ature of the phase transition from the paraelectric state to the ferroelectric one is ~-65°C. Attention is called to the fact that the investigated compound has a gently sloping ϵ/ϵ_k dependence, showing the phase transition to be smeared out.

The relative probability of the Mossbauer effect, f/f_k, first increases as the temperature decreases from room temperature to that of the phase transition (-65°C), owing to the decrease in the amplitude of the thermal vibrations, and then decreases even before the phase transition sets in.

Attention is called to the temperature interval from -145 to -165°C, in which the relative probability of the Mossbauer effect first decreases rapidly, after which it begins to increase. At the same time, the dielectric constant hardly decreases in this temperature interval. Thus, the anomalous change of f/f_k in this temperature region remains as yet unclear.

[1] G. A. Smolenskii and V. A. Isupov, Zh. Tekh. Fiz. 24, 1375 (1954).
[2] V. V. Chekin, V. P. Romanov, B. I. Verkin, and V. A. Bokov, ZhETF Pis. Red. 2, 186 (1965) [JETP Lett. 2, 117 (1965).
[3] V. G. Bhide and M. S. Multani, Phys. Rev. 139, 1983 (1965).

PHOTOMAGNETIC EFFECT IN n-InSb IN THE CASE OF ELECTRON HEATING

R. I. Lyagushchenko, D. N. Nasledov, Yu. G. Popov, and I. N. Yassievich
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 6 July 1967
ZhETF Pis'ma 6, No. 9, 845-849 (1 November 1967)

Observation of an oscillatory photoconductivity and of the photomagnetic effect in p-InSb was reported in the literature earlier [1-3] and was attributed to the heating of the electrons by the radiation [3-5]. Similar effects were observed in electronic n-InSb [6]. However, the oscillations of the photomagnetic effect cannot be interpreted on the basis of simple heating of the photoelectrons, since the photomagnetic effect in n-InSb is determined by the coefficient of ambipolar diffusion, i.e., in practice, by the hole diffusion coefficient.

An interpretation becomes possible if the background of equilibrium electrons is taken into account besides the hot photoelectrons.

Let us consider qualitatively a very simple case. During the course of excitation of an electron-hole pair, practically all the excess energy of the light quantum is transferred to the electron. Owing to the strong interaction with the optical phonons, the photoelectrons. Owing to the strong interaction with the optical phonons, the photoelectrons go immediately into the energy interval 0 - $\hbar\omega_e$ ($\hbar\omega_e$ is the energy of the longitudinal optical phonon). Assume that they retain their energy in this interval. We then have two groups of electrons, namely electrons in equilibrium with the lattice temperature and the hot photoelectrons. The quasineutrality condition leads to the occurrence of an electric field when the hot electrons diffuse inside the sample (their flux is q_{n1}). This field produces a flux of cold electrons (q_{n2}) in a direction opposite to that of q_{n1}. The fluxes q_{n1} and q_{n2} cancel each other to a considerable degree, their difference being equal to the hole flux q_p

inside the sample. When a magnetic field is applied, the flux q_{n1} gives rise to a flux $\Omega\tau(\epsilon_0)q_{n1}$ along the sample, q_{n2} produces a flux $\Omega\tau(\bar{\epsilon})q_{n2}$, and q_n a flux $\Omega\tau_p(m_n/m_p)q_p$ (ϵ_0 is the energy of the hot electrons, $\bar{\epsilon} = 3T_0/2$ is the average energy of the equilibrium electrons, T_0 is the lattice temperature in energy units, $\tau(\epsilon_0)$, $\tau(\bar{\epsilon})$, and τ_p are the momentum-relaxation times of the hot electrons and holes, and Ω is the cyclotron frequency of the electrons.

The result is a photomagnetic current along the sample, with density

$$i_{pm} = e(\Omega\tau(\epsilon_0)q_{n1} - \Omega\tau(\bar{\epsilon})q_{n2} + \Omega\tau\frac{m_n}{m_p}q_p) \quad (1)$$

and recognizing that $q_{n1} - q_{n2} = q_p$ and $m_n/m_p \ll 1$, we have

$$i_{pm} \cong e\,\Omega(\tau_0 - \tau)q_{n1} + e\Omega\tau q_p . \quad (2)$$

The first term in (2) is determined by the electrons and is usually much larger than the second, which corresponds to the usual results of diffusion theory without heating.

