Observation of a coherent coupling of nanosecond CO_2-laser pulses to an amplifying medium

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Coherent effects that occur in the course of amplification of ultrashort pulses in CO_2-amplifiers may have a significant role in the generation of short CO_2-laser pulses of a given shape for use in, for example, thermonuclear investigations. To observe the coherent interaction a 1-nanosec CO_2-laser pulse was formed and propagated through an amplifying medium. A substantial sharpening of the leading pulse front and a splitting into two "2π" pulses is observed. The experimental results are qualitatively confirmed by numerical calculations.

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The effects of coherent coupling of ultrashort pulsed radiation with a resonant amplifying or absorbing medium are well known theoretically and have been examined in detail in the review works.[1-3] The coherent effects (induced self-transparency, separation into "2π" pulses, etc) have been studied experimentally for the case of pulse propagation in various absorbing media, for example Refs. 4–9. In particular, splitting into the "2π" pulses in an absorbing medium, which agrees well with calculations, was observed in Refs. 6 and 7.

The coherent effects may have a significant role in the formation of ultrashort pulses in an amplifying medium, which limit, for example the possibility of obtaining short CO_2-laser pulses with a given shape for use in thermonuclear investigations. In this work we carried out for the first time observations of the splitting of a nanosecond pulse propagating in a CO_2 amplifier, using a setup described earlier.[10]

The initial pulse was formed by means of a system consisting of an atmospheric-pressure CO_2 laser, electrooptical Q-switch, and atmospheric-pressure preamplifier. An optical resonator was used to pass the initial pulse several times in the CO_2 amplifier, where the working gas pressure could be varied over a broad range. The pulse shape was recorded by means of a pyroelectric pickup. The time resolution of the oscillographic equipment was 0.7 nsec. A low-pressure auxillary discharge in the master oscillator was used to provide high pulse shape stability at the preamplifier input. Figure 1a shows an oscillogram. The energy density at the amplifier input was 2×10^{-2} J/cm^2. After the first pass in the amplifier (the product of small-signal gain and active medium length $g_0 L = 3.5$) for a mixture $CO_2 : N_2 : He = 4 : 1 : 5$, and pressures in the range 0.1–0.3 atm only an increase in the pulse length at half height was observed.

The shape of the input pulse was substantially altered after three passes ($g_0 L = 10$, $P = 0.1$–0.3 atm). The leading front is sharpened and, was determined in

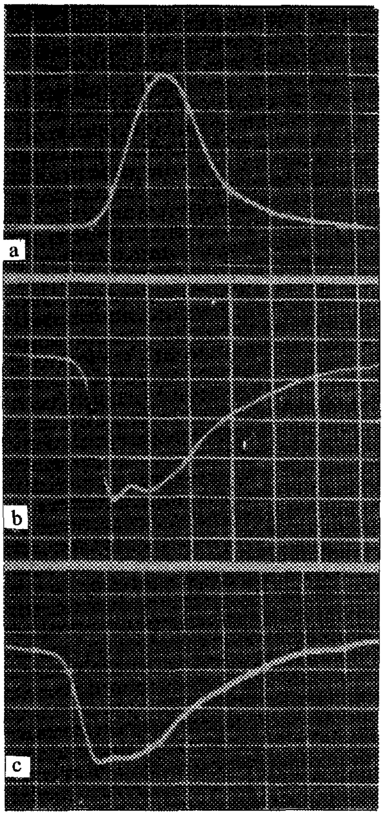

FIG. 1. Pulse shape: a-upon entry into amplifying medium; b-at amplifier output at $P = 0.1$ atm; c-at amplifier output at $P = 0.2$ atm. Scanning 1.0 nsec/div.

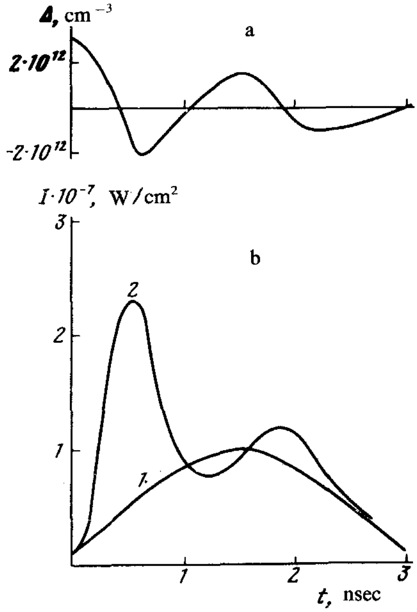

FIG. 2. Spatial dependence of inversion (a) and light intensity (b) in amplifier active medium: 1-light intensity at amplifier input, 2-light intensity after propagation through active medium length of 120 cm. $I_{\text{in}} = 10^7$ W/cm², gas pressure 0.1 atm.

the oscillograms by the time resolution of the equipment, a dip occurred at the pulse peak whose depth was also determined by the time resolution. Figures 1b and c show the characteristic oscillographs for $P = 0.1$ atm (b) and $P = 0.2$ atm (c).

To model the propagation of a pulse in an amplifying medium we used a system of equations that take coherent coupling into consideration.[10] This system also accounts for the rotational and vibrational intra-and inter-mode relaxation. A numerical solution of the system was found for conditions approximating the experimental: $P = 0.1$ atm, $\tau_u = 2$ nsec, and $T_2 = 0.8$ nsec. The results in Fig. 2 of the numerical calculation agree qualitatively with the experiment. In our case the initial value of the pulse "area"

$$\phi_0 = \frac{\mu}{\hbar} \int_{-\infty}^{\infty} \epsilon_0(t) dt \gtrsim 4\pi$$

(μ is dipole moment, 2.4×10^{-20} CGSE, ϵ is the electric field) and a steady-state solution comprises splitting into two "2π" and "π" pulses; however, total stabilization of this occurs over a much greater length of the amplifying medium.

The splitting effect in the experiment is smoothed out (except for the equipment resolution) by the presence of several vibrational-rotational transitions in the master oscillator output. We propose to carry out detailed measurements using instruments with high time resolution (<0.3-nsec "Lotos" oscillograph) at amplifier pressures to 1 atm and the maximum possible $g_0 L$ (~ 15) without producing gain.

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