Final Report on NASA Research Grant NGR-22-009-182
Massachusetts Institute of Technology

Title: Spectrum and Polarization of Laser Light Scattered by Solids

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Objective:

To measure the frequency shift and linewidth of light scattered by thermally excited magnons and phonons in YIG. - thereby determining the magnon and phonon dispersion curves and lifetimes. Also to measure Faraday rotation in $CrBr_3$ near the critical temperature in order to measure the temperature dependence of the conceptibility and field dependence of the magnetization.

Status

1. Scattering of Laser Light from Yttrium Iron Garnet

We have constructed and put into operation a high-resolution Fabry-Perot interferometer, a cooled housing for a near infrared photomultiplier tube, and have assembled a pulse height discrimination system. This system enables us to detect photocurrents as low as one electron per second. We have used it in conjunction with a Nd^{3+}: YAG laser at 1.06μ to detect the light scattered by thermal sound waves in water and KCl. The light scattered by magnetoelastic waves in YIG will be only slightly less intense, but we have been unable to detect it in our present samples because of the very intense scattering from imperfections. We have also experienced difficulty obtaining sufficient single frequency power from our laser. With improved laser power and better samples we shall search for light scattered by magnetoelastic waves, phonons, and magnons in YIG.

2. Faraday Rotation in $CrBr_3$

We have a dewar and temperature control system operating from $4.2^{\circ}K$ to room temperature, and an optical system that enables us to measure the plane of polarization to about 0.003 degrees. Using this system and a pair of Helmholtz coils to provide small magnetic fields, we have observed the susceptibility diverge by a factor greater than 30 and follow the power law

$$\chi = D(T/Tc - 1)^{-\gamma}$$

with γ = 1-21 over the temperature range

$$0.10 < \frac{T-Tc}{Tc} < 0.15$$

We have found it necessary to improve our temperature control to extend our measurements closer to Tc. In addition, we are adjusting an existing 12 inch Harvey Wells electromagnet to this experiment in order to be able to use a much wider range of magnetic fields. When these modifications are complete we shall continue to study the detailed behavior of $CrBr_3$ near Tc.

Summary and Conclusions

Our experiments with light scattering in YIG have proved to be more difficult than we had anticipated, and illustrates that light scattering experiments with infrared light are much more difficult than with visible light. This is due primarily to the reduced scattering cross section (which varies inversely as the fourth power of the wavelength) and the lack of sensitivity of infrared detectors. We believe the experiment to scatter light from magnetoelastic waves is feasible, and shall continue our efforts as time and money permit.

We are very pleased with our results obtained so far with $CrBr_3$. They have shown that Faraday rotation is a useful and sensitive means to study the properties of magnetic systems near the critical point. We plan to extend our studies to include other magnetic systems. Experiments to study Faraday rotation in YIG near the critical point are under way; and we intend also to study EuS; EnO, and $RbNiF_3$ by this method.

We also believe that the Faraday effect in these materials has important practical applications to measure magnetic fields and to modulate laser beams. We have written a proposal seeking NASA support to investigate such potential applications and it is our hope that NASA will act faborably on this proposal.