A paper containing a rigorous kinetic theory for a low illumination level is now in press [7]. If surface recombination can be neglected and the electrons are scattered predominantly by ionized impurities, then the photomagnetic current per unit sample thickness is determined by the simple formula

$$i_{pm} = I_e\,\Omega\tau_0\frac{a\lambda_0^2}{1 + a\lambda_0}, \quad (3)$$

where

$$\lambda_0 = \frac{2}{3}\frac{\epsilon_0\tau(\epsilon_0)t_n(\epsilon_0)}{m_n} \quad (4)$$

is the diffusion length of the electrons with energy ϵ_0, and $t_n(\epsilon)$ is the lifetime of the electron of energy ϵ. In the derivation of this formula, we neglected completely the inter-electron interactions.

Formula (3) differs from the result of ordinary diffusion theory in that the ambipolar diffusion length, which is approximately equal to the hole diffusion length λ_p, is replaced here throughout by the diffusion length λ_0 of the hot electrons.

Similar results are obtained in the case of strong interaction, when a Maxwellian electron energy distribution with effective temperature $T_e \neq T_0$ is established.

Let us consider now the experimental data obtained for n-InSb samples with different electron densities. Figure 1 shows the temperature dependences of I_{pm} for samples with electron densities 4.9×10^{12} - 4.1×10^{14} cm^{-3}. It is seen from the figure that a rather sharp increase of I_{pm} is observed for all samples in the temperature region 15 - 50°K, followed by saturation (I_{pm} increases by one and one-half orders of magnitude in some samples). This growth cannot be attributed to an increase in the lifetime of the carriers, since this requires that the carrier lifetime increase by two or three orders of magnitude, or to 10^{-3} sec at 7°K (at 77°K we have $\tau_n \approx \tau_p \sim 10^{-6}$ sec). However, a study of the relaxation processes of the photomagnetic effect (with pulsed illumination) has shown that the electron and hole lifetimes do not exceed 10^{-6} sec.

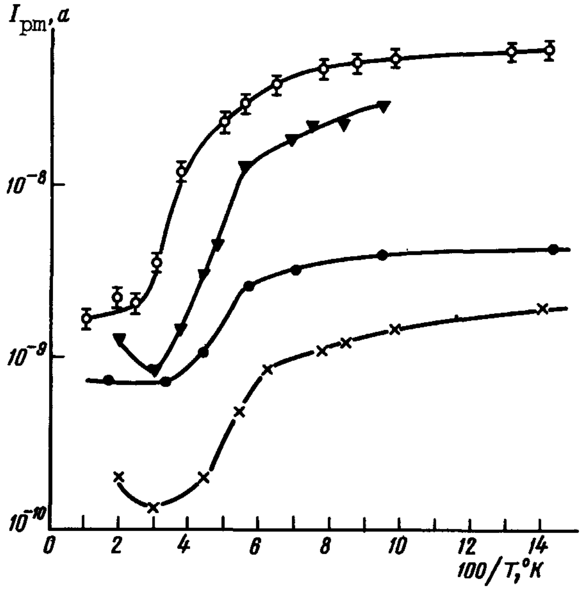

Fig. 1. Temeperature dependences of the short-circuit current for n-InSb samples (o - 1N, ∇ - 2N, • - 3N, × - 4N).

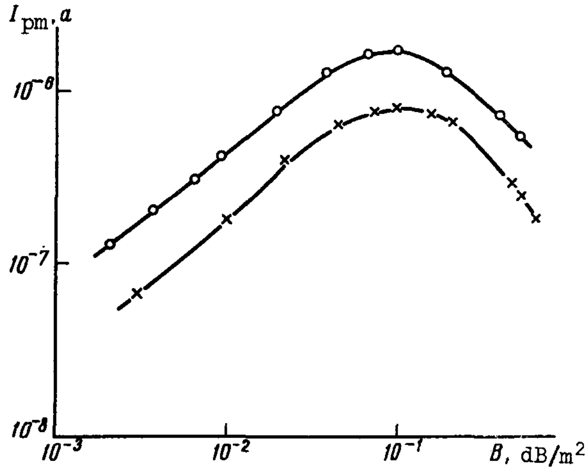

Fig. 2. Dependence of the photomagnetic short-circuit current on the magnetic induction (o - 1N, × - 2N).

In our opinion, the rather abrupt increase of I_{pm} is due to a change in the contribution made to the effect by the high-mobility heated electrons when the temperature is decreased, in accord with (3).

This is also indicated by the results of an investigation of the dependence of I_{pm} on the magnetic field. This dependence is shown for two samples in Fig. 2. It is seen from the figure that surface recombination plays an important role for n-type samples at 7°K and in strong magnetic fields, even if the surface is carefully finished.

