V. I. Bespalov, A. A. Betin, and G. A. Pasmanik. *Reproduction of the light-beam wave front in induced scattering.* It was shown in 1972 that induced backscattering of multimode optical radiation in a lightguide results in inversion of the wave front of the laser wave.[1] It was subsequently found that a similar phenomenon is also observed in focused beams.[2]

The shaping of the Stokes wave reproducing the pump in bounded and, in particular, focused pump beams with radii r_l much larger than the transverse-correlation radius ρ_l differs in some respects from induced scattering in a lightguide.[3,4] The decrease in the average pump intensity toward the periphery of the laser beam results in localization of the Stokes wave near its axis. The small-scale field distribution of the Stokes beam, which is narrower than the pump, becomes mismatched with the laser-wave field as a result of diffraction. As a result, the preferential amplification of the structure reproducing the pump is smaller in bounded beams than the lightguide. An approach based on picking out from the polarization $g|E_l|^2E_s/2$ the projection $C(z)fE_l$ onto the function fE_l, which duplicates the small-scale distribution of the laser field E_l, is used to find a near-optimum structure of the Stokes wave E_s and the value of the increment corresponding to it.[5] The envelope f, which is slowly varying in the scale of ρ_l, is determined by the condition for maximum amplification of the excited polarizations CfE_l of the Stokes components. To find the function f, an integral equation is written for the coefficient $C(z)$ and its solution optimized to determine the largest value of the total increment M and the corresponding envelope f. As a result, we obtain for a monochromatic pump beam with a Gaussian correlation function, a Gaussian envelope, and normal field statistics, assuming $M_c \ll 1$ and $M_l \gg 1$ (M_c and M_l are respectively the total increments on the longitudinal correlation lengths $z_k = k_l\rho_l^2$ and the pump beam diffraction broadening length $z_l = k_l \rho_l r_l$

$$M = 2M_l \zeta \left[1 - \frac{\sqrt{2}}{M_l} - \frac{1}{2M_l^2} \left(\frac{k_l - k_s}{k_s} \right)^2 \frac{z_l^2}{z_k^2} \right], \quad f = \exp\left(- \frac{r_\perp^2 M_l}{\sqrt{2}\, r_l^2(z)} \right), \tag{1}$$

where

$$\zeta = \operatorname{arctg}\left(\frac{F^2 + z_l^2}{E^2} \frac{z}{z_l} - \frac{z_l}{F} \right) + \operatorname{arctg} \frac{z_l}{F}, \quad r_l^2(z) = r_l^2 \left[\left(1 - \frac{z}{F} \right)^2 + \frac{z^2}{z_l^2} \right].$$

With $F = \infty$, $M_l = g\overline{|E_l|^2} z_l \to \infty$ the value of M reverts to the expression arrived at for induced scattering in the lightguide.[6-8]

A similar approach has also been used to estimate the increment of the Stokes component reproducing the pump under conditions of four-photon interaction of Stokes and antiStokes components in forward induced Raman scattering. For $M_c \ll 1$, we have for a pump with a plane envelope

$$M = 2g\overline{|E_l|^2} z \left[1 - \frac{k_l - k_s}{2k_s \delta k z_k} - 2\left(\frac{g\overline{|F_l|^2}}{\delta k} \right)^2 - \frac{1}{2} \left(\frac{k_l - k_s}{g\overline{|E_l|^2} z_k k_s} \right)^2 \right] \quad (\delta k \gg g\overline{|E_l|^2}). \tag{2}$$

It follows from (2) that the increment M decreases with decreasing mismatch of the wave vectors $\delta k = 2k_l - k_s - k_a$ (for $\delta k \leq g\overline{|E_l|^2}$, the increment satisfies $M \leq g\overline{|E_l|^2} z$). At the same time, the increment of the waves that are uncorrelated with the pump is independent of δk for $M_c \ll 1$ and equal to $g\overline{|E_l|^2} z$. Comparing increments, we note that four-photon interaction is detrimental to the reproduction effect.²⁾

In nonmonochromatic spatially inhomogeneous laser-beam fields, the increment of the pump-reproducing wave depends on the form of its statistics. The properties related to this dependence are manifested most curiously in induced backscattering, for which the force $F \sim E_l E_s^*$ that causes pumping of phonons in the medium is found to be proportional to E_l^2. If the pump has normal field statistics, F is a random function of the time with zero mean, and the increment of the reproducing wave decreases with increasing ratio γ_l/γ of the pump and spontaneous-scattering linewidths. We have for a pump with a plane envelope and a Lorentz line in the frequency spectrum

$$M = 2\Gamma_0 z \left(1 - \frac{1}{\Gamma_0 l_k} \right) \left[1 - \frac{1}{2} \left(\frac{k_l - k_s}{\Gamma_0 z_k k_s} \right)^2 \right] \quad (\Gamma_0 l_k \gg 1), \tag{3}$$

where

$$\Gamma_0 = g\overline{|E_l|^2} \left(1 + 2\frac{\gamma_l}{\gamma} \right)^{-1}, \quad l_k = \gamma_l^{-1} \left(\frac{1}{v_l} + \frac{1}{v_s} \right)^{-1}.$$

On the other hand, for a pump $E_l = \mathscr{E}_l(z\mathbf{r}_\perp)\varphi(t - z/v_l)$, the Stokes components of the form $\mathscr{E}_l^* \varphi$ are amplified so that the force $F \sim \mathscr{E}_l^2 |\varphi|^2$ retains a nonzero time-averaged component. The increment of these components for a normal distribution law $\mathscr{E}_l(z\mathbf{r}_\perp)$ and $\varphi(t - z/v_l)$ is

$$M = 2\Gamma_1 z \left(1 - \frac{1}{\Gamma_1 l_k} \right) \left[1 - \frac{1}{2} \left(\frac{k_l - k_s}{\Gamma_1 z_k k_s} \right)^2 \right] \quad (\Gamma_1 l_k \gg 1), \tag{4}$$

where

$$\Gamma_1 = g\overline{|E_l|^2} \left[1 + \left(1 + 2\frac{\gamma_l}{\gamma} \right)^{-1} \right].$$

It is seen on comparison of expressions (3) and (4) that when $\gamma_l/\gamma \gg 1$, $\Gamma_1 \gg \Gamma_0$, i.e., induced backscattering has the property of filtering signals of the form $\mathscr{E}_l \varphi$ against a background of more powerful incoherent radiation.[9]

²⁾Another case in which parametric coupling of the waves lowers the discrimination of the increments is induced Mandel'shtam-Brillouin scattering in media with weak attenuation of sound.[5]

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Translated by R. W. Bowers