AMPLIFICATION OF ANOMALOUS ELASTIC WAVE IN A TRANSVERSE ELECTRIC FIELD

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We considered in [1] the appearance of an anomalously slow elastic wave under conditions when the ultrasonic oscillations are amplified by the carrier drift [2]. We shall show below that a similar effect should be observed also in the case when the carrier drift is perpendicular to the wave front, i.e., when no amplification of the ordinary wave can occur.

Let us investigate radiation in an infinite layer $0 \leq z \leq \ell$ of some uniform plate placed in the plane z = 0. We assume that carriers drift with supersonic speed in this layer along the x axis. For simplicity we assume (cf. [1]) that the material of the layer is isotropic and has as a result of the carrier drift a large constant amplification coefficient α in some cone with aperture angle 2ψ and with symmetry axis x; outside this cone the sound is strongly absorbed. We shall neglect the reflected signals, since amplification is usually effected in a pulsed mode; in addition, scattering from the boundaries can be very large at high frequencies. For $z \leq \ell$, the displacement at a certain point with coordinates (x,y,z) through which the sound rays amplified by the active medium pass from the plate, takes the form [1]

$$u(x,y,z) = Az \int \exp[i(\omega t - kzp) + \alpha zp]\, d\varphi\, dp, \tag{1}$$

where A is a constant, ω is the circular frequency of the plate oscillations, $k = \omega/s$, s is the speed of sound, $p = \cos^{-1}\vartheta$, ϑ and φ are the polar and azimuthal angles at which the radiating element is seen from the reception point. The integration extends over the region of values of ϑ and φ for which the angle γ between the direction of ray propagation and the x axis satisfies the condition $\gamma \leq \psi$. Naturally, account must be taken also of the presence of the boundaries of the radiating plate. Simple geometrical considerations give the following connection:

$$\cos\gamma = \cos\psi \sin\vartheta \tag{2}$$

Let us see what oscillations will be received by a plate located in the plane $z = \ell$. We choose a geometry such that a straight line drawn from any point on the receiving plate parallel to the (x,z) plane at an angle ψ to the x axis crosses the radiating plate, while the area subtended in this manner in the plane z = 0 never reaches the boundaries of the radiating plate. Assume that for the point on the receiving plate with coordinates (x,y) the quantity $\vartheta_0(x,y)$ is that polar angle at which at least one of the rays amplified by the active medium already arrives from the boundary of the radiating plate ($\vartheta_0(x,y) > \psi$). Then, from the condition $\gamma \leq \psi$ we obtain from (2) that the received signal is

$$u(x,y,\ell) = 2A\ell \int_{\sin^{-1}\psi}^{\cos^{-1}\vartheta(x,y)} \exp[i(\omega t - k\ell p) + \alpha\ell p] \cos^{-1}[(p \cos\psi)(p^2 - 1)^{-1/2}]\, dp + A\ell \int' \exp[i(\omega t - k\ell p) + \alpha\ell p]\, d\varphi\, dp, \tag{3}$$

where the primed integral extends only over the region $\vartheta \geq \vartheta_0$ (x,y). If we assume for simplicity that the angle ψ is so small that $\sin\psi \ll 1$, then $p \geq \sin^{-1}\psi \gg 1$, from which follows

$$u(x,y,\ell) = -\frac{2iA\psi}{k}\exp[i(\omega t - \frac{k\ell}{\sin\psi}) + \frac{\alpha\ell}{\sin\psi}]$$

$$+ \frac{2iA\psi}{k}\exp[i(\omega t - \frac{k\ell}{\cos\vartheta_0(x,y)}) + \frac{\alpha\ell}{\cos\vartheta_0(x,y)}] \qquad (4)$$

$$+ A\ell\int' \exp[i(\omega t - k\ell p) + \alpha\ell p]d\varphi dp.$$

We see from (4) that a plane anomalously slow sound wave, with an amplitude that can be quite large, arrives at the receiving plate. This wave, described by the first term of (4), is analogous to that considered in [1]. The two other terms constitute a complicated set of waves propagating along the z axis with velocities smaller than s $\cos\vartheta_m$ (ϑ_m is the minimum of all values of ϑ_0), and are connected with radiation from the boundaries of the plate.

Let the duration of the radiated elastic signal be much shorter than $s^{-1}\ell \sin^{-1}\psi$, and let the electric field be removed after a time $s^{-1}\ell \sin\psi$. Then the signals connected with the second and third terms of (4) will be much smaller than the anomalous wave, since after removal of the electric field there is strong absorption in all directions.

Thus, observation of an anomalous elastic wave in the presence of supersonic carrier drift can occur in principle also in the case when the front of the elastic wave is perpendicular to the direction of carrier motion. The anomalous signal can be quite large, while the usual ultrasonic waves cannot be amplified at all.

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[2] H. Kroger, E. W. Prohofsky, and R. W. Damon, Phys. Rev. Lett. 11, 246 (1963).

INTERACTION OF TRAVELING WAVES IN A RING LASER

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Investigation of the traveling-wave beats produced in a ring laser on a rotating platform makes it possible to study with great accuracy the spectral, statistical, and other characteristics of laser radiation [1,2]. The frequency splitting Δ of the traveling waves occurs, however, only at high rotation speeds v, exceeding a certain critical value v_{cr} (corresponding to $\Delta_{cr} = 2kv_{cr}/\pi$, where v is the linear velocity of the resonator mirrors and k is the wave vector). When $v < v_{cr}$, owing to the coupling of the traveling wave, mutual synchronization takes place and results in a single-frequency operating mode.