INFLUENCE OF A MAGNETIC FIELD ON THE DRAG OF FREE CARRIERS BY PHOTONS IN SEMICONDUCTORS

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An experimental investigation was made of the influence of a magnetic field on the processes occurring in the drag of free holes by photons in p-type Ge. These processes took place during the optical transitions between the heavy- and light-hole valence sub-bands. It was found that the magnetic field produced two mutually perpendicular dragged-hole currents, which were responsible for the appearance of longitudinal and transverse (with respect to the incident light) emf's with characteristic temperature dependences. The experiments were performed with a CO_2 laser ($\lambda = 10.6\ \mu$) in magnetic fields up to 15 kOe.

THE drag of free carriers by photons in semiconductors, resulting in the ordered motion of carriers under the action of sufficiently strong laser radiation, was discovered by Danishevskiĭ et al.[1] Experiments carried out on p-type germanium samples demonstrated that, at high temperatures, the direction of the drag current was parallel to the direction of propagation of light, whereas at low temperatures these directions were antiparallel. The drag current is due to the transfer of the electromagnetic wave momentum to holes during optical transitions of the $V_1 \to V_2$ type (V_1 and V_2 are the heavy- and light-hole valence sub-bands of germanium). This disturbs the equilibrium of the "hot" holes (in the V_2 sub-band) and of the "cold" holes (in the V_1 sub-band) in the k space so that counter-currents of "dragged" carriers appear in the semiconductor.

This process is illustrated in Fig. 1, which gives a two-dimensional representation of the valence band of germanium.

Since the energy and momentum of a photon are fixed, the transitions $V_1 \to V_2$ shown in Fig. 1 may be executed only by the holes located on the L_1 curve. Consequently, the holes in the V_1 sub-band, which are represented by the curve L_1' and are symmetrical with respect to the holes represented by L_1, and the holes in the V_2 sub-band (represented by the curve L_2), are not in equilibrium with respect to the momentum: this gives rise to the drag current. The value of this current is governed not only by the different velocities of the holes to the left and right on the curves L_1' and L_2 but also by the different densities of holes in these states. This is because the excitation probabilities and the densities of the "left" and "right" "active" holes on the L_1 curve are not equal as a result of asymmetrical distributions of their energies and wave numbers. Moreover, the asymmetry of the momentum relaxation times of the "left" and "right" holes on the L'_1 and L_2 curves plays a considerable role because this asymmetry is identical with the lifetime of a hole moving in an ordered manner under the action of the momentum acquired from a photon. Thus, this asymmetry governs the density of the nonequilibrium "active" holes.

Grinberg[2] developed the theory of this phenomenon and considered not only the effect of light but also the influence of an external static magnetic field H_0 applied perpendicularly to the direction of propagation of light. He demonstrated, in particular, that in this case a new photomagnetic effect should be observed: a current of holes generated by the pressure of light should give rise to an electric field E_x (Fig. 2a) at the ends of a sample (provided the longitudinal circuit is not closed). This field should cause a reverse drift of carriers. The application of a magnetic field H_{0z} should give rise to a transverse hole current along the y axis because of the difference between the energy distributions in the optical and drift currents, which exists in spite of the fact that these currents balance each other out. Consequently, an electric field E_y should appear at the lateral faces of the sample.

Outwardly, this is similar to the Nernst-Ettingshausen effect except that the flow of carriers along the x axis is due to the pressure of light and not to a temperature gradient.

However, the interest in the influence of a magnetic field on the drag effect in p-type Ge is not limited to

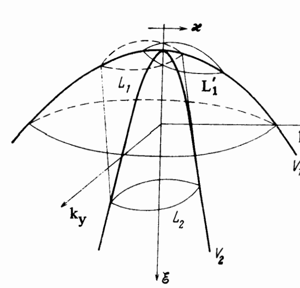

FIG. 1

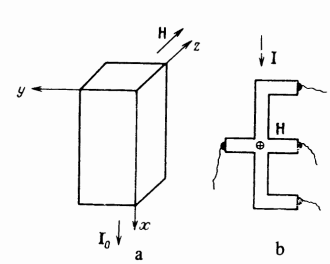

FIG. 2

FIG. 1. Possible optical transitions between the valence sub-bands V_1 and V_2.

