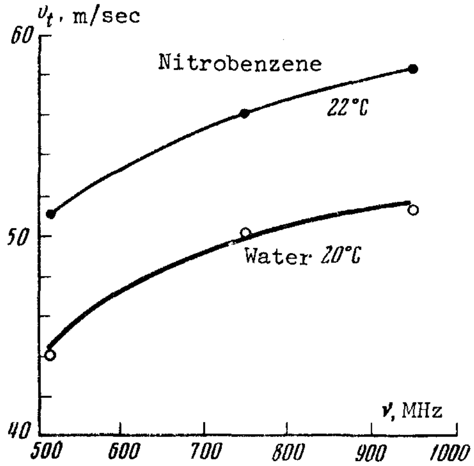

Fig. 2

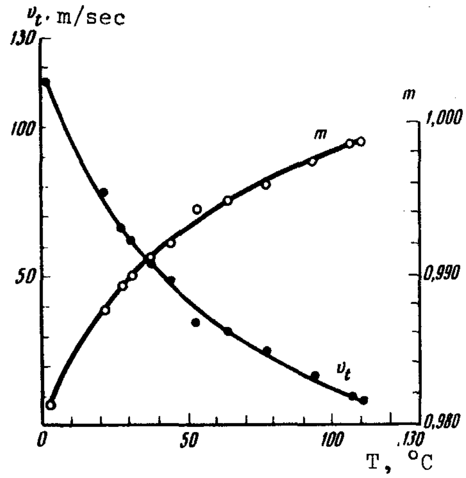

Fig. 3

The obtained transverse-wave propagation velocities for nitrobenzene and water are shown in Fig. 2 as functions of the frequency. When the frequency is varied from 515 to 950 MHz, the velocity of these waves in aniline changed from 74 to 105 m/sec at 22°C and in quinoline from 78 to 110 m/sec at 21°C. The sign of the velocity dispersion and the character of its variation with frequency (Fig. 2) are in qualitative agreement with the results of Maxwell's theory.

Figure 3 shows the temperature dependences of the velocity of the transverse waves in quinoline at 515 MHz. With increasing temperature, the viscosity decreases, and with it the velocity. The values given above for the transverse-wave velocity are accurate within 10 - 20%. It sould also be noted that measurements of the velocities of the transverse waves in the same liquids, carried out using lithium niobate as the radiator, gave velocity values larger by 20 - 30%. Therefore our first results should be regarded as only estimates of the order of magnitude of the velocities of the transverse hypersonic waves in the investigated low-viscosity liquids.

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SELF-FOCUSING AND DEFOCUSING OF SHORT LIGHT PULSES IN MEDIA WITH INERTIAL NONLINEARITY

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1. The subject of this article is an analysis of the features of the propagation of light pulses (or, in the more general case, of optical radiation

with fast amplitude modulation) in media in which the nonlinearity modulation time τ exceeds the pulse duration τ_p (or the period of the AM). Such a situation is encountered in thermal self-focusing and defocusing of radiation of pulsed lasers ($\tau \simeq 1$ sec). The same pertains also to the Kerr self-focusing ($\tau \simeq 10^{-11}$ sec) of picosecond pulses or of multimode radiation.

We describe below the main features of the formation of the focal region of a self-focusing beam with arbitrary initial divergence, in a medium with inertial nonlinearity. It has been established that the nonquasistatic character of the nonlinear response slows down the nonlinear refraction and limits the field at the focus. In our opinion this explains, in particular, the experimentally established differences between the Kerr self-focusing of single-mode radiation [1] on the one hand, and multimode radiation and picosecond pulses on the other [2]. The picture of the motion of the foci [3] is also quite unique (it was considered earlier for quasistatic self-focusing in [4] and elsewhere). We have investigated also the very important and hitherto unconsidered case of nonstationary self-focusing of intense short pulses.

