THE HYBRID CO_2 LASER REACTION TO ECHO SIGNAL

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The intensity transformations of the TEA laser caused by a signal returned to a hybrid CO_2 laser are determined by a numerical simulation done on the basis of the well–known model of the hybrid laser.

A laser response to its radiation reflected or (and) scattered outside the laser cavity (echo signal) is ordinary discussed from two points of view. On the one hand, during the high–precision measurements of lengths, finest shifts, and frequency standards it is necessary to obtain information about the scale of distortions caused by the signal returned to the laser cavity (see Fig. 1). On the other hand, one can use the laser intensity transformations as the data for analysis of characteristics describing the atmospheric path being sounded or the reflector (see Refs. 2–4).

In this brief communication we consider the second type of the problem and represent our simulation of the laser radiation response to the echo signal. As is well known, the solution of the problem depends strongly on the values being measured in the experiments. Below we analyze only the intensity transformations of a hybrid CO_2 laser caused by echo signal.

The cw lasers traditionally used for the investigations of the atmosphere and based on the intracavity mixing and echo–signal reception[2,3] allow one to design highly sensitive lidars with a set of positive features. However, there is a disadvantage of the lidars of such a type. The increase in response of laser radiation intensity to the echo signal can distort the probing laser radiation, thus the problem in determining the atmospheric characteristics becomes unsolvable. In Ref. 5 it was suggested to use a hybrid CO_2 laser as a source and detector in order to overcome this disadvantage. In laboratory experiments it was shown the anomalous high sensitivity of laser radiation intensity to the echo signal injected into the resonator. These experiments have initiated performing a numerical simulation on the basis of the well–known model of a hybrid CO_2 laser.

A few approximations are used in the calculations: We neglect, first, the effect of cw gain section on the process of echo–signal reception and, second, the time variations in phases of both signal and laser radiation. The former is caused by the fact that the main role of the cw laser section is reduced to the extraction of a single mode at the starting stage of pulse lasing and thus, this can change only a leading edge of the pulse. The latter is not applied to the measurements of wind or target velocities or to sounding along the paths with turbulence.

To solve the problem we used the system of equations describing the hybrid CO_2 laser[6]

$$\frac{\mathrm{d}i}{\mathrm{d}t} = -\frac{i}{T_0} + \sigma c\, i\,(n_a - n_b) + \frac{n_a \sigma c}{V} + T^2 \Delta\nu \sqrt{i(t-\tau)i(t)}\,, \quad (1)$$

$$\frac{\mathrm{d}n_a}{\mathrm{d}t} = -\sigma c\, i\,(n_a - n_b) + \gamma_c n_c - (\gamma_a + \gamma_c)\, n_a + W_a\,, \quad (2)$$

$$\frac{\mathrm{d}n_b}{\mathrm{d}t} = \sigma c\, i\,(n_a - n_b) + \gamma_a n_a - \gamma_b n_b + W_b\,, \quad (3)$$

$$\frac{\mathrm{d}n_c}{\mathrm{d}t} = \gamma_c n_a - (\gamma_c + \gamma_{c_0})\, n_c + W_c\,, \quad (4)$$

where i is the laser radiation intensity, n_a, n_b, and n_c are the upper and lower levels of populations of CO_2 and N_2 molecules, respectively, σ is the cross section of stimulated emission, γ_a, γ_b, γ_c, and γ_{c_0} are deactivation constants of the CO_2 and N_2 molecules, W_a, W_b, and W_c are the relevant pumping rates, $V = 100$ cm^3 is the cavity volume, T_0 is the photon lifetime, $T = 0.1$ is the transmittance coefficient of the output mirror, c is the speed of light, τ is the delay time, and $\Delta\nu$ is the intermode frequency. The values of the chosen constants and parameters are the same as in Refs. 6–8.

At the initial conditions we take

$$i(0) = 0\,, \quad n_i(0) = n_i^0\,, \quad i = a,\, b,\, c\,,$$

where n_i^0 are the molecular levels of populations under the atmospheric pressure and room temperature.

The calculation shows that the numerical solutions of Eqs. (1)–(4) without regard for the echo–signal action is identical to the results obtained in Refs. 6–8. In calculations with regard for the echo signal we consider the delay times less than the pulse duration (about 10 μsec). In this case the measurements of the pulse intensity transformations have two typical features: First, a bell–shaped maximum, whose shape is not identical to that of the echo signal, appears in the pulse tail, and, second, the pulse intensity variation is considerably higher than the echo–signal intensity. One of the typically calculated diagrams is shown in Fig. 1.

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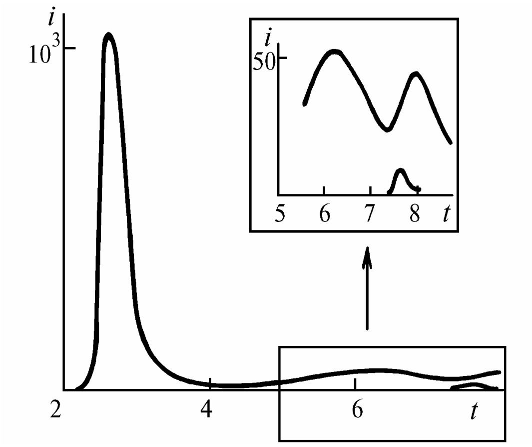

FIG. 1. Pulse shape of the hybrid CO_2 *laser at the echo–signal reception. The time scale is marked every* 400 ns. *The intensity is in relative units. For scale comparison the echo signal is shown separately above the curve of the pulse shape.*

The use of the short delay times, does not limit the applications of this lidar to the short distances only, because in the case of long delay times we can mix the echo signal with any pulse periodically generated by a laser. It means, the sensed range of a hybrid CO_2 laser is determined only by the signal–to–noise ratio for the recorded echo signal. However, this problem requires an independent consideration.

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