XeCl-LASER WITH 200 J OUTPUT PULSE ENERGY

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We present calculated and measured parameters of XeCl *lasers with* 25×25 cm *aperture pumped with two electron counterbeams. The optimal mixture of* Ar:Xe:HCl = 700:10:1 *at a total pressure of* 2.5 atm *provides for the following lasing characteristics: energy of the emission pulse (duration* 250 ns*) measured at half maximum level exceeded* 200 J, *the gain of weak signals g_0 was* $0.065\ \text{cm}^{-1}$, *the unsaturated absorption coefficient* $a_0 = 0.015\ \text{cm}^{-1}$, *and the laser efficiency with respect to the amount of energy deposited into the active medium was* 3%.

At present excimer lasers are still most powerful sources of coherent UV radiation. The output energy delivered from such lasers per pulse reaches several kJ for KrF-lasers,[1–4] and hundreds of Joules for XeCl-lasers.[5–7] To achieve high energy of the output laser emission, normally beams of accelerated electrons are used as the pump sources.

In Ref. 8 the authors reported about the development of a XeCl-laser with the output pulse energy of 200 J. The main feature of this laser is its small size due to the use of an excitation scheme based on a pulsed energy generator equipped with a vacuum insulation designed at the High-Current Electronics Institute (SB RAS, Tomsk).[9]

In this paper we present a description of this laser and its characteristics in a more detail.

Block-diagram of the set up is shown in Fig. 1. The laser consists of two electron accelerators and a laser cell placed between these accelerators. Each accelerator is a metal tank comprising the generator of pulsed voltage and a vacuum diode. The vacuum in the tank reached $2 \cdot 10^{-5}$ Torr. The generator has been assembled according to Arkad'ev–Marx scheme, and consists of 8 stages (capacitors). The capacity of a stage is 0.5 μF and the maximum voltage can reach 100 kV. To decrease the generator inductance, the capacitor is composed of 3 sections each equipped with its own gas discharger. The explosive emission cathode of the vacuum diode (of 94×16 cm size) made from velvet glued on the graphite substrate is introduced into the last stage of the generator. The anode of the diode is a 20 mm-thick titanium foil placed 6 cm off the cathode. The absence of an insulator between the vacuum diode and the generator provides for an additional lowering of the output discharge circuitry inductance (the inductance equals to 0.3 μH).

The electron beam was injected into the laser chamber through a 25×100 cm window covered with another 40 mm-thickness titanium foil stuck on a grating with 85% transparency. The distance between the opposite foils in the laser chamber was 25 cm. The 280 liter chamber was made from a stainless steel. The output 25×25 cm windows were covered with the plates from fused silica. The laser resonator was formed by the external mirror and the chamber windows, or by a convex and concave mirrors (the so called unstable resonator with the magnification factor of 10). The gas mixture of Ar–Xe–HCl was prepared directly in the chamber.

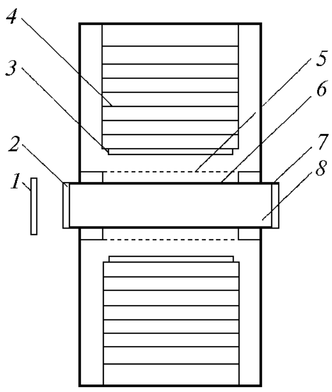

FIG. 1. Experimental set up: Al *mirror (1), windows of the laser chamber (2, 7), cathode (3), generator of pulsed voltage (4), pre-foil* 20 mm Ti *(5), foil* 40 mm Ti *(6), and laser chamber (8).*

The TPI–2–7 calorimeters were used for the laser energy measurements, the C8–14 and 6LOR oscilloscopes were used to record the electric signals, and FEK–22SPU photodiode to analyze the radiation pulses. Beam divergence was estimated by measurements using a spherical mirror with 7.8 m focal length. The difference between a weak signal gain and unsaturated absorption coefficient was estimated from measurements of the output laser emission intensity as a function of the input one for a single-pass of the radiation through the active medium.

