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CONCERNING ONE POSSIBLE MECHANISM OF NEGATIVE CONDUCTIVITY OF THIN FILMS IN A TRANSVERSE QUANTIZING MAGNETIC FIELD

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Submitted 25 October 1967
ZhETF Pis'ma 7, No. 1, 38-41 (15 January 1968)

We consider a thin film placed in crossed electric and magnetic fields. Let the magnetic field be directed along the z axis, perpendicular to the plane of the film, and the electric field along the x axis. The conduction current is due to electron scattering. Scattering changes the potential energy of the electron by $-eE(X_2 - X_1)$ ($X_{1,2} = -L^2 k_{y1,2} + eE/m^*\omega_c^2$ are the coordinates of the center of the electron orbit before and after scattering, respectively; $L = (c\hbar/|e|H)^{1/2}$ is the magnetic radius; $\omega_c = |e|H/m^*c$ is the cyclotron frequency). This change of potential energy can be compensated by the following*: a - transition of the electron to another Landau level, b - absorption of emission of a phonon, c - a combination of processes a and b.

Let us assume that the follwing relations hold**

$$|\omega_0 - M\omega_c| \ll \omega_c, \quad |\omega_0 - M\omega_c| \gg \tau^{-1}, \tag{1}$$

where ω_0 is the limiting frequency of the optical phonons, τ is the relaxation time of the electron in the film, and M is a positive integer.

In addition, we shall assume that the electrons populate only the lower film level and do not go over to higher levels; this occurs when the following inequalities hold [1,2]:

$$\epsilon_0 \gg T, \quad \epsilon_0 \gg |e|\, E L, \quad n < \frac{10}{L_z^3}. \tag{2}$$

Here ϵ_0 is the energy of the first film level, T the temperature in energy units, n_0 the electron density, and L_z the film thickness.

In electric fields $E \ll \hbar\omega_c/|e|L$, which we shall consider, the current due to scattering by the impurities and acoustic phonons is negligibly small (see [2]). We shall therefore take only scattering by optical phonons into account. Since the conduction current is connected with migrations of the center of the electron orbit, we can write in this case

$$j \sim \frac{2\pi e}{\hbar} \sum_{N,\Lambda,q_x,q_y,k_1,k_2} f_N(X_2 - X_1)\,|C_q|^2\,|(\exp iq_x x)_{N\Lambda}|^2 \times$$
$$\times \{(N_0 + 1)\,\delta[eE(X_2 - X_1) + \hbar(\Lambda\omega_c + \omega_0)]\,\delta_{k_{y1},k_{y2}+q_y} -$$
$$- N_0\,\delta[eE(X_2 - X_1) - \hbar(\Lambda\omega_c - \omega_0)]\,\delta_{k_{y1},k_{y2}-q_y}\}, \tag{3}$$

where f_N is the number of electrons on the N-th Landau level, N_0 the number of optical phonons, and $|C_q|^2 \sim q^{-2}$ is the square of the matrix element [3].

Since $|(\exp iq_x x)_{N\Lambda}|^2$ is exponentially small when q_y is large (when $q_y > L^{-1}$) (see [2]), it can be seen from (3) that, owing to the first inequality of (1), the main contribution will be made by processes in which an optical phonon is absorbed and the electron goes over simultaneously from the zeroth to the M-th Landau level, and also processes in which an optical phonon is emitted and the electron goes from the M-th to the zeroth level.

If

$$f_0 N_0 \gg f_M(N_0 + 1), \tag{4}$$

then the contribution of processes in which phonons are emitted can be neglected. We then obtain

$$j \sim -\frac{2\pi e}{\hbar} f_0 N_0 \sum_{q_x, q_y, k_1, k_2} (X_2 - X_1)\,|C_q|^2 |(\exp iq_x x)_{0M}|^2 \times \\ \times \delta\,[eE(X_2 - X_1) - \hbar(M\omega_c - \omega_0)]\,\delta_{k_{y1}, k_{y2} - q_y}. \tag{5}$$

Summing in (5) over k_{y1}, k_{y2}, q_y, and q_x we obtain for M = 1

$$j = \frac{\pi^{3/2}}{\sqrt{2}} \frac{f_0 \hbar^2 \omega_0(\omega_c - \omega_0)}{eE^2 L \tau_{op}} \exp\left[-\frac{\hbar^2(\omega_c - \omega_0)^2}{e^2 E^2 L^2}\right]. \tag{6}$$

We have introduced here τ_{op} - a quantity on the order of the relaxation time on optical phonons.