2. The equation describing the self-focusing of a beam in a relaxing medium [5] has in the case of strong nonstationarity ($\tau > \tau_p$) the form

$$\frac{\partial^2 f}{\partial z^2} = \frac{1}{R_d^2}\left(\frac{1}{f^3} - \frac{f}{P_{cr}\tau}\int_{-\infty}^{\eta}\frac{P_0(\eta')d\eta'}{f^4(\eta', z)}\right). \quad (1)$$

Here z and $\eta = t - (z/u)$ are independent variables, u the group velocity, $f(\eta, z)$ the dimensionless beam width, which is introduced in the expression for the field amplitude $A = (E_0/f)\exp[-r^2/a^2f^2]$, P_{cr} is the critical power, which enters in the stationary theory of self-focusing, $R_d = ka^2/2$ is the diffraction length of the beam, and $P_0(t)$ is the power of the beam at the entrance into the medium (the envelope of the pulse). From (1) follows the condition for nonstationary self-focusing. At $z = 0$, we have $f = 1$, and self-focusing is produced if $\partial^2 f/\partial z^2 < 0$, corresponding to the condition

$$W_0 = \int_{-\infty}^{\infty} P_0(t)\,dt \geqslant W_{cr} = P_{cr}\tau, \quad (2)$$

i.e., the critical parameter is the beam energy. We now turn to the results of the solution of Eq. (1).

3. Geometrical optics in a medium with inertial nonlinearity. For a beam with energy $W_0 \gg W_{cr}$, the action of the diffraction forces can be neglected ($R_d \to \infty$). In this case the radius of the converging beam is

$$f = \left(1 - \frac{z}{R}\right)F(\xi);$$

$$\xi = \frac{z}{\left(1 - \frac{z}{R}\right)R_d}\left(\frac{1}{W_{cr}}\int_{-\infty}^{\eta} P_0(t')dt'\right)^{1/2}, \quad (3)$$

where R is the position of the linear focus.

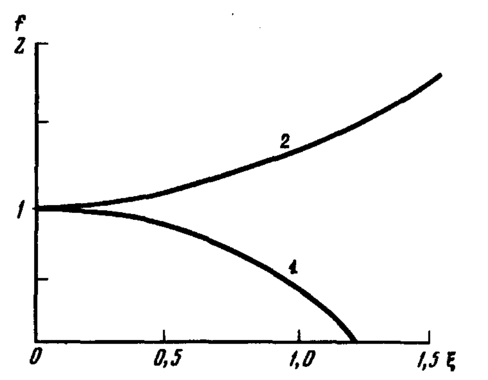

Fig. 1. Dimensionless width of the beam in a medium with inertial nonlinearity. Curve 1 corresponds to a self-focusing medium, curve 2 corresponds to a defocusing medium.

Plots of the solution $F(\xi)$ are shown in Fig. 1. It must be emphasized that in terms of the variables (3) the curves have a universal character for beams with arbitrary initial divergence and with arbitrary law of time variation of the power.

Using the obtained solution, we can trace the dynamics of the formation of the focal region in an inertial medium. This is conveniently explained with a parallel beam ($R \to \infty$) and a rectangular pulse as examples (Eq. (3) contains the energy, and the shape of the pulse is immaterial). The succeeding stages of the self-focusing of a rectangular light pulse are shown in Fig. 2. Prior to the formation of the focus, the maximum compression of the beam corresponds to $\xi = \xi_{max}$. Self-contraction occurs in this region (Fig. 2a) and moves with a velocity lower than the group velocity, $u_{sc} = 2u/3$. Then, at $\xi = 1.22$, the first focal point is produced, $z_f = 1.22R_d(W_{cr}u/P_0R_d)^{1/2}$ (Fig. 2b). The focal region then expands (Fig. 2c). The position of the limiting focal points $z_{f1} = R_d(W_{cr}/P_0t)^{1/2}$ and $z_{f2} = tu - (1.22)^2R_d^2W_{cr}/P_0u^2t^2$ (the instant $t = 0$ corresponds to the entry of the leading front of the pulse into the nonlinear medium). The position of the first focal point at the end of the pulse is $z_{fmin} = R_d(W_{cr}/W_0)^{1/2}$ determines the edge, closest to the sample entrance face, of the damage region resulting from the thermal self-focusing. For converging and diverging beams ($R > 0$ and $R < 0$ respectively), the position of the focal points can be recalculated by means of the formulas used for addition of lenses, analogous to the quasioptic formulas in [6].

4. Field at the focus. The solution obtained makes it possible to estimate the degree of contraction of the beam at the focus. It follows from Fig. 1 that the rate of nonlinear refraction in a medium with inertial nonlinearity is much weaker than in the quasistatic case – as a result of this, the diffraction is capable of limiting the field at the focus. Figure 3 shows the calculated curve for the beam width f_{min}, for which the forces of nonlinear refraction and defraction cancel each other. It is important to note that f_{min} is finite even for $(W_0/W_{cr}) \simeq 10^2$.

