Effect of automatic corona preionization and buffer gases on XeCl laser output parameters

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Received September 2, 1999

The paper describes some results of investigation into the XeCl and N_2 molecular lasers pumped with a symmetric Blumlein generator with automatic corona preionization. A significant effect of the preionizer intensity and a buffer gas (argon or neon) on the output parameters of a XeCl laser excited by a fast discharge is demonstrated. For argon the specific emission power of 0.4 $J{\cdot}l^{-1}{\cdot}atm^{-1}$, was obtained which proved to be twice as large as that for neon regardless of the preionizer intensity. The regions of optimum energy contributions are determined to be from 10 to 25 $J{\cdot}l^{-1}{\cdot}atm^{-1}$ for neon and from 45 to 100 $J{\cdot}l^{-1}{\cdot}atm^{-1}$ for argon in the pumping scheme under study.

The peculiarities of independent discharges with automatic corona preionization in mixtures of Xe:CCl_4 with He and Ar buffer gases were studied in Ref. 1. Volume discharges were obtained in the argon mixtures at up to 2 atm pressure with the specific energy contributions up to 300 $J{\cdot}l^{-1}{\cdot}atm^{-1}$ and in helium mixtures up to the pressure of 4 atm with the specific energy contributions up to 200 $J{\cdot}l^{-1}{\cdot}atm^{-1}$ (Ref. 2). In the majority of cases neon is used as a buffer gas, since it provides for higher output power as compared with argon. Neon is thought to have more favorable effect on both the discharge and kinetic processes of formation of the working excimer molecules. Development of laser systems with large apertures and high output energies faces the problems associated with high working pressure and voltage, which are needed for efficient operation of such systems. Besides, neon is the most expensive buffer gas, therefore argon is a better choice, which, however, is poorly studied. We have studied the effect of automatic corona preionization on stabilization of discharge and output parameters of a XeCl laser pumped with a two-stage power supply providing for long lasing pulses.[3]

This paper describes some results of investigations into the effect of corona preionization on output parameters of XeCl laser pumped by fast discharge with argon and neon used as buffer gases.

Figure 1 shows the electric circuitry of pumping of the EKSIK–2 laser along with the design features of the corona preionizer. The laser was pumped with a symmetric Blumlein circuitry connected as strip lines of KVI–3 ceramic capacitors. The total capacitance of the lines were $C_1 = C_3 = 15.4$ nF and $C_2 = C_4 = 10.5$ nF. A commercial RU–62 triggered spark gap was used as a switch. It provides the maximum charging voltage of 13 kV and the pulse repetition frequency up to 3 Hz. The electrodes were 25 cm in length, the height of the gap between the electrodes was 1.5 cm, and the width of the discharge was 1.2 cm. The active laser volume was 1.4×0.7×25 cm. Automatic corona preionization was induced by an auxiliary cylindrical electrode *1* set behind the mesh-shaped cathode *3* connected to anode *4* and bounded by a quartz tube *2*.

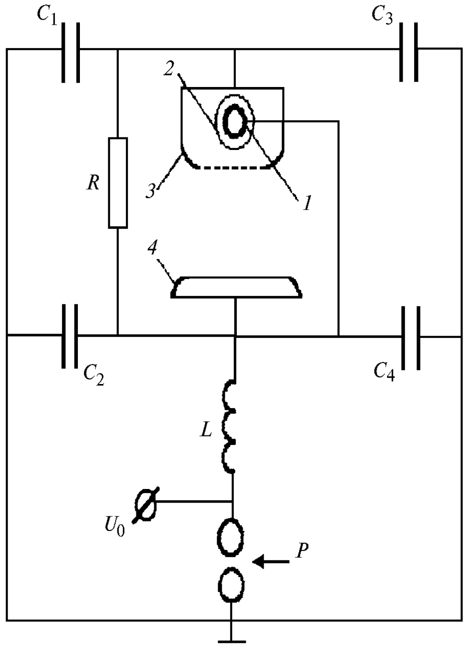

Fig. 1. Electric circuitry of the EKSIK–2 laser: recharge inductance *L* and triggered switch *P*.

