Diffraction of laser radiation by spin waves in yttrium iron garnet

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We report the results of an experimental investigation of the diffraction of laser radiation ($\lambda = 1.15\ \mu$) by parametrically excited spin waves in an yttrium iron garnet under conditions of additional absorption.

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Experiment on the diffraction of a laser beam by magnetostatic, spin, and magnetoelastic waves were reported earlier.[1-6] In these experiments, the excitation was with an alternating magnetic field[1,2,5] or else with a piezoconverter with shear[4] or longitudinal[3,6] oscillation modes. However, one common singularity of these experiments was that the excitation of the spin waves was produced in the linear regime, when the signal frequency was close to the frequency of the ferromagnetic resonance for the given magnetic field.

We report here diffraction of a laser beam by param-

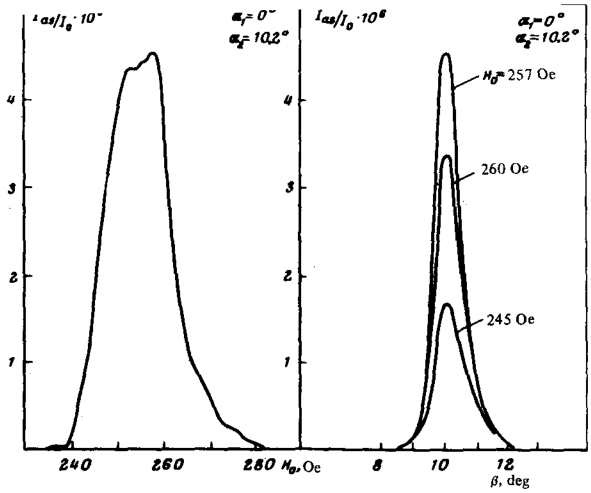

FIG. 1.

etrically excited spin waves in the region of magnetic fields corresponding to the additional absorption.[7] These experiments have made it possible for the first time to determine the absolute values and directions (θ_k) of the wave vectors $\mathbf{k}_s$ of the spin waves parametrically cited following additional absorption in an inhomogeneous magnetic field.

In an yttrium iron garnet sample measuring $3\times3\times10$ mm, placed in a longitudinal magnetic field, the spin wave were excited by an alternating magnetic field produced by the open end of a coaxial cable at the end face of the crystal (with a certain degree of approximation, the alternating magnetic field can be regarded as transverse). The frequency ν_0 of the alternating signal ranged from 0.6 to 2 GHz, and its power was $P\approx 1.5$ W.

The laser beam passed through a crystal at a distance 2.5 mm from its edge. The polarization of the laser radiation was orthogonal to the magnetic field and to the analyzer transmission plane. The scattered radiation was registered with a liquid-nitrogen-cooled photomultiplier (FÉU-62), the signal from which, was fed through

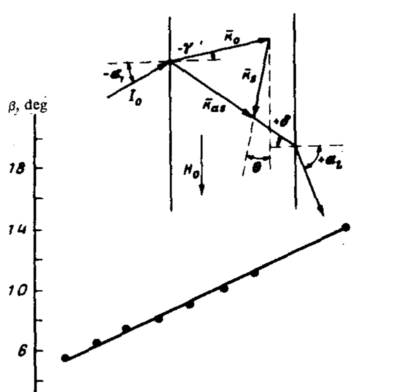

FIG. 2.

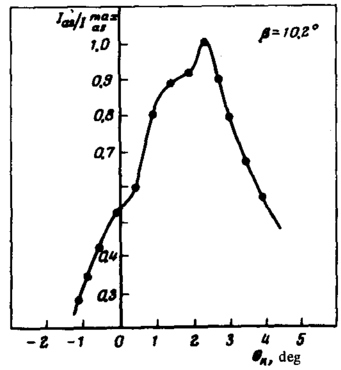

FIG. 3.

an amplifier and a synchronous detector to an automatic recorder.

At an external magnetic field $H_0 < H_{0\,res}$ ($H_{0\,res}\approx 480$ Oe for our sample and the probing point), which corresponds to the condition of additional absorption and excitation of spin waves with $\omega_k = \omega_0/2$, we have observed laser-radiation diffraction, corresponding to spin waves with $|\mathbf{k}_s| \sim 10^{-4}$ cm^{-1}.

The results of the experimental investigations of the intensity of the anti-Stokes component for the frequency $\nu_0 = 1.1$ GHz as a function of the magnetic field are shown in Fig. 1, where β is the angle between the incident and diffracted light fluxes (a_1 and a_2 could be varied independently in the experiment). It follows therefore that spin waves with a constant wave vector $|\mathbf{k}_s| = 9.6\times10^3$ cm^{-1} are excited in the entire additional-absorption region where diffraction is observed ($H_0 = 240$–280 Oe).

With changing microwave-signal frequency and with the corresponding change of the constant magnetic field, a change takes place in the wave vector of the excited spin waves and in the angle θ_k (Fig. 2), namely,

$$k_s = 2k_0 \sin\frac{\delta-\gamma}{2}; \qquad \theta_k = \frac{\delta+\gamma}{2}$$

where k_0 is the wave vector of the light wave, and the + and − signs of δ and γ represent clockwise and counterclockwise directions from the normal to the boundary. These results indicate unequivocally that the most effective is parametric excitation of the spin waves in the vicinity of the intersection of the spin-wave spectra and the transverse elastic oscillations. Investigations of the polarization characteristics of the incident and diffracted radiation[5] have shown that the diffraction is from the spin wave. At a constant magnetic field $H_0 = 255$ Oe, which corresponds to the maximum amplitude of the excited spin waves at $\nu_0 = 1.1$ GHz, the dependence of the intensity of the diffracted radiation, both the Stokes and anti-Stokes components, on the angle θ_k is shown in Fig. 3. It follows from these results that the spin waves most effectively excited are those with $\theta_k = 2°20'$, and the width of the angle spectrum, determined from half the intensity of the diffracted radiation, is $\Delta\theta_k \sim 4°$. The wave vector in the entire angular spectrum remains likewise unchanged at $|\mathbf{k}_s| = 9.6\times10^3$ cm^{-1}.

Our experimental investigations have provided, for the first time, an unequivocal answer to the question of the character of the excited spin waves under conditions of additional absorption and an inhomogeneous internal magnetic field.

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