The observed effect may be useful in the investigation of the nature of local fields and the differences between them in the domain boundary and in the domain, and also in the development of a number of technical devices. The authors are grateful to A.G. Lesnik and V.F. Taborov for a useful discussion of the experimental data.

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ELECTROMAGNETIC GENERATION OF SOUND IN Bi

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In experiments on electromagnetic excitation of sound in Bi single crystals placed in a constant magnetic field $H_0 < 100$ Oe, there was observed a significant temperature dependence of the amplitude of the acoustic resonances at helium temperatures [1, 2]. Since no excitation of sound was observed at all in ordinary metals under these conditions, it can be assumed that the effect is due to the specific features of the electronic spectrum of bismuth. The sound generation can be described by the action of the ponderomotive force $\vec{F}_n = c^{-1}\vec{j} \times \vec{H}_0$. However, the distinguishing features of the structure of the Fermi surface do not come into play in this case, since the effectiveness of this mechanism in the case of a skin layer that is thin compared with the length of the acoustic wave depends only on H_0 and on the total skin current, i.e., the amplitude H(0) of the electromagnetic wave incident on the sample. We analyze below another mechanism, which is sensitive to the electronic spectrum of the system.

The Fermi surface of semimetals consists of electronic and hole "valleys," the distance between which in p-space greatly exceeds their dimensions. The electromagnetic field disturbs the equilibrium in the system - both inside each valley and between the valleys. The latter means that the concentrations of electrons belonging to different valleys can vary (with the entire system remaining electrically neutral). This non-equilibrium behavior, peculiar to semimetals, is connected with the occurrence of carrier-density gradients and gives rise to a number of essential singularities in the electric conductivity and in the skin effect [3, 4]. Owing to the thermodynamic non-equilibrium of the system, there should arise also volume forces that deform the lattice. These in fact are the well-known deformation forces

$$\mathbf{F}_g = \sum_{\alpha=1}^{N} \vec{\nabla} \int d\tau_p \hat{\lambda}^\alpha f^\alpha$$

($\hat{\lambda}^\alpha$ is the deformation potential of the α-th valley, f^α is its distribution function, and $d\tau_p = (2/h^3)d^3p$); these forces were obtained by Kontorovich [5].

In ordinary metals with a singly-connected Fermi surface (H = 1), F_g is determined only by the p-dependent part $\lambda = \lambda_1(p)$, since $\vec{\nabla}^g \int d\tau_p f = \vec{\nabla} n = \vec{\nabla} n_1 = 0$ by virtue of the electroneutrality ($n = n_0 + n_1$, where n_1 is the deviation of the electron density from the equilibrium value n_0). The distinguishing feature of semimetals is expressed in the fact that, owing to the occurrence of

$\vec{\nabla} n_1^\alpha \neq 0$, the main contribution to F_g is made by the p-independent parts $\hat{\lambda}^\alpha = \hat{\lambda}_0^\alpha$ ($F_g = \sum_\alpha \lambda_0^\alpha \vec{\nabla} n_1^\alpha$ at $\sum_\alpha n_1^\alpha = 0$)[1]. It is also known that λ^α is the order of the width of the overlapping bands.

To estimate the deformation excitation of the sound in semimetals, it is necessary to find $\vec{\nabla} n_1^\alpha$. The latter depends on the anisotropy of the conductivity tensor of the α-th valley; calculations of n_1^α in different cases have been made in [3, 4]. We present here approximate estimates for the case when the anisotropy of the conductivity is due mainly to the presence of a strong magnetic field parallel to the surface of the metal (for Bi a field $H_0 \sim 10 - 100$ Oe is strong, since $\Omega\tau = \gamma^{-1} >> 1$, where Ω is the cyclotron frequency and τ is the intravalley relaxation time). The principal aspect of the situation can be described here by the simplest model, wherein the Fermi surface consists of electron and hole spheres, the transitions between which require a long recombination time $T >> \tau$.

