SPIN MANDEL'SHTAM-BRILLOUIN EFFECT

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Submitted 20 January 1971
ZhETF Pis. Red. 13, No. 5, 229 - 232 (5 March 1971)

The scattering of spin waves by crystal-lattice vibrations, the so-called "spin Mandel'shtam-Brillouin effect," was predicted and calculated theoretically in [1, 2]. A direct observation of this effect by the known methods [3] is made difficult by the weak coupling between the electromagnetic and the spin waves. This difficulty can be partly circumvented by using a pulsed observation method similar to that used in the investigation of ferrite delay lines (FDL) [4]. In this method the spin Mandel'shtam-Brillouin effect is revealed by the delay of the initial radio pulse, and the intensity of the effect is independent of the distribution of the internal constant field in the sample (unlike the effect employed in FDL, where the electromagnetic waves are converted into spin waves by the field inhomogeneities [5]). The purpose of the present investigation was to observe the spin Mandel'shtam-Brillouin effect by the indicated method.

The measurements were performed by a procedure similar to that described in [4] at ~1200 MHz. A sample of yttrium iron garnet (YIG) with $\Delta H \sim 1$ Oe was prepared in the form of a rectangular parallelepiped measuring 5.4 × 2.5 × 2.5 mm. The larger dimension of the sample coincided with the crystal [100] axis. Elastic vibrations of ~10 MHz frequency were excited in the sample with the aid of an X-cut quartz plate glued to the end face of the sample. The electric power of the excitation source did not exceed 1 - 2 W. At high power, the sample was noticeably heated. The distribution of the magnetic field in the sample was varied by moving polycrystalline YIG rods (coaxial with the sample) measuring 10.0 × 2.5 × 2.5 mm to and from the sample end faces (at a distance L) in a manner similar to that used in [6]. During the course of experiments we observed for the first time the spin Mandel'shtam-Brillouin effect of both the first-order (single conversion with an upward frequency shift of 10 MHz) and the second-order (double conversion to the initial frequency)[2]. Oscillograms of the delayed pulses are shown in Fig. 1. The first-order effect gives a somewhat smaller delay time (by 1 - 2 μsec), and a somewhat larger amplitude (by ~5 dB) than the second-order effect. The intensities of the first- and second-order effects depend only linearly on the intensity of the elastic vibrations in the sample (in the indicated power range). The minimum insertion loss for the first-order effects was 35 dB, and that of the second order was 40 dB. The insertion loss for conversion in an inhomogeneous field (under the same conditions) was 20 dB. The first-order effect was observed at magnetizing fields from H_s - 20 Oe to H_s + 3 Oe, where H_s is the field at which the turning point is in the middle of the sample. The second-order effect was observed in fields from H_s - 1 Oe to H_s + 2 Oe (in somewhat weaker fields, the observation was hindered by conversion on the field inhomogeneities).

The delay time depended little on the magnetizing field and on the frequency of the elastic vibrations. When these parameters were varied considerably, the delay time changed by 1 - 2 μsec. Figure 2 shows a plot of the ratio of the intensities of the first-order spin Mandel'shtam-Brillouin effect and of the effect of conversion on the field inhomogeneities as a function of the symmetry of distribution of the internal magnetic field in the sample (to this end, a polycrystalline rod was brought closer to one of the end faces of the sample). At $L \to \infty$, the field is symmetrical (parabolic distribution with top at the center of the sample). At $L \to 0$, the field is asymmetrical (the top of the parabola is outside the sample). In the latter case the intensity of the pulse delayed by conversion on the field inhomogeneities, decreases by 50 - 70 dB, whereas the intensity of the pulse delayed by the first-order spin Mandel'shtam-Brillouin effect remains practically unchanged. The foregoing is

