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A slab Xe laser excited by a non-self-sustained discharge

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Abstract. Repetitively pulsed lasing with a high repetition rate of 10 – 20 kHz is obtained for the first time in the near-IR region from Xe atoms excited by a non-self-sustained dc discharge with preionisation by high-voltage pulses. For an active medium with dimensions 190 mm × 20 mm × 20 mm, the average output power was ~100 mW and the peak power was ~5 W. The relative intensity of lasing transitions can be controlled by varying the dc discharge input power and selecting the composition and pressure of a gas mixture.

Studies of gas-discharge lasers have inspired a renewed interest in an atomic Xe laser emitting at several transitions in the wavelength range from 2 to 3 μm. When passing from excitation by a longitudinal low-pressure dc discharge to excitation by a transverse medium-pressure ($\sim 10^2$ Torr) high-frequency discharge, the laser output power increased by three orders of magnitude, and the laser was assigned to a class of high-power lasers [1 – 4]. The best results were obtained in systems with a planar geometry of the active medium [3, 4].

It was found in Refs [5, 6] that the spatial structure of the radiation field and of the gain of the Xe laser in the transverse cross section of the discharge exhibits some specific features. Comparing the experimental data with the results of simulation showed that lasing in the high-frequency discharge ($\sim 10^8$ Hz) is determined only by narrow near-electrode regions of a spatial discharge. Making a comparison with the possibilities of the transverse self-sustained dc discharge is complicated because of its instability in such a geometry.

In this paper we studied a Xe laser excited by a transverse non-self-sustained slab discharge. A gas-discharge chamber of length 190 mm was formed by two ceramic Al_2O_3 plates separated by 2 mm and by two copper side walls 20 mm apart, which served as electrodes. The electrodes and ceramic plates were cooled with running water. A totally reflecting concave mirror with a radius of curvature 4 m and a plane mirror with transmission ~30% were separated by 210 mm and offset by 10 mm from the ends of a slab channel.

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A homogeneous non-self-sustained discharge in a planar discharge chamber was excited by short (~500 ns) high-voltage (up to 10 kV) preionisation pulses. The pulse repetition rate could be varied from 10 to 20 kHz. The discharge scheme was different from that used earlier in CO_2 lasers [7, 8], in which preionisation was performed by using additional electrodes that were pressed to dielectric plates from the outside.

We measured the energy, temporal, and spectral characteristics of the output radiation for different electric parameters of the discharge, composition, and pressure of the operating mixture. The volt – ampere characteristics of the discharge are of the rising type; i.e., the discharge is non-self-sustained.

Fig. 1 shows the experimental dependence of the average output power, measured with a calorimeter, on the input discharge power. At the initial interval (0 – 50 W), when only the pulsed discharge was excited, the input power was controlled by varying the amplitude of pulses with a repetition rate of 20 kHz. In the range from 50 to 130 W, the input power was increased by adding the power from a dc voltage unit to a maximum power (50 W) of our pulsed generator (shown by the vertical arrow). The maximum power of the dc voltage unit was about 80 W (for the voltage ~300 V and the mean current ~0.3 A) and was limited by the development of an arc discharge.

In the Ar : He : Xe = 50 : 50 : 1 mixture at a pressure of about 200 Torr, the average output power was above 100 mW and the peak power was ~5 W. The average power is comparable with the cw output ~200 mW obtained in Ref. [2] by high-frequency pumping (130 W) of an active medium of similar dimensions.

Fig. 2 shows typical traces of the discharge current pulse (on a 2 A div^{-1} scale) and of the corresponding lasing pulse detected with a Ge – Au photodetector with a time resolution

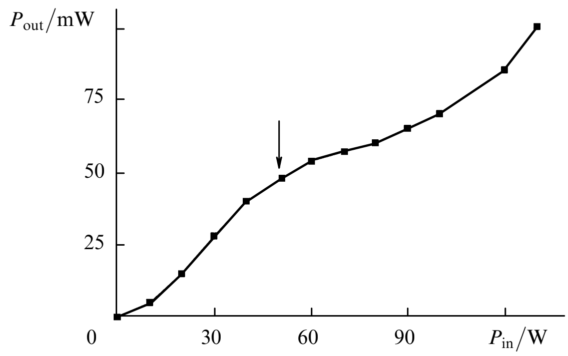

Figure 1. Dependence of the average lasing power on the input discharge power.

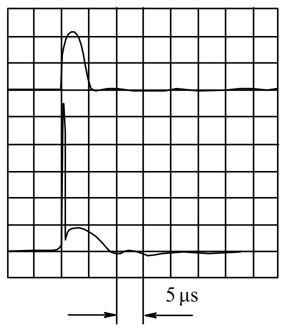

Figure 2. Traces of the laser pulse (top) and the corresponding discharge current pulse (bottom).

