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Effect of the degree of preionisation of a gas on the homogeneity of a volume discharge and generation of radiation in a wide-aperture XeCl-laser

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Abstract. **The results of investigation of an electric discharge XeCl laser with active region apertures 8×11, 10×15, and 15×15 cm are presented. The preionisation of the Ne – Xe – HCl working mixture was performed by soft X-rays and a low-current electron beam, which provided the initial concentration n_0 of electrons in the gas from 10^6 to 2×10^{13} cm^{-3}. For $n_0 < 10^{12}$ cm^{-3}, the homogeneity of the initial electron concentration and of an electric field in the discharge gap have a considerable effect on the homogeneity of the volume discharge and output characteristics of the laser. For $n_0 \geqslant 10^{12}$ cm^{-3}, a homogeneous volume discharge is ignited and is stable if the inhomogeneity of the electric field in the discharge gap does not exceed 10 %. A storage capacitor charged to double the voltage of the quasi-stationary discharge operation is sufficient for discharge formation. It is shown that an improvement of the volume discharge homogeneity and a decrease in the size of the discharge chamber make it possible to increase the efficiency of a wide-aperture XeCl laser.**

Keywords: *XeCl laser, volume discharge, wide-aperture laser.*

1. Introduction

A large number of publications [1 – 5] have been devoted to the design and development of wide-aperture electric discharge XeCl lasers. The output pulse energy was raised to 50 – 60 J by using pump oscillators based on waterproof pulse-forming lines and soft X-rays for preliminary gas ionisation. The main problem connected with the laser scaling is to provide conditions necessary for producing a stable homogeneous discharge in a large volume of the gas.

Because of the inhomogeneity of the electric field near the electrodes and walls of the discharge chamber and of the inhomogeneous distribution of the initial electron concentration in the gas, the volume discharge undergoes microchanneling at the stage of its formation, and diffusion channels with a high conductivity shunting the volume discharge are created [6 – 9]. In this connection, measures are taken to level out the distribution of electric field strength in the discharge gap. Intense illumination of the gas provides an accumulation of electrons up to the required initial concentration and compensates for the departure of electrons from the cathode under the action of the applied voltage. Moreover, the fastest growth of voltage is maintained in the discharge gap during the formation of volume discharge.

It was shown in Refs [7 – 9] that a volume discharge with a sufficiently homogeneous current distribution is formed for an initial electron concentration $n_0 \sim 10^9$ cm^{-3} and for a steepness $\mathrm{d}U/\mathrm{d}t > 1$ kV ns^{-1} of the voltage build-up. The reduced electric field strength in the discharge gap achieves 2.5 kV cm^{-1} atm^{-1}, which is about four times larger than the value observed in quasistationary volume discharge. For a large aperture of the active region, the discharge initiation voltage achieves 100 kV, and the probability of breakdown over the surface of the input insulators or along the walls of the discharge chamber (if they are made of a dielectric) increases sharply. To preclude the breakdown, the length of the insulators should be approximately three times greater than the separation between the electrodes [4]. As the size of the discharge chamber increases, the growth of its inductance complicates the matching of the impedances of the pump oscillator and the volume electric discharge plasma. As a result, the possibility of the fullest utilisation of the energy stored in the accumulators is limited, and the optimisation of the specific power of gas excitation and of the electric field strength in the plasma, which determine the efficiency of transformation of the input energy into the laser radiation energy, is hampered.

This study aims at an analysis of the effect of the degree of preionisation of a working gas mixture Ne – Xe – HCl in the concentration range $n_0 = 10^6 - 2 \times 10^{13}$ cm^{-3} on the discharge gap breakdown voltage in a wide-aperture XeCl laser, the rate of formation of the volume discharge and its homogeneity, and the laser pumping efficiency.