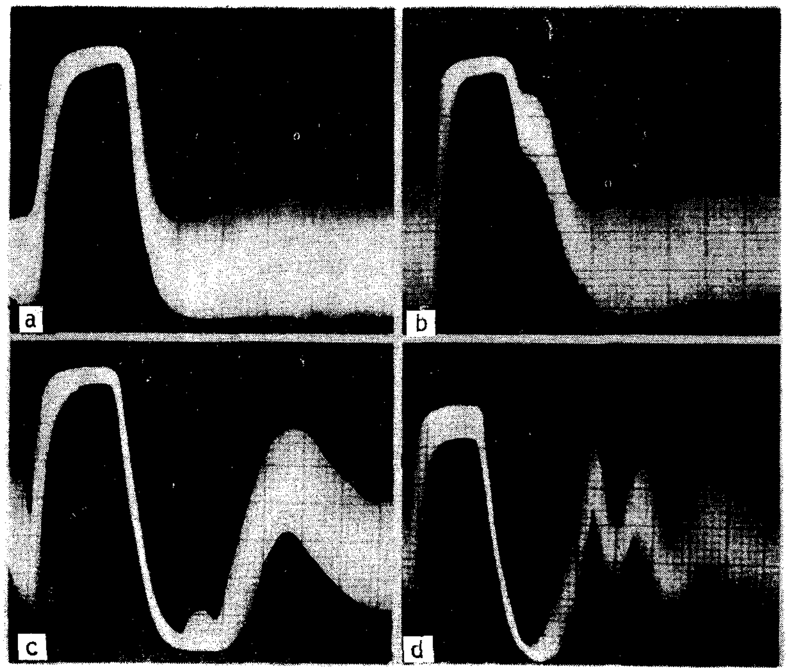

Fig. 1. Oscillograms of spin Mandel'shtam-Brillouin (MB) effect. One major division corresponds to 1 μsec. The sample is subjected to elastic vibrations of frequency $F = 10$ MHz and a radio pulse of frequency $f_0 = 1200$ MHz. a - Pulse at frequency $f = f_0 + F = 1210$ MHz at a field $H_s - 50$ Oe; it is observed because of the spatially-homogeneous modulation of the magnetic field, there is no delay; b - pulse at $f = f_0 + F = 1210$ MHz at a field $H_s + 2$ Oe; in addition to the pulse shown in (a), we see here an additional pulse delayed by about 1 μsec, due to the spatially-inhomogeneous field modulation (first-order MB effect); c - pulses at $f = 1200$ MHz at a field $H_s + 2$ Oe; on the left side there is the attenuated input pulse, and on the right the pulse is delayed as a result of the second-order effect; d - pulses at $f = 1200$ MHz at a field $H_s - 1$ Oe; in this field we see, in addition to the second-order MB effect (central double pulse), also the effect of conversion on the field inhomogeneities (extreme right pulse). H_s is the field at which the turning point is in the middle of the sample.

manifested by a sharp rise of the curve at $L \to 0$. A similar result is obtained when the homogeneity of the field is varied but the symmetry is maintained (by bringing polycrystalline rods closer to both ends of the sample). The intensity of the effect of conversion by the field inhomogeneities decreases in this case by ~20 dB from its initial value, while the intensity of the spin Mandel'shtam-Brillouin effect remains unchanged, thus confirming the nature of the latter.

The authors are grateful to V.V. Lemanov and co-workers for advice on the excitation of elastic vibrations, and to V.B. Kravchenko and I.G. Avaeva for supplying the samples of yttrium iron garnet.

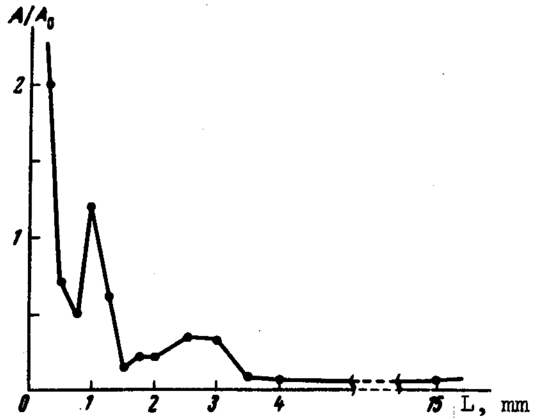

Fig. 2. Ratio of the intensity A of the first-order spin Mandel'shtam-Brillouin effect to the intensity A_0 of the conversion on the field inhomogeneities, as a function of the symmetry of the internal field in the sample. L - distance between the nearest faces of the investigated sample and the polycrystalline rod.

[1] Ya.A. Monosov, Author's certificate (Patent), 1968, Class 21a^4, gr. 73, No. 219642.
[2] N.N. Kiryukhin and F.V. Lisovskii, Fiz. Tverd. Tela 10, 709 (1968) [Sov. Phys.-Solid State 10, 556 (1968)].
[3] N. Bloembergen, Nonlinear Optics, Benjamin, 1963.
[4] Schloman, Joseph, and Cohane, Proc. IEEE (Russ. transl.) 53, No. 10, 1685 (1965).
[5] E. Schlomann, J. Appl. Phys. 35, 1, 159 (1964).
[6] A.G. Gurevich, B.M. Lebed', S.A. Mironov, S.S. Starobinets, and K.V. Shevlyagin, Fiz. Tverd. Tela 8, 2958 (1966) [Sov. Phys.-Solid State 8, 2362 (1967)].

EXPERIMENTAL INVESTIGATION OF THE DIFFERENTIAL CROSS SECTION OF ELASTIC SCATTERING OF EXCITED ATOMS BY ELECTRONS OF A GAS-DISCHARGE PLASMA

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Submitted 19 January 1971
ZhETF Pis. Red. 13, No. 5, 232 - 235 (5 March 1971)

The investigation referred to in the title was performed in the following manner: Radiation from a single-mode helium-neon laser ($\lambda = 6328$ Å) was absorbed in a gas-discharge tube with neon (solid arrow in Fig. 1) and produced a "Bennett peak" in the distribution of the atoms Ne($3s_2$) (i.e., Ne atoms at the $3s_2$ level) with respect to the velocity v. When Ne($3s_2$) collides with the plasma electrons, Ne(j) atoms at the level j are produced (dashed arrow in Fig. 1), having a different distribution with respect to v. Modulation of the laser light makes this fraction of the atoms at j alternating and facilitates its measurement by determining the emission in the $j \to i$ transitions (wavy arrow of Fig. 1). The line contour[1)] of the modulated $j \to i$ radiation is given by

[1)]Our experiment is analogous to that of [1], except that we measured the line contour, whereas the integrated line intensity was measured in [1].