γ-rays by the decay of mesons that arise in the interactions of cosmic rays with interstellar matter. Since electrons at these energies lose their energy predominantly via synchrotron radiation in the galactic magnetic field, one should observe roughly the same total energy in synchrotron radiation at the earth as in γ-ray energy. For electrons of 2×10^{14} eV in a field of 3×10^{-6} gauss, the peak of the synchrotron emission is at 3 Å; in a stronger field this will happen at lower electron energies. It has been shown[4] that x rays in this wavelength region are not appreciably absorbed over interstellar distances.

With this one experiment it is impossible to completely define the nature and origin of the radiation we have observed. Even though the statistical precision of the measurement is high, the numerical values for the derived quantities and angles are subject to large variation depending on the choice of assumptions. However, we believe that the data can best be explained by identifying the bulk of the radiation as soft x rays from sources outside the solar system. Synchrotron radiation by cosmic electrons is a possible mechanism for the production of these x rays. Ordinary stellar sources could also contribute a considerable fraction of the observed radiation.

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STRONG ACOUSTOELECTRIC EFFECT IN CdS

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When a sinusoidal acoustic wave propagates through a semiconductor, it gives rise to an ac electric field traveling through the crystal with the velocity of the acoustic wave. A dc field, under the action of the traveling ac field, is generated across the crystal while the wave traverses the crystal. This was defined as an acoustoelectric effect by R. H. Parmenter.[1] We have observed the effect in CdS.

The dc acoustoelectric field generated in CdS is about six orders of magnitude larger than that in n-type germanium crystals,[2,3] because an ac field much larger than that due to the deformation potential is produced in CdS by piezoelectric coupling with the acoustic wave. Illumination and dc voltage applied to a CdS crystal affect the magnitude and polarity of the observed acoustoelectric voltage across the crystal. This will be explained by consideration of acoustic-wave amplification in the crystal.[4]

A shear-wave piezoelectric amplifier was built in the configuration described by Hutson, McFee, and White.[4] Fused quartz buffers one-inch long provided time delay and electrical insulation between the ferroelectric ceramic transducers and the CdS crystal. The crystal, obtained from the Eagle-Picher Co. with a dark resistivity of 10^7 ohm-cm, was oriented for k_{15} electromechanical coupling, and cut to the dimensions 0.2 cm^2 by 0.3 cm. Pulsed rf signals applied to the input transducer at 33 Mc/sec were used to generate the applied acoustic waves. Control of the crystal conductivity was provided by varying the intensity of a mercury vapor lamp.

First we will consider the case with no external dc field applied. Under the assumption of the conservation of momentum, Weinreich[5] has derived a relationship between the absorption coefficient of acoustic waves and the acoustoelectric field[6]:

$$\alpha = \delta n e V_s E_{\mathrm{ae}}/Q, \qquad (1)$$

where α is the attenuation per unit length due to conduction electrons in nepers-cm^{-1}; n, the density of conduction electrons in cm^{-3}; V_s, the acoustic-wave velocity in cm-sec^{-1}; Q, the acoustic-power density in watt-cm^{-2}; E_{ae}, the acoustoelectric field in volt-cm^{-1}; and δ, the numerical factor depending on the scattering processes of conduction electrons.

Supposing that the input acoustic-power density is designated by Q_0, the power density at point x would be $Q_x = Q_0 \exp(-\alpha x)$. Inserting Q_x into Eq. (1) and integrating over the whole crystal length L, and then dividing by L, we have the average acoustoelectric field:

$$\bar{E}_{ae} = (Q_0/\delta n e V_s L)[1 - \exp(-\alpha L)]. \tag{2}$$

Our measurements of the CdS crystal shown in Fig. 1(a) indicate linear variation of $\bar{E}_{ae}$ with Q_0, which agrees with Eq. (2). The direct current due to E_{ae} is carried by conduction electrons in the crystal, moving in the direction of acoustic-wave propagation. These measurements were made at a crystal conductivity $\sigma = 5.5 \times 10^{-5}$ (ohm-cm)$^{-1}$ and $\alpha = 2$ nepers-cm^{-1}.

