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ALTERNATIVE METHODS AND MEANS FOR PUMPING METAL-VAPOR LASERS

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Abstract

Results of an experimental study of energy deposited in a gas-discharge tube (GDT) of lasers operating on copper and lead vapors and processes affecting the distribution of vapors of a working substance in a laser active volume are presented. Methods and means for improving the laser efficiency by increasing the vapor density in the laser active volume and using a combined pulsed discharge in the pumping process are proposed.

It was shown in [1] that the space and time distribution of the electric field along the active volume of a GDT in a periodically pulsed discharge is essentially nonlinear (especially at the initial stage of a pulsed discharge). The highest electric field strength and, consequently, specific energy deposited in a gas discharge are achieved in the near-electrode regions. In this case, the near-cathode potential fall in the discharge is always larger than the near-anode fall. Thermocouple measurements performed in [1] showed that the cathode and the near-cathode region were always more strongly heated in a periodically pulsed discharge than the anode and the near-anode region. This suggests that the thermal diffusion flow of working-substance vapors along the GDT is directed toward the anode.

An experimental comparison of the amount of vapor of the working substance condensed on the anode and the cathode during a long operation time of both lead and copper lasers shows that the amount of condensate on the cathode is an order of magnitude larger than that on the anode (see Fig. 1). This experiment shows that the main reason for the outflow of working substance from the GDT is not the thermal diffusion, but the transfer of working substance towards the cathode by the current of a periodically pulsed discharge. To decrease the rate of working-substance outflow from a GDT, one should periodically change the current direction in the gas-discharge spacing or use a slow gas flow through the GDT in order to compensate the removal of working substance from it caused by the discharge current.

Figure 2 presents experimental dependences of the average radiation power of a lead vapor laser ($\lambda =$ 722.9 nm) on the wall temperature in the active volume of a GDT for three initial temperatures: room temperature (1), 700°C (2), and 800°C (3). Temperatures of 700 and 800°C were obtained by cooling the GDT of the switched-off laser from a temperature of 850°C.

One can see from the experimental results that the short cooling time of the GDT (curve 3) corresponds to a higher temperature threshold of lasing, a narrower range of operating temperatures, and a lower output of laser energy in comparison with the case of the longer cooling time (curve 2). This dependence can be attributed to a high rate of vapor condensation during GDT cooling (vapors are condensed on the entire inner GDT surface) and the fact that the evaporation rate of the working substance is small in comparison with the condensation rate (the substance is evaporated from the surface of separate droplets and the evaporation rate is retarded by the low rate of vapor diffusion in the GDT volume). The latter shows that the concentration of working-substance vapors averaged over the active volume does not reach its saturated value during a long time of GDT heating, which is supported by the results of [2]. An increase in evaporation rate, concentration

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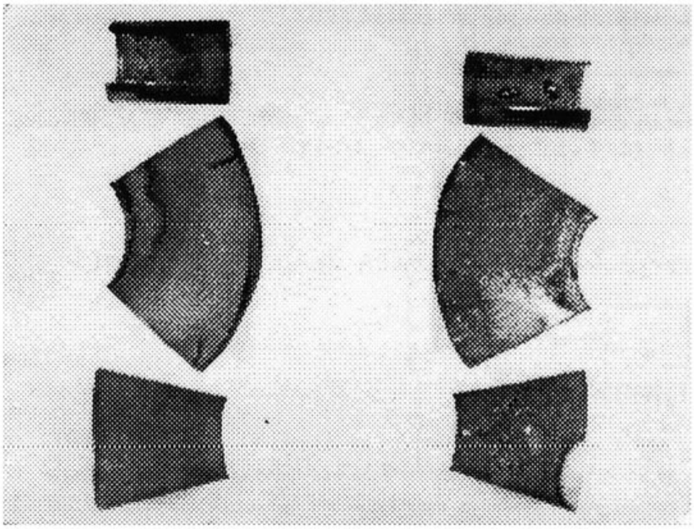

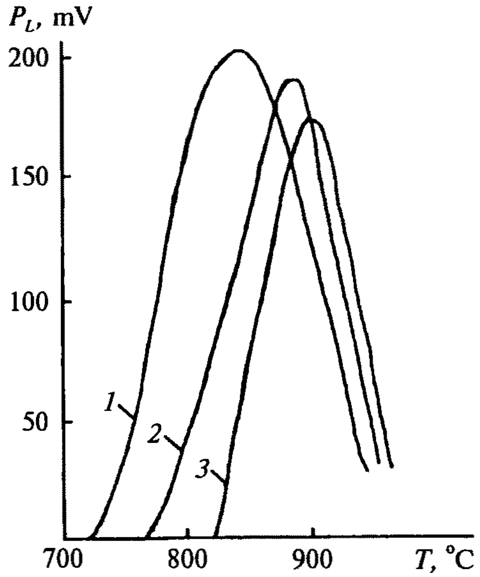

Fig. 1. Fragments of cathodes (on the right) and anodes (on the left) with lead condensate formed in a GDT of a lead-vapor laser in a long operation time.

