An estimate of the conductivity σ in the front of the rarefaction wave was obtained by the following methods: 1) estimate of σ from the dynamics of the radial distribution of the magnetic field, under the assumption that the penetration of the rarefaction pulse is described by the diffusion equation; 2) calculation of σ by Ohm's law using data from the electric probes (E_r, E_ϕ) and the azimuthal current density i_ϕ determined from the magnetic signals.

Under optimal conditions, both methods yield a value $\sigma \leq 10^{12}$ sec^{-1} for the conductivity. The classical plasma conductivity under the experimental conditions is 10^{13} - 10^{14} sec^{-1}.

Thus, in a magnetized plasma at $\omega_{He}/\omega_{pl} \simeq 3\times10^{-2}$ there can exist a super-Alfven rarefaction wave that moves across the magnetic field. The penetration of the magnetic-field rarefaction pulse into the plasma has a diffuse character. The anomalously low value of the conductivity in the front indicates that this diffusion is turbulent in nature.

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SINGULARITIES IN THE PROPAGATION OF HELICONS IN n-InSb IN THE QUANTUM LIMIT

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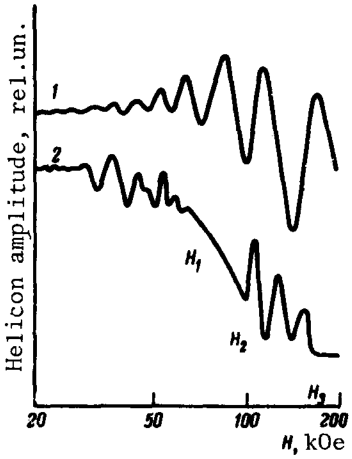
Alternation of regions of transmission and damping of a helicon in n-InSb as a result of variation of the magnetic field was observed in a field up to 200 kOe. The characteristic features of the phenomenon are attributed to singularities in the statistics and electron scattering in the quantum limit.

The propagation of weakly damped electromagnetic waves (helicons) in an electron plasma in semiconductors in quantizing magnetic fields has a number of singularities connected with the complex dependence of the diagonal components of the conductivity tensor on the magnetic field. Under these conditions, Furdyna [1, 2] observed Shubnikov - de Haas oscillations of helicon damping in n-InSb at 4.2°K in fields up to 100 kOe, and has shown, in addition, that in a sample with electron density $n = 1.1\times10^{16}$ cm^{-3} the damping of the helicon increases strongly in fields $\gtrsim$ 35 kOe, owing to the growth of the transverse conductivity in the quantum limit with increasing magnetic field following scattering by ionized impurities in a degenerate electron gas [3]. We have investigated helicon propagation in n-InSb in stronger fields (up to 250 kOe), and observed the qualitatively new effects predicted in [4], namely, the appearance of alternating regions of "transparency" to and "absorption" of helicons.

Physically, these phenomena consist of changes in the character of the dependence of the dissipative conductivity $\sigma_{xx}(H)$ with increasing magnetic field. In a weak magnetic field (but one in which the quantum limit is reached) we have $\sigma_{xx} \sim H$ for degenerate electrons scattered by ionized impurities, so that the condition for weak helicon damping, $\sigma_{xx} < \sigma_{yx} = nec/H$, is violated in a certain field H determined by the condition $\sigma_{xx}(H_1) \sim \sigma_{yx} = nec/H_1$, and in fields $H > H_1$ the helicon is strongly damped. Further increase of the magnetic field lifts the degeneracy [5] (this is aided by the effect of magnetic "freezing" [6]) and leads to a dependence $\sigma_{xx} \sim H^{-2}$ [3], which ensures the appearance of a new region of weak helicon damping ($\sigma_{xx} < \sigma_{yx}$) in fields $H > H_2$, where H is determined by the condition $\sigma_{xx}(H_2) \sim \sigma_{yx} = nec/H_c$. In still stronger fields, the helicon damping can increase again (see below).

The experiments were performed at 32 GHz by an interferometer procedure at 32 GHz similar to that described in [1]. The figure shows the experimental results on helicons passing through n-InSb samples with electron density $n = 2\times10^{16}$ cm^{-3} at 78°K and 4.2°K. Unlike the interference pattern obtained at 78°K, the pattern at 4.2°K shows clearly the alternation regions of weak and strong helicon damping. The boundaries of these regions, H_1 = 70 kOe, H_2 = 90 kOe, and H_3 = 160 kOe, are marked in the figure.



Dependence of the amplitude of a helicon passing through an n-InSb sample 4.6 mm thick on the magnetic field. The electron density is $n = 2\times10^{16}$ cm^{-3}, and the wave frequency is 31.6 GHz. The temperature T is 78°K (1) or 4.2°K (2). Curve 1 was obtained using a Fabry-Perot interferometer, and curve 2 with a more sensitive Rayleigh interferometer system. Curve 2 shows Shubnikov-de Haas oscillations at $H \lesssim 70$ kOe. The monotonic shift of the null signal in both cases is induced by the pulsed magnetic field.

The presence of "cutoff" of the helicons in the field H_1 is due, as already mentioned, to singularities in the scattering of the degenerate electrons by the ionized impurities in the quantum limit. In this case $\sigma_{xx} \sim H$ [3] and the condition for weak helicon damping is violated in a field H_1 given by the relation [4]

$$\Omega(H_1)\tau_{I_0} \equiv \left(\frac{\epsilon_{F_0}\tau_{I_0}}{\hbar}\right)^{3/2} \quad (1)$$

Here $\Omega(H) = eH/m^*c$ is the electron cyclotron frequency, and ϵ_{F_0} and τ_{I_0} are the Fermi energy and the momentum relaxation time of the electrons at $H = 0$. An estimate using (1) yields for n-InSb a value $H_1 \sim 80$ kOe at an electron density 2×10^{16} cm^{-3}. This estimate agrees well with the experimental value of the magnetic field H_1 corresponding to the start of the "opacity" region.