We used quartz tubes 11 mm in outer diameter with changeable thickness of tube walls (from 1.4 to 2.8 mm). Changing the preionizer capacitance, we controlled its intensity at the same initial conditions of excitation of the active medium with argon and neon as buffer gases. Dielectric mirrors formed the laser cavity. The reflectance of the output mirror *R* could be varied from 10 to 35%. The output power was measured with an IMO–2N calorimeter. The shape of a laser pulse was displayed on a S8–2 oscilloscope with the help of the FEK–22SPUM photodetector.

0235-6880/99/11 974-03 $02.00

For this scheme of a power supply, i.e., fast pump by “avalanche discharge,” concentrations and concentration ratios among the gaseous component were optimized. No matter what the buffer gas is, the maximum output parameters were observed for the optimal ratio Xe:HCl = 5:1 with HCl = 4 Torr. Besides, the output power depended on the Q-factor of the cavity. Figure 2 shows the dependence of the output power Q for neon mixtures at the pressure of 3.5 atm on the reflectance of the output mirror and the charging voltage. The optimum reflectance was found to be 20%. This cavity was used in the experiments that followed. The pulse length was 7 ns at halfmaximum and 15 ns at the base.

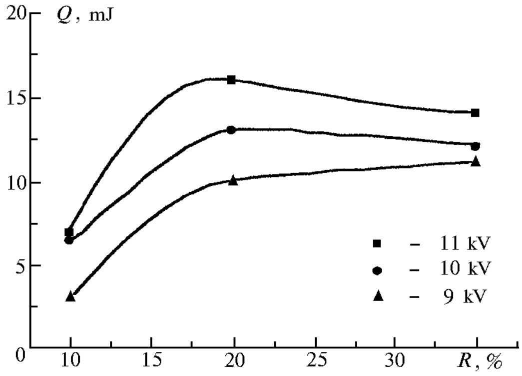

Fig. 2. Radiation power for the mixture (Ne) Xe:HCl = 5:1 (4 Torr) at the pressure of 3.5 atm vs. the reflectance of the output mirror and the charging voltage.

Experiments were conducted to study the effect of the preionizer intensity on the output parameters of the XeCl laser. Figure 3 shows the dependence of the output power emitted from the optimal mixture Xe:HCl = 5:1 (4 Torr) with argon and neon as buffer gases on the charging voltage and working pressure at different intensity of the preionizer: W_{uf} (curve *1*) and $2W_{uf}$ (curve *2*), where W_{uf} is the conditional power contributed in the preionizer.

For preionizer *1* the output power in argon mixtures increased with increasing pressure and charging voltage and achieved 10 mJ. This is related to the fact that as the charging voltage increased the breakdown voltage increased too, that is, the power contributed into the discharge increased thus extending the region of working pressure up to 1.5 atm. The optimum pressure for argon was about 1 atm. The working pressure for neon mixtures varied from 2 to 3.5 atm. The lower limit was determined by low breakdown voltage in neon, whereas the upper one by the design features of the laser chamber. For neon mixtures the output power weakly depended on the charging voltage $U_0 \le 11$ kV (for higher voltage, higher working pressure was needed). The maximum output power of 15 mJ was obtained at the pressure of 3.5 atm and $U_0 = 11$ kV.

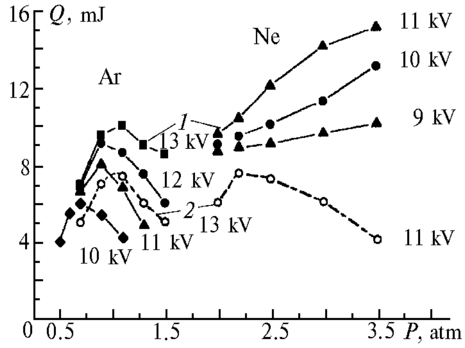

Fig. 3. Typical dependence of the output power emitted from the mixture Xe:HCl = 5:1 (4 Torr) with buffer gases on the working pressure, charging voltage, and the preionization intensity.

With the preionizer *2* the same maximum output power of 7 mJ was observed in both argon and neon mixtures. In argon it was obtained at $U_0 = 13$ kV and pressure of 1 atm, whereas in neon it was achieved at $U_0 = 11$ kV and the optimum pressure of 2.25 atm. As the pressure increased, the output power decreased. Consequently, the doubling of the intensity of automatic corona preionizer for fast pumping resulted in a decrease of the output power by 30% in argon mixtures and by 50% in neon mixtures, what is connected with a decrease in time and amplitude of the rise of the breakdown voltage, as well as with the growth of photoionization processes in these media.[2,4] The effect of the preionizer on the buffer gases is illustrated with data presented in Fig. 4.