FIG. 2. Shape of the samples and their orientation relative to the light beam and the magnetic field.

the phenomenon just described. We may expect this magnetic field to alter the very nature of the processes responsible for this effect. The relaxation times which govern the ordered motion of carriers decrease appreciably as the value of H_0 increases. The magnetic field alters also the asymmetry of the "active" "left" and "right" holes, and this further changes the longitudinal drag current.

The present paper describes the results of an experimental investigation of the drag effect in a magnetic field. However, before presenting these results, we must consider briefly some theoretical relationships which will be required in the qualitative and quantitative descriptions of the effect.

1. BASIC RELATIONSHIPS

The expression for the density of the drag current $\mathbf{j}$ in the presence of a magnetic field $\mathbf{H}_0$ is:[2]

$$\mathbf{j}=\sum_{\alpha=1}^{2}\Big(\frac{e^2p_\alpha}{m_\alpha}\{\langle\tau_\alpha^*\rangle\mathbf{E}-\langle\tau_\alpha\tau_\alpha^*\rangle[\Omega_\alpha\mathbf{E}]+\langle\tau_\alpha^2\tau_\alpha^*\rangle\Omega_\alpha(\Omega_\alpha\mathbf{E})\}+\frac{\omega e\bar{n}\beta}{c\hbar k_0}\frac{\partial}{\partial k_0}(\mathscr{E}_{k_0}^{(2)}-\mathscr{E}_{k_0}^{(1)})\{[\tau_\alpha^*]\mathbf{I}_0-[\tau_\alpha\tau_\alpha^*][\Omega_\alpha\mathbf{I}_0]+[\tau_\alpha^2\tau_\alpha^*]\Omega_\alpha(\Omega_\alpha\mathbf{I}_0)\}\Big). \quad (1)$$

Here, the subscript α denotes the serial numbers of the sub-bands V_1 and V_2, so that Eq. (1) represents the total current density of the heavy and light holes; p_α are the equilibrium densities of the free holes in the two sub-bands; m_α are the effective masses of the holes. The brackets $\langle\,\rangle$ and $[\,]$ represent different types of averaging of the quantities enclosed by them;[2]

$$\tau_\alpha^*=\tau_\alpha(1+\Omega_\alpha\tau_\alpha)^{-1},\qquad \Omega_\alpha=\frac{e\mathbf{H}_0}{\hbar^2c}\frac{1}{k}\frac{\partial\mathscr{E}_k^{(\alpha)}}{\partial k}, \quad (2)$$

$\Omega_\alpha = eH_0/m_\alpha c$ for the parabolic dispersion law; τ_α is the relaxation time; $\hbar\kappa$ is the photon momentum; $\hbar\kappa_0$ is the quasi-momentum of a hole participating in an optical transition, computed without allowance for the shift by the photon momentum; β is the absorption coefficient of light ($\lambda = 10.6\ \mu$) for transitions between the V_1 and V_2 sub-bands; I_0 is the incident light flux; $\mathbf{E}$ is the electric field intensity; $\bar{n}$ is the refractive index.

If $\mathbf{H}_0 \perp \kappa$, and the component of the current along the magnetic field (j_{H_0}) vanishes, Eq. (1) derived in the quadratic law approximation for the dispersion in the V_1 and V_2 sub-bands transforms to:

$$\mathbf{j}=\sum_{\alpha=1}^{2}\Big(\frac{e^2p_\alpha}{m_\alpha}\{\langle\tau_\alpha\rangle\mathbf{E}-\langle\tau_\alpha\tau_\alpha^*\rangle[\Omega_\alpha\mathbf{E}]\}+\frac{e\bar{n}\beta\hbar\omega}{c}\frac{m_1-m_2}{m_1m_2}\{[\tau_\alpha^*]\mathbf{I}_0-[\tau_\alpha\tau_\alpha^*][\Omega_\alpha\mathbf{I}_0]\}\Big). \quad (3)$$

