EXPERIMENTAL OBSERVATION OF THE ELECTROACOUSTOMAGNETIC EFFECT IN CdS

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Submitted 20 December 1972
ZhETF Pis. Red. 17, No. 3, 144 - 147 (5 February 1973)

The electroacoustomagnetic effect, whereby a constant magnetic moment appears when current is made to flow through a piezosemiconductor, was observed experimentally. The phenomenon is connected with the anisotropy of the directivity pattern of the phonon radiation in supersonic carrier drift.

The possible existence of a new effect, called electroacoustomagnetic (EAM) and consisting of the occurrence of a constant magnetic moment in an initially-homogeneous semiconductor to which a voltage higher than a certain threshold value is applied, was predicted in a number of papers [1 - 3].

The physical cause of the EAM is as follows. When the electron drift velocity in a semiconductor or a semimetal exceeds the phase velocity of sound, phonons are generated. The acoustic phonons, which build up in space, exert a reaction on the stationary state of the semiconductor plasma, so that this state becomes essentially inhomogeneous over the volume. The character of the inhomogeneity is determined entirely by the symmetry properties of the directivity pattern of the phonon radiation, which, in turn, depend on the orientation of the crystallographic axes relative to the electron drift direction. If the drift directions and the symmetry axes of the crystal do not coincide, then the character of the inhomogeneity is such that a non-potential, i.e., solenoidal component is produced in the conduction current, and it is this current which produces the constant magnetic moment in the sample (see [1, 2] for details). In homogeneous samples having a regular shape, the magnetic moment is even with respect to the polarity of the applied voltage, this being physically connected with the self-consistent mechanism that produces the inhomogeneity [3], and follows mathematically from the invariance of the axial magnetic-moment vector against the inversion operation in a bounded medium.

The presence of a threshold and the even parity with respect to the voltage were the main attributes with which it was proposed to discern the sought effect[1], and the choice of the crystal was influenced by accompanying

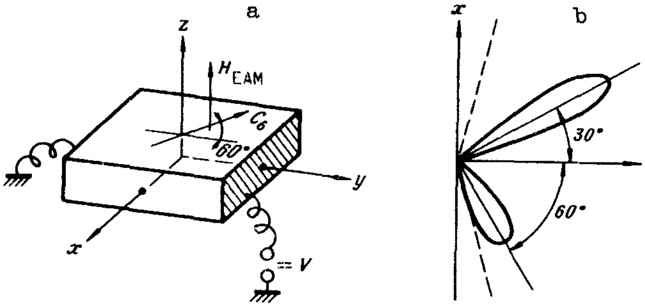

Fig. 1. a) Experimental setup, CdS sample 6 × 7 × 2 mm; b) directivity pattern of phonon radiation at the chosen orientation.

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[1] There are published data on another mechanism producing a magnetic moment and connected with propagation of a surface wave, namely the acoustomagnetic effect [5]. It is smaller than the EAM by an approximate factor (L/r_d), i.e., by six orders of magnitude, and its influence can certainly be neglected. Here r_d is the Debye radius and L is the characteristic inhomogeneity dimension in the EAM.

phenomena, namely the saturation of the current-voltage characteristic and the transverse acoustoelectric effect, which occur under the same conditions as the EAM and have already been observed earlier [3]. It was precisely from these considerations that a homogeneous photosensitive CdS sample was chosen, with dark-current conductivity $\sigma_0 = 10^{-9}$ $(\Omega\text{-cm})^{-1}$, oriented so that the C_6 axis was inclined 60° to the current lines. At such an orientation, the directivity pattern of the radiation of the transverse acoustic waves had two asymmetrically located maxima at approximate angles 30 and -60° relative to the current lines [4], as shown schematically in Fig. 1.

In the present experiment, the magnetic moment was determined from the produced field, which was measured in turn with Hall pickups. The required conductivity was accomplished by illuminating the crystal with transmitted light. The experiment was performed with direct current in a bath with liquid nitrogen, thereby ensuring good cooling of the crystal and of the pickups. A comparison of the pulsed and static current-voltage characteristics has shown that the crystal heating was negligible. The magnetic fields registered by the pickup, which result from the inhomogeneity of the illumination, from the flow of current through the sample, or from unequal reflection conditions on the side faces, are all odd functions of the current, and the first two also have thresholds. The pickups were placed in such a way that there were no interference signals picked up as a result of the current flowing through the sample.