Figure 1(b) gives the relationship between $\bar{E}_{ae}$ and σ for $Q_0 = 1.2$ watts-cm^{-2}. Equation (2) predicts the linear variation shown by the dashed line, under the assumptions that only n and $\bar{E}_{ae}$ vary, and that n is directly proportional to the conductivity σ. It is noted, however, that most of the experimental points deviate from this line. This is due to the fact that α is not independent of σ. Curve II of Fig. 1(b) shows the measured dependence of α and σ, in which zero neper represents the dark attenuation. The measured α is total acoustic attenuation, which includes mechanical losses, the effects of temperature rise, Ohmic losses due to conduction electron motion produced by acoustic waves, etc.

Figure 1(c) represents the approximate equivalent circuit for the acoustoelectric effect. R_c and C_c are the crystal resistance and capacitance, respectively.

Now we will consider the case with external dc field applied. Pulses of 100μsec length with low repetition rates were used as the external applied field E_{dc} to avoid overheating the CdS crystal. Pulsed rf signals of 10μsec duration were used to generate acoustic waves. A triggering system was devised so as to have the acoustic wave coincide with the E_{dc} pulse in the crystal to permit the crystal to be operated as an acoustic amplifier.[4] Figure 2(a) gives the circuit configuration for the measurement of $\bar{E}_{ae}$. The portion enclosed by dashed lines is the equivalent circuit described by Fig. 1(c). The voltage developed across the measurement resistor of 1 kΩ is designated by

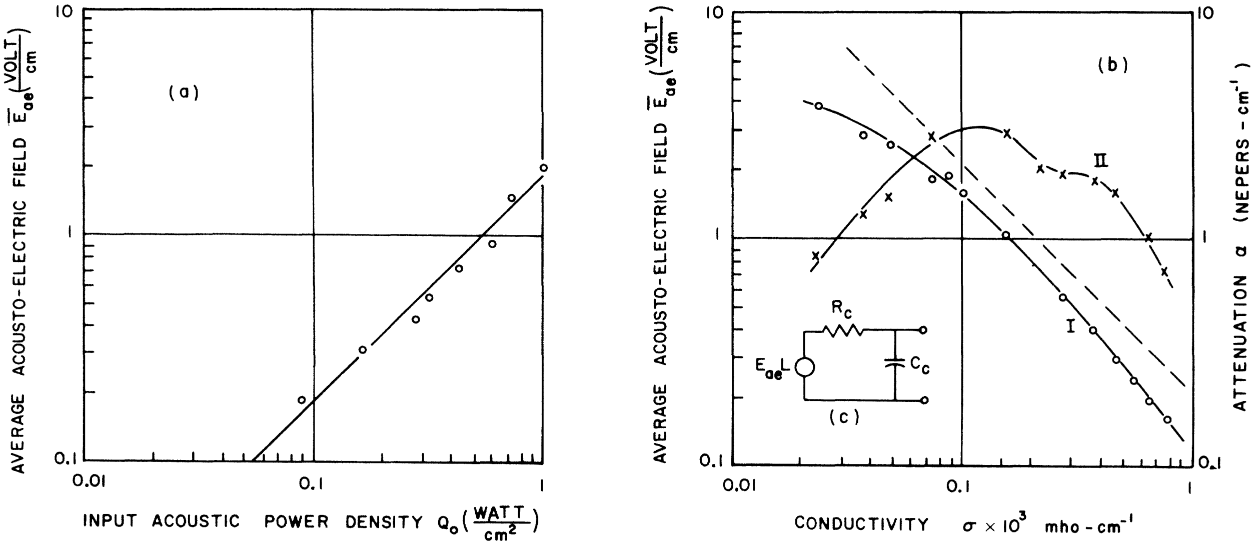

FIG. 1. (a) Measured average acoustoelectric field as a function of input acoustic-power density for CdS, 5.5 $\times 10^{-5}$ mho-cm^{-1} conductivity, and 2 nepers-cm^{-1} attenuation. (b) Curve I: Average acoustoelectric field as a function of conductivity. Curve II: Attenuation as a function of conductivity. (c) Approximate equivalent circuit for the acoustoelectric effect. R_c and C_c are resistance and capacitance of the CdS crystal. $C_c \approx 2$ pF for the crystal described.