Using the well known expressions for the magnetoconductivity $\sigma_\perp(H_0)$ directed normally to the magnetic field and for the Hall mobility $\tilde{\mu}_p$, which are of the following form in the case of p-type germanium:[1)]

$$\sigma_\perp(H_0)=\frac{\sum_1^2+\sum_2^2}{\sum_1},\qquad \tilde{\mu}_p(H_0)=\frac{c}{H}\frac{\sum_2}{\sum_1}, \quad (4)$$

$$\textstyle\sum_1=\sum_{\alpha=1}^{2}\frac{e^2p_\alpha}{m_\alpha}\langle\tau_\alpha^*\rangle,\qquad \sum_2=\sum_{\alpha=1}^{2}\frac{e^2p_\alpha}{m_\alpha}\langle\tau_\alpha\tau_\alpha^*\Omega_\alpha\rangle, \quad (5)$$

and introducing the notation

$$F^*=\frac{3(m_1-m_2)^2}{m_1m_2}\sum_{\alpha=1}^{2}[\tau_\alpha^*], \quad (6)$$

$$\mathscr{F}^*=\frac{3(m_1-m_2)^2}{m_1m_2}\frac{c}{\tilde{\mu}_pH}\sum_{\alpha=1}^{2}[\tau_\alpha\tau_\alpha^*\Omega_\alpha], \quad (7)$$

$$b=\frac{e\beta\bar{n}\hbar\omega}{3(m_1-m_2)c}, \quad (8)$$

$$\mathbf{H}_0=\mathbf{v}H_0, \quad (9)$$

we can rewrite Eq. (3) in the more compact form:

$$\mathbf{j}=\sum_{\alpha=1}^{2}\frac{e^2p_\alpha}{m_\alpha}[\langle\tau_\alpha\rangle\mathbf{E}-\langle\tau_\alpha\tau_\alpha^*\Omega_\alpha\rangle[\mathbf{v}\mathbf{E}]]+b\left[F^*\mathbf{I}_0-\frac{\tilde{\mu}_pH_0}{c}\mathscr{F}^*[\mathbf{v}\mathbf{I}_0]\right]. \quad (10)$$

The first two terms in Eq. (10) represent the drift current generated by the induced electric field $\mathbf{E}$ in the presence of H_0. The last two terms, which contain the intensity of the incident light I_0, are the "active" components of the drag current originating from the momentum of the light wave transmitted to the holes. In the selected geometry (Fig. 2b), the expressions for the components of the current along the x and y axes are:

$$j_x=\sum_{\alpha=1}^{2}\frac{e^2p_\alpha}{m_\alpha}[\langle\tau_\alpha^*\rangle E_x+\langle\tau_\alpha\tau_\alpha^*\Omega_\alpha\rangle E_y]+bF^*I_{0x},$$

$$j_y=\sum_{\alpha=1}^{2}\frac{e^2p_\alpha}{m_\alpha}[\langle\tau_\alpha^*\rangle E_y-\langle\tau_\alpha\tau_\alpha^*\Omega_\alpha\rangle E_x]-b\frac{\tilde{\mu}_pH_{0z}}{c}\mathscr{F}^*I_{0x}. \quad (11)$$

The system of equations (11) can be used to obtain formulas for practically all the cases of interest. In particular, Danishevskiĭ et al.[1] considered the drag current j_x for $E_x = 0$ in the absence of a magnetic field. In this case

$$j_x=bFI_{0x},\qquad F=\frac{3(m_1-m_2)^2}{m_1m_2}\sum_{\alpha=1}^{2}[\tau_\alpha]. \quad (12)$$

We can now analyze the following experimental situations: 1) a longitudinal short-circuit current in a magnetic field; 2) a transverse emf which appears in a magnetic field because of the current of dragged carriers.

