are comparable. This fact, and the assignment of n in Table II, are understandable from the work of Gilman and Johnston on dislocations in LiF, in which it was shown that dislocations introduced by quenching were in the form of individual loops, while mechanical deformation produced slip bands of thousands of dislocations. It should also be pointed out that the increase of scattering due to the alignment of dislocations in slip planes is of quite a different nature than that proposed by Klemens,[12] since the effective phonon wavelength is considerably less than the mean interdislocation distance $\sigma^{-\frac{1}{2}}$.

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[14]$V_y < b$ for $R/r_0 < 1000$. For metals with $\sigma \sim 10^{11}$ cm^{-2}, $R \sim \sigma^{-\frac{1}{2}} \sim 50 r_0$.

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De HAAS–van ALPHEN TYPE OSCILLATIONS IN THE INFRARED TRANSMISSION OF BISMUTH

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We have found that single crystals of pure bismuth show a pass band for radiation between approximately 20 and 50 microns. A transmission spectrum for a crystal 4×10^{-3} cm thick at 2°K is shown in Fig. 1. The end of the pass band at long wavelength in the region of 55 microns is associated with the plasma frequencies and has been discussed previously in relation to reflection type experiments.[1] In this note we shall discuss only the measurements that have been made in the short-wavelength region of the pass band. The most striking feature that we observe here is a magneto-oscillatory transmission coefficient which is periodic in $1/H$. This property is shown in Fig. 2 which is a reproduction of the recorder trace of the transmitted signal through a crystal. The direction of propagation and the

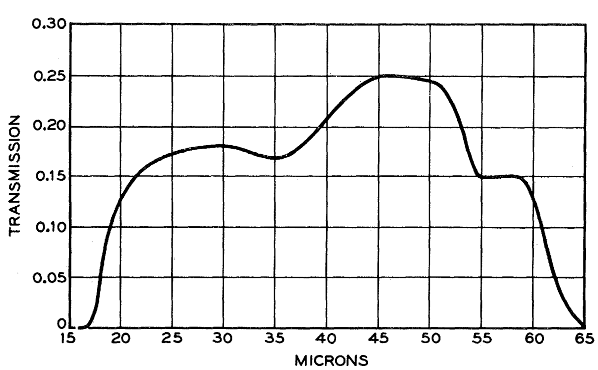

FIG. 1. The infrared transmission of a Bi crystal, 5×10^{-3} cm thick and at 2°K, for propagation along a binary axis.

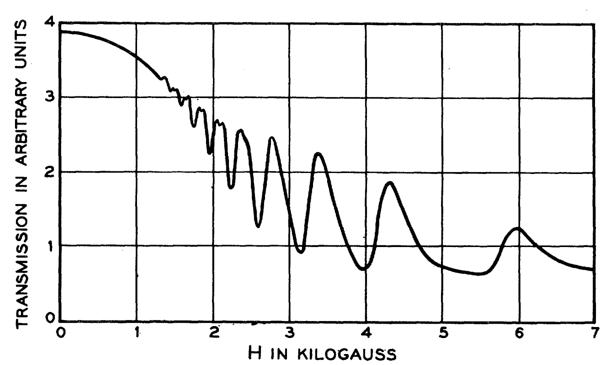

FIG. 2. The field dependence of the transmission coefficient of Bi at 2°K with the direction of propagation and H both along a binary axis of the crystal; $\lambda = 18.7$ microns.

magnetic field were both along a binary axis, the wavelength of the radiation was fixed at 18.7 microns, and the magnetic field increases uniformly from left to right. Measurements made at a fixed magnetic field show no such oscillations as a function of frequency, but rather changes in both the slope and position of the end of the pass band in such a way as to be consistent with the results shown in Fig. 2 where the magnetic field is the variable.

The experimental conditions necessary to observe the results shown in Fig. 2, though readily reproduced, are critically dependent on both the orientation and perfection of the sample. A misorientation of 3° splits the pattern into two separate sets of oscillations which are difficult to resolve at low fields. The doublet structure at small fields which appears in Fig. 2 is due, in fact, to just such a small misorientation, in this case, of less than 0.5°. We have also found that unless the samples were heavily etched to remove strain, all of the oscillatory effects were absent.

The period (in $1/H$) of the oscillations shown in Fig. 2 is such that if we ascribe this effect to the low-mass electron valleys in the conduction band, use a cyclotron mass of $0.01m_0$ and an expression $E_f = (n+\gamma)\hbar\omega_c$ for the positions of the maxima or minima, we obtain a Fermi energy E_f of 0.017 ev. Here γ is a constant phase factor and ω_c is the cyclotron angular frequency eH/m^*c.

The cause of the magneto-oscillations in transmission and the reason for the high-frequency cutoff are elucidated to some extent by experiments performed on samples which have been doped with small quantities of a tin impurity. It has been established previously that this lowers the Fermi energy and so reduces the number of electrons and increases the number of holes. We find that in these tin-alloyed samples, the edge at 20 microns moves to longer wavelengths and the period in $(1/H)$ of the oscillations increases. Using the same value for the cyclotron mass for the low mass of the electrons, we find that the change in the Fermi energy is equal to the shift in energy of the edge of the pass band.

These data can be interpreted in part according to the following model. The zero-field end of the pass band occurs when it becomes energetically possible to excite electrons from a lower lying band or group of discrete states up to the Fermi surface. It must be a transition up to the Fermi surface, rather than from the Fermi surface up to a higher lying state, because of the motion of the edge to longer wavelengths when the Fermi energy is lowered. The position of the edge at 20 microns would set the lower lying states about 0.05 ev below the Fermi surface. The oscillatory absorption then follows as a consequence of the oscillations in the Fermi level produced by the usual magnetic field dependence of the density of states in the low-mass electron band. Brailsford[2] has considered the problem of the motion of the Fermi level with magnetic field in a semimetal like bismuth with overlapping bands. The shape of the oscillations in the Fermi level predicted by this theory and the $1/H$ periodicity agree with the experimental curve shown in Fig. 2. This mechanism does not, however, provide an explanation for the monotonic decrease in transmission with field.

The authors are pleased to acknowledge the help obtained in discussion of the interpretation of these results with A. D. Brailsford and L. C. Hebel.

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