2. Experimental results

2.1 Experimental conditions and computational data

We studied laser cross sections 8×11, 10×15, and 15×15 cm of the active region of the volume discharge (Fig. 1). The polyethylene discharge chamber (*2*) had internal dimensions $19 \times 19 \times 70$ cm and was capable of withstanding a pressure $p = 2.5$ atm of the working gas mixture. The active region of length 45 cm and aperture 8×11 cm was formed by two profiled electrodes (*3*, *4*) (Fig. 1a). The

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side walls of the discharge chamber virtually did not influence the formation and the development of the volume discharge in any way. We studied the regimes of formation and operation of the volume discharge and of lasing in an inhomogeneous electric field in the discharge gap using flat electrodes rounded at the edges and having dimensions approximately equal to the internal dimensions of the discharge chamber (Fig. 1b). For an aperture 15 × 15 cm, the active region of the volume discharge was confined by the discharge chamber walls. The active region of discharge having an aperture 10 × 15 cm and length 60 cm was confined by a 3-mm thick polyethylene frame fastened to an earthed electrode. The windows for outcoupling the output radiation were covered by an aluminium mirror and a plane-parallel quartz plate with a dielectric coating. The *Q*-factor of the resonator at a radiation wavelength of 308 nm was 0.3.

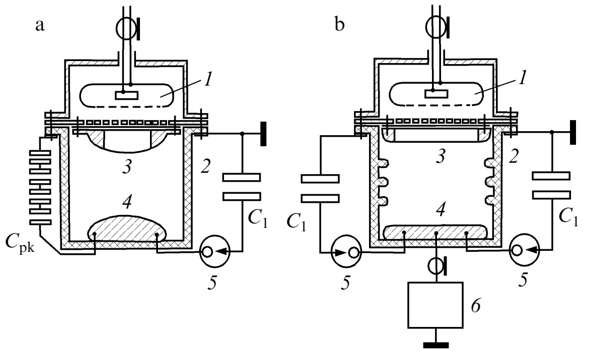

Figure 1. Schemes of a laser with single-sided (a) and double-sided (b) pumping; (*1*) plasma cathode of an electron accelerator, (*2*) discharge chamber, (*3,4*) profiled electrodes, (*5*) spark gap, (*6*) triggering pulse generator.

In a laser with a single-sided pumping, a storage and a peaking capacitor in a double-circuit power supply of the volume discharge were placed near the side walls of the discharge chamber and distributed over the length and height of the discharge gap. This provided the minimum inductance of the discharge circuits and significantly improved the homogeneity of the electric field E in the discharge region.

The electrode profiles and the electric field distribution in the discharge gap were calculated by the methods described in Refs [10–12] and verified experimentally [3, 13]. In the case of profiled electrodes, the local inhomogeneity $\Delta E/E$ of the electric field in the discharge gap did not exceed 1 %. The storage capacitor C_1 consisted of two small-size KMI pulsed capacitors and had a capacity of 0.1 μF. The inductance of the discharge circuit of the storage capacitor was 100 nH. The peaking capacitor C_{pk} was assembled from KVI-3 capacitors and had a capacitance of 7 nF. Pulsed charging of the storage capacitor made it possible to use as the multichannel switch (*5*) an extended two-electrode spark gap with electric field amplification near the anode tip [14]. For a charging voltage $U_0 = 100$ kV and a switching current of 150 kA, the calculated number of channels in the spark gap was 20 and the switching time was about 10 ns.

Preionisation of the Ne–Xe–HCl working mixture was performed by a 100–200-keV homogeneous electron beam or by soft X-rays with energy up to 100 keV generated by an electron accelerator with a plasma cathode [15]. The accelerated electrons and X-rays were introduced into the gas through a window in the earthed electrode of the discharge chamber, covered by a Dacron film of thickness 150 μm and a fine-mesh grid of stainless steel.