1) We shall start by considering the first case on the assumption that $E_x = E_y = 0$. It then follows from Eq. (11) that

$$j_x=bF^*I_{0x}. \quad (13)$$

The expression (13) gives the longitudinal component of the "active" current in a magnetic field. A comparison of this expression with Eq. (12) shows that F is now replaced with F*. It also follows from Eq. (11) that there is a longitudinal as well as a transverse component of the "active" current in a magnetic field, and the latter is given by

$$j_y=-b\frac{\tilde{\mu}_pH_0}{c}\mathscr{F}^*I_{0x}. \quad (14)$$

If the transverse current circuit is opened (i.e., $E_y \neq 0$), the current of dragged carriers along the y axis produces an electric field E_y given by:

1)We can easily show that Eqs. (4) and (5) can also be obtained directly from Eq. (3) for $I_0 = 0$.

$$E_y = b\frac{\tilde{\mu}_p H_{0z}}{\sigma_\perp^*(H_0)c}\mathscr{F}^* I_{0x}, \tag{15}$$

where $\sigma_\perp^*$ is the magnetoconductivity along the y direction for short-circuited longitudinal contacts (i.e., along the x direction).[2)] The field E_y causes a drift current consisting not only of the "active" but of all the other holes (mainly the heavy holes because the equilibrium light holes represent only 4%). The magnetic field acting on this current gives rise to a drift component of the longitudinal current j_x, whose numerical value is

$$j_{x\,\text{drift}} = b(\tilde{\mu}_p H_{0z}/c)^2 \mathscr{F}^* I_{0x}. \tag{16}$$

Thus, the total longitudinal current for short-circuited longitudinal contacts ($E_x = 0$) is given by the following expression:

$$j_x = b\left[F^* + \left(\frac{\tilde{\mu}_p H_{0z}}{c}\right)^2 \mathscr{F}^*\right] I_{0x}. \tag{17}$$

2) If $j_x = 0$ and $j_y = 0$, i.e., if the longitudinal and transverse current circuits are open, the incident light flux I_{0x} and the applied magnetic field H_{0z} produce a transverse electric field E_y (as mentioned earlier). The system of equations (11) yields directly the value of this field:

$$E_y = \frac{b}{\sigma_\perp(H_0)}\left[\frac{\tilde{\mu}_p H_{0z}}{c}(\mathscr{F}^* - F^*) I_{0x}\right]. \tag{18}$$

Equation (18) can be interpreted quite easily. The motion of holes along the longitudinal direction produces an electric field

$$E_x = -\frac{b}{\sigma_\perp(H_0)}\left[F^* + \left(\frac{\tilde{\mu}_p H_{0z}}{c}\right)^2 \mathscr{F}^*\right]. \tag{19}$$

This field produces a drift hole current, which is turned by the magnetic field and produces an electric field E_y' given by

$$E_y' = -\frac{b}{\sigma_\perp(H_0)}\frac{\tilde{\mu}_p H_{0z}}{c}\left[F^* + \left(\frac{\tilde{\mu}_p H_{0z}}{c}\right)^2 \mathscr{F}^*\right] I_{0x}. \tag{20}$$

On the other hand, the magnetic field produces a current of "active" holes along the y axis and this generates an electric field E_y'':

$$E_y'' = b\frac{\tilde{\mu}_p H_{0z}}{\sigma_\perp^* c}\mathscr{F}^* I_{0x} = b\left[1 + \left(\frac{\tilde{\mu}_p H_{0z}}{c}\right)^2\right]\frac{\tilde{\mu}_p H_{0z}}{\sigma_\perp c}\mathscr{F}^* I_{0x}. \tag{21}$$

Consequently, the expression for the total transverse field $E_y = E_y' + E_y''$ is given by Eq. (18).

In the experiments, which will be described later, the impurity concentration was such that—in the investigated range of temperatures—the carrier relaxation times were governed mainly by the lattice scattering in which acoustical and optical phonons participated.[3] If the dispersion law $\mathscr{E}(k)$ is quadratic for both sub-bands, the expressions for F^* and $\mathscr{F}^*$ become:

$$F^* = \frac{\tau_1}{1+(\Omega_1\tau_1)^2}\left[5 - \frac{2\mathscr{E}_{k_0}^{(1)}}{k_B T} + \frac{1-(\Omega_1\tau_1)^2}{1+(\Omega_1\tau_1)^2}k_0\frac{\partial \ln \tau_1}{\partial k_0}\right]$$
$$- \frac{\tau_2}{1+(\Omega_2\tau_2)^2}\left[3 + 2\frac{m_1}{m_2} - \frac{2\mathscr{E}_{k_0}^{(2)}}{k_B T} + \frac{1-(\Omega_2\tau_2)^2}{1+(\Omega_2\tau_2)^2}k_0\frac{\partial \ln \tau_2}{\partial k_0}\right], \tag{22}$$

