10 J DISCHARGE XECL LASER

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Design and performance characteristics of discharge repetitively pulsed XeCl *laser with active volume of* 4×7×100 cm^3 *are described in the paper. The laser device includes a cylindric discharge chamber with a fan, heat exchanger, and a source of soft X–rays. Active medium is pumped by a thyratron magnetic generator with stored energy of* 500 J. *Output energy of* 10 J *in a* 50 ns *pulse and output power density of* 10 MW/cm^2 *are obtained in a gas mixture of* Ne:Xe:HCl = 1560:0:1 *at the total pressure of* 4 atm. *Preliminary examination of the laser performance at* 20 Hz *has been carried out.*

The laser developed can be used for remote sensing of the atmosphere. The main units of laser are discharge chamber and a thyratron magnetic generator of the excitation pulses.

The cylindric discharge chamber 45 cm in diameter and 150 cm in length is made of stainless steel. Vacuum diode of soft X–ray source was mounted on a side flange of the chamber together with a tubular heat exchanger and a fan. Discharge volume of 4×7×100 cm^3 is formed by two profiled electrodes. Construction of feeder insulator and a feedback wire determines the inductance of the discharge chamber to be about 20 nH.

X–rays that are generated in the vacuum diode are used for preionization of the gas mixture. This radiation penetrates into the discharge gap through the window in the grounded electrode. The window is closed with titanium foil or a perforated plate. The vacuum diode of the X–ray source is of a reversed type with cold explosive emitting cathode. This cathode is made of 25 μm thick tantalum foil strips fixed on a supporting grid. Tantalum foil 100 μm thick serves as a taget on the anode. The residual gas pressure is kept at the level of 10^{-2} mm Hg by a 2NVR–5DM pump.

The vacuum diode is pumped by 5 nF capacitor of K15–10 type via a KVI–120 cable and a controllable spark gap. Experiments with the pulsed gas discharge as a switch and pulsed transformer as a power supply for vacuum diode were carried out too. At the amplitude of accelerating voltage of 65 kV and rise time of 50–70 ns the diode demonstrated stable performance at a pulse repetition rate up to 200 Hz. The current density in the diode reaches 2 A/cm^2 and pulse duration of bremsstrahlung of 300 ns at the charging voltage of 60 kV. The energy of quantum is 25–30 keV. The radiation dose measured in the discharge area reached 1 R. This dose causes initial electron number density about 10^9 cm^{-3} in the gas mixture Ne:Xe:HCl at the total pressure of 4–5 atm that is necessary for homogeneous discharge formation.[1–3]

Gas circulation is provided by means of a fan 200 mm in diameter and 1200 mm long. Rotation of the fan is made using direct–current motor via a magnetic coupling. The drive power is 2.3 kW. When the fan makes 1500 revolutions per minute the gas circulation speed is 5 m/s.

Tubular heat exchanger is manufactured of alluminimum alloy. Water is used as a heat carrier.

Output laser radiation passes through the window 140 mm in diameter. Optical cavity is formed of a dielectric mirror with 99% reflectivity at 308 nm and a plane parallel quartz plate.

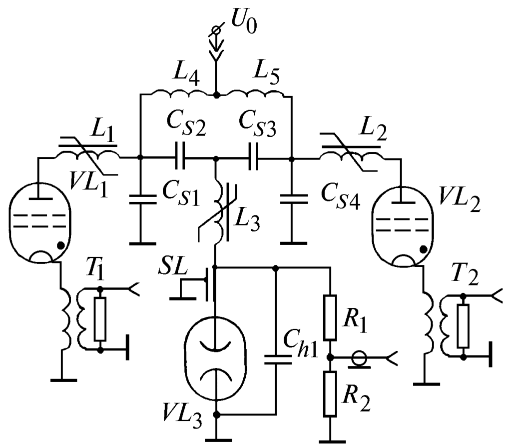

Fig. 1.Circuitry of a thyratron magnetic generator.

