate the GdIG specimen except in the immediate vicinity of its compensation temperature. To obtain measurements at various temperatures, the garnet was placed in a cryostat cooled by a temperature-regulated nitrogen gas flow to ±0.25°C. The analyzer was oriented at 45° to the polarizer to give a maximum variation of the transmitted light intensity as the plane of polarization is rotated by the sample. The rotation angle θ_F is given by

$$\theta_F = \frac{1}{2}(I_+ - I_-)/(I_+ + I_-) \qquad (1)$$

where I_+ and I_- are the intensities at the detector with a saturating magnetic field in the positive and negative directions respectively.

Figure 1 shows the measured Faraday rotation per unit length, θ_F/d, in GdIG as a function of temperature from −140 to 40°C at wavelengths of 2.05 and 2.60 μ. Two reversals are noted in the sense of the rotation at each wavelength. The higher temperature reversal in each case occurs at the magnetic compensation temperature (20°C in this specimen)[6] where the resultant magnetic moment of the material vanishes. Our measurement method fails in the immediate vicinity of the compensation temperature since it depends on the ability to reverse the magnetization with an applied field. The Faraday rotation at this temperature is obtained from the dashed extrapolations shown in Fig. 1. Since the rotation associated with the ferrimagnetic absorption may be expected in GdIG to vary as the total magnetization and hence to vanish at the compensation point, the observed rotation there is due entirely to electronic transitions occurring at shorter wavelengths. The reversal in the sense of the rotation is a discontinuous one due to the reorientation of the entire magnetic structure relative to the external field on passing through this temperature. This is entirely analogous to the reversal in sense of Faraday rotation in $Y_3Fe_{5-x}Ga_xO_{12}$ observed by Matthews et al.[3] as the gallium content is increased through the value required to give magnetic compensation in this system. It will be noted that above the compensation point

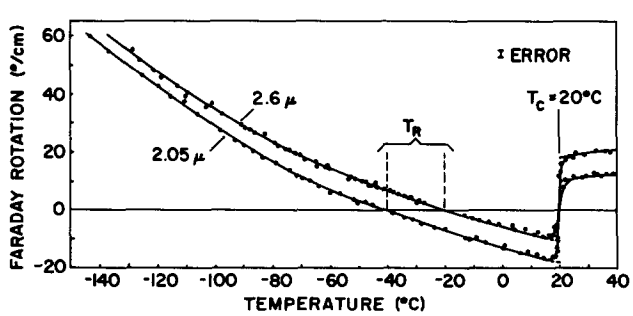

Fig. 1. Faraday rotation of GdIG—the sense of the rotation when viewed in the same direction as the applied field is positive when the rotation is clockwise.

where the total magnetization is in the same direction as the magnetization of the tetrahedral iron sublattice, the rotation in GdIG is positive; below the compensation point, where the total magnetization is opposite in direction to that of this sublattice, the rotation is negative. This is in accord with the previous observations on the yttrium iron–yttrium gallium garnet system.[3]

On either side of the compensation temperature, the magnetization of the material reappears giving rise to a contribution to the rotation from the ferrimagnetic resonance. The results of Fig. 1 show this contribution to be positive, as expected from its origin, and hence to add on to the electronic portion of the rotation above and to subtract from it below the compensation point. As the magnetization and hence also the ferrimagnetic resonance contribution to the rotation increase to large values below the compensation point, another reversal in the sign of rotation occurs at a temperature T_R; at this temperature the opposing contributions to the rotation just cancel each other, while below this point the contribution associated with ferrimagnetic resonance dominates. T_R decreases with decreasing wavelength because of the increase in the electronic contribution to the rotation at shorter wavelengths. At a sufficiently short wavelength, it presumably reaches 0°K; at still shorter wavelengths, the electronic contribution dominates at all temperatures below the compensation point so that no low-temperature reversal occurs. At longer wavelengths, T_R may be expected to increase until, as the electronic effect becomes negligible, it reaches the compensation temperature. At this point the rotation-temperature curve may be expected to parallel the magnetization-temperature curve.

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[5] G. S. Krinchik and M. V. Chetkin, *Soviet Phys. JEPT* **14,** 485 (1962).

[6] The fact that the compensation point of our sample was somewhat higher than some of the previously reported values[1] is probably due to small amounts of impurities in the octahedral sites.