Photo-emf induced by a photon pulse accompanying optical transitions between Landau levels

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The resonance, alternating photo-emf accompanying optical transitions between Landau levels is observed experimentally for the first time in electron-type indium antimonide. The effect arises due to selective, with respect to the direction of the velocities, photo-excitation of electrons and the difference between their momentum-relaxation times in different Landau levels.

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The appearance of light-induced drift of particles, assuming that their scattering in the buffer medium is different in the excited and unexcited states, was first predicted theoretically in Ref. 1. An analogous phenomenon, namely, the appearance of a photocurrent (or photo-emf) in semiconductors accompanying optical transitions of electrons between Landau levels, was predicted in Refs. 2 and 3. The essence of this effect lies in the selective excitation of electrons due to the Doppler effect and the difference between their mobilities in different Landau levels.

We performed experiments on the observation of this effect under cyclotron resonance conditions. The specimen, nondegenerate indium antimonide, was placed in a cryostat at $T = 4.2$ K between the poles of an electromagnet. A submillimeter laser with radiation wavelength $\lambda = 119$ μm served as a source of radiation. The radiation was brought up to the specimen along a metallic light guide and was incident on the specimen [(211) plane] at an angle of $\sim 30°$ to the surface. The magnetic field was oriented parallel to the plane of the specimen. In this geometry, with uniform illumination of the specimen, the surface has no emf associated with the inhomogeneous absorption of radiation in the volume of the specimen.

The signal induced by the component of the photon pulse along the direction of the magnetic field $K_{\parallel}$ was extracted from the contacts, as shown in Fig. 1. To eliminate the background illumination from the thermal parts of the cryostat, the specimen was covered with black polyethylene, and the contacts were protected from being illuminated by the laser radiation. A polarizer was placed in front of the specimen in such a way that the electric field vector of the radiation incident on the specimen was parallel to the surface; this eliminated the possible emf associated with the surface photovoltaic effect.[4] The energy spacing between Landau levels under the fixed frequency of the laser radiation was adjusted by a magnetic field. The emf signal was measured with an amplifier with a synchronous detector while modulating the laser radiation with a frequency of 500 Hz.

While measuring the magnetic field in the region of the cyclotron resonance, the emf indicated in Fig. 1 appeared. The sign of the emf changes with passage through

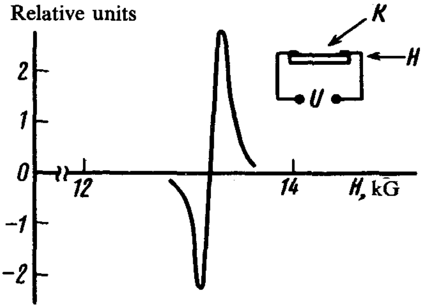

FIG. 1. Dependence of the photo-emf on the magnetic field in the region of the cyclotron resonance.

the point of the cyclotron resonance $H_c = \omega_0 m^* c/e$ (ω_0 is the frequency of the incident radiation, and m^* is the effective mass of electrons).

With a change in the direction of the incident radiation, when the component of the photon momentum along the magnetic field $K_{\|}$ changes sign, the polarity of the photo–emf being studied changes. It was established that at $H < H_c$ the electron drift occurs in the opposite direction to the orientation of the incident radiation, while at $H > H_c$ the electron drift occurs in the same direction. This behavior of the photo-emf can be explained by the fact that the relaxation time in the upper Landau level is shorter than in the lower level.

Although in our case the collisional width of the transition exceeds the Doppler width by more than an order of magnitude, at $H > H_c$ the transitions of electrons with momenta oriented opposite to $K_{\|}$, nevertheless, occur with higher probabiity. In this case, the resulting flux of electrons is determined by the uncompensated electrons with momenta along the direction $K_{\|}$ in the lower Landau level, where the momentum relaxation time is greater. At $H < H_c$, the electrons with momenta along the direction $K_{\|}$ are predominantly excited and electrons in the lower level with momenta opposite to $K_{\|}$ make the main contribution to the emf, which leads to a change in the polarity of the emf.

The rather high peak to the right of the cyclotron resonance is apparently due to the usual entrainment effect, symmetrical relative to detuning of the magnetic field from the cyclotron resonance field.

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[1]F. Kh. Gel'mukhanov and A. M. Shalagin, Pis'ma Zh. Eksp. Teor. Fiz. **29**, 773 (1979) [JETP Lett. **29**, 711 (1979)].

[2]É. M. Skok and A. M. Shalagin, Pis'ma Zh. Eksp. Teor. Fiz. **32**, 201 (1980) [JETP Lett. **32**, 184 (1980)].

[3]A. M. Dykhne, V. A. Roslyakov, and A. N. Starostin, Dokl. Akad. Nauk SSR **254**, 599 (1980) [Sov. Phys. Dokl. **25**, 741 (1980)].

[4]V. L. Al'perovich, V. I. Belinisher, V. N. Novikov, and A. S. Terekhov, Pis'ma Zh. Eksp. Teor. Fiz. **31**, 581 (1980) [JETP Lett. **31**, 546 (1980)].

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