It is seen directly from (6) that when $\omega_0 > \omega_c$ the current is directed against the field, i.e., absolute negative conductivity is obtained.

We note that condition (4) can be satisfied only in the case of non-equilibrium electrons or phonons, for example if $f_0 \gg f_0^{(eq)}$, $f_M \approx f_M^{(eq)}$, and $N_0 \gtrsim 1$ ($f_N^{(eq)}$ is the number of electrons on the N-th Landau level in the state of equilibrium).*** In practice such an electron distribution can be effected by exposing the film to sufficiently intense light of frequency equal to the frequency of transition from the zeroth Landau level in the valence band to the zeroth Landau level in the conduction band.

We call attention to the fact that the applicability of formula (6) is limited by the condition $E \ll \hbar\omega_c/|e|L$ as well as by the relation $E \gg \hbar|e|\tau L$, for when $E \sim \hbar/|e|\tau L$ it is necessary to take into account the broadening of the levels as a result of the collisions. It follows from these inequalities, when (1) is taken into account, that formula (6) is applicable in a sufficiently broad interval of fields.

The author is deeply grateful to A. D. Gladun, E. I. Rashba, and A. S. Tager for a discussion of the work and useful advice.

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* We assume (see [2]) that the electrons do not go from one film level to another.

** Satisfaction of the second condition of (2) was postulated in order to be able to neglect the level broadening by collision (see also the remark made at the end of the article.

*** For equilibrium electrons and phonons $f_0 N_0 \sim f_M(N_0 + 1)$, since $\omega_0 \sim M\omega_c$.

ASYMPTOTIC SU(3) SYMMETRY, CABIBBO ANGLES, AND SUM RULES FOR THE CONSTANTS OF COUPLING BETWEEN PSEUDOSCALAR MESONS AND BARYONS

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ZhETF Pis'ma 7, No. 1, 41-43 (15 January 1968)

We discuss in the present note certain dispersion sum rules for vertex functions. These rules are derived under the following assumptions:

1. The consequences that follow from unbroken SU(3) symmetry are satisfied for the vertex form factors in the asymptotic region of large momentum transfers.

2. The dispersion integrals are saturated by the contribution of the nearest poles in the t-channel. Let us consider the matrix element of the weak hadron current between the states of the baryon octet. Cabibbo [1] advanced the hypothesis that the current operator is of the form

$$J_\mu = V_\mu + A_\mu, \tag{1a}$$

$$J_\mu = \cos\theta(J_\mu^1 + iJ_\mu^2) + \sin\theta(J_\mu^4 + iJ_\mu^5), \tag{1b}$$

where V_μ and A_μ are the vector and axial currents, and the unitary indices i = 1, 2, 4, 5 determine the terms of the current octet with strangeness selection rules $\Delta S = 0, 1$. Determination of the parameters of the theory in accordance with the experimental data yielded the following values [2]:

$$\sin\theta_V = 0.21 \qquad \sin\theta_A = 0.27$$
$$D/D + F = 0.665 \pm 0.018. \tag{2}$$

Recognizing that the leptonic baryon decays used to derive (2) are accompanied by small momentum transfers, we make the following assumption: in the asymptotic region $t \to \infty$ all the form factors $F^\lambda(t)$ of the local current (1a) are described by the three parameters θ_∞, $F_F^\lambda(t)$, and $F_D^\lambda(t)$, where the indices λ = V, A, T, P characterize the spin structure and the values of θ_∞ and D/F can differ from (2). The introduction of the t-dependent Cabibbo angles into the weak-interaction Lagrangian would be equivalent to a nonlocal coupling of the hadron and lepton currents. Unlike (1b), we introduce the angles θ_∞ simply as a method of parametrizing the form factors in the region $t \to \infty$. We shall consider below the "superconverging" dispersion relations

$$\int_0^\infty \mathrm{Im}\, G(t)dt = 0, \tag{3}$$