# Nitrogen laser with the pulse repetition frequency of 1 kHz pumped by a longitudinal discharge from the generator with an inductive energy storage and a SOS-diode

**I.D. Kostyrya and V.F. Tarasenko**

*Institute of High-Current Electronics, Siberian Branch of the Russian Academy of Sciences, Tomsk*

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We present a nitrogen UV-laser with the pulse repetition frequency of 1 kHz pumped by a longitudinal discharge from the generator with an inductive energy storage and SOS-diode. To increase the mean radiation power at high pulse repetition frequencies, the discharge was excited between two ceramic tubes thus yielding an annular output beam. At the pulse repetition frequency of 1 kHz, we have obtained mean radiation power of 25 mW.

To increase the pulse repetition frequency in lasers operated on self-terminated transitions pumped with a longitudinal discharge, the tubes are used of a small diameter, made from specific material or the tubes of a special construction, where the distance from the central part of the discharge to the side walls is reduced.[1–4] This enables one to improve the cooling of discharge area and increases the ion recombination rate and deactivation of the excited particles on the walls of the laser tube. In Ref. 2 it was an increase of the pulse energy and mean radiation power of the molecular nitrogen UV-laser using rectangular and ring-shaped geometry of the output beam (second positive system, electronic bands $C^3\Pi_u - B^3\Pi_g$, transition 0–0, $\lambda = 337.1$ nm). Increase of the radiation energy in the pulse was achieved due to the increase of active volume and the mean radiation power increases due to the conservation of relatively small distance from the central part of the discharge to the sidewalls of the laser chamber. In Ref. 4, the pulse repetition frequency was 200 Hz.

Recently, generators with inductive energy storage and semiconductor current switch have been applied[5–9] for excitation of the nitrogen laser with a longitudinal discharge. However, the pulse repetition frequency of the nitrogen lasers constructed did not exceed 100 Hz because the tubes of relatively large diameter,[5–9] have been used whereas the inductive energy storages on the basis of SOS-diodes,[10] can operate in the laser modes at the pulse repetition frequencies higher than 10 kHz.[11,12]

The aim of this study was to construct a nitrogen UV-laser with the pulse repetition frequency up to 1 kHz, at excitation by a longitudinal discharge using a generator with an inductive energy storage and a SOS-diode.

The laser excitation circuitry used in our study is similar to that described in Ref. 9. The laser set-up consisted of a pulse generator and a laser tube. The pumping was performed with an inductive energy storage with a SOS-diode. The electric circuit used for pumping the SOS-diode is standard (Fig. 1).

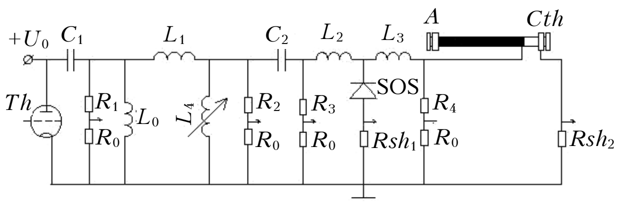


**Fig. 1.** The electric circuit of the nitrogen laser pumping generator with an inductive energy storage on the basis of a semiconductor current switch: $+U_0$ is the charging voltage of positive polarity; *Th* is the thyratron; $C_1$ is the primary capacitance energy storage; $C_2$ is the secondary energy storage; $L_0$ is the charging inductance; $L_1$ is the linear inductance; $L_2$ is the inductive energy storage; $L_3$ is the inductance of conductors feeding the laser chamber; $L_4$ is the choke coil; SOS is the SOS-diode; $R_0$–$R_4$ and *Rsh* are the resistance voltage dividers and a shunt; *A* and *Cth* are the anode and the cathode of laser chamber.

As compared with Ref. 9, the capacities of the capacitors $C_1$ and $C_2$ were reduced, and the spark–gap was replaced by a magnetic key. The primary pumping circuit of the SOS-diode was switched on by a TGI 1000/25 thyratron. The second circuit was triggered by a saturated single-turn magnetic choke coil $L_4$, made from a set of 60 ferrite rings of M2000 HM1 material with the outer diameter 28 mm and the inner one of 16 mm and thickness of an individual ring of 9 mm. The ferrite rings were assembled on a copper tube of the corresponding diameter. The capacitors $C_1$ and $C_2$ were assembled using KVI-3 ceramic capacitors (10 kV, 3300 pF) connected in series and in parallel $C_1 = C_2 = 2.2$ nF with the discharge half-period of 200 ns. Special silicon SOS-diode[10] was used as a current switch with the maximum reverse voltage of 120 kV and maximum amplitude of the cutoff current of 4.0 kA.

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Construction of the laser chamber is presented in Fig. 2. The discharge was initiated between two ceramic tubes *5* and *6*. The external ceramic tube *5* was 280 mm long and its inner diameter was 9 mm. The second ceramic tube *6* of 300 mm in length was placed inside this tube; its outer diameter was 8 mm.