The current density of the electron beam was controlled by changing the current of the pulsed arc discharge at the plasma cathode with the help of limiting resistors. For a maximum current density 0.1 A cm^{-2} of the electron beam, the beam current pulse duration was 30 μs. As the current density was reduced to 5×10^{-3} A cm^{-2}, the current pulse duration achieved 800 μs. The X-rays were generated by placing a 100 μm-thick titanium target in the path of accelerated electrons in a diode. A change in the beam current density j_{b} from 0.1 to 10^{-5} A cm^{-2}, as well as a change in the intensity of the X-rays, led to a variation of the initial electron concentration in the working gas mixture from 2×10^{13} to 10^{6} cm^{-3}.

The distribution of the energy released by the electron beam in the gaseous mixture Ne–Xe–HCl was estimated by the Monte Carlo method [16]. For a beam current density $j_{\text{b}} = 0.1$ A cm^{-2}, the rate of formation of free electrons at a distance equal to 0.25 of the maximum mean free path of electrons in the gas was $S_0 = W_{\text{b}}/(t_{\text{b}}\varepsilon) = 2\times10^{-19}$ cm^{-3} s^{-1}, where W_{b} is the energy supplied by the electron beam into 1 cm^3, t_{b} is the beam current pulse duration, and $\varepsilon = 35$ eV is the energy of formation of an electron–ion pair. In the absence of an electric field, the electron losses are mainly associated with electron–ion recombination characterised by the coefficient $\alpha = 5 \times 10^{-8}$ cm^{-3} s^{-1}. Under the action of the electron beam, the stationary concentration $n_{\text{st}} = (S_0/\alpha)^{1/2}$ established in the working mixture of gases during a time $t_{\text{st}} \approx 3/(4\alpha S_0)^{1/2}$ achieves 2×10^{13} cm^{-3} for $j_{\text{b}} = 0.1$ A cm^{-2}. Measurements of the laser parameters upon a decrease in j_{b} were made for a 5 μs delay of the volume discharge relative to the onset of the beam current pulse. By this time, the arc discharge plasma fills the cathode of the accelerator uniformly and a uniform distribution of the current density over the beam cross section and maximum power of the accelerator are achieved.

When the gaseous mixture was preionised by X-rays at a current density $j_{\text{d}} = 0.67$ A cm^{-2} in the diode obtained by diaphragming the cathode, the rate S_0 was 0.4×10^{16} cm^{-3} s^{-1}, while the initial electron concentration achieved 2×10^{10} cm^{-3}. The concentration of electrons obtained at the onset of the volume discharge was varied through an appropriate choice of the parameters S_0 and t_{b}. The technique described in Refs [7, 17] was used to measure the exposure dose of X-rays in the active laser region and to calculate the ionisation rate of the gaseous mixture by X-rays.

To analyse the processes associated with the formation of a discharge under the action of an electric field, we carried out numerical calculations of the plasma particle concentration in a gaseous mixture Ne : Xe : HCl = 1000 : 10 : 1 under a pressure of 3 atm in the approximation of the homogeneous plasma distribution over the gap. The technique described in Ref. [12] was used to estimate the effect of the electric field inhomogeneity on the time of stable discharge operation. The dependence of the discharge formation time t_0 on the degree of preionisation n_0 and the average voltage growth rate $\mathrm{d}U/\mathrm{d}t$ over time t_0 were calculated. The particle concentration and the discharge conductivity were determined by simultaneous solving the Boltzmann equation and the balance equations for particles taking into account the real electric supply circuit.

Calculations show that in the case of preionisation by an electron beam ($j_b = 0.1$ A cm^{-2}, $n_0 = 2 \times 10^{13}$ cm^{-3}), the application of an electric field leads to an insignificant increase in the concentration of vibrationally excited HCl molecules to 10^{15} cm^{-3}. Therefore, the electron losses caused by their attachment to HCl molecules in the ground and vibrationally excited states are insignificant. The discharge is formed over a period of ~ 40 ns, mainly due to a step-by-step ionisation of the gas.