$$\mathscr{F}^* = \frac{\tau_1^2}{m_1[1+(\Omega_1\tau_1)^2]}\left[5 - \frac{2\mathscr{E}_{k_0}^{(1)}}{k_B T} + 2k_0\frac{\partial}{\partial k_0}\ln \tau_1 \frac{1}{1+(\Omega_1\tau_1)^2}\right]$$
$$- \frac{\tau_2}{m_2[1+(\Omega_2\tau_2)^2]}\left[3 + 2\frac{m_1}{m_2} - \frac{2\mathscr{E}_{k_0}^{(2)}}{k_B T} + 2k_0\frac{\partial}{\partial k_0}\ln \tau_2 \frac{1}{1+(\Omega_2\tau_2)^2}\right]. \tag{23}$$

Here, τ_α is the total momentum-relaxation time governed by the scattering of holes on the optical and acoustical phonons, $\tau_\alpha = t_\alpha^{ac}/\varphi$; $\tau_\alpha^{ac} = AT^{-1}\mathscr{E}^{-1/2}$ is the momentum relaxation time due to the scattering of holes on the acoustical phonons alone;

$$\varphi_\alpha = 1 + \frac{B}{A}\frac{\Theta}{T}(e^{\Theta/T} - 1)\left[\left(1 + \frac{k_B\Theta}{\mathscr{E}_{k_0}^\alpha}\right)^{1/2} + e^{\Theta/T}\left(1 - \frac{k_B\Theta}{\mathscr{E}_{k_0}^\alpha}\right)^{1/2}\right], \tag{24}$$

where $k_B\Theta$ is the optical phonon energy; $\mathscr{E}_{k_0}^\alpha$ is the energy of the "active" holes in the V_1 and V_2 sub-bands computed ignoring the phonon momentum; $B/A = (1/2)(\mathscr{E}_{opt}/\mathscr{E}_{ac})^2$, where $\mathscr{E}_{opt}$ and $\mathscr{E}_{ac}$ are the deformation potential constants for the optical and acoustical phonons in p-type Ge.

2. EXPERIMENTAL RESULTS AND DISCUSSION

Our experiments on p-type germanium samples with a hole density of $p = 1.5 \times 10^{14}$ cm^{-3} were carried out under the conditions considered in the preceding section. We determined the temperature dependences of the drag current in a magnetic field and of the transverse emf's appearing in the case of closed and open longitudinal contacts.

A CO_2 laser ($\lambda = 10.6\ \mu$), operating under Q-spoiling conditions and producing 3 kW pulses, was used as the source of coherent monochromatic radiation. The duration of a light pulse was 0.3–0.4 μsec. The light was directed downward onto a sample placed between the poles of a magnet in a small dewar. It was focused by a long-focus lens made of barium fluoride. The shape of the samples and the experimental geometry are shown in Fig. 2b. During the measurements of the longitudinal drag current the sample was shunted by a very small resistance. This resulted in the shorting of that circuit which was longitudinal with respect to the light beam. The temperature dependence of the drag current was determined in the absence of a magnetic field and in a field of 15 kOe. The experimentally determined curves and the results of the numerical calculations based on Eqs. (15), (22) and (23) are presented in Fig. 3. We can see that the best agreement between the experimental and theoretical values is obtained, as in[1], by selecting the effective mass m_2 of the "active" light holes to be 0.08 m_0, i.e., $m_2/m_1 = 0.24$.

It is evident from Fig. 3 that the current j_x increases in a magnetic field and the point of inversion of its sign shifts in the direction of lower temperatures. As mentioned earlier, the drag current in a magnetic field ($E_x = 0$) has the "active" and drift components. The results of the calculations show that the "active" component decreases with increasing magnetic field due to a reduction in the relaxation times of the heavy and light holes. However, the total short-circuit current increases because of the appearance of the drift component j_x in the magnetic field.

