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ACOUSTIC BIREFRINGENCE IN ANTIFERROMAGNETIC $MnCO_3$

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An oscillatory dependence on the magnetic field was observed in the intensity of transverse hypersound passing through an antiferromagnetic $MnCO_3$ crystal.

Below 32°K, $MnCO_3$ is an antiferromagnet with weak ferromagnetism. The spins lie in the basal plane perpendicular to the threefold axis. As a result of the interaction of the low-frequency oscillations of the electronic antiferromagnetic system with the nuclear magnetic system, the two branches of the electron-nuclear resonance, which were investigated in [1, 2], are observed.

The presence of low-frequency electron-nuclear branches with a strong field dependence was reason for hoping to observe the influence of a magnetic field on the passage of sound at frequencies 100 MHz and higher. We investigated the passage of transverse hypersound of frequency 104 and 204 MHz through single-crystal $MnCO_3$. The samples were plates (1 - 10 mm^3) whose plane coincided with the basal plane. The $MnCO_3$ crystals were grown by N. Yu. Ikornikova at the USSR Academy Crystallography Institute by a hydrothermal method.[1)]

The sound propagated in the sample along the threefold axis. The sound was generated and received by U-cut quartz plates with natural frequency 5 MHz. A continuous procedure was used. An aluminum foil 15 microns thick was used to screen against direct passage of the electromagnetic wave.

When an external magnetic field is applied in the basal plane, oscillations are observed in the intensity of the transmitted hypersound as a function of the magnetic field (Fig. 1). The period of the oscillations increased very rapidly with the field and the sound intensity is practically independent of the field in fields stronger than 4 kOe. When the magnetic field is inclined to the basal plane, the curve stretch into the region of strong fields and coincide with one another if the abscissas represent the field projection on the basal plane. Similar oscillations were observed in [3] following the passage of hypersound through iron garnets.

This phenomenon is attributed to the presence in the garnets of acoustic birefringence

Fig. 1

1)I am grateful to N. Yu. Ikornikova for kindly supplying the crystals.

that depends on the magnitude of the magnetic field when the sound propagates perpendicularly to the direction of the magnetic field. The presence of birefringence leads to rotation of the plane of sound polarization; this rotation is manifest in the oscillation of the intensity of the received sound.

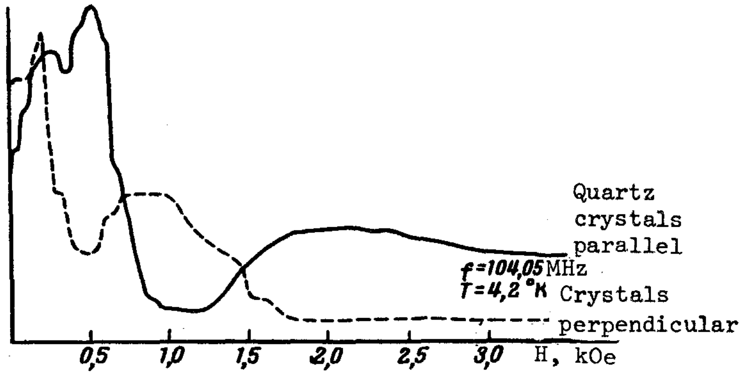

Fig. 2

To verify that rotation of the polarization plane was observed also in our experiments, a control experiment was performed, in which the polarization of the receiving quartz was rotated 90° relative to the polarization of the transmitting quartz (they were parallel in the preceding experiments). The results of the experiment are shown in Fig. 2. They confirm the assumption made, since the positions of the maxima and minima are interchanged.