Figure 1 presents electric circuitry of a thyratron magnetic generator that is used for laser excitation.[4] Two TGI 1–2500/50 thyratrons are connected with storage capacitors C_{s1}–C_{s4} through protective inductances L_1 and L_2. The compression inductance L_3 connects output ends of the doubling circuit with the capacitor C_{h1} that feeds the glow discharge in the chamber VL_3. Electric energy is stored in 0.1 μF KMCh–100 kV capacitors. Cores of the protective inductances are assembled of 200 VNP–K ferrite rings 125 × 80 × 10. One–turn compression inductance of coaxial construction includes 8 3–K magnetic cores 360 × 200 × 25 made of 50 NP–0.01 alloy and provides a 4–fold pulse compression of the voltage applied to C_{h1} capacitor. Specially developed capacitor C_{h1} of 140 nF capacity and natural inductance of 5 nH is coupled to the laser gap by a section of strip line SL. The inductance of the discharge loop of C_{h1} capacitor is 29 nH. In 70 ns after thyratrons are switched the inductances L_1 and L_2 are saturated and the capacitors C_{s1} and C_{s4} are overcharged to the voltage of the opposite sign during 700 ns. Under the influence of doubled voltage applied to the connected in series capacitors C_{s1}–C_{s2} and C_{s3}–C_{s4} the compression inductance L_3 is saturated near the end of the current pulse through thyratrons and storage capacitors are discharged on C_{h1} during 180 ns. Peak voltage observed at the generator output reaches 70 kV at a charging voltage of 50 kV.

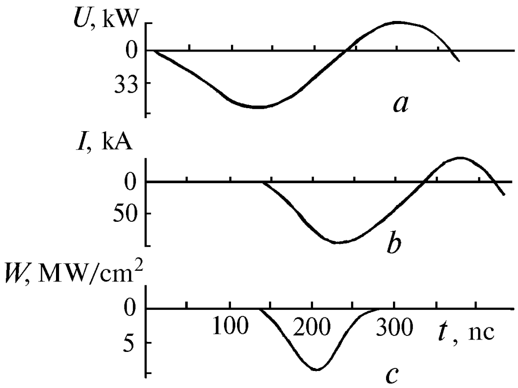

Fig. 2. Waveforms of the voltage across the capacitor C_{h1}*(a), the discharge current density (b), and the output radiation (c). Gas mixture* Ne:Xe:HCl=100:10:1, p = 4 atm, U_0 = 50 kV.

Pulse shapes of the voltage across C_{h1}, discharge current, and the laser emission are presented in Fig. 2. To avoid the occurrence of filaments near the cathode caused by electron drift under the influence of the field applied, the discharge was initiated before the end of the X–ray pulse.[5] The E/p value at the quasi–stationary discharge stage is calculated to be 0.7–0.9 kV/cm·atm in the gas mixture of Ne:Xe:HCl=100:10:1 at the total pressure of 4 atm. When the mixture was diluted to concentration ratio 1560:10:1 E/p value decreased to 0.5–0.6 kV/cm·atm. Current density of the glow discharge reached 300÷350 A/cm^2 whereas specific pumping power reached 0.7–0.9 MW/cm^3. Maximum output energy density was 0.52 J/cm^2, peak output power was 10 MW/cm^2, and total pulse energy was 10 J.

Laser efficiency reached is 2% based on the amount of energy stored in capacitors of the generator and 3.3% based on the amount of energy stored in the capacitor C_{h1}.

The beam divergence obtained is 3 mrad in a plane–parallel resonator. An unstable cavity configuration with M = 5 provides an order of magnitude lower beam divergence. It was measured to be 2×10^{-4} rad at a level of half total energy and 3.5×10^{-4} at a level of 0.75 total energy. In these experiments the output energy was 20% lower as compared to that obtained with plane–parallel resonator. Relatively high divergence is determined by high gain in the active medium (> 0.075 cm^{-1}), large beam aperture, and short laser pulse duration being comparable with the time of low divergence formation.

When the laser device operated at 20 Hz without the system of gas purification, the two–fold drop of the output energy was observed after 10 minutes. No influence of gas heating was evidenced up to 32°C.

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