SOME POSSIBILITIES OF INCREASING THE EFFICIENCY OF N_2 LASERS PUMPED WITH AN ELECTRIC DISCHARGE

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In this paper, a summary of experimental data on a compact low pressure discharge pumped nitrogen laser is presented. Some practical considerations concerning the development of compact nitrogen lasers are discussed. Plasma or corona preionization source located behind a grid electrode are shown to provide an arbitrary configuration of the laser output beam cross section.

Compact, repetitively pulsed UV lasers, specifically nitrogen and excimer ones, are widely used for pumping dye lasers, plasma diagnostics, sounding of the atmosphere, in medicine, biology, etc. However, such parameters of these lasers as weight, size, reliability, beam quality, and price often do not meet modern requirements. Since compact N_2 lasers are simple in construction and have lower price as compared to that of excimer lasers, there is a considerable interest in these laser devices shown both by companies producing lasers and by their consumers.

In this paper our experience in design of compact discharge N_2 lasers is summarized.[1–4] Transverse electric discharge was used for pumping the active medium. Automatic UV preionization was provided by spark,[5] corona,[3] or surface[2,6] discharge. In Ref. 5, the most simple and reliable technique of pumping the nitrogen laser was described in detail. Excitation circuit includes storage and peaking capacitors with the inductive spark preionization that has been successfully used in our experiments with excimer lasers. It should be noted that all N_2 lasers described here operate at low gas pressure (about 120 Torr).

So, in Ref. 1, output energy of a laser system ELAN-01M was examined. The active volume was $2.5\times1\times70$ cm^3.

The energy stored in the primary capacitor (W_{ch}) reached 30 J. Preionization was provided by two raws of 20 spark gaps located symmetrically with respect to the main discharge gap. All sparks were initiated during charging of the peaking capacitor. Laser was equipped with a plane-parallel optical cavity which consisted of Al mirror and quartz plate. Output energy was measured by means of IMO-2N calorimeter. The shape of the laser pulse was monitored with the aid of an FEK-22SPUM photodiode and S8-14 oscilloscope. Waveforms of discharge current and voltage across the laser gap were detected using a low-inductance shunt with the resistance of 0.1 Ω and a voltage devider, respectively. The same type of hardware including optical cavity was employed in experiments with other N_2 lasers. ELAN-01M provided output energy up to 10 mJ at the optimal gas pressure of 120 Torr. Output pulse duration was 5 ns, FWHM, peak radiation power reached 2 MW. These parameters correspond to the best data obtained with nitrogen lasers. The system operated at a pulse repetition rate of 5 Hz; standard trigatron was used as a switch. On the base of this laser a number of compact laser systems has been developed that performed successfully as excimer lasers.

Using the configuration of the laser gap with two plasma electrodes, we managed to obtain laser action in nitrogen for the first time in laser device EKSIK-1 of $0.6\times0.7\times20$ cm^3 active volume.[2] Maximum output energy was 0.5 mJ at a gas pressure of 100 Torr. Output pulse duration was 5 ns, FWHM. Laser operated at a pulse repetition rate of 10 Hz. The specific feature of the laser performance in this case is the existence of two discharge stages. First stage of surface discharge formation with preionization of the gas[6] is followed by the second one when discharge current flows between plasma electrodes. Two-stage discharge pumping leads to a rectangular or square output beam profile. It should be pointed out that stabilization of the glow discharge was observed also in the case when the width of the discharge was larger than the electrode separation. At an elevated gas pressure, only surface discharge is observed, and output pattern consists of two narrow lines. Thus, this system allows one to obtain output beam of two different configurations, either rectangular cross section or two narrow lines separated at a distance equal to that between discharge electrodes can be observed. Operation of this laser with one plasma electrode was examined too. In this case, laser output beam has a usual cross section[1] corresponding to the discharge configuration with electrode separation two times larger than the discharge width. The active volume was $0.9\times0.5\times20$ cm^3. Laser output energy peaked at a pressure of 150 Torr and reached 0.9 mJ in 5 ns pulse. An RU-73 controllable spark gap was employed as a switch. It determined the upper level of charging voltage U_0 = 20 kV.

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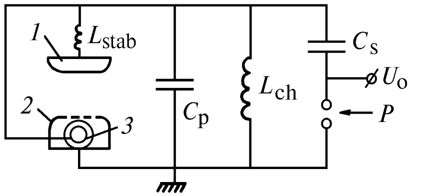
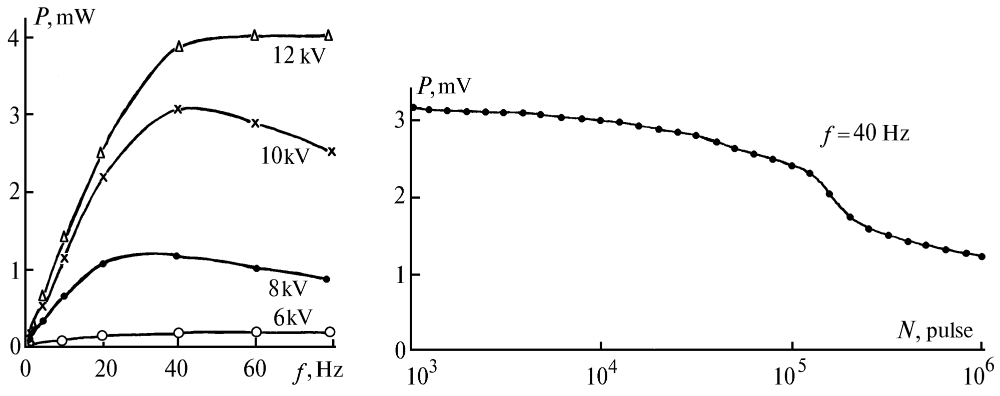