T a b l e

	n, cm^{-3}	μ_{nT}, cm^2/V.sec (80°K)	μ_{nT}, cm^2/V.sec (7°K)	μ_{nc}, cm^2/V.sec (7°K)
1N	$8 \cdot 10^{13}$	$2.4 \cdot 10^5$	$4.3 \cdot 10^4$	$1.1 \cdot 10^5$
2N	$4.1 \cdot 10^{14}$	$2.5 \cdot 10^5$	$9 \cdot 10^4$	$9.2 \cdot 10^4$

From the dependence of I_{pm} on H we estimated, by the Kurnik-Zitter method, the mobility of the carriers that take effective part in the photomagnetic effect. The values of the mobility are listed in the table, which gives also the electron mobilities and densities in darkness. As seen from the table, the obtained mobilities are electronic (the hole mobility does not exceed 3×10^4 cm^2/V-sec). The larger value of the photoelectron mobility $\mu_{n\ell}$ in the sample 1N, in which the dark mobility μ_{nd} is smaller than in 2N, is due in our opinion to the lower interelectronic interaction in this sample (the density of the dark electrons is approximately one-fifth that in 2N). Thus, the experimental results are in good qualitative agreement with the theory.

[1] M. A. Habegger and J. J. Fan, Phys. Rev. Lett. 12, 99 (1964).
[2] H. J. Stocker, H. Levinstein, and C. R. Stannard, Phys. Rev. Lett. 12, 163 (1964).
[3] D. N. Nasledov, Yu. G. Popov, Yu. S. Smetannikova, and I. N. Yassievich, Fiz. Tverd. Tela 8, 2853 (1966) [Sov.-Phys.-Solid State
[4] V. F. Elecin and E. A. Manykin, Fiz. Tverd. Tela 8, 2945 (1966) [Sov. Phys.-Solid State 8, 2353 (1967].
[5] H. J. Stocker and H. Kaplan, Phys. Rev. 150, 619 (1966).
[6] D. N. Nasledov, D. G. Popov, and Yu. S. Smetannikova, Fiz. Tverd. Tela 6, 3728 (1964) [Sov. Phys.-Solid State 6, 2989 (1965)].
[7] R. I. Lyagushchenko and I. N. Yassievich, Fiz. Tverd. Tela 9, No. 12 (1967).

SPECTRA OF CALCIUM IONS Ca XV AND Ca XVI OBTAINED BY FOCUSING LASER EMISSION ON A TARGET

N. G. Basov, V. A. Boiko, Yu. P. Voinov, E. Ya. Kononov, S. L. Mandel'shtam, and G. V. Sklizkov
P. N. Lebedev Physics Institute, USSR Academy of Sciences

Submitted 13 July 1967; resubmitted 14 September 1967
ZhETF Pis'ma 6, No. 9, 849-851 (1 November 1967)

It was shown in [1] that when a laser giant pulse is focused on a solid target in vacuum, a dense high-temperature plasma is produced and contains multiply-ionized atoms of the target material, which emits an intense line spectrum in the vacuum-ultraviolet region. In particular, the lines Ca XIII and Ca XIV were obtained and identified.

By improving the conditions for the focusing of the laser emission (energy 10 J, duration 15 nsec at half-height), we succeeded in obtaining spectrograms in which a number of lines were identified as belonging to Ca XV and Ca XVI. These lines, like the previously-considered Ca XIII and Ca XIV lines, are due to transitions of the type $2s^2 2p^n - 2s2p^{n+1}$, where n = 4, 3, 2, and 1 for Ca XIII, Ca XIV, Ca XV, and Ca XVI, respectively, and lie in the interval 120 - 240 Å.

The fact that the Ca XV spectrum was obtained in the laboratory is of considerable astrophysical interest. The intense yellow corona line λ = 4694 Å is interpreted as a forbidden magnetic-dipole transition between the fine-structure components $^3P_0$ - $^3P_1$ of the ground state of the Ca XV ion [2]. This interpretation is based on extrapolating the corresponding terms in the isoelectronic series, and is not universally accepted to date. The λ = 5694 Å line does not always appear in the spectrum of the corona, characterizing apparently very hot condensations, and a reliable identification of this line is very important for the interpretation of these observations. By obtaining under laboratory conditions the resonance Ca XV lines, which are located in the vacuum region of the spectrum, it is possible to measure directly the splitting of the ^3P term. We are presently measuring the obtained spectrograms, and the preliminary results do not contradict the assumed interpretation that the λ = 5694 Å line is the $^3P_0$ - $^3P_1$ line of Ca XV.