Anomalous diffraction of light by spin waves

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We have observed experimentally an "anomalous" diffraction of light by waves in a ferromagnetic crystal. This diffraction exists in a wide range of angles between the diffraction maxima *corresponding to magnetostatic and magnetoelastic waves.*

Diffraction of light by magnetostatic waves (MSW) and magnetoelastic waves (MEW) in ferromagnetic crystals was observed earlier.[1–4] Magnetostatic waves correspond to diffraction angles $\theta=\theta_{MSW}=2\sin^{-1}(\lambda_L/2\lambda_{MSW}) \lesssim 0.5-1°$, and magnetoelastic waves correspond to angles $\theta=\theta_{MEW}=2\sin^{-1}(\lambda_L/2\lambda_{MEW}) \sim 20-23°$ (in the given experiment), where λ_L is the wavelength of the light, and λ_{MSW} and λ_{MEW} are the lengths of the magnetostatic

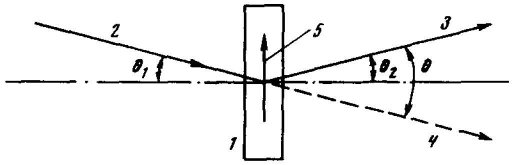

FIG. 1. Geometry of experiment: 1-ferrite sample; 2, 3, 4-incident, diffracted, and transmitted light beams, respectively; 5-spin wave.

and magnetoelastic waves, respectively (see Fig. 1). We report here experiments in which in addition to the known diffraction regimes, we observe for the first time an "anomalous" diffraction (AD), which takes place in a wide range of angles θ, starting from θ_{MSW} to θ_{MEW}, with gradual decrease of the diffraction intensity with increasing angle.

The experiments were performed with longitudinal-magnetized single-crystal prisms of yttrium iron garnet. We used two samples: sample 1 with dimensions $10.7\times3.0\times2.9$ mm and with edges directed along axis of the [100] type, and sample 2 with dimensions $5.5\times2.8\times2.7$ mm, the edge orientations of which differed from all the principal crystallographic directions. The prism was mounted together with the magnet on a rotating stage, the rotation of which during the plotting of the angular-distribution curves of the diffracted radiation was coupled to the rotation of the photoreceiver in such a way that the condition $\theta_1=\theta_2$ was always satisfied for waves having the corresponding wave number and traveling along the prism. The spin waves were excited at 1200 MHz by means of a straight wire antenna at the edge of the prism. A "meander" type modulation of the microwave power was used, with the maximum pulse power reaching 1 W.

Light from the laser ($\lambda_L=1.15\ \mu$), after passing through the polarizer plate and the focusing lens ($f\approx 80$ cm) was incident on the center of the sample and wave diffracted by the waves in the crystal. The diffracted light passed through an analyzer, a lens, and a slit and was registered with a photoreceiver. A narrow-band amplifier and a synchronous detector were used to increase the sensitivity.

We investigated in the experiment the dependence of the intensity of the diffracted radiation on the diffraction angle θ. Figure 2 shows plots of the relative level of the diffracted radiation against the diffraction angle, and the insert of Fig. 2a shows the section of the same curve for small values of the diffracted angle, obtained at increased angular resolution of the system.[1)]

Three regions can be distinguished on the curves of Fig. 2: a) a maximum at small angles $|\theta|\lesssim 1°$, corresponding to diffraction by the MSW; b) maxima at angles $|\theta|\sim 20-23°$, corresponding to diffraction by the transverse MEW; c) a large AD maximum with center at small angles, serving as a sort of "pedestal" for the MSW maximum. Diffraction in this angle interval was never reported before. We note that the angle width of the AD maximum in the direction perpendicular to the plane of incidence was small and did not exceed

