form of the field dependence of G - T. Hysteresis phenomena due to change in frequency were always accompanied by a peak of generation power at the center of the absorption line [1], since the conditions for the occurrence of the hysteresis were more stringent than the conditions for the appearance of the generation-power peak [1]. It has been noted that the generation growth time was always much shorter than the cessation time, in agreement with the results of Kazantsev et al.

When the discharge current in the amplification tube was varied (Fig. 3), the hysteresis region depended on the generation frequency, approximately doubling when tuned to the center of the absorption line.

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INFLUENCE OF EXTERNAL ELECTRIC FIELD ON THE SPEED OF SOUND IN CdS

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Increasing attention is being paid at present to the nonlinearity of the electron-phonon interaction processes, since they limit the amplification of sound and cause formation of stationary waves in piezoelectric semiconductors.

It turns out that in a number of cases an important role is played in these processes by the dependence of the speed of sound w on the external electric field [1]. The linear theory of this dependence, developed by White [2], leads to the following result:

$$w = w_0 \left(1 + \frac{K^2}{2}\phi\right),$$

where (1)

$$w_0 = \sqrt{\frac{c}{\rho}}, \quad \phi = \frac{(q/\kappa)^2 (1 + q^2/\kappa^2) + (\omega - qv)^2 \tau_\sigma^2}{(1 + q^2/\kappa^2)^2 + (\omega - qv)^2 \tau_\sigma^2},$$

c - elastic modulus, ρ - density, K - electromechanical coupling coefficient, q - wave vector of the sound wave, κ - reciprocal Debye radius, ω - sound frequency, v - electron drift velocity, and τ_σ - conductivity relaxation time.

The value of φ depends not only on the carrier density in the sample, but also on their drift velocity in the external electric field. The smaller the difference between the electron velocity and the sound wave, the more effective the screening of the piezoelectric interaction. Therefore, a maximum in the change of velocity at a given conductivity should be observed when v = w.

Thus, the speed of sound in piezosemiconductors depends on the parameter φ, which characterizes the degree of screening of the piezoelectric fields of the sound wave by the free carriers, and can vary between two limiting values: w_0 (total screening, $\varphi = 0$), and $w_0(1 + K^2/2)$ (no screening, $\varphi = 1$). The total relative change of the speed of sound $\Delta w/w_0$ does not exceed in this case $K^2/2$, i.e., approximately 1.8% [3].

We measured the dependence of the speed of sound on the intensity of the drift field E in CdS. The measurements were made with the setup illustrated in Fig. 1.

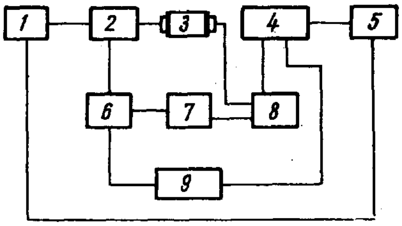

Fig. 1. Block diagram of experimental setup.

The synchronizer 1 triggers generator 2. A radio pulse from the generator is fed to a "Y-cut" quartz converter cemented to sample 3. On the other end of the sample is placed a similar converter, the radio signal from which is fed to mixer 8, and is then amplified in amplifier 4, detected, and fed to oscilloscope 5. At the same time, the signal from the transmitter is fed to a second mixer 6, a common heterodyne 7 being used for both mixers.

The transformed radio pulse from the transmitter, at a frequency 30 MHz, is fed to a calibrated variable-dely line 9 and through it to the same amplifier 4, where it interferes with the signal passing through the sample. At a given value of the drift field, the amplitude of the interfering signal is minimized with the aid of the variable-delay line 9. Variation of the field changes the speed of sound. By varying the delay with the aid of 9 it is possible to minimize the signal amplitude again. The value of the introduced delay determines the relative change of the speed of sound in the sample. The error of the described method is of the order of 0.03%.

We used for the measurements a CdS sample in the form of a rectangular 3 x 6 x 8 mm parallelepiped. Electric contacts were deposited by vacuum sputtering on the plane-parallel optically-polished end surfaces of the crystal. The quartz converters were cemented to these contacts. The direction of propagation of the transverse sound wave and of the drift field was perpendicular to the c axis of the crystal, and the polarization of the sound coincided with the direction of this axis. The measurements were made at 250 MHz.

The sample was illuminated with a DKSSh-200 xenon lamp through light filters OS-12 and OS-13. The conductivity changed upon illumination from the dark value 10^{10} to 10^{-3} $\text{ohm}^{-1}\text{cm}^{-1}$. The electron mobility determined from the amplification of the sound in this sample was 120 $\text{cm}^2/\text{V-sec}$.

The main measurement results are shown in Fig. 2. The solid lines are the experimental curves. The strong attenuation of the ultrasound made it impossible to obtain at large values of the conductivity the sections of the curves located in the region of less-than-critical drift fields.

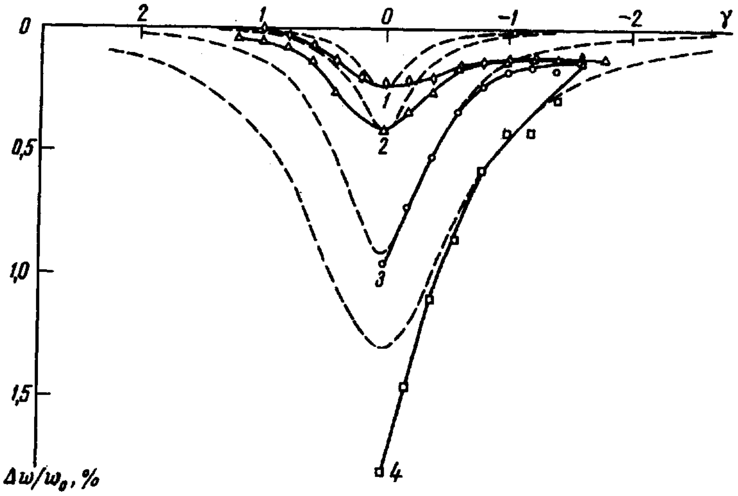

Fig. 2. Relative change in the speed of sound $\Delta w/w_0$ vs. the supercriticality parameter $\gamma = 1 - (v/w_0)$.
1) $\sigma = 3 \times 10^{-5}$ ohm^{-1}cm^{-1};
2) $\sigma = 6 \times 10^{-5}$ ohm^{-1}cm^{-1};
3) $\sigma = 2 \times 10^{-4}$ ohm^{-1}cm^{-1};
4) $\sigma = 5 \times 10^{-4}$ ohm^{-1}cm^{-1}.

The dashed curves were plotted in accordance with the linear theory. The speed of sound at the point $\gamma = 1$ corresponds to the value characteristic of CdS with the given conductivity level in the absence of an external field.

Figure 2 shows that the experimental curves agree in general with the theoretical ones. At low sample conductivity (curves 1 and 2) the maximum relative change and the position of the minimum are in sufficiently good agreement with the theoretical values, but the experimental minimum is much broader. The best agreement between theory and experiment is observed for medium conductivities (curve 3). At large conductivities (curve 4) the experimental values exceed the theoretical ones.

The observed agreement with experiment can be regarded as satisfactory if account is taken of the fact that, owing to the non uniform illumination, the local conductivity in the sound channel differs from the measured mean value. The broadening of curves 1 and 2 may be connected with the fact that in the case of low conductivity the electric inhomogeneity of the sample should exert a relatively stronger influence.

In conclusion we note that the experimental curves, unlike the theoretical ones, are asymmetrical. This deviation from the linear theory at large values of the supercriticality can be attributed to the influence of the traps and to nonlinear effects.

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