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2) The relationship between $\sigma_\perp^*$ and the original quantity $\sigma_\perp$ can be obtained easily from Eqs. (4) and (11):

$$\sigma_\perp^*(H_0) = \sum_{\alpha=1}^{2}\frac{e^2 p_\alpha}{m_\alpha}\langle\tau_\alpha^*\rangle = \frac{\sigma_\perp(H_0)}{1+(\tilde{\mu}_p H_{0z}/c)^2}.$$

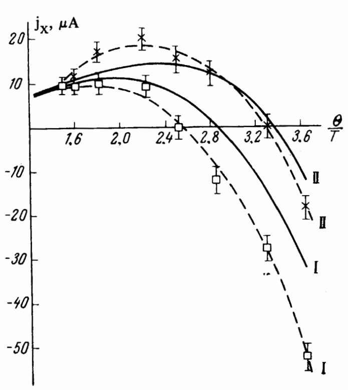

FIG. 3. Temperature dependences of the short-circuit current j_x in a magnetic field. The dashed curves are the plots of the experimental results and the continuous curves are theoretical. I) $H_0 = 0$; II) $H_0 = 15$ kOe.

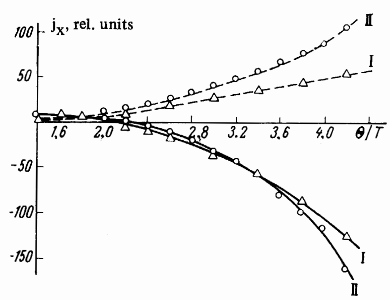

FIG. 4. Calculated temperature dependences of the longitudinal light- and heavy-hole currents. The dashed curves represent the light-hole current $j_x^{(2)}$ and the continuous curves the heavy-hole current $j_x^{(1)}$. I) $H_0 = 0$; II) $H_0 = 15$ kOe.

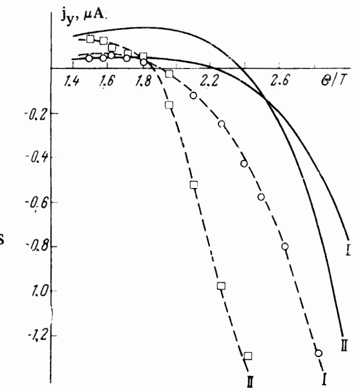

FIG. 5. Temperature dependences of the transverse current j_y in the case of closed longitudinal contacts. The dashed curves are the plots of the experimental results and the continuous curves are theoretical. I) $H_0 = 5$ kOe; II) $H_0 = 13$ kOe.

Examination of the expressions for F^* and $\mathcal{F}^*$ shows that we can separate the terms corresponding to the heavy and light "active" holes. Since $\tau_1 \gg \tau_2$ in $H_0 = 0$, the contribution of the light "active" holes to the drag current is less than the contribution of the heavy holes. However, according to Eq. (2), the relaxation time of the light holes, whose energies are higher, decreases much less in a magnetic field than the relaxation time of the heavy holes. Consequently, the relative contribution of the light-hole current increases when a magnetic field is applied. This can be seen from Fig. 4, which presents the temperature dependences of $j_x^{(1)}$ and $j_x^{(2)}$ for $H_0 = 0$ and $H_0 = 15$ kOe, calculated from Eq. (17).

It should be mentioned that although the second term in Eq. (17) is due to the drift current, it includes the quantity $b\tilde{\mu}_p H_0 \mathcal{F}^* I_{0x}/c$, which is numerically equal to the y component of the "active" current. Therefore, we may speak of the enhancement of the role of the light "active" holes, compared with the heavy holes, when a magnetic field is applied. Since the heavy- and light-hole currents are oppositely directed, the inversion temperature is reduced by the magnetic field, as demonstrated in Figs. 4 and 5.

In the investigations of the temperature dependence of the transverse emf in a magnetic field, we analyzed the two cases considered in the theoretical section: 1) the longitudinal contacts closed (a real drag current in $E_x = 0$); 2) the longitudinal contacts open (no current and the flux of the "active" holes balanced by the field E_x).

