case, obviously, the exciton system is dense already at $nr_0 \sim 1$, corresponding to a concentration $n \lesssim 10^6$ ($r_0 \gtrsim 10^{-6}$ cm).

In addition to exciton formation, surface superconductivity (more accurately, quasisuperconductivity; see above), which results in the equilibrium case from attraction between electrons (see [10, 13]), is worthy of attention. Under non-equilibrium conditions (in the case of inverted population), the superconductivity should arise, to the contrary, when there is repulsion between electrons or holes [14].

Thus, there is indeed a large circle of interesting problems (including also the actions of the magnetic field, allowance for anisotropy, and other factors not mentioned above), which can serve as the subject of various theoretical and experimental researches.

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EFFECTS OF THE OPTICAL "NUTATION" TYPE IN MULTIPLE PHOTON ECHO

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We consider theoretically the propagation of two ultrashort pulses (USP) of light in a dense resonant medium.

1. Coherent interaction of powerful optical pulses with a resonant medium leads to a large number of nonstationary nonlinear-optical effects [1 - 3]. One presently well-known effect is photon echo [1], where in the action of two optical pulses separated by a time interval τ produces in a medium a coherent quantum state that leads to the emission of a third light pulse at the instant 2τ. Equally well established is the phenomenon of optical nutation [2], where a rectangular optical pulse produces in a medium periodic variation of the

initial state with frequency $dE/\hbar$ (d is the reduced matrix element of the dipole transition and E is the amplitude of the electric field), correspondingly modulating the radiation of the medium. Both effects have a clear-cut physical meaning only if the reaction of the medium is small or if the radiation produced in the medium is much weaker than the external field. Such a situation can be produced artificially by using a sufficiently rarefied medium or very small thicknesses.

The situation changes radically in dense media or at large thicknesses. We present here the results of a theoretical analysis of the action of two pulses of light on a dense resonant medium with allowance for its reaction on the transmitted radiation. It has turned out that in this case the phenomenon does not reduce to the expected photon echo effects, but is governed to a considerable degree by effects of the optical "nutation" type. This result is particularly important for the explanation of the previously observed multiple photon echo [1].

2. To analyze the photon-echo effects with allowance for the reaction of the medium, we must simultaneously solve a system of nonlinear differential equations, some of which are Maxwell's equations and the others are analogous to Bloch's equations

$$\begin{cases} \dfrac{\partial e}{\partial z} + ke + \dfrac{1}{\sqrt{\pi}} \displaystyle\int_{-\infty}^{\infty} g(x) v_x dx = 0 \\ \dfrac{\partial v_x}{\partial \tau} + \gamma v_x + x u_x + n_x e = 0 \\ \dfrac{\partial u_x}{\partial \tau} + \gamma u_x - x v_x = 0 \\ \dfrac{\partial n_x}{\partial \tau} - v_x e = 0 \end{cases}$$

All the quantities in this system are dimensionless: e is the slowly varying amplitude of the electric field in the medium and is connected with the true field E by the relation

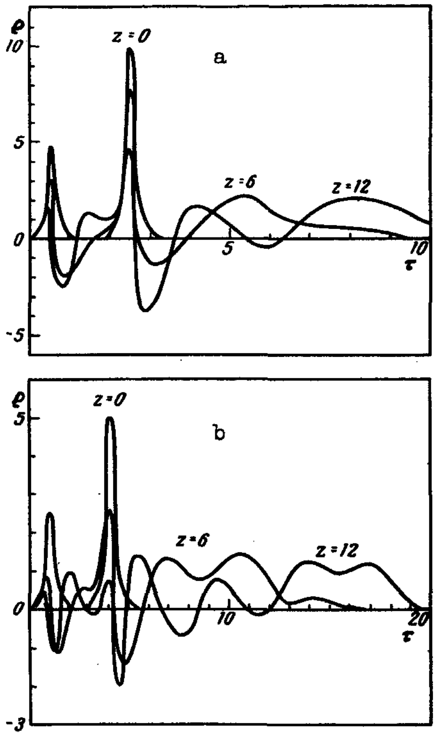
$$e(z, \tau) = d T_2^* \hbar^{-1} E(z, \tau),$$

where T_2^* is a time characterizing the inhomogeneous broadening of the energy levels, and $g(x) = (1/\sqrt{\pi})e^{-x^2}$ describes the shape of the inhomogeneously broadened line. The quantities u_x, v_x, and n_x pertain to one molecule and have the meaning of slow polarization and inversion amplitudes. The coefficients k and γ describe phenomenologically the processes of nonresonant losses in the medium and the processes of polarization relaxation, which are connected with the homogeneous broadening of the energy levels. The variables z and τ are connected with the true coordinate Z and with the time T by the relations

$$z = k_0 Z/2; \qquad \tau = (t - Z/c) T_2^{*-1},$$

where k_0 is the weak-signal absorption coefficient, $k_0 = 4\pi^2 \omega d^2 N_0 g(0)/\hbar c$.

