atoms does indeed not cause a shift of the absorption band in the spectra. The exceptional similarity between the details of the complex IR spectra of the germanium dichalcogenides indicates that their crystals are isostructural [2, 3].

The spectra of the mono- and dichalcogenides of germanium differ substantially both in form and in the position of the most intense vibrational absorption bands. For example, in GeS these bands lie in the range from 285 to 235 cm^{-1}, whereas the main band of GeS_2 lies in the region of 370 cm^{-1}. At the same time, an appreciable change takes place in the mean interatomic distances, from 2.58 Å for GeS to 2.15 Å for GeS_2. This indicates a change in the character and in the binding forces between the S^{2-} and Ge^{2+} or Ge^{4+} ions. In particular [5], the IR spectra of amorphous films evaporated from crystalline GeS possesses only a band with maximum at 370 cm^{-1}, which is produced when there are bonds between the S^{2-} and Ge^{4+} ions; this band is transformed into the complex band of GeS only after the film becomes crystallized. However, when amorphous films are evaporated from GeS_2 and $GeSe_2$ crystals, the characteristic and most intense band of these compounds appears immediately. The Ge^{4+} ion apparently plays a special role in the formation of the crystal structures of germanium chalcogenides. This is evidenced, in particular, by the coincidence of the positions of the weak high-frequency absorption bands of GeS and GeSe with the positions of the most intense bands in the spectra of GeS_2 and $GeSe_2$.

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CYCLOTRON RESONANCE ON NON-EXTREMAL ORBITS

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A new phenomenon - cyclotron resonance on non-extremal orbits - was observed at the limit of the cyclotron-frequency spectrum. This limit was produced artificially by adjusting the sample thickness to cut off the orbits of electrons belonging to Fermi-surface thicknesses larger than a certain limit. The phenomenon, observed in bismuth at ~9 GHz and 0.35°K, uncovers a possibility of investigating the properties of electrons belonging to non-extremal sections of the Fermi surface.

All methods used to investigate the dynamics of definite groups of metal conduction electrons, based on the use of cyclotron resonance (CR), quantum oscillations, size effects, etc., yield information only on the electrons belonging to extremal sections of the Fermi surface (FS). In the case of a convex FS (Fig. 1a), these are the central section and the limiting point, corresponding to the extremal values of the effective mass m* and of the cyclotron frequency $\Omega = eH/m^*c$ (Fig. 1b). The only known possibility, in principle, of investigating the properties of electrons belonging to intermediate sections of the FS is to use quantum CR [1], which should occur at the discrete intermediate frequencies that result from the breakup by the $\Omega(p_y)$ spectrum of the Landau