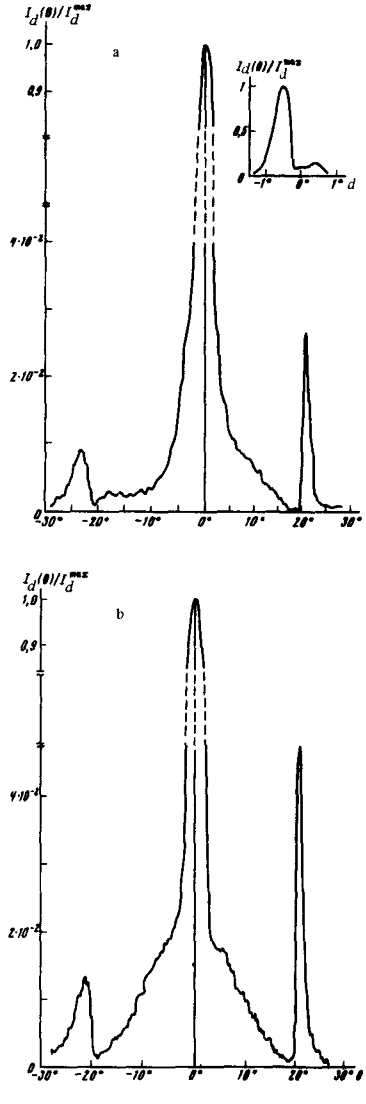

FIG. 2. Intensity of the diffracted radiation $I_d(\theta)/I_d^{max}$ vs. the diffraction angle ($I_d^{max}\approx 10^{-6}$ W at a laser power 10 mW). The incident light was polarized perpendicular to the diffraction plane. $P_{microwave}\approx 1$ W: a) curve for sample 1, $H=590$ Oe; b) curve for sample 2, $H=580$ Oe.

resolution of the apparatus (~1°). The intensity of the diffracted radiation in the AD regime was synchronously modulated with the modulation of the microwave power, so that the observed scattering could not be produced by inhomogeneities.

The following was observed in the investigation of the AD: 1) The AD is observed in approximately the same field interval as diffraction by MSW,[4] but when the field is lowered below the cutoff value the intensity of the diffracted radiation decreases much more rapidly than for MSW.

2) The dependence of the orientation of the major axis of the polarization ellipse of the diffracted radiation on the orientation of the polarization plane of the incident radiation differs from the analogous dependence for MSW. Figure 3 shows both curves. We see that the curve for the AD oscillates about the bisector of the

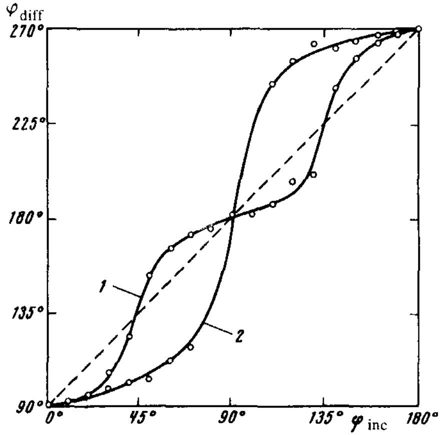

FIG. 3. Polarization characteristics of diffracted radiation for sample 1: $H = 590$ Oe, $P_{microwave} \approx 1$ W: 1) anomalous diffraction, 2) diffraction by MSW.

coordinate angle at twice the frequency and at a smaller amplitude than the curve for the diffraction by MSW. In addition, a calculation carried out for the case of diffraction by spin, elastic, and magnetoelastic waves shows that the polarization characteristics for the indicated types of diffraction differ from the experimentally obtained relations for AD.

3) The AD intensity depends on the microwave power nonlinearly and has a tendency to saturate. This gives grounds for assuming the existence of a connection between the AD and the nonlinear processes in the ferrite (for example, parametric excitation of spin waves).

We note in conclusion that the presently available information does not permit a final conclusion concerning the nature of anomalous diffraction, and further research is necessary.

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[1)]This has made it possible to resolve the positive and negative first orders of the diffraction by MSW, which were not resolved on the principal curves of Fig. 2.

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