The fact that we were unable to observe the shift of the λ point in a singly-connected loop is the consequence of the effect of quantum closeness. When the linear velocity near the rotation axis is not large enough to disrupt the superfluidity, the ψ function of the Bose condensate penetrates also into those regions in which the linear velocity is in general sufficient to transform the He II into the normal state. The internal cylinder makes it impossible for the ψ function of the s-component to exert any influence on the state of the liquid He in the gap, and consequently makes it possible for the λ point to shift.

Thus, we attained in this experiment a critical velocity ω_{c_2} at which the superfluidity vanishes at a lower temperature than for stationary helium. The presence of a second critical velocity ω_{c_2}, which greatly exceeds the first critical velocity ω_{c_1} at which the first vortex is produced in the superfluid component, allows us to establish a new far reaching analogy between the behavior of rotating superfluid liquids and the behavior of superconductors of the second kind.

As is well known, for such superconductors there exist two critical magnetic fields H_{c_1} and H_{c_2}, corresponding to the occurrence of the first Abrikosov vortex [2] and to the destruction of superconductivity.

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PLASMA RESONANCE ON NONEQUILIBRIUM CARRIERS IN SEMICONDUCTORS

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Observation of plasma resonance on nonequilibrium carriers produced in a semiconductor at exciting-light intensities on the order of 10^{25} quanta/cm^{2}sec under conditions when there is still no damage to the surface of the sample would make it possible to estimate the density Δn of nonequilibrium carriers and the relaxation (scattering) time τ of the carriers from the position and depth of the minimum of the reflection coefficient R; such a minimum is characteristic of plasma resonance. As shown by us in [1], the density of such carriers reaches only about $(3 - 7) \times 10^{19}$ cm^{-3} in Si and GaAs, and accordingly the plasma resonance and the increase of R should be observed in the wavelength region $\lambda = 5 - 10$ μ.

We have investigated the change of the reflection coefficient ΔR at a wavelength $\lambda = 10.6$ μ as a function of the intensity of the exciting light for Ge, Si, and GaAs. The experimental setup is shown in Fig. 1. The use of a Q-switched ruby laser ($t_{pulse} \approx 4 \times 10^{-8}$ sec) to produce non-equilibrium carriers called for the use of a low-inertia infrared receiver (photoresistor of Ge doped with gold) and of a powerful source of probing radiation (CO_2

laser).

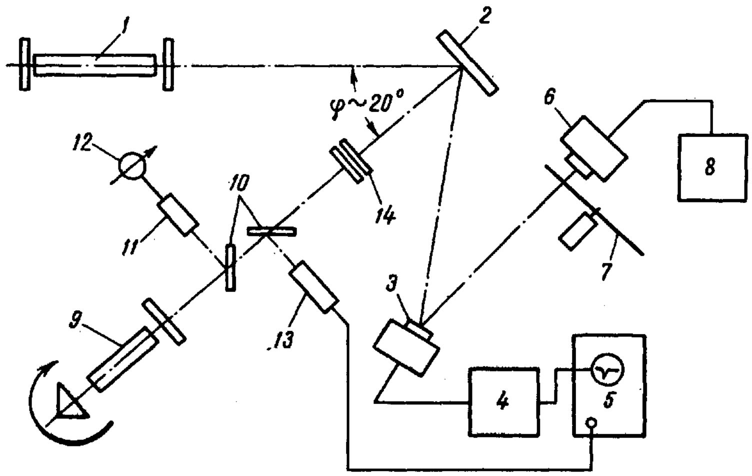

Fig. 1. Block diagram of the setup for measuring ΔR: 1 - CO_2 laser, 2 - sample, 3 - photoresistor for recording ΔR, 4 - broadband amplifier, 5 - S1-11 oscilloscope, 6 - photoresistor for the control of the intensity of the probing radiation, 7 - beam interrupter, 8 - 28IM amplifier, 9 - ruby laser, 10 - plane-parallel glass plates, 11 - calorimeter to monitor the laser-pulse energy, 12 - galvanometer, 13 - multiplier to trigger the oscilloscope, 14 - neutral light filters.

We used undoped samples with polished front surface and ground rear surface, with reflection coefficients that did not depend on the wavelength range $\lambda = 0.7 - 10\ \mu$.

The results of the experiment are shown in Fig. 2. Plots of ΔR against I, meaning also against Δn, for Ge and GeAs show the minima characteristic of plasma resonance; in the case of silicon, no increase of R was observed as yet for the given values of I. This is seen from the oscillograms shown in the insert of Fig. 2. The leading front of the ΔR pulse for Ge and GaAs has a shape characteristic of plasma resonance. The fall-off of the pulse is determined by the inertia of the photoreceiver; this inertia was taken into account in the calculation of the ΔR(I) dependence. (The absolute value of ΔR was determined accurate to ~50%).

To determine the values of the density Δn and the relaxation time τ, we plotted the calculated dependence of R on Δn for different τ, using the following formulas, which describe well the experimental data for doped semiconductors [2]:

$$R = \frac{(\bar{n} - 1)^2 + k^2}{(\bar{n} + 1)^2 + k^2}, \tag{1}$$

$$\bar{n}^2 - k^2 = \epsilon_L - \frac{4\pi \Delta n e^2}{m^*} \frac{\tau^2}{1 + \omega^2 \tau^2}; \quad 2\bar{n}k = \frac{4\pi \Delta n e^2}{m^* \omega} \frac{\tau}{1 + \omega^2 \tau^2}. \tag{2}$$

Here $\bar{n}$ and k are respectively the refractive index and the absorption coefficient, ϵ_L the dielectric constant of the unexcited crystal, ω the angular frequency of the probing radiation, and m^* the combined effective mass

$$m^* = m_e h_e/(m_e + m_h).$$

Formulas (2) were written out for two types of carriers under the assumption that the electrons and holes have the same relaxation time, owing to the predominance of the electron-hole (e-h) scattering [3]. Indeed, regardless of the ratio of the masses m_e and m_h, the electrons and holes lose in e-h scattering the momentum acquired in the field E within the same time τ_{eh} (from the momentum conservation law we have $P_e(E) + P_h(E) = 0$ at any instant of time).

