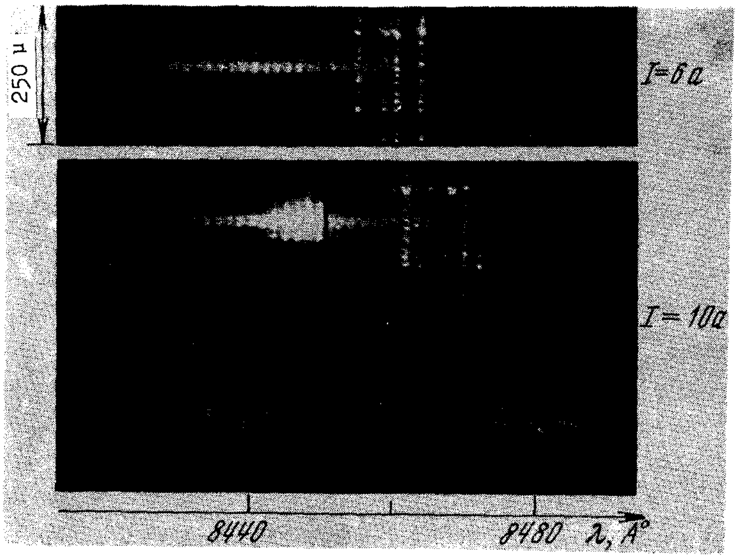

Fig. 2. Spectral-spatial picture of radiation of a diffusion laser diode.

along the p-n junction in a superconducting structure is the change of the refractive index, due to the uneven width of the forbidden band.

This conclusion is of practical interest because it suggests a procedure for the investigation of optical inhomogeneities in p-n junctions. Furthermore, by investigating the refractive-index gradient along the p-n junction, we can advance a hypothesis explaining the formation of the generation channels in injection lasers.

The refractive-index gradient calculated on the basis of Fig. 1, $dn/dx = 10^{-4}\ \mu^{-1}$, is quite sufficient to bend appreciably the trajectory of a light beam propagating perpendicular to the refractive-index gradient. The presence of a maximum of the function n(x) should lead in this case to focusing of the radiation and to formation of a generation channel in the vicinity of this maximum, as is indeed seen from Fig. 2. The occurrence of generation channels is observed also in regions with minimum refractive-index gradients, as is clearly seen in Fig. 1.

The observed regularities of the channeling of radiation in p-n junctions of laser diodes confirm the hypothesis that the presence of the refractive-index gradients along the p-n junction leads to the formation of generation channels in injection lasers.

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RAMAN SCATTERING OF LIGHT BY SPIN WAVES IN NONFERROMAGNETIC METALS

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The conduction electrons of a metal form a Fermi liquid. This circumstance leads to the existence of spin waves in nonferromagnetic metals [1]; these were recently observed experimentally [2].

In this communication we consider Raman scattering of light by spin waves in nonferromagnetic metals, particularly alkali metals. Alkali metals become relatively transparent in the short-wave part of the optical range. Thus, the limit of the transparency region is 2100 Å for Na and 3150 Å for K. Experiments in this frequency region can be carried out, in particular, by using the facilities of modern nonlinear optics; for example, a twofold frequency doubling of the frequency ω_{Nd} of a neodymium laser yields radiation of wavelength $\lambda \approx 2500$ Å.

To determine the cross section of the Raman scattering it is necessary to relate the polarization at the shifted frequency with the electric field of the incident wave. To this end we write out the equation for the density matrix of a quasiparticle (conduction electron) in the mixed representation [3]

$$\frac{\partial\rho}{\partial t} = -\frac{i}{\hbar}[\epsilon,\rho] - \frac{1}{2\hbar}\left\{\frac{\partial\epsilon}{\partial\mathbf{k}},\frac{\partial\rho}{\partial\mathbf{r}}\right\} - \frac{1}{2\hbar}\left\{\frac{\partial\epsilon}{\partial\mathbf{r}},\frac{\partial\rho}{\partial\mathbf{k}}\right\} - \frac{e}{2\hbar^2 c}\left\{\left[\frac{\partial\epsilon}{\partial\mathbf{k}}\times\mathbf{B}_0\right]\frac{\partial\rho}{\partial\mathbf{k}}\right\} - \frac{e\mathbf{E}}{\hbar}[\vec{\Omega},\rho] - \frac{e\mathbf{E}}{\hbar}\frac{\partial\rho}{\partial\mathbf{k}}, \tag{1}$$