When the preionisation is accomplished by X-rays, the impact ionisation of the gas under the action of the applied electric field leads to a significant variation in the electron concentration from 10^9 to 10^{13} cm^{-3}. In this case, the stability and homogeneity of the volume discharge depend considerably on the homogeneity of electric-field distribution and on the initial electron concentration n_0 between the electrodes. In particular, for $\Delta E/E \sim 1\,\%$, the stable operation time of the volume discharge is estimated at 200 ns. If, however, $\Delta E/E \sim 5\,\%$, the volume discharge state exists only during the peak capacitance discharge in the gap between the electrodes.

For large variations in the electron concentration in a gas under the action of the applied electric field, it is interesting to study the dependence of the discharge formation time on the rate of voltage growth $\mathrm{d}U/\mathrm{d}t$ and on the initial concentration n_0. Such dependences are shown in Fig. 2, where it is tentatively assumed that the time t_0 corresponds to the time in which the voltage attains its peak and the discharge formation is virtually terminated.

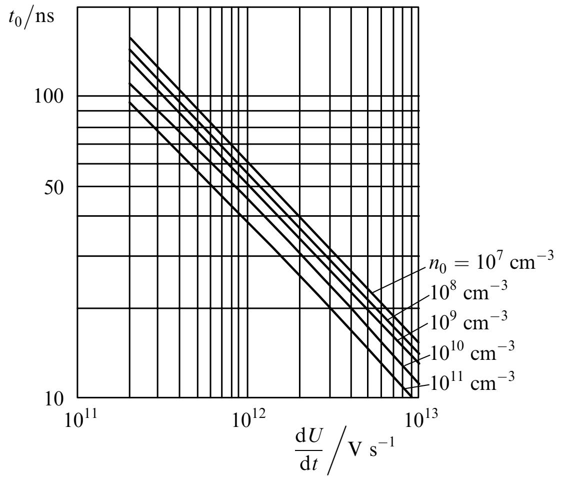

Figure 2. Dependences of the time t_0 of volume discharge formation on the rate $\mathrm{d}U/\mathrm{d}t$ of voltage growth in the discharge gap for different initial concentrations n_0 of electrons in an Ne : Xe : HCl mixture of composition 1000 : 10 : 1 under a pressure $p = 3$ atm and for a discharge gap of length $d = 10$ cm.

2.2 Single-sided laser pumping in a homogeneous electric field

Experimental investigations of the dependences of the volume discharge characteristics and the generated radiation on the rate of preionisation of the Ne–Xe–HCl mixture by a beam of accelerated electrons under conditions of a homogeneous electric field prevailing in the discharge gap were performed for a discharge region cross section 8 × 11 cm. The electron-beam current densities achieved at the beginning of the volume discharge formation were specified either by limiting the current in the power supply circuit for the plasma cathode of the accelerator, or by delaying the initiaion of the volume discharge relative to the onset of the beam current pulse. It was interesting to compare the laser parameters for such methods of variation of j_b, because an increase in the discharge delay time not only reduced the current density j_b, but also enhanced the inhomogeneity of its distribution over the beam cross section up to 20 % or more [15].

When a discharge delay time was 5 μs, the value of j_b decreased from 0.1 to 5×10^{-4} A cm^{-2}, and the electron concentration in the gas was decreased from 2×10^{13} to 4.5×10^{11} cm^{-3}, the cross section of the active region of the volume discharge and the laser output energy remained virtually unchanged. Upon a decrease in j_b, the reduced electric field strength E/p achieved in the discharge gap during its breakdown caused by the peaking capacitance increased from 1.8 to 2.4 kV cm^{-1} atm^{-1}, and the discharge current in the storage capacitor increased by 50 % due to the appearance of inhomogeneities partially shunting the volume discharge.