From a comparison of the experimental R(I) curves with the calculated R(Δn) curves we obtained the following values of Δn and $d\tau_{eh}$ at the excitation intensity corresponding to the minimum of R: $\Delta n = 2 \times 10^{19}$ cm^{-3} and $\tau_{eh} = 1 \times 10^{-14}$ sec for Ge, $\Delta n = 0.9 \times 10^{19}$ cm^{-3} and $\tau_{eh} = 2 \times 10^{-14}$ sec for GaAs, and $\Delta n < 2 \times 10^{19}$ cm^{-3} and $\tau_{eh} > 2 \times 10^{-13}$ sec for Si.

The foregoing values of Δn coincide, accurate to 2 - 3, with the values previously obtained from absorption on non-equilibrium carriers [1].

We note that the Conwell-Weisskopf formula, modified for the case of e-h scattering [3] and taking account of the carrier degeneracy [4],

$$\tau_{eh} = 0{,}6\,(\Delta n)^{-1}\epsilon_L^2 e^{-4} m^{*1/2} E_F^{3/2}[\ln(1+16 r_L^2(\Delta n)^{-2/3} e^{-4} E_F^2)]^{-1}, \qquad (3)$$

yields a value $\tau_{eh} \approx 10^{-14}$ sec for Ge and GaAs at densities Δn corresponding to the minimum of R. Here E_F is the energy of the electron or the hole (they are approximately equal and

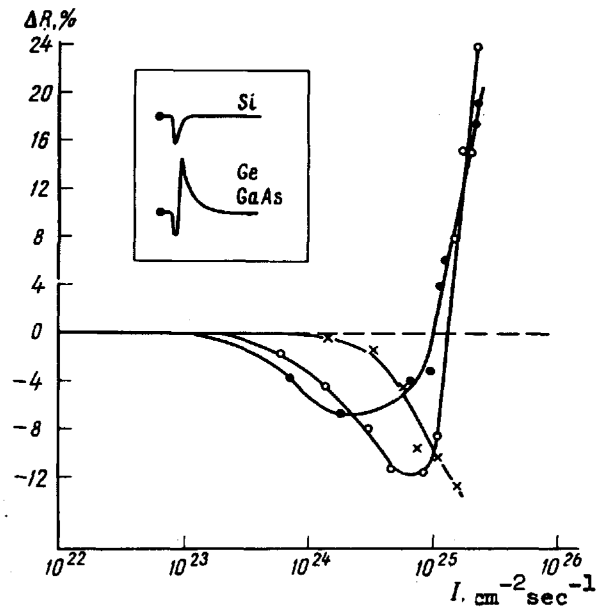

Fig. 2. Plot of ΔR at a probing radiation wavelength 10.6 μ vs. the ruby-laser exciting-light intensity. × × × - Si, ● ● ● - Ge, o o o - GaAs. The insert shows the form of the ΔR oscillograms.

amount to ~0.05 eV) at the Fermi quasilevels. This estimate agrees well with the experimental value of τ_{eh}, although formula (3) is based on the Boltzmann kinetic equation, whose validity creterion $W_k \gg h/\tau$ is not satisfied in our case (W_k - kinetic energy of the carriers).

It should be noted that in the case of intense excitation of the semiconductors by light from a powerful laser ($I \approx 5 \times 10^{25}$ quanta/cm^{2}sec), a sharp increase was observed in their reflection coefficient in the visible part of the spectrum, too [1,5,6]. It was assumed in the cited papers that this effect is due to the high density Δn of the non-equilibrium carriers produced by the photoexcitation. However, as shown in the present paper (and also in [1]), the attained nonequilibrium-carrier density is insufficient for this purpose. An increase of R in the visible region is possible only as a result of the sharp increase (by two orders of magnitude) of the density of the free equilibrium carriers when the surface layer of the crystal is molten. It is no accident that this increase is always accompanied by damage to the surface.

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INTERACTION OF ELECTRONS WITH PARAMAGNETIC IMPURITIES IN SUPERCONDUCTORS

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The problem of the scattering of an electron in a superconductor by a paramagnetic impurity is solved by a dispersion method that employs the unitarity relations and the analytic properties of the scattering amplitude. Such an approach to the problem was already used by Maki [1]. He, in particular, formulated the unitarity conditions. However, as noted by Maki himself, the expressions obtained by him for the scattering amplitudes have incorrect analytic properties (energy pole on the physical sheet). In the present paper we derive an expression for the scattering amplitudes for the particular case of unity spin and zero non-exchange part of the interaction. The obtained solution satisfies the unitarity conditions, has correct analytic properties with respect to the energy, and goes over to the expression for the scattering amplitudes in the normal metal if $|\omega| \gg \Delta$ (ω is the energy reckoned from the Fermi surface and Δ is the gap). With the aid of this expression it is possible to calculate the temperature of the transition into the superconducting state and the gap at zero temperature for a superconductor with a low density of paramagnetic impurities.

It turns out that when the exchange part of the interaction between the electron and the impurity has a negative sign and a certain large characteristic energy ϵ_0 ($\epsilon_0 \gg \Delta$) the transition temperature and the gap increase when the impurities are introduced, rather than decrease as usual [2]. This phenomenon is essentially due to the same cause as the