We used a computer program MUFLON[10] in calculations of the spatiotemporal distribution of the electron beam energy absorbed in the active laser medium. This program uses actual oscillograms of the current and voltage at the vacuum diode as an input data. The geometry of electron beam injection and the separating foils were taken into account. To calculate the laser radiation parameters, we used a program that incorporates a kinetic model[11] while calculating the energy distribution of electrons by means of the weighted discrepancy method.[12] The main features of this method are its stability and high accuracy of calculations. This program allows one also to calculate parameters of the electric-discharge lasers.

Oscillograms of current pulses and accelerating voltage of the vacuum diode at the charge voltage of the pulsed generator of 90 kV are shown in Fig. 2. The maximum values of the current and voltage are seen to be 64 kA and 550 kV, respectively. All results discussed in this paper have been obtained at these working parameters of the accelerators.

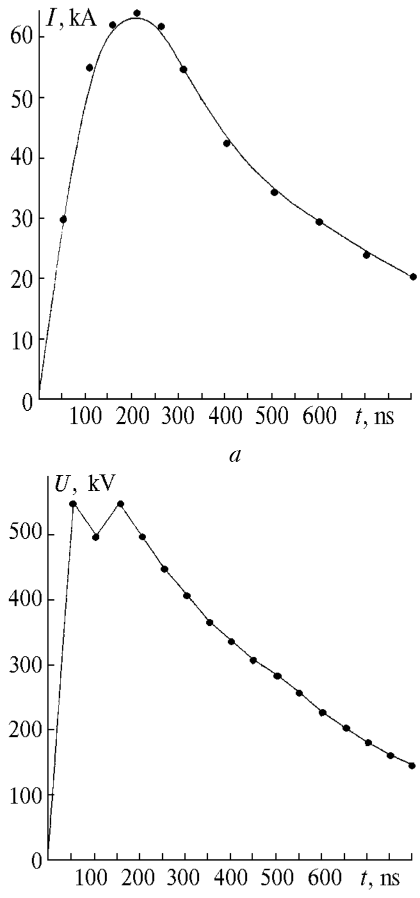

FIG. 2. Oscillograms of the current pulses (a) and accelerating voltage (b) in the vacuum diode. The charge voltage is 90 kV.

The distribution of energy and of the pump power in the active volume (25×25×100 cm^3) at the laser medium pressure of 2 atm is shown in Fig. 3. The pump power inhomogeneity is seen to not exceed 25%. The calculations have led to the following energy balance: from 13.7 kJ energy deposited into the laser chamber, only 5.5 kJ is a contribution to the active volume, 3 kJ are absorbed by the opposite foils, and the remaining amount of energy is dissipated out of the active volume or absorbed by gases or the chamber walls.