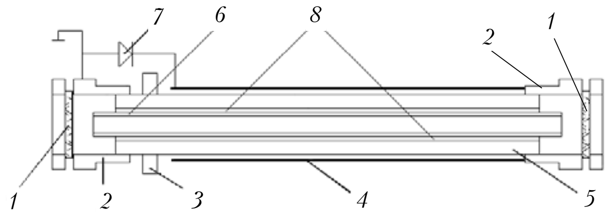


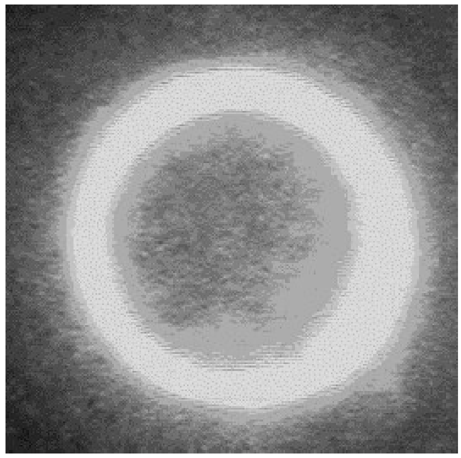

**Fig. 2.** Block-diagram of the laser chamber elements in the axial section: *1* are the mirrors; *2* are the brass electrodes and adjustment units simultaneously; *3* is the teflon insulator; *4* is the reverse current-conducting wire; *5* is the external ceramic tube of the laser chamber; *6* is the internal ceramic tube; *7* is the SOS-diode; *8* is the discharge gap between the ceramic tubes.

The internal tube was filled with epoxy resin. Investigations were carried out at two positions of the internal tube relative to the external one. In the first case, the central axes of both tubes coincided that gave an identical gap between the tubes, equal to 0.5 mm. Figure 3*a* presents the laser radiation beam geometry visualized with a luminescent screen. In the second case, the internal tube *6* touched the inner surface of the external one *5* that gave laser beam geometry of a sickle shape (Fig. 3*b*).

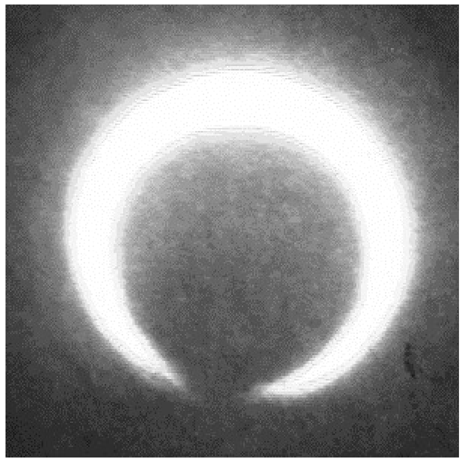
The cavity was formed by an aluminum coated flat mirror and a plane-parallel quartz plate. Energy and mean radiation power were measured with an IMO-2N calorimeter, radiation pulse shape was recorded using a PEK-22 photodiode. Voltage and current oscillograms were recorded by means of the resistance voltage dividers, current shunts or a Rogowsky loops. Electric signals were recorded with a TDS3032 oscilloscope.

The pulse repetition frequency could be varied from hertz to 1 kHz. At the enhanced frequencies, laser chamber and electrodes were overheated, therefore, the laser chamber was cooled by the airflow, and nitrogen was pumped through the discharge area. Time of laser operation without overheat depended on pulse repetition frequency and was about 5 minutes at 1 kHz.

Using the laser constructed we have investigated the dependences of its mean radiation power on pressure and pulse repetition frequency. Such a dependence for the annular output beam is shown in Fig. 4. Optimal pressure made about 13 Torr. The maximum mean power (31 mW) was obtained at a frequency of 0.6 kHz. Further increase of the pulse repetition frequency, led to heating of the internal ceramic tube that affected the lasing. It has led to a decrease of the mean power of output radiation. This problem can be solved by cooling the internal tube using water; however, this would complicate the laser construction.



*a*



*b*

**Fig. 3.** Photographs of the screen in the luminescence light under the action of UV-laser radiation. The outer diameter of the beam is about 10 mm.

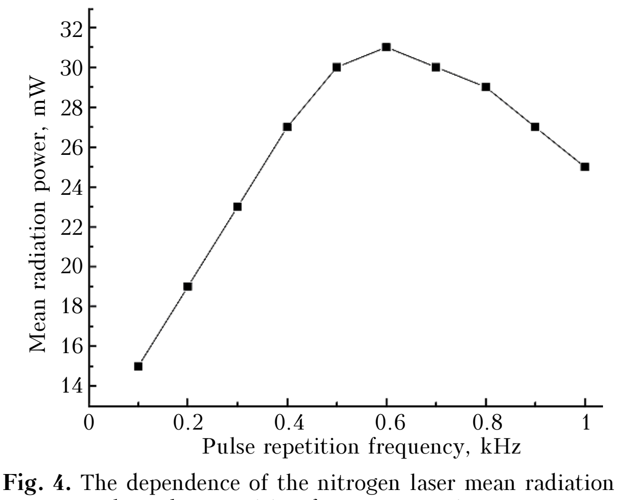



**Fig. 4.** The dependence of the nitrogen laser mean radiation power on the pulse repetition frequency at nitrogen pressure of 13 Torr.

Setting of the internal tube on the surface of the external one (output beam photo is shown in Fig. 3*b*) led to a decrease of the optimal nitrogen pressure (down to 9 Torr) and of the pulse repetition frequency giving maximum to the mean output power down to 0.4 kHz. The maximum mean power also decreased (approximately twice). The decrease is connected with poorer cooling of the discharge area and excitation homogeneity over the laser chamber cross section.

Thus, in this paper we have reported on generation of the nitrogen UV-laser pumped by a longitudinal discharge from a generator with an inductive energy storage and SOS-diode. Stable lasing is obtained at a pulse repetition frequency of 1 kHz with the ring-shaped output beam. To increase the mean radiation power at high pulse repetition frequencies, the discharge was excited between two ceramic tubes. The maximum mean radiation power of 31 mW was obtained at the pulse repetition frequency of 0.6 kHz and annular output beam.

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