~1 μs. The duration of current pulses varied from 10 to 20 μs, depending on the dc voltage, pressure, and gas composition. Dependences of the duration of lasing pulses (at the 0.1 level) on pressure of the gas mixture mentioned above are presented in Fig. 3a for two laser lines at 2.03 and 2.65 μm. These lines carry virtually total output power.

The intensity of the third 1.73 μm line in the output spectrum is low (the amplitude of pulses is an order of magnitude lower). Fig. 3b shows dependences of the relative amplitude on the gas pressure of lasing pulses for the two strong lines. The dashed lines correspond to excitation only by a pulsed discharge with input power ~50 W (the dc voltage is zero), and the solid lines correspond to combined excitation, with the same pulse parameters and a dc voltage close to a breakdown voltage, which is between 300 and 450 V, depending on the gas pressure.

By varying the gas pressure and the dc discharge input power, one can control the relative intensity of lasing transitions. In addition, the relative intensity of the 2.03 μm line increases when the content of argon in the gas mixture is decreased. For example, in the He : Xe = 100 : 1 mixture,

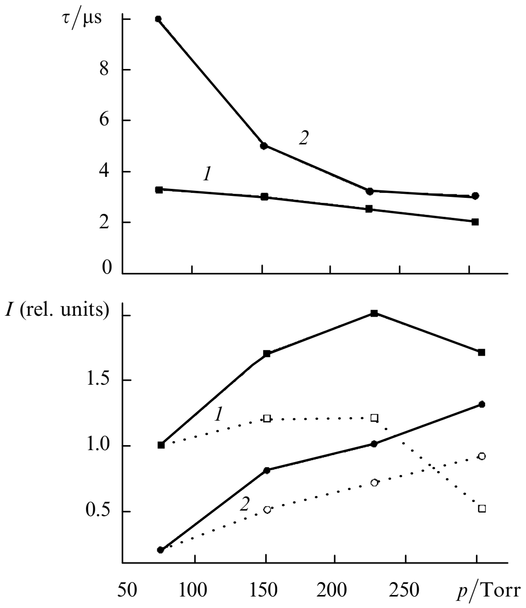

Figure 3. Dependences of (a) the duration and (b) amplitude of laser pulses on the gas pressure upon excitation by pulsed (dashed lines) and combined (solid lines) discharge at 2.03 (1) and 2.65 μm (2).

more than 90% of the output power (~100 mW) is concentrated in the 2.03 μm line.

When the repetition rate of preionisation pulses was varied from 10 to 20 kHz, the average output power changed proportionally to the repetition rate. Because a high-voltage high-frequency generator was not available, we extrapolated the output power for the repetition rates when each preionisation pulse acts on a medium in which the recombination has been completed. According to our estimates, the maximum repetition rate upon combined excitation is ~60 kHz. In this case, the expected average output power is ~300 mW. When only pulsed pumping is used, the repetition rate can be increased to ~500 kHz without substantial changes in the physics of processes. However, because of the technological restrictions, a maximum frequency of a high-voltage generator that can be actually achieved by retaining pulse parameters is only about 200 kHz, which corresponds to an average output power ~1 W and a peak power ~5 W.

Such a laser is promising for use in Doppler lidars because the wavelength region between 2 and 3 μm is optimum for operation at distances of several kilometres from the Earth surface [9].

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References

1. Udalov Y B, Peters P J M, Heeman-Ilieva, et al. Appl. Phys. Lett. **63** 721 (1993)
2. Tskhai S N, Udalov Y B, Peters P J M, et al. Appl. Phys. Lett. **66** 801 (1995)
3. Tskhai S N, Udalov Y B, Peters P J M, et al. Appl. Phys. B **62** 11 (1996)
4. Vitruk P P, Morley A J, Baker H J, et al. Appl. Phys. Lett. **67** 1366 (1995)
5. Ochkin V N, Tskhaĭ S N, Kochetov I V, et al. Preprint FIAN, No. 51 (Moscow, 1996)
6. Ilyukhin V I, Ochkin V N, Tskhaĭ S N, et al. Kvantovaya Elektron. (Moscow) **25** 512 (1998) [Quantum Electron. **28** (1998)]
7. Kuznetsov A A, Novgorodov M Z, et al. Opt. Atmos. Okean. **10** 1296 (1997)
8. Generalov N A, Zimakov V P, Kosynkin V D, et al. Kvantovaya Elektron. (Moscow) **9** 1549 (1982) [Quantum Electron. **12** (1982)]
9. Hannon S M, Henderson S W, Thomson J A, et al. Proc. SPIE **2832** 76 (1996)