In crossed alternating electric and magnetic fields E and H_0, the change of the concentration at the boundary is produced by the drift flux of the electrons and holes, equal to $n_0 cE/H_0$ (in the case $\hat{\gamma} << 1$). The appearance of concentration gradients hinder the diffusion flux $\hat{D}\vec{\nabla} n_1$ ($D \sim (1/3)\tau v_F^2 \gamma^2$ is the coefficient of diffusion in a direction perpendicular to H_0) and the direct intervalley transitions. The continuity equation can be written in the form

$$\frac{d}{dz}\left(D\frac{dn_1}{dz} - \frac{n_0 c}{H_0}E\right) = \frac{n_1}{T} \quad \text{or} \quad \frac{d^2 n_1}{dz^2} - \frac{n_1}{L^2} = \frac{3en_0}{2\epsilon_F \gamma}\frac{dE}{dz} \tag{1}$$

$L = \sqrt{DT} \sim (v_F/\Omega)\sqrt{T/\tau}$ is the intervalley diffusion length. The redistribution of the concentrations, generally speaking, changes the value of the surface impedance [4], i.e., the effective depth of penetration of the field E. But here we confine ourselves to the case when the field E attenuates mainly over a depth δ, something realized when $\delta >> L$. Then we can leave out d^2n_1/dz^2 from (1), and obtain for n_1 an estimate independent of the boundary conditions:

$$n_1 \sim L^2 \frac{en_0}{\delta \epsilon_F \gamma} E. \tag{2}$$

We then use the deformation force in (2) in the equation of motion of the elastic medium. The boundary condition for a surface that is not fixed is [5]

$$\rho s^2 \frac{du}{dz}\bigg|_{z=0} = \Lambda n_1(0)$$

(ρ - density, s - speed of sound, Λ - sum of deformation potentials of the electrons and holes). Leaving out the simple intermediate steps, we present the result for the amplitude of the sound wave in the interior of the crystal:

$$u_g \sim \frac{\Lambda}{\epsilon_F}\frac{T}{\tau} l^2 \frac{\omega}{s}\frac{H_0 H(0)}{4\pi\rho s^2}, \quad l = v_F\tau. \tag{3}$$

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[1]) Analysis shows that the part of F_g due to $\hat{\lambda}_1^\alpha(p)$ gives a much smaller contribution to the excitation of the sound - practically the same as at N = 1.

For comparison we note that

$$\frac{u_g}{u_n} \sim \frac{\Lambda}{\epsilon_F}\left(\frac{\omega L}{s\gamma}\right)^2$$

(u_n is the amplitude of the wave produced under the action of the ponderomotive force). In Bi we have $\Lambda/\epsilon_F \sim 100$ [6], and at helium temperatures and $\omega \sim 10^7$ Hz and $H_0 \sim 100$ Oe we have $\omega L/s\gamma \sim 1$. Consequently, under these conditions (corresponding to the experimental conditions in [1, 2]), the main mechanism of excitation of sound is the deformation mechanism. The amplitude of the acoustic resonance, which is proportional to u_g^2, should vary like H_0^2, and its temperature dependence is determined by the temperature variation of the quantity τ^2T^2. Since violation of the equilibrium distribution of the electrons between the valleys is possible only if $T >> \tau$, the mechanism in question can appear only at temperatures where the momentum of the thermal phonon is much smaller than the intervalley distance in p-space. For Bi, these temperatures are $<< 30°K$.

As noted above, the redistribution of the carriers can occur in the absence of a constant magnetic field, provided the conductivities of the electrons of individual valleys are anisotropic. In this case, however, the amplitude of the excited sound depends strongly on the anisotropy of the electron spectrum and is much smaller in value. A detailed calculation and analysis of the experimental data will be published separately.

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UPPER LIMITS OF LUMINOSITY OF CERTAIN EXTRAGALACTIC OBJECTS IN THE HARD γ-RAY REGION

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In recent investigations of certain extragalactic objects (nuclei of Seyfert and N galaxies, quasars), unexpected important results were obtained. In particular, intense infrared radiation of a number of sources was discovered [1, 2], and their variability in the optical and radio bands was observed [3]. A study of the processes occurring in such objects is of great interest both for the understanding of the physics of the processes and for the elucidation of the role of these objects in cosmology, particularly their contribution to the background metagalactic electromagnetic radiation in different energy bands. Information concerning the radiation of such sources in the hard γ-ray band