Thus, we have obtained a model for the interaction of quantized fields with parity *nonconservation, invariant against the algebra* (1)

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POSSIBLE INSTABILITY, DUE TO TRIPLE RECOMBINATION, OF THE STATES OF A SEMICONDUCTOR ILLUMINATED BY INTENSE LIGHT

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1. There are several recent experimental investigations [1 - 3] of the processes occurring in superconductors that have absorbed laser radiation of high intensity. Vavilov and co-workers [1] have shown that at high photoexcitation levels the dominant process is the band-band (triple) or Auger recombination, and determined the coefficient C of this recombination. It turns out here that the experimental value of the coefficient C differs from that calculated in accordance with [4] for silicon by four orders of magnitude, and in addition the temperature dependence predicted in [4] was not observed experimentally.

In this paper we call attention to the fact that at high light intensities the heating of the electrons and holes due to triple recombinations becomes significant. Indeed, the recombining electron gives up an energy on the order of ΔE (ΔE is the width of the forbidden band) to the electron-hole gas, which is characterized by an effective temperature θ larger than the lattice temperature T. We shall show in addition that this heating leads to instability of the stationary state of the semiconductor.

The physical reason of the instability lies in the fact that the probability of triple recombination increases rapidly with temperature θ (like $\exp[-\Delta E/\theta]$). Therefore an increase of θ as a result of recombination heating increases the probability of triple recombination, leading in turn to further increase of the temperature and so on.

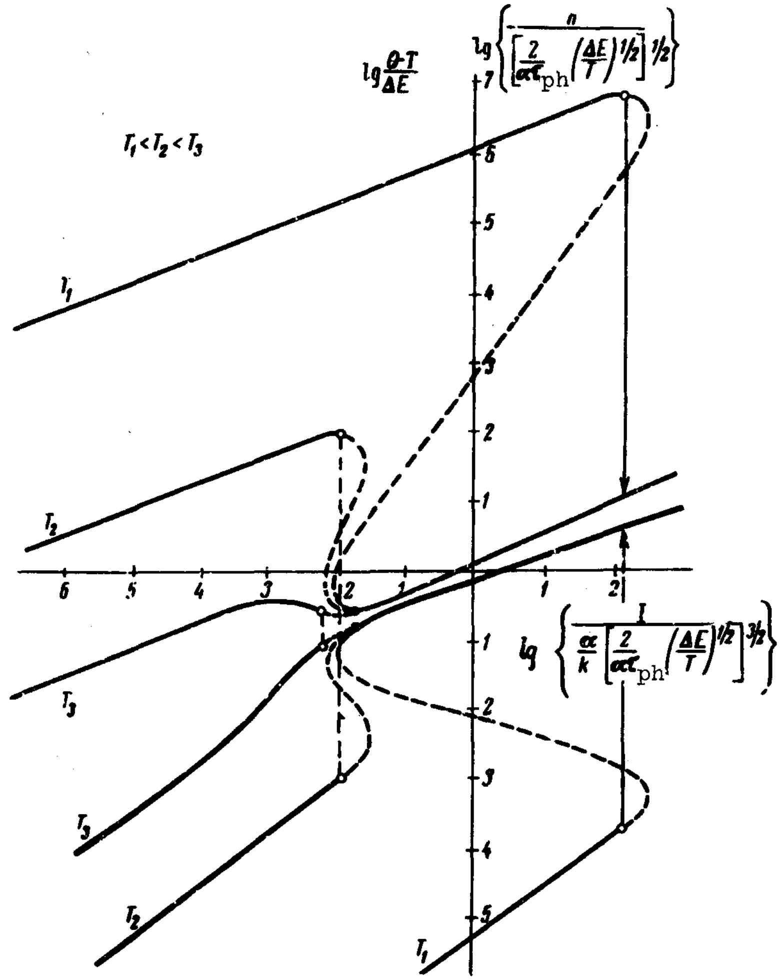
2. We confine ourselves throughout to the simplest two-band model with a quadratic dispersion and equal electron and hole masses. We shall assume that the electrons (holes) are not degenerate and take into account only triple recombination (case of large I).

