Observation of new Mandel'shtam-Brillouin components in the spectrum of light scattered by ZnO crystal with application of a constant electric field

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A new line is observed in the Mandel'shtam-Brillouin spectrum of a ZnO crystal when the constant electric field applied to the crystal exceeds a critical value.

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We studied the gain for hypersound as a function of frequency over a wide range of variation of the external electric field in single-crystal specimens of ZnO, in which we previously[1] studied the increase in intensity of the Mandel'shtam-Brillouin component (MBC) due to scattering of light by a transverse piezoactive wave.

During the course of this investigation, we observed the appearance of a new MBC, situated between the thermal MBC and the central or Rayleigh line in the spectrum of scattered light. The additional component appeared only when the intensity of the constant electric field applied to the specimen exceeded a critical value. The light corresponding to the newly observed spectral line is polarized as in the main MBC.

Two different specimens of single-crystal ZnO were studied and the new line was clearly observed in both cases. In the first specimen, the electron mobility $\mu = 100$ cm^2/V s, the electrical conductivity (average) $\sigma = 3.23 \times 10^8$ 1/s, and the dimensions were $8.6 \times 6.6 \times 4.7$ mm. In the second specimen, $\mu = 140$ cm^2/V s, $\sigma = 5 \times 10^8$ 1/s, and the dimensions were $9.25 \times 5.8 \times 4.3$ mm.

As an example, the trace of the molecular light scattering spectrum for a ZnO crystal is shown in Fig. 1; figure 2 shows the trace of the spectrum when an electric field E is applied to the crystal.

In the first specimen, the frequency shift of the new line ν_1 was of the order of 0.7 and in the second it was of the order of 0.45 of the frequency shift ν_0 of the spectral line due to scattering of light by the transverse piezoactive wave.

The dependence of $\ln(I_E/I_T)$ on the electric field intensity at a fixed point in the crystal is shown in Fig. 3. Here I_T is the intensity of light at the maximum of the MBC of the main curve (curve 1) and additional curve (curve 2) in the electric field. As follows from the figure, the intensity of the main line varies exponentially with the field, while the intensity of the new line for the same values of the electric field intensity first varies exponentially and then exhibits a tendency to saturate.

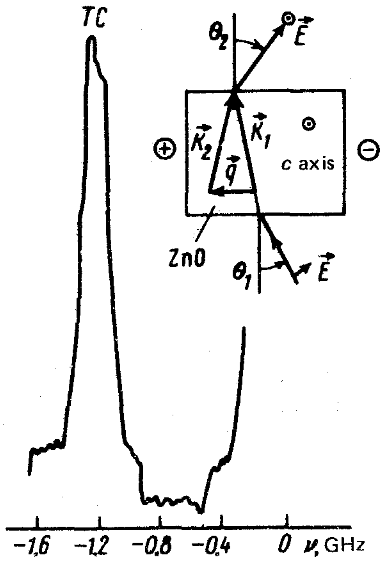

FIG. 1. Spectrum of light scattered by a ZnO crystal (specimen No. 2) at a point located at a distance $x = 7.9$ mm from the cathode. $\theta_1 = 0°$, $E = 0$. TC indicates the Stokes MB component, which is attributable to scattering of light by the transverse piezoactive wave. The section of the specimen in the scattering plane is shown in the insert: $\mathbf{k}_1$, $\mathbf{k}_2$, and $\mathbf{q}$ are the wave vectors of the incident and scattered light and of the sound wave, respectively. ⊖, ⊕ are the cathode and anode contacts in the crystal.

The appearance of a new MBC in the spectrum of light scattered by the ZnO crystal is attributable to nonlinear processes occurring in the crystal placed in the electric field.[2]

On the other hand, if the conditions necessary for propagation of second sound are realized in the crystal,[3] then it should also be manifested in the scattered light

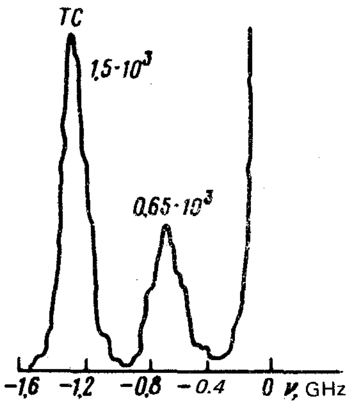

FIG. 2. Spectrum of light scattered by a ZnO crystal when an electric field $E = 2.27$ kV/cm is applied to the specimen. The MBC intensity in Fig. 2 is measured relative to the magnitude of the MBC at $E = 0$ (Fig. 1), which is taken as unity.

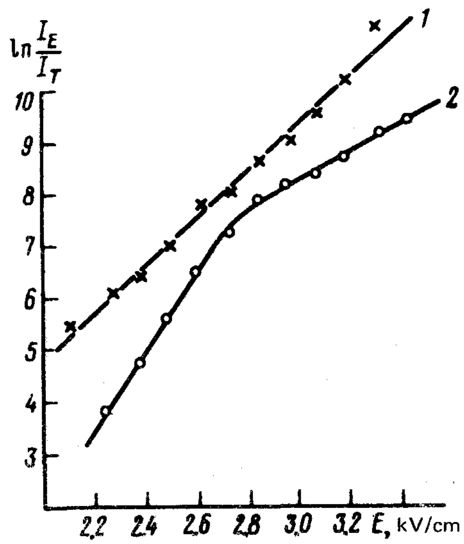

FIG. 3. $\ln(I_E/I_T)$ as a function of the field intensity E. Curve 1 corresponds to $\nu_0 = 0.98$ GHz and curve 2 corresponds to $\nu_1 = 0.68$ GHz (new component). Specimen No. 1, $x = 1$ mm, and $\theta_1 = -6°$.

spectrum as a new additional spectral line in the frequency range indicated.

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