FIG. 1. Excitation circuit of EKSIK-01F laser: cathode 1, mesh anode 2, quartz tube with corona preionization 3, storage capacitor C_s, peaking capacitor C_p, contrallable spark gap SG, charging inductance L_{ch}, and stabilizing inductances L_{stab}.



a *b*

FIG. 2. Average output power as a function of pulse repetition rate at different values of charging voltage (a) and the number of laser shorts in the sealed-off operation mode (b) at U_0 = 10 kV, p = 120 Torr, C_s = 6 nF, C_p = 2.6 nF.

TABLE I. Low-pressure nitrogen lasers pumped by transverse discharge.

Laser	Preionization (switch)	U_0, kV	W_{ch}, J	L, cm	D, cm	H, cm	V, cm^3	W_g, J·cm^{-3}	ε_{out}, mJ	ε_{out}, mJ·cм$^{-3}$	P_{max}, MW	P_{out}, kW·cm^{-3}	$\tau_{h/2}$, ns	f_{opt}, Hz
ELAN-01M	Spark (trigatron)	30	27	70	2.5	1	175	0.15	10	0.06	2	10	5	5
EKSIK-1	1-plasma electrode (RU-73)	20	5	20	0.9	0.5	9	0.55	0.3	0.03	0.06	6.6	5	10
	2-plasma electrode				0.6	0.7	8.4	0.55	0.5	0.06	0.1	11.8		
EKSIK-2 (Blumlein)	Corona (RU-62)	12	4	25	1.4	0.7	25	0.16	0.8	0.03	0.16	6.4	5	3
EKSIK-01F	Corona (RU-62)	12	0.3	20	0.4	0.7	5.6	0.05	0.13	0.02	0.03	5.5	5	40

Note: L is the electrode length; D is the electrode separation; H is the electrode width; W_g is the specific energy deposited into the gas; $\tau_{h/2}$ is the FWHM pulse duration.

Output energy obtained from EKSIK-2 laser with active volume of $1.4\times0.7\times25$ cm^3 and corona preionization reached 0.8 mJ at a gas pressure of 120 Torr. The charging voltage was limited by RU-62 spark gap to be not higher than 13 kV. Blumlein excitation circuit formed by KVI-3 capacitors was used. It allowed pulse repetition rate up to 3 Hz. As compared to the devices developed earlier, this one has other preionization source. This laser preionization was provided by corona discharge limited by grid electrode.[7–9] Experiments performed with this laser were aimed at developing a compact repetitively pulsed sealed-off laser device. Laser action in nitrogen was obtained also from EKSIK-01F laser with active volume of $0.4\times0.8\times20$ cm^3, volume of laser chamber of 1 liter, and corona preionization. Figure 1 shows the capacitor two-circuit excitation circuit with corona preionization limited by a grid anode. An RU-62 spark gap was used as a switch. Maximum output energy was 0.13 mJ at a gas pressure of 120 Torr, output pulse duration being about 5 ns, FWHM. The charging voltage varied from 6 to 12 kV.

Figure 2*a* presents average output power as a function of pulse repetition rate and charging voltage in sealed-off operation mode. The maximum average power is 4 mW. Figure 2*b* plots average output power versus number of laser shots N at $U_0 = 10$ kV, $p = 120$ Torr, $C_s = 6$ nF, $C_p = 3$ nF. Two-fold decrease of the average output power was observed after $N = 3\cdot10^{15}$ pulses at the optimal pulse repetition rate of 40 Hz. The service lifetime of laser is apparently determined by discharge configuration, specifically, by the fact that its width is two times larger than the electrode gap. Table I summarizes parameters of N_2 lasers developed.

Thus, the following conclusions can be drawn from our data:

1. Excitation circuit including storage and peaking capacitors is preferable.
2. Plasma or corona discharge limited by a grid electrode is most appropriate as a source of preionization providing specific configuration of the output laser beam.
3. Commercially available comparatively low voltage (10 kV) controllable spark gaps can be used as switches.
4. Sealed-off nitrogen laser operation is feasible.
5. Compact N_2 lasers are shown to provide rather high specific output parameters.

The author hopes that these conclusions could be useful for development of compact low pressure nitrogen lasers.

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