Let a semiconductor be illuminated by light of intensity I and frequency ω somewhat higher than the width of the forbidden band ($\hbar\omega \gtrsim \Delta E$). Then the system is described by the following equations for the electron density n and the effective temperature θ:

$$\frac{dn}{dt} = Ik - \alpha n^3\left(\frac{\Delta E}{\theta}\right)^{3/2} \exp\{-\Delta E/2\theta\}, \tag{1}$$

$$\frac{3}{2}\frac{d(n\theta)}{dt} = -\frac{\theta - T}{\tau_{ph}}\left(\frac{\theta}{T}\right)^{1/2} n + \frac{\Delta E}{2}\alpha n^3\left(\frac{\Delta E}{\theta}\right)^{3/2} \exp\{-\Delta E/2\theta\}, \tag{2}$$

which are obtained in the usual manner from the kinetic equation. In (1), the



Dependence of the carrier density n and their temperature on the radiation intensity I. The instability region is shown dashed. Thin lines - $\log\{n/[(2/\tau_{ph}\alpha)(\Delta E/T)^{1/2}]^{1/2}\}$. Thick lines - $\log(\theta - T/\Delta E)$.

first term describes the production of conduction-band electrons by absorption of light with an absorption coefficient $k(\omega)$, and the second term is responsible for the impact recombination. The first term of (2) is equal to the rate of energy transfer to the lattice, with the characteristic time τ_{ph}, and the second takes into account the heating of the electron gas as a result of triple recombination. It is assumed in (1) and (2) that the concentration of the non-equilibrium carriers greatly exceeds the concentration of the equilibrium carriers, and the following notation is used:

$$\alpha = \frac{2^4\pi^{5/2}}{3}\,\frac{e^4\hbar^3}{m_e^2\kappa^2}\,|F_1F_2|^2(\Delta E)^{-3} \approx 1.6\cdot 10^{-27}\left(\frac{m_0}{m_e}\right)^2\frac{|F_1F_2|^2}{\kappa^2(\Delta E[\mathrm{eV}])^3},$$

where κ is the dielectric constant and F_1 and F_2 are the overlap integrals of the ψ functions of the conduction and valence bands.

3. The solution of Eqs. (1) and (2) in the stationary state is shown in the figure. It is seen from the figure that at low intensities, when $\theta \simeq T$, n depends on the intensity like $I^{1/3}$. With increasing I, the growth of n slows down. The change of the dependence is connected with the heating of the carriers and is effectively manifest in an increase in the recombination probability, in qualitative agreement with the experimental results [1]. At the same time, the stationary states of the system turn out to be unstable in the

assumed model already at small degrees of superheat.

4. By the usual procedure [5] we find that the system becomes unstable in the temperature region

$$\theta_1 \leqslant \theta \leqslant \theta_2, \text{where } \theta_1 \approx T[1 + 2(T/\Delta E)]; \quad \theta_2 \approx \Delta E/7.$$

The value of the critical intensity of the light (corresponding to $\theta = \theta_1$) is

$$I_1 \approx \frac{a}{k}\left(\frac{2}{a\tau_{ph}}\right)^{3/2}\left(\frac{T}{\Delta E}\right)^{15/4} \exp(\Delta E/4T).$$

An estimate for silicon at $T \approx 300$°K, illuminated with a neodymium laser, gives a value $I_1 \approx 4 \times 10^{24}$ quanta/cm²sec. It is interesting to note that the obtained value is close to the threshold intensity at which destruction of the sample takes place [3].

An analysis of the system of equations (1) and (2) gives grounds for assuming that under certain conditions there is realized a regime in which the density n and the temperature θ experience periodic oscillations.

In conclusion, we are grateful to Yu.A. Bykovskii and V.A. Furmanov for valuable discussions.

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DAMPING OF HIGH FREQUENCY SOUND IN A FERMI-BOSE LIQUID

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With decreasing temperature, solutions of He^3 in He^4 become laminated at an He^3 concentration in the solution $x > 6 \times 10^{-2}$ ($x = n_3/(n_3 + n_4)$, where n_3 and n_4 are the numbers of He^3 and He^4 atoms per unit volume). At $x < 6 \times 10^{-2}$ and $T \ll T_F$, where T_F is the degeneracy temperature of the Fermi component ($T_F = 0.3$°K at $x = 6 \times 10^{-2}$), the solution forms a mixture of Fermi and Bose liquids. We shall henceforth make use of the phenomenological theory of a Fermi-Bose liquid [1, 2]. Calculation shows that the contribution of the phonons to the damping of the sound at $T \ll T_F$ can be neglected in a wide range of concentrations, and then the dissipation is determined by the collisions of the Fermi excitations with one another. In the collisionless region there can propagate in a Fermi-Bose liquid, in general, both first sound (density oscillations) and zero sound, but the available data on the Landau f-function [3] indicates that zero sound experiences a strong Landau damping in the solution.