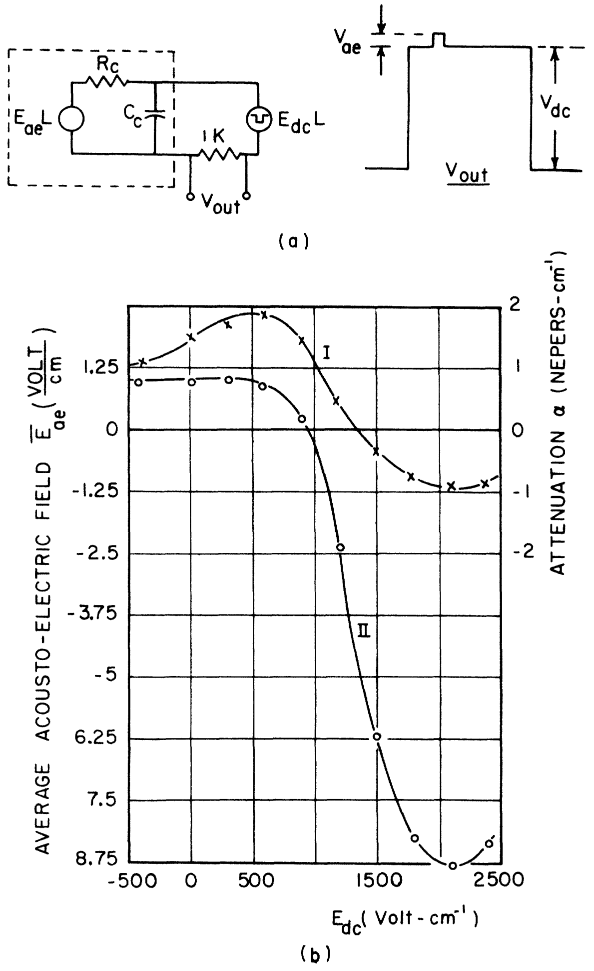

FIG. 2. (a) Left: Circuit configuration for measurement of average acoustoelectric field $\overline{E}_{ae}$, when the external dc voltage $E_{dc}L$ is applied. L is the crystal length. Portion enclosed by dashed lines is the equivalent circuit for acoustoelectric effect. V_{out} is the voltage drop across the measurement resistor of 1 kΩ. Right: Observed form of V_{out}. V_{ae} and V_{dc} are the voltage drop caused by $\overline{E}_{ae}$ and E_{dc}, respectively. V_{ae} is greatly exaggerated in the figure. (b) Curve I: Attenuation as a function of external dc field applied. Zero neper is taken as reference at the dark attenuation. Curve II: Average acoustoelectric field as a function of external dc field applied. Both curves were taken at $\sigma = 8\times 10^{-5}$ mho-cm^{-1} and $Q_0 = 0.6$ watt-cm^{-2}.

"V_{out}" and is depicted in the left drawing. V_{out} is composed of two parts, of which V_{ae} is the voltage drop caused by $\overline{E}_{ae}$, and V_{dc} is the voltage drop caused by E_{dc}. Therefore, by measuring V_{ae}, the magnitude of $\overline{E}_{ae}$ can be obtained.

E_{dc} is considered to be positive when the drift velocity of the electrons caused by E_{dc} is in the direction of acoustic-wave propagation. Curve I of Fig. 2(b) gives the observed acoustic attenuation α as a function of E_{dc}; $-\alpha$ represents gain. Curve II of Fig. 2(b) gives the relation between $\overline{E}_{ae}$ and E_{dc}; or indirectly, it shows the dependence of $\overline{E}_{ae}$ on α since α is a function of E_{dc}. Inserting the measured α (as a function of E_{dc}) into Eq. (2) gives us the expected variation of $\overline{E}_{ae}$ with applied field. Agreement with the measured $\overline{E}_{ae}$ vs E_{dc} curve of Fig. 2(b) is poor. Further, the zero of $\overline{E}_{ae}$ is not found at zero α as is expected from Eq. (2).

It is thought that the discrepancies result from losses which are not considered in Weinreich's derivation of Eq. (1), and from the poor quality of the crystal. Further sources of error are thought to result from a lowering of acoustic gain due to heating at high dc fields.

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