Upon an increase in the volume discharge delay time relative to the onset of the beam current pulse from 5 to 27 μs for a maximum value of $j_b = 0.1$ A cm^{-2}, the inhomogeneity of the current distribution in the beam was less than 20 %, while pulse energy decreased by no more than 25 %. Upon a decrease in the maximum beam current density to 0.01 A cm^{-2}, a delay of more than 5 μs in the discharge and, hence, an increase in the current distribution inhomogeneity up to 20 % in the beam, led to a sharp decrease in the radiation energy. At the termination of the beam current (when $j_b = 5 \times 10^{-3}$ A cm^{-2}), the volume discharge narrowed down to one third, and the radiation energy was 25 % of its initial value. These results and the observed difference in the brightness of the volume discharge over the length of the discharge chamber show that for an initial electron concentration below 10^{13} cm^{-3} in the gas, an inhomogeneity of over 20 % in the intensity distribution of the ionising radiation over the active region of the volume discharge leads to the macroinhomogeneity of the volume discharge and, consequently, to an uneven pumping of various regions of the active region of the laser, thus drastically deteriorating the lasing efficiency.

To compare the effect of the smoothly varying macroinhomogeneity in the current density distribution over the beam cross section and of the local beam inhomogeneities distributed uniformly over the length and width of the discharge chamber on the homogeneity of the volume discharge, a 0.5-cm thick aluminium plate with holes of diameter 1 cm drilled at a distance of 3 cm from each other was mounted in the window of the earthed electrode in the path of the accelerated electrons. For a fixed delay time of 5 μs of the volume discharge and upon a variation of the beam current density from 0.1 to $\sim 5 \times 10^{-4}$ A cm^{-2}, the duration of the volume discharge operation and the energy of the emitted radiation did not change and were comparable with the values obtained for a uniform current distribution over the beam cross section.

An analysis of the laser energy parameters for a homogeneous electric field in the discharge gap and for different rates of preionisation of the mixture by X-rays revealed the following facts. For preionisation rates $S_0 = 0.4 \times 10^{16}$ cm^{-3} s^{-1} of the mixture and a concentration $n_0 = 2 \times 10^{10}$ cm^{-3} of electrons accumulated during the discharge delay of 5 μs, the laser output energy was found to be equal to the energy generated during the preionisation by the electron beam. Upon a decrease in S_0 to 2×10^{14} cm^{-3} s^{-1} and hence in n_0 to 10^9 cm^{-3}, the radiation energy did not change significantly (see Fig. 3a). Subsequent simultaneous decrease in the values of S_0 and n_0 in the discharge gap of the laser led to a rapid decrease in the lasing efficiency. 'Autographs' of laser radiation indicate a deterioration of the homogeneity of the volume discharge over the entire cross section of the discharge gap. The formation of a large number of microchannels is observed near the cathode in a gas layer of thickness up to 1 cm. Fig. 3b shows the dependence of the laser radiation energy on the duration of preionisation of the mixture by X-rays for $S_0 < 2 \times 10^{13}$ cm^{-3} s^{-1}. One can see from the data presented in the figure that for preionisation of the gas by X-rays in zero electric field in a discharge gap for ~ 300 μs, the attachment of electrons to HCl molecules virtually does not affect their accumulation. Efficient lasing begins for $n_0 = 5 \times 10^8$ cm^{-3}. As n_0 increases to 10^9 cm^{-3}, the radiation energy achieves its maximum and subsequently varies proportionally to S_0 with increasing the delay time relative to the onset of preionisation of the gas. The maximum radiation energy is ~ 50 % of the energy generated for $S_0 \geqslant 0.4 \times 10^{16}$ cm^{-3} s^{-1}.