Estimates show that the degeneracy is lifted in a magnetic field ~ 100 kOe at a density 2×10^{-16} cm^{-3}. In the field H_2, determined by the relation

$$\Omega(H_2)\tau_I \cong 2 \quad (2)$$

the condition for weak damping of the helicon begins to be satisfied. Here $\tau_I \sim 1/n(H)$ is the time of momentum relaxation of the nondegenerate electrons on the ionized impurities. Estimates based on (2) (without allowance for the magnetic "freezing" of the electrons, which, as shown in [7], starts in a field ~ 130 kOe), yields $H_2 \sim 100$ kOe for n-InSb with electron density 2×10^{16} cm^{-3}, which agrees with the experimental value of the magnetic field H_2, corresponding to the start of a new "transparency" region.

In magnetic fields $H > H_2$ the conductivity σ_{xx} decreases until the decisive role is assumed by the transverse conductivity due to the high-temperature scattering of the nondegenerate electrons by acoustic phonons, a conductivity independent of the magnetic field. In the latter case $\sigma_{xx} \sim H^0$ [3] and in the field H_3 defined by the relation [4]

$$\Omega(H_3)\tau_{ph} \cong \left[\frac{\hbar\Omega(H_3)}{2kT}\right]\Lambda \quad (3)$$

the condition for weak helicon damping should be violated anew. In [3], τ_{ph} is the time of relaxation of the electron momentum by the acoustic phonons, and Λ is the "cutoff" logarithm. An estimate based on formula (3) yields $H_3 \sim 1000$ kOe.[1)] Thus, one cannot expect a strong helicon damping in the considered mechanism. It is possible, nevertheless, to observe the growth of helicon damping in our region of magnetic fields (corresponding to the field H_3 in the figure). Quantitative estimates of this phenomenon are in satisfactory agreement with the experimental results.

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[1)] In such a field, the scattering by acoustic phonons is already of the low-temperature type [8], and relation (3) does not hold. A detailed analysis shows that $\sigma_{xx} \sim \sigma_{yx}$ is unattainable in scattering of nondegenerate electrons by acoustic phonons in n-InSb. One cannot exclude the possibility that under our conditions it is necessary to take into account scattering for point deffects; for this scattering we also have $\sigma_{xx} \sim H^0$ in the quantum limit [3].

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MEASUREMENT OF THE PERTURBATION OF ATOMIC LEVELS BY INTENSE LIGHT USING THE PROCESS OF RESONANT MULTIPHOTON IONIZATION

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A new method is proposed for measuring the Stark shift of high atomic levels in a strong optical field. The method is based on observing resonant multiphoton ionization of the atom. The multiphoton ionization of the 2^3S metastable state of the helium atom is investigated, and the values of the Stark shift are obtained for a number of levels.

The possibilities of investigating the perturbation of atomic levels in an optical field have been greatly expanded of late. In the experimental domain, this is due to the development of high-power lasers, which make it possible to observe the perturbations in a strong field [1]; theoretically, this is made possible by exact knowledge of the electron wave functions in a complex atom and by the development of various new computation methods, which make it possible to calculate the dynamic polarizability of atoms [2]. The fundamental circumstance in this case is that sufficiently high level can be excited in an optical field only as a result of multiphoton transitions, the probability of which is high enough only if the field intensity is high enough. Typical of such excited levels is the large probability of the induced transition to a high-energy state, when compared with the probability of spontaneous relaxation. Under these conditions no classical method, whether emission spectroscopy or absorption of auxiliary light, makes it possible to observe the perturbation of the levels. We have developed a new method of measuring the perturbation of such states; this method is based on observing resonant multiphoton ionization of the atom.

Within the framework of perturbation theory, the probability of multiphoton ionization of an atom is connected with the radiation intensity F by the relation [3]

$$W(F) = A(F)\,F^{k_0} = \mathrm{const}\left|\sum_{\ell_1 \ldots i \ldots n} \frac{\langle f|r|\ell\rangle \ldots\ldots \langle n|r|0\rangle}{\ldots[E_i(F) - E_0(F) - k\hbar\omega - i\gamma_i(F)]\ldots}\right|^2 F^{k_0}, \quad (1)$$

where $k_0 = \langle (I/\hbar\omega) + 1\rangle$; I is the ionization potential of the atom; $k < k_0$; r is the electron coordinate; $E_i(F)$ and $\gamma_i(F)$ are the energy and width of the i-th level in the radiation field.

If the energy of a certain number $k < k_0$ of quanta coincides with the energy $E_i(F)$ of some atomic level, the dependence of the multiphoton-ionization probability on the light intensity has a typically resonant character and contains information on the shift and broadening of the resonant state in the light field [4]. We shall henceforth assume for simplicity that only one level is at resonance [5]. In this case, the corresponding energy denominator in expression (1) is much smaller than all the remaining ones, we can neglect all but the resonant term in the summation, and (1) goes over into

$$W(F) = \mathrm{const}\,\frac{F^{k_0}}{[E_i(F) - E_0(F) - k\hbar\omega]^2 + \gamma_i^2(F)}. \quad (2)$$