Coherent-interaction effects in the amplification of short optical pulses in neon

A. I. Odintsov and V. P. Yakunin

Moscow State University

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Modulation of the pulse envelope, a change in the propagation velocity, and a spittling of the spectral band of the pulse were observed in a neon laser amplifier ($\lambda = 5400$ Å transition) under conditions when the phase memory of the atoms was preserved during the pulse duration.

1. Coherent interaction of optical pulses with gas systems have been investigated so far mainly for absorbing media, where the effects of self-induced transparency and photon echo were observed.[1-3] In this paper we report experiments on coherent interaction of pulses with an amplifying gas medium with inhomogeneously broadened transition line.

2. The pulse generator was a neon laser ($2p_1 - 1s_4$ transition, $\lambda = 5400$ Å) operating in the superradiance regime with one mirror.[4] The laser discharge tube was cooled with liquid nitrogen. One spatial mode of the superradiance and linear polarization was separated. The input signal was a single pulse of duration 2 nsec at half-height and power density 2 kW/cm^2 at the maximum. The amplifier consisted of two sections in tandem. The first section had an active length 70 cm and operated at room temperature, and the second was 50 cm long and was cooled with liquid nitrogen. The neon pressure (referred to room temperature) was 4 Torr in the generator tube and 2 Torr in the amplifier tube. The tubes were fed from a common pulsed high-voltage source, with optimization of the delay in the amplifier sections. A system of diaphragms separated a fraction of the beam, of 1 mm diameter and homogeneous over the cross section. The loss due to the beam divergence was

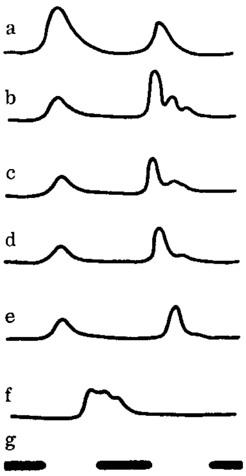

FIG. 1. Oscillograms of amplifier output pulses (the input pulse is shown on the left): a) cold amplifier, b) $\theta_{in} \sim \pi$, c) 0.3π d) 0.1π, e) $10^{-2}\pi$, f) inhomogeneous beam, g) 10 nsec markers.

estimated at ~8 dB. The net gain in both sections was 42 dB (17 and 25 dB, respectively). The results were recorded with an FÉK-16 coaxial photocell and an I2-7 oscilloscope.

3. We investigated the dependence of the waveform of the output signal on the "area" of the input signal $\theta_{in} = \mu/\hbar \int \mathcal{E}(t)\,dt$ ($\mathcal{E}(t)$ is the field amplitude and μ is the transition matrix element). The quantity θ_{in} was varied in the range from 0.01π to 1.1π. A narrowing of the pulse, to 1.3–1.5 nsec at $\theta_{in} \sim \pi$ was observed at the output of the first amplifier section. The oscillograms of the pulses passing through both sections of the amplifier are shown in Fig. 1. We see that at $\theta_{in} \approx \pi$ the pulse breaks up into two or three peaks with decreasing amplitudes. The area of the first peak is close to π and remains the same when θ_{in} decreases down to $\theta_{in} \sim 10^{-2}\pi$. The succeeding peaks decrease in amplitude with decreasing θ_{in} and vanish. Figure 2 (curve 1) shows the dependence of the gain, determined from the maximum of the first peak, on θ_{in}. Any disturbance in the homogeneity of the beam, or the absence of a preferred polarization in the amplifier, leads to a "smearing" of the structure in the pulse envelope (see Fig. 1f). The pulse waveform is not reproduced in this case. When the second amplifier section was operated without cooling, the modulation of the pulse was much less pronounced, a fact that can be attributed to a decrease in the gain because of the broadening of the Doppler line.

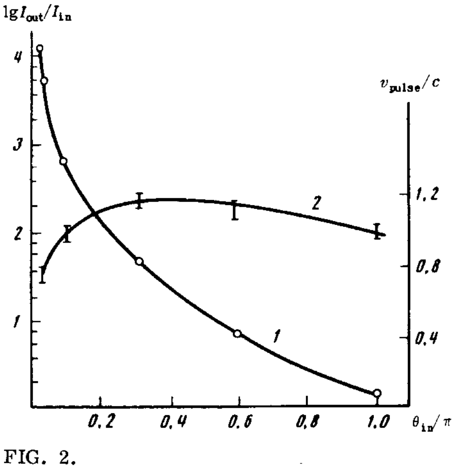

FIG. 2.

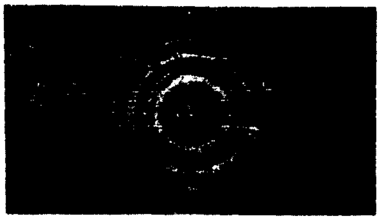

FIG. 3. Spectrum of output pulse at $\theta_{in} \sim \pi$.

4. We observed a change in the pulse propagation velocity v_{pulse}, determined from the maximum of the first peak of its envelope, with changing θ_{in}. Figure 2 (curve 2) shows the average values of v_{pulse} calculated with allowance for the entire length of the amplifier. The pulse delay at small $\theta_{in} \sim 10^{-2}\pi$ (in an amplification regime close to linear) agrees satisfactorily with a formula that takes into account the influence of the dispersion of the medium on the group velocity.[5]

5. We investigated the behavior of the output-pulse spectrum with the aid of a Fabry-Perot interferometer. At large $\theta_{in} \sim \pi$, when the modulation of the output-signal envelope is strongly pronounced, the spectrum of the signal consists as a rule of two and sometimes three components with a typical separation 350 MHz (Fig. 3). (The spectrum of the input pulse has one component of width 300 MHz.) At small θ_{in}, when the output pulse has a simple form only one component remains in its spectrum. The behavior of the spectrum agrees qualitatively with the Fourier transform of the pulse, if it is assumed that the second peak in the pulse envelope is a "negative spike."

6. An analysis of the lifetimes of the transition levels (with allowance for the quenching by electrons), and also a comparison of the obtained data with the available theoretical calculation,[6] give grounds for assuming that in our experiment a coherent interaction took place between the pulse and the amplifying medium provided the condition $T_2^* < \tau_{pulse} \lesssim T_1, T_2$ are satisfied (T_1 and T_2 are the population-relaxation and polarization times, and T_2^* is the inhomogeneous relaxation time).

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