where {A, B} and [A, B] denote the anticommutator and the commutator, respectively, $\vec{\Omega}$ - interband part of the quasiparticle coordinate operator, B_0 - magnetic induction, $\epsilon = \epsilon_0 + \overleftrightarrow{W}\vec{S} + \delta\epsilon$, $\delta\epsilon$ - change of quasiparticle energy due to change of the distribution function, S - spin operator, and W describes the quasiparticle spin-orbit interaction, whose matrix elements differ from zero only for interband transitions. We assume here, in the spirit of the main premises of the Landau Fermi-liquid theory, that the classification of the quasiparticle levels corresponds to the single-electron approximation. The velocity operator is defined as $v_{nt} = i\omega_{nt}\Omega_{nt} + \hbar^{-1}\partial\epsilon_{nt}/\partial k$, where n and t are the band indices and $\hbar\omega_{nt} = \epsilon_{0n} - \epsilon_{0t}$. The deviation of the density matrix from the equilibrium value $\delta\rho = (\nu + \vec{S}\mu)\delta(\epsilon - \epsilon_F)$ is expressed [4] in terms of the spin-wave creation and annihilation operators C^{+}_{qi} and C_{qi}:

$$\vec{\mu} = \frac{(2\pi\hbar)^{3/2}}{m v_F^{1/2}}\sum_{ql}(2\hbar\omega_{ql})[\vec{\mu}_{ql}(\mathbf{k})C_{ql}\exp(i\mathbf{q}\mathbf{r} - i\omega_{ql}t) + \text{c.c.}], \tag{2}$$

where $\vec{\mu}_{qi}(\vec{k})$ is the solution of the equation that determines the spin-wave spectrum; ϵ_F and v_F are the energy and velocity on the Fermi surface. Solving (1), we obtain the following expression for the polarization at the mixed frequency:

$$P_a(\omega - \omega_{ql}) = -\frac{i\omega\omega_{ql}^{1/2}e^2}{2\pi^{3/2}v_F^{1/2}m}C^{+}_{ql}\sum_{t,l,d}\int d\mathbf{k}\left[\frac{\Omega^a_{nt}\Omega^b_{tl}W^d_{ln}}{\omega_{ln}(\omega^2_{tn} - \omega^2)} - \frac{\Omega^b_{nt}\Omega^a_{tl}W^d_{ln}}{\omega_{ln}(\omega^2_{tl} - \omega^2)}\right]\mu^d_{ql}\delta(\epsilon - \epsilon_F) \times E_b(\omega)\,. \tag{3}$$

It is assumed here that all the operators except ϵ_0 depend weakly on $\vec{k}$, otherwise expression (3) assumes a somewhat more complicated form, but the results remain essentially unchanged. Using (3), we obtain an expression for the differential cross section of scattering in a unit solid angle, $d\sigma/do$, in the simplified form

$$\frac{d\sigma}{do} = 5\pi^2 \frac{\omega^4}{C^4} \frac{\hbar^4 \omega_{ql}}{m^4 v_F^5} \left(\frac{\omega}{\omega_e} \frac{W}{\hbar \omega_e} \frac{e^2 a^2}{\hbar \omega_e} n \right)^2, \tag{4}$$

where n - electron density, ω_e - characteristic frequency of interband transition, and a - characteristic value of Ω_{nt}, for which we can use in estimates its classical value $a \sim \epsilon_F^{1/2} m^{-1/2} \omega_e^{-1}$.

Thus, for K with $a \sim 10^{-8}$ cm, $\omega_e \sim 10^{-16}$ sec^{-1}, $n \sim 10^{23}$ cm^{-1}, $\omega \simeq 8 \times 10^{15}$ sec^{-1} ($\omega = 4\omega_{Nd}$), $B_0 \sim 5 \times 10^4$ Oe, $v_F \sim 10^8$ cm/sec, and $W/\hbar\omega_e \sim 10^{-2}$ [5] we get $d\sigma/do \sim 10^{-10}$ cm^2. For comparison we indicate that the cross section $d\sigma/do$ for Raman scattering of ruby-laser light by nitrobenzene [6] is 5×10^{-9} cm^2.

It follows from the momentum conservation law that the wave vector $\vec{q}$ of the spin wave from which the scattering takes place satisfies the relation $g = 2k \sin(\theta/2)$, where k is the wave vector of the electron-magnetic wave and θ is the angle between the wave vectors of the incident and scattered light. Thus, by varying the observation angle θ it is possible to investigate the dispersion law of the spin waves ω_{qi} in a sufficiently wide range, including when $qR \gg 1$, where R is the cyclotron radius. For example, when $\theta \approx \pi/2$, $k \sim 10^5$ cm^{-1}, $B_0 \sim 5 \times 10^4$ Oe we have $qR \sim 50$. In an experiment aimed at observing spin waves [2] they used the phenomenon of selective transparency of metal films at the spin-wave frequency, and $qR \lesssim 1$ at reasonable values of B_0 and of the film thickness. The region of spin-wave wave vectors $qR \gg 1$ was not investigated experimentally.

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RADIATION OF SOUND BY A DISLOCATION EMERGING TO THE SURFACE OF A CRYSTAL

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We call attention in this paper to one mechanism of sound radiation by a moving dislocation, which, insofar as the author knows, has not been discussed in the literature, namely, the radiation produced when a dislocation passes through an elastic-modulus discontinuity plane, for example through grain boundaries in a polycrystal, on emerging to the surface of