The observed birefringence in $MnCO_3$, as in the case of ferrites, is connected with the fact that the interaction of the transverse acoustic waves depends strongly on the direction of their polarization relative to the direction of the antiferromagnetic sublattices. The resultant difference in the sound velocities depends on the magnetic field, since the frequency of the magnetic branches of the crystal spectrum, which interact with the sound, increases with increasing magnetic field. A peculiarity of the crystal under consideration is the fact that it contains both electron spin and nuclear spin waves. For a quantitative interpretation of the observed phenomenon it is therefore necessary to investigate theoretically the triply-connected electron-nuclear-acoustic system, something not performed as yet. However, certain qualitative features can be indicated even now. When the magnetic field is inclined to the basal plane, the dependence of the frequency of the electron-nuclear branches on the field decreases, and the dependence of the frequency on the field becomes the same for different angles, if one plots in terms of the projection of the magnetic field on the basal plane, just as in our case. The presence of a large line width of the electron-nuclear branch several hundred Oe) does not make it possible to obtain a distinct picture in weak fields, where the largest changes of the speed of sound and of the rotation of the plane of polarization should take place.

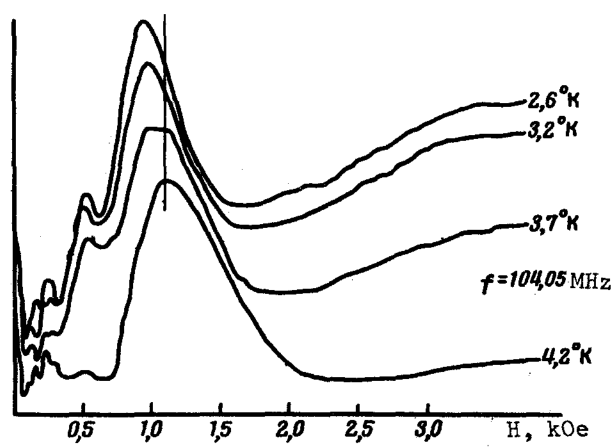

Fig. 3

At lower temperatures the curves are compressed towards smaller fields (Fig. 3), corresponding to an increase of the spin-wave frequency. The increase of frequency with decreasing temperature occurs for the upper branch of the electron-nuclear resonance. In the paramagnetic region (above 32°K) the dependence of the hypersound intensity on the magnetic field disappears.

In conclusion, I am grateful to P. L. Kapitza for interest in the work and to A. S. Borovik-Romanov for valuable hints.

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INJECTION SEMICONDUCTOR LASER WITH COMPOUND RESONATOR

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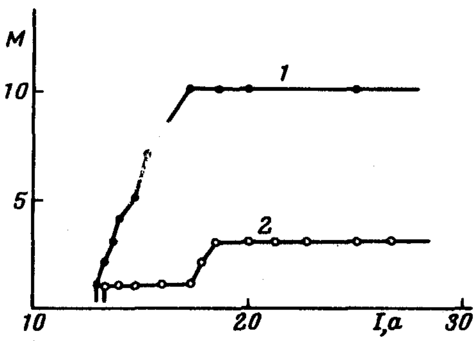
In injection semiconductor lasers (SL) the number of spectral modes excited is usually quite large, leading to an appreciable broadening of the generation band. To improve the spectral characteristics of SL, it is possible to use an interference effect in a resonator having more than two mirrors [1]. A system of parallel aperiodically arranged mirrors can be used to select individual axial modes [2], a fact already observed in SL with electron excitation [3]. In the present investigation we used for injection SL a system (compound resonator) comprising a semiconducting diode with parallel faces and a transparent dielectric plane-parallel plate in optical contact with the face of the diode. Observations of the generation spectra of SL based on GaAs and on GaP_xAs_{1-x} with an ordinary Fabry-Perot resonator and with a compound resonator (77°K) yielded the following results:

1. In the compound resonator, the excitation thresholds of the oscillation modes following the first modes are greatly increased, as shown by the example illustrated in the figure. The output power in the single-mode regime was in this experiment about 0.5 W (at a wavelength λ = 7401.5 Å).

2. The generation bandwidth, at a considerable excess above threshold (50 times in one experiment), remains within 4 - 8 Å in the compound resonator, whereas in an ordinary resonator it is 3 - 5 times larger. The obtained CW output power is 90 mW in a 4 Å band (GaAs, current 1 A).



Number of excited modes M vs. current in an injection SL based on GaP_xAs_{1-x} (λ ≈ 7400 Å) with an ordinary resonator and with a compound resonator (1 and 2, respectively). The diode resonator length is 525 μ, the supplementary plate is of SiC and is 50 μ thick.