Fig. 2. Dependences of the output power of a lead vapor laser on the GDT wall temperature measured for a GDT heated from room temperature (1); upon cooling the GDT to a temperature of 700°C (2); upon cooling the GDT to a temperature of 800°C (3). The laser has a two-section scheme of GDT pumping [8] with 10 mm aperture; each of the gas-discharge spacings is 300 mm long; 15-kHz pulse repetition rate; storage capacitor with $C = 2\times2000$ pF; 3-kV supply voltage; 10-torr neon pressure in a GDT.

of working-substance atoms and, consequently, laser output power can be obtained by using a slow flow of a buffer gas through the gas-discharge spacing of the GDT [3] formed by a weak-current gas-discharge pump in the by-pass channel connecting the GDT ends [4] or with the help of a vibration or acoustic device [5] used to clean the evaporating surface of the working substance or sputter it in the active volume of the GDT.

Figure 3 presents a new design of a metal-vapor laser using a combined transverse-longitudinal discharge for pulsed gas-discharge pumping [6].

The laser contains a high-voltage rectifier 1, a generator 2 forming pulses for triggering a switch, a high-voltage storage capacitor 3, a shunt inductance 4, a switch 5, distributed electrodes 6 [7], a gas-discharge channel 7 filled with working-substance vapors, a vacuum-tight envelope 8 of the discharge tube, output windows 9, and mirrors 10 of an optical resonator.

The laser operates in the following way.

Prior to forming a triggering pulse by the generator 2, the high-voltage rectifier 1 charges the high-voltage storage capacitor 3 through the shunt inductance 4. Upon triggering the switch 5 with a pulse formed by the generator 2, the voltage from the capacitor 2 is applied across the distributed electrodes 6 having a finite resistance (resistors). The electrode ends are connected to different poles of the power supply. The voltage applied across the distributed electrodes 6 forms in the interelectrode spacing the transverse component 11 of the discharge current with the transverse component of the electric field strength.

Between the end points of distributed electrodes 6, which are connected to a power supply, there is formed the longitudinal component 12 of the discharged current with the longitudinal component of the electric field in the gas-discharge channel 7 placed in the vacuum-tight envelope 8. This component is due to the finite resistance of the distributed electrodes. As the plasma conductivity increases in the course of its development,

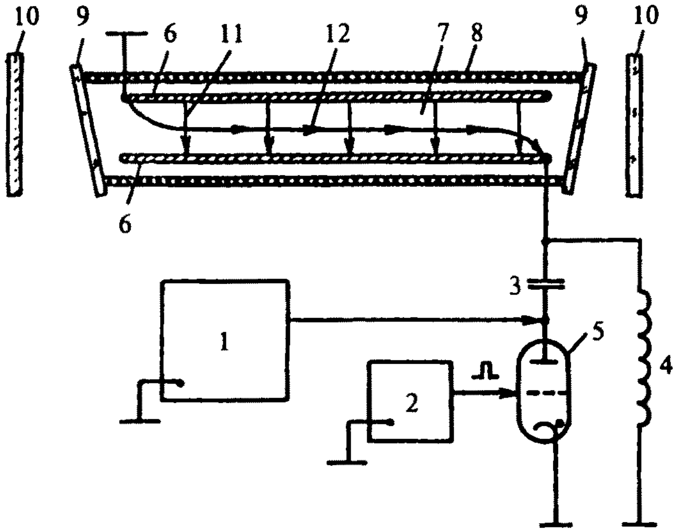

Fig. 3. Schematic diagram of a laser with combined discharge.

the transverse components of current and electric field strength decrease, and the longitudinal components increase in magnitude. The high electric field strength in a gas-discharge plasma at the beginning of the discharge pump pulse leads to an increase in efficiency characterizing the excitation of working-substance vapors in the gas-discharge channel.

The laser radiation travelling along the gas-discharge channel and passing through output windows 9 is outcoupled from the laser resonator through a semitransparent mirror.

The distributed electrodes may be made in the form of coaxial spirals or other modifications.

The use of both transverse and longitudinal discharge components for pumping a working substance makes it possible to increase the laser efficiency and output power by a factor of 1.5–2.0. As an example, we performed experiments with molybdenum spirals 12 and 18 mm in diameter which were arranged in a coaxial configuration with a spacing of 2 mm. In the case where the external spiral was connected to the negative pole and the internal spiral to the positive one, the efficiency and output power of the lead–copper laser ($\lambda = 722.9$ nm) increased by 60 % in comparison with the opposite spiral polarities.

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