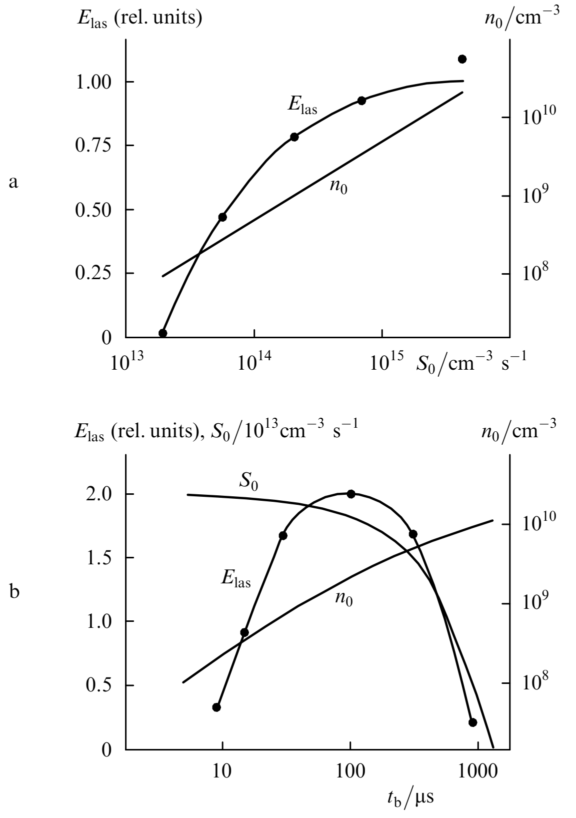

Figure 3. Dependences of the laser radiation energy E_{las} and the initial concentrations n_0 of electrons on the mixture preionisation rate S_0 for a beam current pulse duration $t_b = 5$ μs (a), as well as the dependence of E_{las} (for $S_0 < 2 \times 10^{13}$ cm^{-3} s^{-1}), S_0 and n_0 on t_b (b) for a Ne : Xe : HCl mixture of composition 1000 : 10 : 1 under a pressure $p = 2.5$ atm for $U_0 = 100$ kV and $C_{pk} = 2.5$ nF.

Upon a change in the charging voltage U_0 at the storage capacitor of the pump oscillator from 100 to 55 kV, and preionisation of the Ne–Xe–HCl mixture by an electron beam with current density 0.1 A cm^{-2}, the homogeneity of the volume discharge did not deteriorate. However, a decrease in the laser pump power led to a contraction of the active region of the volume discharge, thus preserving the necessary conditions for sustaining the discharge. A decrease in U_0 from 100 to 70 kV did not change the laser output energy. The efficiency of utilisation of the energy accumulated in the storage capacitor increased by a factor of more than two. This was mainly determined by the best matching of the wave resistance of the discharge circuit of the pump oscillator with the active resistance of the discharge gap in the laser chamber. For $U_0 = 55$ kV, the radiation energy decreased by 40 % due to a decrease in the ionisation rate of the mixture and the rate of energy transfer to the electronic states of Xe [18]. For $E/p < 0.4$ kV cm^{-1} atm^{-1}, a breakdown in lasing occurred in the plasma at the quasistationary stage of discharge operation.

If the Ne–Xe–HCl mixture is preionised by X-rays, a decrease in U_0 leads to a much faster decrease in the output energy than in the case of preionisation by an electron beam. This is explained by the fact that for low charging voltages and $n_0 < 10^{10}$ cm^{-3}, a decrease in the rate of formation of the excited XeCl* molecules is accompanied by a deterioration of the conditions of formation of a homogeneous volume discharge at the stage of impact ionisation of the gas. Experiments on optimisation of the composition of the working gaseous mixture, carried out for different charging voltages of the storage capcitor, show that the gaseous mixture must be diluted by the buffer neon gas with decreasing U_0. As in the case of preionisation by an electron beam, the highest values of the output energy and efficiency of the laser were achieved for a mixture in the proportion Ne : Xe : HCl = 1000 : 10 : 1. The reduced electric field strength in the discharge gap upon breakdown of the mixture was ~ 2.4 kV cm^{-1} atm^{-1}, while its value during the pump pulse was less than 0.6 kV cm^{-1} atm^{-1}.