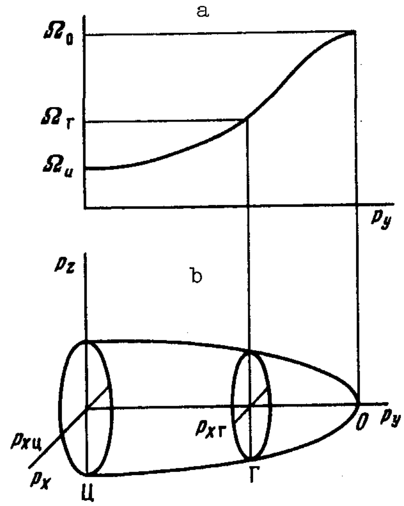

Fig. 1

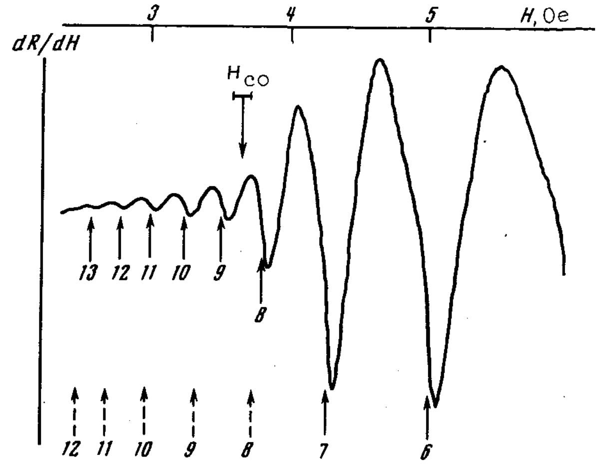

Fig. 2. CR spectrum of bismuth single crystal 190 μ thick, $\vec{H} \parallel C_2 \perp \vec{E}$, $\vec{k} \parallel C_3$, f = 9.14 GHz. The numbers under the curve indicate the order of the observed CR. H_{co} is the CR cutoff field calculated from the momentum of the electrons of the FS central section [7]. The lower part of the figure shows the calculated positions of the CR lines on the central section of the FS.

quantum level. The extremely stringent resolution conditions, however, make it impossible to observe quantum CR on samples of quality attainable at the present time.

We describe in this communication the nature and the first experiments aimed at the observation of a new effect, namely cyclotron resonance on non-extremal orbits. This effect permits the study of electrons belonging to intermediate FS sections.

We consider electron motion in a flat metallic plate of thickness d_z, placed in a magnetic field $H = H_y$ parallel to its surface (x, y). The electron trajectory diameters are equal to $D_z = 2p_x c/eH$, where $2p_x$ are the diameters of the corresponding FS sections. If D_{zc}, the diameter of the central section, exceeds d_z, then cutoff of the CR takes place [2] and motion without collision with the metal surface is possible only for electrons belonging to the sections of the part of the FS from the limiting point L to the boundary section B (Fig. 1) determined by the equation $D_{zb} = d_z$. Thus, an artificial boundary $\Omega_b(p_{yb})$, on which classical CR is possible, is produced in the $\Omega(p_y)$ spectrum (Fig. 1b). The amplitude of this CR on a non-extremal orbit should be smaller than the CR on the central section, owing to the relative smallness of the state density. Taking into account the existence of specular CR [3], it should be noted that observation of CR on a non-extremal orbit requires that the volume relaxation time of the electrons greatly exceed the surface time.

A direct result of the study of CR on non-extremal orbits is the determination of the $m^*(p_x)$ dependence. The fact that the electrons of the non-central sections have a Fermi-velocity component v_H parallel to $\vec{H}$ leads to a Doppler splitting (or shift) of the resonances when the field $\vec{H}$ is inclined to the surface of the sample; measurement of this effect for a known FS makes it possible to find the distribution of the high-frequency field in the metal [4].

The experiments aimed at observing CR on non-extremal orbits were performed on thin flat bismuth single crystals grown in a quartz mold [5]. Figure 2 shows a plot obtained for an experiment of thickness d_z = 190 μ, with the trigonal axis normal to the sample surface. The frequency of the measuring field was $f = \omega/2\pi$ = 9.14 GHz and the sample temperature was 0.35°K. The sample quality is characterized by the parameter $\omega\tau$ = 85 - 90 (τ is the relaxation time). The recorded dR/dH signal was obtained as a result of the H-dependence of the amplitude of the signal of frequency ω from a self-oscillator containing a resonator with the sample in the feedback loop.

If the field exceeds the cutoff value, $H > H_{co} = 2p_{xc}c/ed_z$, the CR of order n = 1 - 8 are observed at the central section of the FS, and are periodic in H^{-1}. At $H < H_{co}$, CR is observed on the non-extremal boundary section (B, Fig. 1), the position of which on the FS is given by $p_{xb} = eHd_z/2c$, under the condition

$$\omega/n = \Omega_b = eH/cm_b^*(p_{xb}),$$

where the order of the resonance is n > 8. The non-extremal CR are weaker than the extremal ones by about one order of magnitude, and their position in the field is not connected with any periodicity whatever. Experiments in which ω was varied and $\vec{H}$ was inclined give results that agree fully with the described features of the phenomenon.

The measurements have shown that the effective mass on the electronic FS of bismuth, for a field parallel to the major axis of the ellipsoid, increases by 8 ± 1% when p_x decreases from p_{xc} to $0.75p_{xc}$.

The observed cyclotron resonance on the non-extremal orbits can be readily found in a number of metals. This effect makes it possible to investigate the properties of these groups of electrons which could not be studied experimentally before.

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