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LIGHT SCATTERING FROM SPINWAVES AND MAGNETOOPTIC HYSTERESIS MEASUREMENTS ON EuO AND EuS.

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Résumé.- La diffusion lumineuse par des ondes de spin de volume et de surface constatée antérieurement sur EuO /4/ a été observée également sur des monocristaux et sur de minces films évaporés de EuS. On montera qu'au cas où les essais seront effectués sur des échantillons clivés, les écarts entre les fréquences d'ondes de spin observées et les valeurs théoriques sont dus à des champs de désaimantation qui peuvent être démontrés à l'aide des mesures d'hystérésis magnéto-optiques. Dans le cas de films minces, les ondes de spin de volume disparaissent avec la réduction en épaisseur de la couche. En même temps, les ondes de surface deviennent plus prononcées et montrent un comportement de polarisation anormal.

Abstract.- Light scattering from bulk and surface spinwaves previously reported for EuO /4/ has now also been observed on single crystals and thin evaporated films of EuS. It can be shown that in the case that the experiments are performed on cleaved samples, deviations in the observed spinwave frequencies from their theoretical values are partly due to demagnetizing fields. These can be tested by magnetooptic hysteresis measurements. In the case of thin films with decreasing film thickness volume spin waves disappear. At the same time surface waves become more pronounced and show anomalous polarization properties.

Lightscattering from acoustic type spinwaves /2/ is a relatively new tool to obtain information on important magnetic parameters from suitable systems. For example it has recently been demonstrated that the method is capable to yield information on saturation magnetization $J_0$ and g-factor in the case of metallic glasses /1/ and the exchange constant in the case of Yttrium Iron Garnet (YIG) /2/ and films of substituted YIG /3/ used in bubble device technology. In the case of magnetic semiconductors however it was found that for the frequencies of bulk and surface spinwaves there were large deviations between the experimental and the theoretical values /4/. It has been argued that surface effects could be responsible of this. We have now performed a detailed and systematic investigation of this point and extended the previous investigations on EuO also to single crystals and thin evaporated films of EuS. All the experiments were supplemented by magnetooptic hysteresis measurements by using the information contained in the polarization state of the laser light reflected from the sample surface. In this experiment the reflected laser light for an applied in plane field $B_0$ where the sample saturates in that direction (0.2 T) is brought to extinction by properly setting an analyzer and a $\lambda/4$ plate. $B_0$ then is swept until the sample saturates in the opposite direction and back and the light intensity $I$ observed. The $I$ versus $B_0$ plots display the usual hysteresis curves which in the present case however were governed almost entirely by the high demagnetizing fields. Thus the demagnetizing field can this way be determined from the same spot on the sample from which also the spinwave frequencies are measured via the light scattering experiment. Particular effort was also made to obtain as small demagnetizing fields as possible. For nonellipsoidal samples this is important because only then can the sample be approximated by an ellipsoid. Simply by cleaving we were not able to obtain demagnetizing factors $N$ below 0.04 /5/. In the present case the samples on one side were carefully ground to a thickness of ~ 100 µm which yielded $N < 0.02$. In figure 1 are displayed the spinwave frequencies versus external field $B_0$. The saturation magnetization of EuO is 2.4 T but at the temperature of 32 K where the experiments were performed it is somewhat reduced to a value of $J = 2.16$ T. The demagnetizing factor $K = 0.015$ was deter-
mined from the field where the magnetooptic signal as described above saturates. These values have been inserted into the formula for the frequency $v_B$ of the volume spinwave

$$v_B = \frac{1}{2\pi} \left[ B_1 (B_1 + J) \right]^{1/2}$$

(1)

and $v_s$ for the surface spinwave

$$v_s = \frac{1}{2\pi} (B_1 + J/2)$$

(2)

where $\frac{1}{2\pi} = 0.28 \times 10^{-11}$ $\text{T}^{-1}\text{s}^{-1}$ and $B_1 = B_0 - NJ$.

An ideal case to investigate this point would be thin films of EuS. Here the inplane demagnetizing field is essentially zero and the surface roughness can be kept at a minimum. Unfortunately in this case stoichiometry is still a problem and the values for $J$ are too uncertain to make such an analysis meaningful. A characterization of the samples by means of FMR to yield values for $J$ would be desirable.

Let us now turn to some observations on EuS films which are more of a qualitative nature. Spectra of films with thickness $d = 90$ nm and $d = 60$ nm are displayed in figure 2.

Equations (1) and (2) are in figure 1 represented by the full lines. The experimental points are average values from different experiments, the error bars indicate the scattering when different spots on the sample surface are chosen. Thus the following statement can be made. The observed volume spinwave frequencies are within the experimental error in agreement with eq. (1) the surface wave frequencies are too low as compared to eq. (2). Essentially the same result has also been found for bulk samples of EuS. At present we cannot say if this means that the theory of Damon and Eshbach is not adequate in the present situation or if there are still experimental shortcomings like for example the surface roughness of the samples.

Essentially the same result has also been found for bulk samples of EuS.

Let us now turn to some observations on EuS films which are more of a qualitative nature. Spectra of films with thickness $d = 90$ nm and $d = 60$ nm are displayed in figure 2.

For $d = 90$ nm a volume wave with $v_B = 15$ GHz is observed. There is only a faint indication of the surface wave at $v_s = 22$ GHz. For $d = 60$ nm the surface wave is clearly visible while the bulk wave has decreased its intensity. The effect of a reversal of the magnetic field is quite surprising. In one case both waves are only observed on the Stokes (S) side (neg. frequency shift) in the other with approximately equal inten-
sities on the S and the Antistokes (AS) side. This means /4/ that they both show nonreciprocal behaviour but also the anomaly due to the magnetooptic effects /9,2/. The latter is further confirmed by rotating both the polarization of the incident light and the analyzer direction for the polarization of the scattered light by 90°. For $B_0$ down both waves then are only observed AS. For the volume wave in thick samples nonreciprocal behaviour is not possible from symmetry considerations. Also the magnetooptic anomaly of the surface wave has never been found in bulk samples of neither EuO nor EuS. The experiment thus indicates a mixing of bulk and surface mode character for both waves in thin films.

To conclude it has been shown that the frequencies of surface spinwaves in bulk samples of the magnetic semiconductors EuO and EuS are not adequately being described by the Damon Eshbach theory /7/. At present it is not known if this is due to the surface roughness of these samples. For thin films of EuS mixing of bulk and surface type character has been found.

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References

/8/ Köhne, J., Mair, G., Rasula, N., Saftic, B., Zinn, W., at this conference.