The 'autographs' of the laser emission obtained in pumping regimes studied by us and the scanning of the laser-beam cross section with a power meter showed that the radiation energy was distributed nonuniformly in the discharge gap and the peak of its density was shifted from the centre of the discharge gap to the storage capacitor of the pump oscillator. The stratification of the discharge over its cross section, observed upon double-sided laser pumping and a specific pump power of the Ne–Xe–HCl mixture equal to 1.2 MW cm^{-3} [4], is attributed to the skin effect. In our experiments, the discharge region was displaced towards the storage capacitor at much lower specific pump powers (0.2–0.6 MW cm^{-3}), apparently due to the effect of inductance (~ 10 nH) of the electrodes and the discharge gap. A variation in the discharge current led to a voltage drop over this inductance comparable with the average voltage of quasistationary operation of the discharge.

2.3 Double-sided laser pumping in a homogeneous electric field

For a double-sided laser pumping in two-circuit oscillators, the introduction of a peaking capacitor between the storage capacitor and the discharge chamber leads to a considerable increase in the inductance of the discharge circuit of the storage capacitor. An analysis of the dependence of discharge and output parameters of a laser on the magnitude of the peaking capacitance C_{pk} showed the following. For intense preionisation of the Ne–Xe–HCl mixture by an electron beam and a homogeneous electric field in the discharge gap in the interval $C_{\text{pk}} = 0.5 - 7$ nF, the output energy varies insignificantly. The homogeneity of the volume discharge was preserved for 300 ns, right until the termination of the first half-period of oscillations of the storage capacitor discharge current. For $C_{\text{pk}} < 0.5$ nF, the variation in the volume discharge parameters and a decrease in the radiation energy by 20 %–30 % occurred mainly due to a change in the parameters of current switching by a multichannel discharge gap. If the peaking capacitor is replaced by a 10-Ω resistance distributed along the length of the discharge chamber, the formation of the volume discharge after activation of the multichannel gap occurs under the action of a storage capacitor charged to double the voltage of the quasistationary discharge operation, while the radiation energy is stabilised at a level attained for $C_{\text{pk}} > 1$ nF.

Upon preionisation of the gaseous mixture by X-rays at a rate $S_0 = 0.4 \times 10^{16}$ cm^{-3} s^{-1} and at the initial electron concentration $n_0 = 2 \times 10^{10}$ cm^{-3}, the radiation energy began to decrease rapidly when the capacitance C_{pk} was lower than 1 nF and the energy stored in it was less than 2×10^{-3} J per each 1 cm^3 of the mixture. For $C_{\text{pk}} = 0$ and the formation of the volume discharge under the action of a storage capacitor, the radiation energy was reduced by half.

The lasing regimes upon double-sided pumping of the active medium and in the case of the homogeneous electric field in the discharge gap were studied for a cross section 8 × 11 cm of the active region of the volume discharge. Storage capacitors C_1 having a capacitance 0.1 μF and charged to 100 kV were placed on both sides of the discharge chamber. The capacitors were connected to the discharge chamber through multichannel spark gaps (*5*) (see Fig. 1). The gaps were actuated by the triggering pulse generator (*6*) having an impact capacitance of 1 nF and forming voltage pulses with an amplitude of −100 kV and the leading front duration equal to 10 ns. The actuation time of the spark gaps had a spread of about 1 ns. For preionisation of the mixture Ne–Xe–HCl by X-rays, the parameters of the discharge gaps in the gas-discharge chamber and multichannel spark gaps of the pumping generator were selected in such a way that for a given steepness of the voltage growth at the output of the triggering pulse generator, the electron concentration in the active region of the volume discharge first increased to $10^{12} - 5 \times 10^{13}$ cm^{-3}, after which the multichannel gaps were actuated before the breakdown. This prevented the growth of diffusion channels in the volume discharge and reduced the constraints on the current build-up rate during the formation of the volume discharge, which is a necessary condition for its uniform operation. For such a scheme of laser excitation during preionisation of the Ne–Xe–HCl mixture by an electron beam as well as by soft X-rays, the current–voltage characteristics of the volume discharge were analogous to those obtained during pumping by a two-loop generator with a peaking capacitor. The energy of the radiation generated in this way was distributed almost uniformly over the beam cross section, and its density was about 190 mJ cm^{-2}.

