C_3F_7I laser installation with radiation energy 20 J and pulse duration 3.0 nsec

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We investigated the possibilities and prospects of using optical decoupling in single-pulse iodine lasers. A radiation pulse of 3.0 nsec duration and 20 J energy was obtained with an installation consisting of a driving generator and a single-stage amplifier, with a total weak-signal gain $\sim 10^6$.

To assess the prospects of realizing controlled thermonuclear fusion by means of a laser, the investigations of the high-temperature plasma call for the development of high-power laser pulses with energy $\sim 10^4-10^5$ J and pulse duration $\sim 10^{-9}$ sec.

Neodymium-glass installations with energy 10^3 J and nanosecond durations were developed by the authors of[1,2]. Further increase of the emission energy of such installations calls for an increase of the number of their elements and of the volume of the neodymium glass. From this point of view, gas lasers, for example photodissociation lasers,[3–6] offer definite advantages. Such a laser, with an emission power $\sim 10^9$ W, using the CF_3I molecule, is described in[7].

Essential problems in the development of high-power pulsed lasers are the production of short-duration pulses ($\tau_1 \sim 10^{-9}$ sec) and the prevention of self-excitation of the amplifying systems. In[7] they succeeded in avoiding self-excitation without using the coupling elements between the amplifier stages by using a specially developed pumping system with duration $\sim 1-2$ μsec.

We have investigated the feasibility of a photodissociation laser using optical decoupling to prevent self-excitation in a system with a relatively large pump duration ($\tau_p \geq 10^{-5}$ sec). The use of decoupling elements makes it possible to increase the number of amplifier stages and thus also the output energy of the system.

The experimental setup is illustrated in Fig. 1.

The driving generator (DG) with Kerr cell in the resonator shapes a radiation pulse of duration ~ 3.5 nsec and a rise time ~ 1.0 nsec. The radiation energy is ~ 0.4 J, and the C_3F_7I pressure is ~ 100 Torr.

The electric pulse that opens the Kerr cell, with voltage ~ 50 kV, was shaped with a cable generator. The open time τ_s of the shutter ranged from 30 to 40 nsec. A typical light pulse at the output of the Kerr cell with duration ~ 40 nsec is shown in Fig. 2a (1).

At a resonator length 1.5 m and a Kerr-cell transmission time 40 nsec, the driving generator shapes a sequence of pulses spaced $2L/C$ apart, where L is the optical path length [Fig. 2a(2)]. An increase of L leads to a corresponding change in the time interval between pulses [see Fig. 2a(3)]. A single pulse of energy 0.4 J and duration 3.5 nsec was obtained at a resonator length 2.5 m and a Kerr-cell open time 30 nsec [see Fig. 2b(1)].

The formation of the single pulse is completed in three passes of the light wave through the active part of the resonator, owing to the high gain (~ 1000), and therefore the amplitude of the single pulse is quite sensitive to its changes.

The inflection observed on the decreasing section of the single pulse (see Fig. 2b) may be due to relaxation between the sublevels of the hyperfine structure of

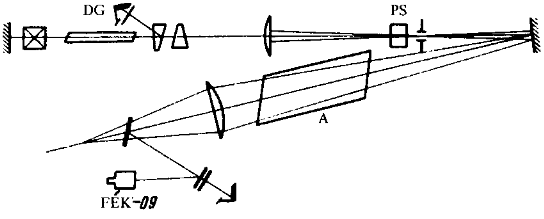

FIG. 1. Optical diagram of the setup.

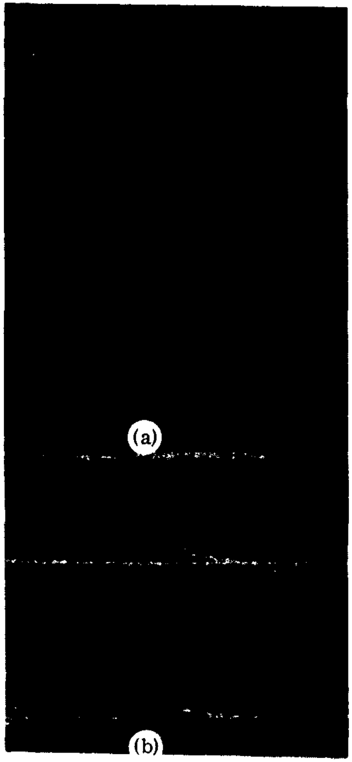

FIG. 2. Waveform of radiation pulse: a) $\tau_s = 40$ nsec; the time markers show intervals of 10 nsec; b) $\tau_s = 30$ nsec; calibration frequency 400 MHz.

the $^3P_{1/2}$ state of atomic iodine. This assumption agrees with the calculated[8] rate of sublevel mixing of the state $5^2P_{1/2}$ (the initial concentration of the excited particles in our case was $\sim 7.5 \times 10^{17}$ cm^{-3}). With further shortening of the pulse duration one should expect a 30% decrease in the amplifier efficiency, owing to the insufficiently rapid relaxation between the sublevels of the $^2P_{1/2}$ state of atomic iodine.

The signal from the driving generator passes through a passive shutter (PS) (atomic iodine1)) and a diaphragm to the input of the amplifier (A) with diameter 9 cm. The weak-signal gain attained in the amplifier is $\sim 10^3$. Under these conditions, at C_3F_7I pressure ~25 Torr and an input-signal energy 0.2 J, a single pulse with radiation energy 12 J is obtained at the amplifier output. Using a working mixture of C_3F_7I at 25 Torr and Xe at 300 Torr and the same input signal, the radiation energy was increased to 20 J. This was due to the increase in the stored energy as a result of the broadening of the atomic-iodine luminescence line. The pulse duration decreases to 3 nsec [see Fig. 2b(2)].

Stable operation of the system is attained when the attenuation of the passive shutter is ~10 for a signal of density $\sim 10^4$ W/cm^2.

The cell of the driving generator and the amplifier were pumped with xenon lamps at current-pulse durations (at the base) 20 and 100 μsec, respectively.

Thus, laser systems based on atomic iodine make it possible to shape single pulses of 3 nsec duration. The use of a passive atomic-iodine shutter in conjunction with a diaphragm makes it possible to decouple the amplifying system, with a total weak-signal gain 10^6.

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1) Unexcited atomic iodine was obtained by thermal dissociation of I_2 molecules.

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