Figure 2 shows the current-voltage characteristics and the averaged (over several experiments) magnetic field recorded by the pickup, as functions of the applied voltage. It is seen that the magnetic moment is produced immediately when the current deviates from the ohmic value, i.e., when phonon generation begins. This rule held at different values of the sample conductivity, regardless of the applied voltage. The magnetic field increases rapidly with increasing voltage, reaches a maximum, and then decreases slowly, in spite of the fact that the current continues to increase and deviates from the ohmic value. The apparent reason is that at low excesses of the field above threshold the contribution to the acoustoelectric force is made by transverse phonons of the directivity-maximum closest to the current line, i.e., by the phonons moving at a 30° angle. With further increase of the voltage, the aperture angle of the generation cone increases, and the contribution of the phonons whose wave vectors make sharp negative angles with the current lines becomes appreciable. Their action enhances the longitudinal component of the acoustoelectric force, contributing thereby to further saturation of the current, but decreases the transverse component, on which the magnitude and sign of the magnetic moment

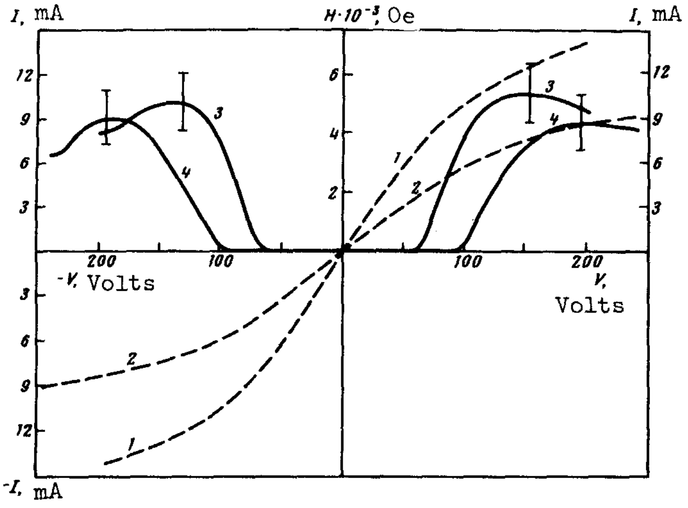

Fig. 2. Current voltage characteristics and the magnetic field registered by the pickups at $\sigma_0 = 6 \times 10^{-5}$ $\Omega^{-1}\text{cm}^{-1}$ (1, 3) and $\sigma_0 = 3 \times 10^{-5}$ $\Omega^{-1}\text{cm}^{-1}$ (2, 4).

depend [3]. In addition, generation of longitudinal waves may set in and also contribute to a decrease of the transverse component of the acoustoelectric force (its sign may even reverse when the voltage is increased).

There was no change in the sign and magnitude of the magnetic field when the polarity of the applied voltage was reversed. This even behavior remained in force in all the experiments and, together with the threshold, is a distinguishing attribute of the effect. The magnetic field direction was reversed when the sample was rotated 180° relative to the current lines; the reason for this reversal is that such a rotation reverses the direction of the transverse component of the acoustoelectric force in the laboratory coordinate frame.

Theoretical estimates based on [2, 3] yield, at the experimental values of the current, a magnetic field 10^{-3} - 10^{-2} Oe, which agrees in order of magnitude with the results obtained here.

The author thanks Yu.P. Mukhrotov and V.I. Pustovoit for constant interest in the work and for useful discussions.

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POPULATION INVERSION IN THE ACTIVE MEDIUM OF AN ELECTROIONIZATION CO_2 LASER AT A WORKING-MIXTURE PRESSURE UP TO 20 ATMOSPHERES

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Submitted 21 December 1972
ZhETF Pis. Red. 17, No. 3, 147 - 150 (5 February 1973)

The present study, devoted to the time dependence of the inverted population in an active medium of an electroionization laser, has shown experimentally that raising the pressure of the working mixture to 20 atm does not lead to any qualitative changes of the processes of excitation and relaxation of the laser levels. The rates of all the excitation and relaxation processes increase with pressure without a change in their ratios, which are known for TEA lasers and low-pressure lasers [1, 2].

The experimental procedure consisted of measuring the value of the time dependence of the gain of the active medium of an electroionization CO_2 laser [3, 4] operating with compressed carbon dioxide, using a TEA test laser (λ = 10.59 μ). The radiation receiver was a Ge:Au photoresistor cooled with liquid nitrogen. The resolution of the recording apparatus was $\sim 2 \times 10^{-7}$ sec.

Measurements of the gain distribution over the cross section (1.8 × 2 cm) of the active medium have shown that the gain is almost uniform over the entire cross section. The gain decreased by ∼25% on going from the anode to the cathode and by ∼20% on going in the perpendicular direction from the center to the edge of the active region. Figures 1 and 2 show the gain averaged over the active-region cross section as a function of the pump energy (W_p) and the