2.4 Double-sided laser pumping in an inhomogeneous electric field

For a cross section 10 × 15 cm of the active region of the volume discharge, the electric field was distorted at the rounded tips of the flat anode and near the edges of the polyethylene frame fastened to the cathode. For an intense preionisation of a 1000 : 10 : 1 mixture of Ne : Xe : HCl by an electron beam with $j_{\text{b}} = 3 \times 10^{-2}$ A cm^{-2}, the volume discharge remained homogeneous for a period of 300 ns, i.e., until the completion of the first half-period of current oscillations. By the end of the first half-period, the discharge current was short-circuited at the diffusion channels formed at the end faces of the discharge chamber and along the edges of the polyethylene frame. Upon a decrease in the value of j_{b} to 3×10^{-4} A cm^{-2}, the shunting action of the channels led to a quenching of lasing , but not to a decrease in the duration of the volume discharge operation. A further decrease in the value of j_{b} to 3×10^{-5} A cm^{-2} led to a practically complete shunting of the volume discharge by diffusion channels.

In a discharge chamber having walls with ribs and an active region aperture 15 × 15 cm, the inhomogeneity of the electric field near the ribs was about 10 %. For a beam current density $j_{\text{b}} = 3 \times 10^{-2}$ A cm^{-2} and an initial electron concentration $n_0 \approx 10^{13}$ cm^{-3}, the duration of the volume discharge was ~ 250 ns, and the intensity of spontaneous emission of the excited mixture was proportional to the discharge power. Because of a relatively low specific pump power (0.12 MW cm^{-3}), the lasing threshold was not achieved. Photographs of the integrated glow of the discharge gap reveal diffusion channels that are formed at the ends of a discharge chamber without ribs and partially shunt the volume discharge. Upon a decrease in the beam current density j_{b} to 3×10^{-4} A cm^{-2}, the volume discharge was accompanied by the formation of diffusion channels localised at the ends of the electrodes near the ribs of the discharge chamber and distributed almost uniformly over the length of the chamber.

3. Conclusions

A comparison of the regimes of volume discharge operation and emission of a wide-aperture XeCl-electric discharge laser at initial electron concentrations n_0 from 10^6 to 2×10^{13} cm^{-3} in a Ne–Xe–HCl mixture shows that for $n_0 < 10^{12}$ cm^{-3}, the initial stage of the volume discharge formation occurs under conditions of impact ionisation of the gas, while diffusion channels shunting the volume discharge partially are formed in the regions where the electric field is distorted ($\Delta E/E \geqslant 1$ %). Upon an increase in the value of n_0 from 10^8 to 10^{10} cm^{-3}, the uniformity of operation of the volume discharge ignited and sustained by a two-circuit power supply system improves, and the laser output energy increases. If a weak-current electron beam creates an initial electron concentration higher than 10^{12} cm^{-3} in the mixture, the volume discharge is mainly formed through a step-by-step ionisation of the gas, a uniform volume discharge is ignited and operates steadily for electric field inhomogeneities up to 10 % in the discharge gap. In this case, it is no longer necessary to use a peaking capacitor or an auxiliary generator for forming the discharge, and it is sufficient to have a storage capacitor charged to double the voltage of quasistationary operation of the discharge.

An improvement in the homogeneity of the volume discharge operation and a decrease in the discharge chamber size nearly to the size of the active region help increase the efficiency of a wide-aperture XeCl laser. A reliable operation of such a laser in the repetitively pulse regime is provided by low power consumption and a high reliability of the weak-current electron accelerator with a plasma cathode, as well as by the possibility of extracting the accelerated electrons through a thick grid- or perforated electrode. Apparently, this method of preionisation of the gas is most suitable for lasers with an active region aperture exceeding 10 × 10 cm, or for solving the problem of obtaining radiation with a high spatial homogeneityy and a low divergence.

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