is proportional to the scattering probability and therefore should go through a maximum if the resonance condition is satisfied (cf. [1,5]). It must be borne in mind, however, that intervalley transitions are usually much less frequent than intravalley transitions, and therefore the oscillating contribution from them will not always be noticeable against the corresponding background.

The probability of intervalley transitions can be measured also directly by investigating different acoustic effects in semiconductors [8,9]. Gantsevich and the author [10] have already discussed the possibility of using these effects to study magnetophonon resonant oscillations of the probability of intervalley transitions. The same paper contains also an expression for the probability of intervalley impurity scattering in the case when $\Delta\epsilon_{\alpha\beta} = 0$. The quantitative analysis in [10] can be extended with almost no modification to include the case $\Delta\epsilon_{\alpha\beta} \neq 0$.

A study of the magnetic-impurity resonance can yield interesting information on the electron spectrum of semiconductors, on the value of $\Delta\epsilon_{\alpha\beta}$ for different energy minima, and on the probabilities of intervalley transitions.

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STIMULATED EMISSION OF AN ENSEMBLE OF SCATTERING PARTICLES WITH NEGATIVE ABSORPTION

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1. The presently known quantum generators constitute an optically homogeneous medium with negative absorption and a configuration of elements that return the radiation to the medium in order to effect feedback. If the radiation is returned with the aid of a system of mirrors, such as a Fabry-Perot resonator [1], then the feedback is resonant, and if backward scattering is used, then the feedback is nonresonant [2]. We considered in [3] a case

of generation in which the feedback was effected by scattering particles distributed in the active medium, but even there the medium with the negative absorption was "optically" homogeneous, since the mean free path of the quantum due to scattering was much larger than the generator dimension.

The purpose of this letter is to demonstrate the possibility of generating light by means of an aggregate of scattering particles with negative absorption in the case when the mean free path of the photon due to scattering is much smaller than the dimensions of the system, i.e., when the motion of the photons is diffuse. We shall obtain below the generation threshold and the emission line width of such a generator, the threshold condition being analogous to the condition for critical multiplication of neutrons in a homogeneous nuclear reactor without a reflector. When the threshold condition is satisfied, such a generator emits in all directions radiation with an exceedingly narrow spectrum.

2. Let us consider an ensemble of identical scattering particles whose density N_0 and with negative absorption. Let the mean free path of the photon due to scattering be $\Lambda_s = 1/N_0Q_s$, where Q_s is the scattering cross section, and let the cross section for negative absorption by the scattering particle be $Q_a(\omega)$, where the dependence of Q_a on the frequency of the photon is connected with the resonant character of the negative absorption. We shall assume that the dimensions of the medium are $R \gg \Lambda_s \gg \lambda$. Then the change in the photon density can be described in the diffusion approximation:

$$\frac{1}{c}\frac{\partial \Phi}{\partial t} = D\Delta\Phi + N_0 Q_a(\omega)\Phi, \tag{1}$$

where c is the velocity of light, $D \simeq \Lambda_s/3(1 - \bar{\mu})$ is the diffusion coefficient, and $\bar{\mu}$ is the average cosine of the scattering angle. We see that this equation is similar to the diffusion equation for monoenergetic neutrons in a homogeneous medium (see [4]).

The general solution of (1) is

$$\Phi(\mathrm{r}, t) = \sum_n a_n \Psi_n(\mathrm{r}) \exp[-(D\beta_n^2 - N_0 Q_a) ct, \tag{2}$$

where $\Psi_n(r)$ and B_n are the eigenfunctions and eigenvalues of Eq. (1) with $\partial\Phi/\partial t \equiv 0$, and a_n are arbitrary constants determined by the initial distribution of $\Phi(r, t)$ when $t = 0$.

From (2) we get the threshold condition

$$DB^2 - N_0 Q_a(\omega) = 0, \tag{3}$$

where B is the smallest eigenvalue B_n (usually $B = B_1$). The value of B is determined by the geometry of the medium and, for example, in the case of a spherical distribution we have $B = \pi/R$, where R is radius of the medium [4].

The cross sections Q_s and $Q_a(\omega)$ are determined by the geometry of the scattering particles, by the dielectric constant ϵ_0, and by the coefficient $\alpha(\omega)$ of negative absorption of the particle material per unit length. For example, for spherical particles of radius a we have for two limiting cases of ka [5]:

$$Q_s = \frac{8}{3}(ka)^4\left(\frac{\epsilon_0 - 1}{\epsilon_0 + 2}\right)^2 G,\ Q_a = \frac{4}{\epsilon_0 + 2}\, a\,\alpha(\omega)\, G,\ ka \ll 1 \qquad (4')$$

$$Q_s \simeq G, \quad Q_a \simeq 2\eta a \alpha(\omega) G, \quad ka \gg 1, \qquad (4'')$$