Thus, we should expect in experiment an appreciable change in the form of the focal region as a result of the inertia of the nonlinearity; this is just the circumstance explaining the results of the experiments of [2]. We note that in thermal self-focusing, unlike Kerr self-focusing, the characteristic thermal-diffusion time $\tau_T = (\rho C_p a^2/\kappa)$ decreases in the vicinity of the focus;

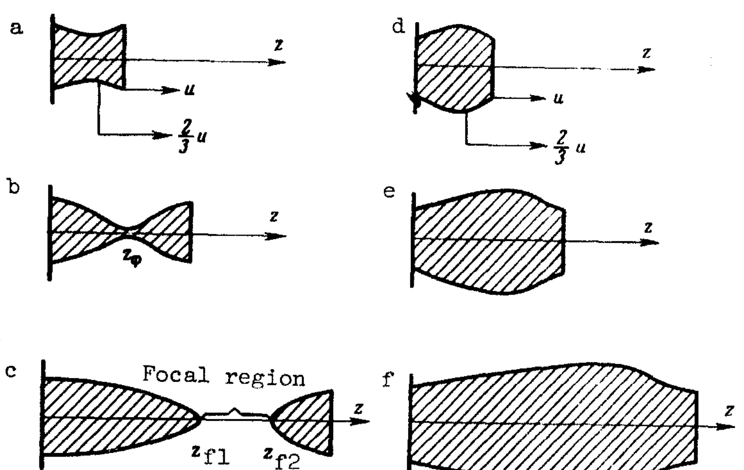

Fig. 2. Dynamics of nonstationary self-focusing (a, b, c) and self-defocusing (d, e, f) of a light pulse in a medium with inertial nonlinearity. The shaded region is occupied by the beam.

as a result, a definite contribution to the dimension of the focal spot may be made by effects of thermal conductivity (this was indicated in [7]).

5. Nonstationary thermal self-focusing was cited by a number of writers [8] as an explanation for the damage to crystals and glasses in the field of laser pulses of duration from 10^{-4} to 10^{-8} sec. However, the authors of these papers used the formulas of the stationary theory.

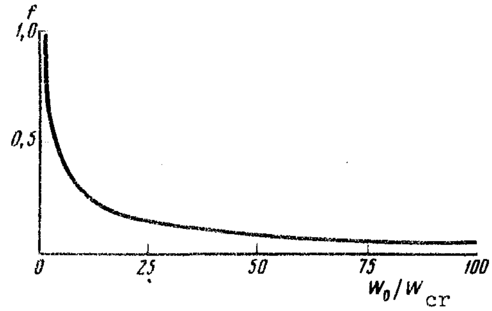

Fig. 3. Dependence of the dimensionless width of a Gaussian beam at the focus on the ratio of the beam energy to the critical energy. We see that the inertia of the nonlinearity leads to a limitation of the field at the focus ($f_{min} \neq 0$) even for $(W_0/W_{cr}) \geq 10^2$.

The foregoing results enable us to determine quantitatively the dimensions and the positions of the regions of the strong field and to determine distinctly the contribution of the thermal self-focusing to damage to dielectrics.

6. Self-defocusing in a medium with inertial nonlinearity. The foregoing procedure is fully applicable to an analysis of nonstationary self-defocusing. The corresponding solution of the equation for the defocusing medium is shown in Fig. 1, curve 2. The dynamics of the nonstationary defocusing is shown in Figs. 2d, 2e, and 2f. The region of maximal expansion moves with a velocity $u_p = (2/3)u$. The divergence of the radiation is different for different sections of the pulse; the latter leads to strong distortions of the shape of the light pulse on the axis $P_0(\eta)/f^2$.

It should be emphasized that the foregoing approach makes it possible to calculate the internal self-defocusing which takes place for the case when the beam of a powerful laser diverges strongly in the nonlinear medium itself.

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LUMINESCENCE OF THE LOCAL CENTER OF A CRYSTAL IN THE PRESENCE OF UNIAXIAL DEFORMATION

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The Jahn-Teller instability, which is produced in an excited F-term of an octahedral local center because of the interaction with tetragonal (E)