In the first case, the appearance of the field E_y is apparently analogous to the usual Hall effect because a current flows along the x direction. However, this current is due to a very special mechanism and, therefore, the expression for E_y is different from the expression which gives the field in the case of a current generated by an electric field. This is because a magnetic field exerts a strong influence on the actual establishment of the drag current and, particularly, on the distribution functions and the velocities of the "active" holes, as well as on their relaxation times. During an optical transition in the presence of a magnetic field, the holes acquire a velocity component along y and, if the transverse contacts are closed ($E_y = 0$), we observe the "active" current $j_y = -b\tilde{\mu}_p H_{0z} \mathcal{F}^* I_{0x}/c$, whereas $j_x = bF^* I_{0x}$ ($E_x = 0$). These two currents are due to the drag effect, i.e., due to the direct interaction between the light beam and carriers. Thus, the measurement of the electric field along the y direction is of interest and it gives additional information on the drag processes in a magnetic field. Figure 5 gives the temperature dependences of the current j_y for various values of the magnetic field (these dependences were deduced from the measured values of the emf across the transverse contacts when the longitudinal contacts were closed). We can see that the experimental and theoretical dependences are in basic agreement. When the magnetic field is increased, the inversion point of the sign of j_y shifts somewhat along the temperature scale but the experimental value of this shift is less than that predicted theoretically.

We also measured the emf which appeared across the transverse contacts when the longitudinal contacts were open. The signals were found to be half as large as in the case of closed longitudinal contacts but the sign of the emf was the same in both cases. Reversal of the magnetic field reversed the polarity of the signals, in accordance with the expected behavior.

All these observations can be explained in a natural manner on the basis of the theory presented in Sec. 1. The field E_y is the sum of the fields E'_y and E''_y, which have opposite signs. Since the sign of the transverse electric field is not affected by the opening of the longitudinal contacts, it follows that the field E''_y due to the "active" flux of holes is greater than the field E'_y due to the drift flux of holes. This is expected because the velocities in the ensemble of "active" holes in the V_1

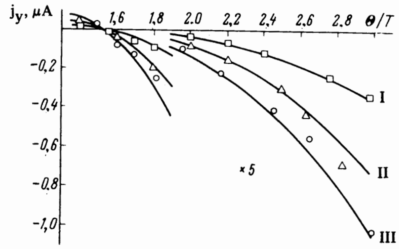

FIG. 6. Temperature dependences of the transverse current j_y in the case of open longitudinal contacts. □) H_0 = 3 kOe; △) H_0 = 7 kOe; ○) H_0 = 15 kOe. I, II, and III are the theoretical curves for H_0 = 3, 7, and 15 kOe, respectively.

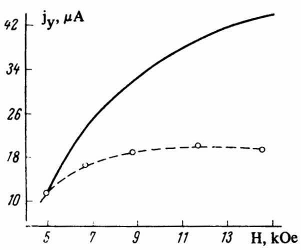

FIG. 7. Dependence of the transverse current j_y on the magnetic field in the case of open longitudinal contacts. The dashed curve is the plot of the experimental results and the continuous curve is theoretical. T - 77°K.

and V_2 sub-bands are higher than the average velocity of the thermalized holes and the "active" holes are affected more strongly by the magnetic field.

We determined also the sign of the transverse emf as a function of the directions of the light beam and of the magnetic field. We found that the sign was the same as that of the Hall emf which would have appeared in the presence of a current flowing along the direction of the incident light beam.

The temperature dependence of j_y, deduced from the measured values of the emf in various magnetic fields, and the corresponding theoretical curves are presented in Fig. 6. It is clear that the theory and experiment are in good agreement within the investigated range of temperatures. However, in this case, the best agreement between the theoretical and experimental curves is obtained for m_2/m_1 equal to 0.2 and not 0.24.

In conclusion, we must mention the dependence of the transverse current j_y on the magnetic field in the case of open longitudinal contacts (Fig. 7). The effect of the magnetic field reaches saturation, in agreement with the theoretical predictions. However, the experimental results indicate saturation in weaker fields than those found by calculation. Evidently, this is because the influence of the scattering by impurities on the observed effect is ignored in the theoretical calculations.

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