where $G = \pi a^2$ is the geometric cross section, η the average transmission coefficient on the particle boundary, and $\bar{\mu} \simeq 0$. Expressions (3) - (4) determine the threshold (critical) dimension of the particle ensemble π/B_{thr}:

$$\frac{\pi}{B_{thr}} = \frac{9^3}{(ka)^2}\left(\frac{\epsilon_0 + 2}{\epsilon_0 - 1}\right)\sqrt{\frac{2a(\epsilon_0 + 2)}{\alpha(\omega)}}, \quad ka \ll 1, \qquad (5')$$

$$\frac{\pi}{B_{thr}} \simeq 9^3\sqrt{\frac{32a}{3\eta\alpha(\omega)}}, \quad ka \gg 1, \qquad (5'')$$

where $g = N_0^{-1/3}/2a$ is the ratio of the average distance between particles to their diameter. In the case, say, of a spherical distribution of ruby particles with radius $a = 2 \times 10^{-4}$ cm ($\lambda = 7 \times 10^{-5}$ cm), $\eta \simeq 1$ with $g \simeq 2$ and with a gain at the maximum of $\alpha(\omega_0) \simeq 1\ \mathrm{cm}^{-1}$ (at 77°K) the critical radius of the region $R_{thr} = \pi/B_{thr}$ is, in accord with (5"), $\simeq$3.7 mm.

3. When threshold is reached, owing to the dependence of the negative-absorption cross section $Q_a(\omega)$ on the frequency, the radiation spectrum becomes narrower. It follows from (2) that if $Q_a(\omega) = Q_0/\{1 + [\eta|(\omega - \omega_0)/\Delta\omega_0|]^2\}$ the narrowing of the spectrum is given by $\Delta\omega(t) \simeq \Delta\omega_0/\sqrt{Q_0 N_0 ct}$. The spectrum narrows down to a limiting width determined by the fluctuations. *If the random frequency shift occurring during each scattering act has an* average value $\delta\omega \ll \Delta\omega_0$ (for example, owing to the random motion of the scattering particles), then the limiting width of the spectrum can be obtained with the aid of the equation for the frequency diffusion of the photons. As a result, the emission line shape $\Phi_0(\omega)$ is determined in the stationary case by the expression

$$\Phi_0(\omega) = A \exp\left[-\frac{(\omega - \omega_0)^2}{\Delta\omega_0\,\delta\omega}\sqrt{2\frac{Q_0}{Q_s}}\right], \qquad (6)$$

where A is a normalization constant. The generation line width can be smaller by several orders of magnitude than the amplification line width $\Delta\omega_0$, and reach values lower than 1 kHz.

4. A quantum generator in the form of an aggregate of simultaneously scattering and amplifying particles is a modification of a quantum generator with nonresonant feedback. Its emission is spatially incoherent and similar in this sense to "black body" radiation. However, unlike thermal or luminescence sources of the "black body" type, the radiation remains monochromatic.

The only resonant element in this generator is the active medium. Therefore the generation frequency does not depend on the dimensions of the generator, and its stability is determined by the degree to which the frequency of the atomic resonance remains static. A generator of this type can be used as a highly stable optical frequency standard. Another possible application is for the investigation of laser action in substances which cannot be produced in the form of homogeneous large crystals (powders).

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LEVEL POPULATION IN PULSED ARGON-ION LASER

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It is known that the line widths depend essentially on the optical thickness of the emitting layer. In the case of an absorbing medium, the line width increases with increasing optical thickness of the layer. An increase in the optical thickness of a layer of an amplifying medium, i.e., a medium with inverse population, leads to a decrease in the line width. This dependence of the line width on the optical thickness of the layer is used in the present communication to determine the difference in level population in the plasma of a pulsed gas discharge used to obtain generation at the argon-ion lines.

The experimental setup consisted of a glass tube of 100 cm length and 4.5 mm inside diameter, with windows inclined at the Brewster angle. In most experiments, the discharge tube was filled with a mixture of Ar and He. Many experiments were made with pure argon. The gas-discharge tube was fed from a circuit generating rectangular pulses of ~4.5 msec duration and a voltage 5 - 10 kV. The pulse repetition frequency was 40 Hz.

A plot of the charged-particle density, determined from the Stark broadening of the H_β hydrogen line, is shown in Fig. 1. As seen from the figure, the density increased from 0.5×10^{14} to 4×10^{14} cm^{-3} when the current increases from 70 to 200 A. This indicates that the degree of ionization reaches 10% even if we disregard the forcing out of the gas from the capillary (which certainly takes place).

Simultaneous oscillography of the current and of the spontaneous emission or of the current and the generation emission has shown that both the spontaneous emission and the generation occur simultaneously with the current. To the contrary, when the current drops to zero, both the spontaneous and the stimulated emission exist for several microseconds.