The self-consistent system of equations was solved numerically. The program was based on the iteration procedure of the prognosis and correction method [4]. The integral term in the field equation was calculated by the method of quadrature integration. The results pertain to exact resonance and to a



Propagation of two ultrashort pulses of light with boundary conditions $\theta_1(0) = \pi/2$ and $\theta_2(0) = \pi$ in a dense resonant medium. e is the amplitude of the electric field in the light wave, τ is the retarded time, z is the depth of penetration of the light into the medium, $\delta_{1,2}$ are the durations of the optical pulses, and T is the interval between them. The parameters of the curves are: $k = \gamma = 10^{-6}$; a) $\delta_1 = \delta_2 = 0.4$, $T = 0.2$; b) $\delta_1 = \delta_2 = 0.8$, $T = 3.0$.

symmetrical form of the inhomogeneously broadened line.

As is well known, the initial system of equations contains the effect of self-transparency of the medium, i.e., it describes solitary steady-state solutions or "solitons," which satisfy the condition of equality of the area of the field envelope $\theta = 2\pi$ ($\theta = d\hbar^{-1}\int_{-\infty}^{\infty}E(t)dt$ [3]. We used this fact to adjust the program.

3. Figures a and b show the result of a numerical calculation, describing the propagation of two ultrashort pulses in a resonant medium. The input field pulses had the shape of the hyperbolic secant with truncated "wings."

We see that the character of propagation of the light pulses is essentially nonlinear. Thus, the attenuation of the field amplitude in Figs. a and b at z = 12 does not exceed several times, whereas the corresponding attenuation of the weak signal ($\theta \ll 1$) is of the order of $e^{-12} \approx 10^{-5}$. At the depth z = 3, the photon-echo signal, as expected, occurs approximately at double the distance between the exciting pulses, and moreover one can see an additional pulse that can correspond to multiple photon echo. The same diagram, however, shows clearly the occurrence of negative "spikes" of the electric field of the pulses. The reversal of the sign corresponds to the resonant interaction conditions, when the phase of the resultant field of the medium lags the phase of the external field by π. Since the experimentally observed quantity is the intensity ($\sim e^{-2}(\tau)$), the "spikes" manifest themselves as additional pulses. It is also seen from the figures that the negative "spikes" are produced both by the first and by the second pulse. As a result, the difference between the first and second pulses, the photon echo, and the additional pulses vanishes with increasing distance. The occurrance of additional pulses can be readily attributed to optical nutations, due in this case to the field generated by the medium itself. The period of the "nutations" is inversely proportional to the amplitude of the corresponding "spike."

Thus, there is no clear-cut distinction between optical "nutation" and photon echo in a dense resonant medium. In the case of multiple echo, there is no fundamental difference at all between these phenomena.

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ENERGY DEPENDENCE OF DYNAMIC STRESSES PRODUCED WHEN RELATIVISTIC CHARGED PARTICLES PASS THROUGH A SOLID

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The excitation of mechanical oscillations in solids by passage of relativistic charged particles has been the subject of a large number of experimental [1 - 2] and theoretical studies [3 - 5]. It is indicated in these studies that ultrasonic waves are produced in the target, but the mechanism of excitation of the oscillations has not yet been fully studied [4, 5]. It is shown in [6] that the ratio of the energy lost by a fast particle and consumed in the excitation of acoustic oscillations to the ionization loss is a very small quantity

$$\frac{\Delta E_{ac}}{\Delta E_{ion}} = \frac{1}{2\ln\frac{m^3}{\pi N_e e^2}}(a\kappa)^{-4} << 1, \tag{1}$$

where N_e is the average number of electrons per unit volume, a is the average distance between atoms, and $\kappa = me^2Z^{1/3}$ ($\hbar = c = 1$) is the reciprocal screening radius of the atomic potential. No account was taken in these investigations, however, of the direct generation of a stress tensor by the electromagnetic field of the passing particle.

We consider in this connection the excitation of mechanical vibrations in a thin metallic target by passage of relativistic charged particles. We write down the equation for the longitudinal oscillations in a thin plate [7]

$$\Delta u_\rho - \frac{1}{s^2}\frac{\partial^2 u_\rho}{\partial t^2} = \frac{2(1+\sigma)}{E}F(\rho, t), \tag{2}$$

where u_ρ is the radial displacement, s is the speed of sound, E is Young's modulus, and σ is the Poisson coefficient; $F(\rho, t)$ is the force per unit volume of the material. Thus, the main problem of the interaction between charged particles and elastic waves reduces to a determination of the explicit form of the force $F(\rho, t)$. The force with which the passing particle acts on the target can be written as the devergence of the stress tensor or

$$F_i = \oint \sigma_{ik} n_k df. \tag{3}$$

The stress tensor σ_{ik} is determined by the electromagnetic field of the passing particle

$$\sigma_{ik} = \frac{1}{4\pi}(E_i E_k - \frac{E^2}{2}\delta_{ik}). \tag{4}$$

Substituting (4) in (3) and integrating over the closed surface passing through