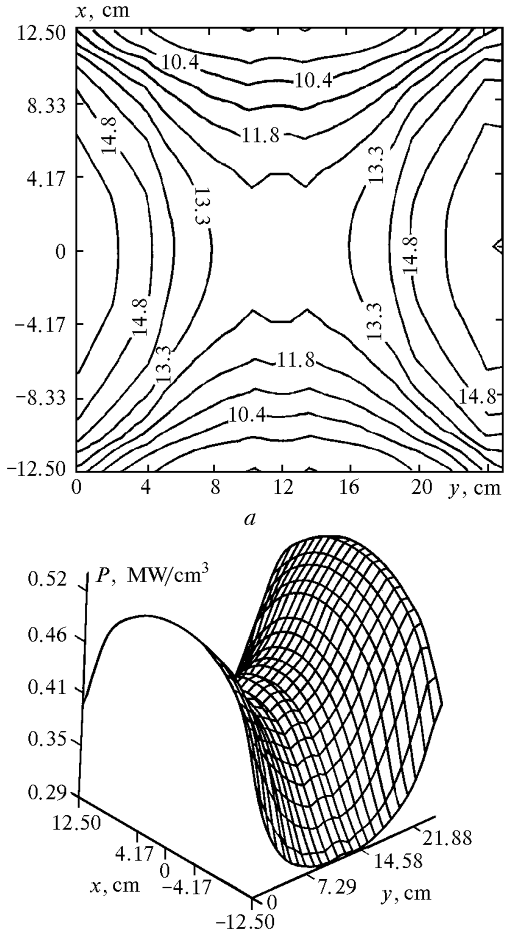

FIG. 3. Curves of equal absorbed energy integrated over the laser chamber length during a pulse (a). Spatial distribution of the specific pump power in the active volume. The pressure is 2 atm *(b).*

The maximum output energy of 210 J per pulse was reached in the Ar:Xe:HCl = 700:10:1 gas mixture at $P = 2.5$ to 3 atm (see Fig. 4). However, the best homogeneity of the lasing energy distribution across the laser beam was observed at $P = 2$ atm. The laser efficiency calculated based on the total energy deposited into the active volume at $P = 2$ atm was equal to 3%.

The calculated parameters of laser radiation are in a good agreement with the measured ones. The measured and calculated shape of the laser pulses, as well as the temporal dependence of a weak signal gain and the absorption coefficient are shown in Fig. 5. The time delay of the lasing generation pulse with respect to the pumping pulse is 80 ns, and its duration measured at half-maximum level is 250 ns. The calculated value of the gain at maximum intensity of pumping is $g_0 = 0.0645\ \text{cm}^{-1}$, and the absorption coefficient is $\alpha_0 = 0.0145\ \text{cm}^{-1}$. The measured value of $(g_0 - \alpha_0)$ was equal to $0.048\ \text{cm}^{-1}$, that is in a reasonably good agreement with the calculated one.

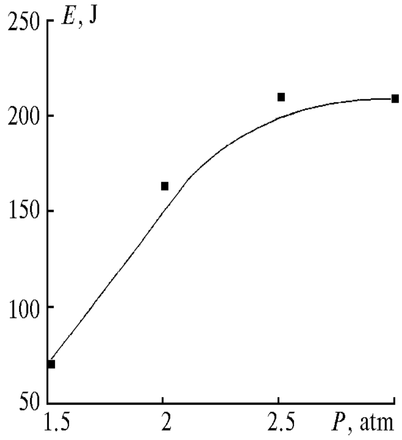

FIG. 4. The lasing generation energy for a laser with the stable resonator versus the pressure of an Ar:Xe:HCl = 700:10:1 *gas mixture.*

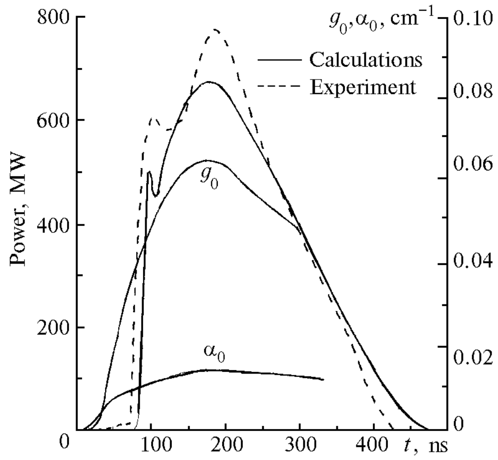

FIG. 5. Time behavior of the radiation pulse, the weak signal gain (g_0) *and the unsaturated absorption coefficient* (α_0)*. Pressure of the mixture is* 2.5 atm *(solid curves denote calculations; dotted curves denote measurements).*

The value of the radiation divergence (for a plane-parallel resonator) was estimated to be about 8 mrad. Use of an unstable resonator resulted in a two-time decrease of the lasing energy, and in the decrease of the radiation divergence down to 0.6 mrad.

At present time, this laser is used in an amplifier system designed for generating high-power pulsed UV laser radiation.

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