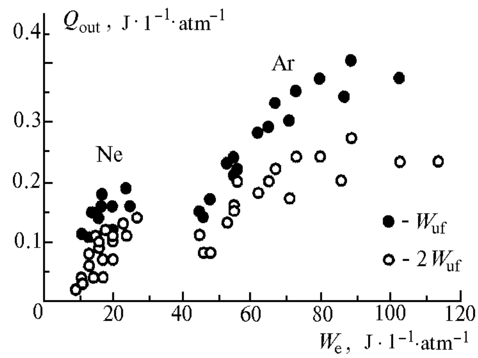

Fig. 4. Specific output power Q_{out} vs. the specific energy contribution W_e and the preionizer intensity in argon and neon mixtures.

It was thought that only 50% of power accumulated in the capacitors is contributed to the discharge. For neon the specific energy contribution varied from 10 to 25 J·l^{-1}·atm^{-1} at the maximum specific output power of 0.2 J·l^{-1}·atm^{-1}, which was practically twice as large as that for a lower intensity preionizer. Similar dependence was observed in argon, but at higher energy contributions: from 45 to 100 J·l^{-1}·atm^{-1}. At the same time, the specific output power in argon was maximum: 0.4 J·l^{-1}·atm^{-1}. Note that the specific output power in argon was almost twice as large as the that for neon regardless of the preionizer intensity. This fact is indicative of the larger effect of photoionization process on argon in comparison with neon. Consequently, argon is most promising buffer gas for reliable and economical lasers with high specific parameters.[5–7]

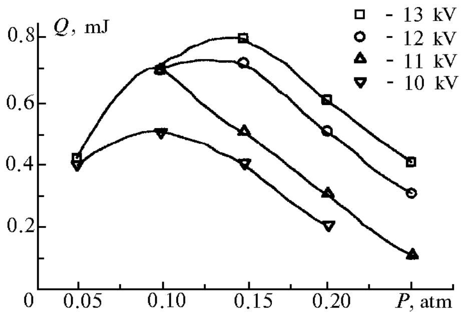

Fig. 5.

Besides, we have studied with this laser the output parameters of a N_2 laser. Figure 5 shows the typical dependence of the nitrogen laser output power on the working pressure and charging voltage. The maximum power of 0.8 mJ was observed at the pressure of 0.15 atm and U_0 = 13 kV. The pulse length at halfmaximum was 5 ns. It should be noted that this pump system provides for high output parameters of the N_2 lasers. At the same time, they are an order of magnitude lower than those for the XeCl lasers. However, in reality the output power parameters in nitrogen lasers are far lower.

In conclusion we would like to note that application of the automatic corona preionization bounded by a mesh-shaped cathode allows one to obtain higher specific output power at a fast pumping of XeCl laser. For argon mixtures this power can be 0.4 $J \cdot l^{-1} \cdot atm^{-1}$ as high, what is twice as large as that in neon mixtures, regardless of the preionizer intensity. These results allow us to look forward for further promises of argon as a buffer gas in small-size and high-power lasers.

References

1. M.N. Kostin, V.F. Tarasenko, and A.I. Fedorov, Zh. Tekh. Fiz. **50**, No. 6, 1227–1230 (1980).
2. A.I. Fedorov, "XeCl *and* XeF *Molecular Excimer Lasers Excited by Independent Discharge*,B *Author's Abstract of Cand. Phys.-Math. Sci. Thesis* (Tomsk, 1982), 17 pp.
3. A.I. Fedorov, Zh. Tekh. Fiz. (1999), in press.
4. V.Yu. Baranov, V.M. Borisov, and Yu.Yu. Stepanov, *Electric Discharge Excimer Lasers at Halogenides of Inert Gases* (Energoatomizdat, Moscow, 1988), 216 pp.
5. A.I. Fedorov, V.F. Tarasenko, and Yu.I. Bychkov, Pis'ma Zh. Tekh. Phys. **4**, No. 3, 132–135 (1978).
6. R.C. Sze, J. Appl. Phys. **50**, No. 7, 4596–4598 (1979).
7. M. Steyer and H. Voges, Appl. Phys. **42**, 155–160 (1987).