Operation of a Capacitive Pumped CuBr Laser in a Reduced Energy Deposition Mode

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Abstract – **The results of the operation of a capacitive pumped CuBr laser in a reduced energy deposition mode are presented. A high radiation-pulse repetition rate of 100 kHz in the active medium of copper bromide vapors was obtained. The results of OrCAD simulation of the high-frequency metal vapor active media pumping source with capacitive pumping are presented.**

Index Terms – **Pumping source, high pulse repetition frequency, pulse duration, reduced energy deposition, active media.**

I. INTRODUCTION

ACTIVE MEDIA on metal vapors are used in science and technology, in particular in problems of visual testing of objects and fast processes taking place, under conditions of powerful background illumination [1–5]. High speed of these processes imposes certain requirements on the frequency of the visualization system. The frequency of data recording of optical systems directly depends on the repetition rate of radiation/amplification pulses of the active medium. The limitation of high repetition rates of such media arises due to both physical and technical problems. In a number of experimental and theoretical studies, it was shown that it is possible to increase the repetition rates of radiation pulses in metal vapors active media when using the reduced energy deposition into the discharge [6-8]. It is possible to carry out a reduced energy deposition mode in several ways, one of which is to reduce the pump pulse duration. To pump the active medium with short high-frequency pulses (above 100 kHz), it is advisable to use semiconductor pump sources as in [9] or a source built on a hybrid switch, as it is described in [10].

When the active medium is pumped by high-frequency pulses, difficulties arise with the breakdown of the wall of the gas discharge tube (GDT) and its failure. Therefore, the actual problem is to find the safest pumping schemes. A capacitive-pumped circuit is one of such schemes, since in this case one of the GDT electrodes is always connected to the common bus of the device.

Earlier, in one of our publications, a model of a pumping source operating according to a typical circuit of a partial discharge of a capacitance to a resistive load was presented. In [10], a real plasma model obtained from the kinetic model is used as a load of a pumping source. This study presents the results of simulating the operation of the pumping source based on a capacitive-pumped circuit [11], as well as the results of experimental studies of the mode of reduced energy deposition into the discharge.

II. EXPERIMENTAL TECHNIQUES

The quartz GDT with a working channel length of 38 cm and an inner diameter of 1 cm was used in experiments. The electrodes were located on the outer wall of the gas discharge tube, so that the electrical connection between the plasma inside the GDT and the pumping source components was capacitive. A gas discharge tube was located inside an insulated heater in which a temperature of 480-500°C was maintained. The active substance was located in quartz containers, which were in thermostabilized heaters. The temperature inside the heaters was chosen optimal for obtaining the most powerful radiation. The laser pumping circuit is shown in Fig. 1. One gas discharge tube electrode is connected to a high-voltage source through the R3 resistor, as well as to a hybrid switch that connects the GDT electrode to the common bus. While the VT1 transistor, connected in series in the cathode circuit of the VL1 modulator lamp, is closed, a relatively slow charge of the electrode capacities occurs. After the control pulse is applied to the transistor, the composite switch turns on and the electrode capacitors recharge, a breakdown of the gas-discharge gap is formed and current flows through the GDT. After removing the control pulse, the resistance of the composite switch increases sharply and the electrode capacitors charge from the high voltage source. Further, all processes are repeated.

This pumping source makes it possible to obtain on GDT high-voltage pulses (up to 10 kV) of short duration (20 ns and longer).

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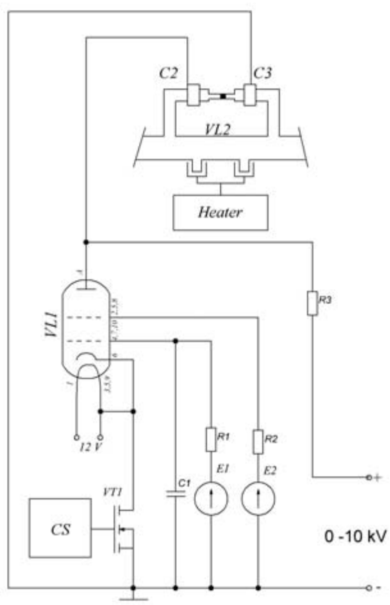


Fig. 1. Laser pumping circuit.

III. EXPERIMENTAL RESULTS

The OrCAD simulation results are shown in Fig. 2. The model description and modeling technique are presented in more details in [10]. The diagrams show: current pulse of the GDT electrode connected to the VL1 lamp (Fig. 2a), the anode voltage of the VL1 lamp and the drain voltage of the VT1 transistor (Fig. 2b). When the transistor turns on the anode potential of the VL1 lamp becomes equal to the common bus potential, the electrode capacitances begin to discharge, current flows through the GDT. The reverse current of the GDT after the transistor switches off is due to the charge of the GDT electrode capacitances.

Experimental waveforms of the operation of a pumping source for GDT with capacitive electrodes are shown in Fig. 3 and Fig. 4.

The active medium operated in generator (laser) mode at a pulse repetition rate of 100 kHz. The GDT current pulse duration equals 64 ns for the experiments shown in Fig. 3, and it is 56 ns for the cases shown in Fig. 4.

Waveforms in Fig. 3 show that in order to obtain lasing at longer pulse duration, it is necessary to reduce the voltage value of the high-voltage power supply. So, for example, for the experiment shown in Fig. 3a, the voltage of the high-voltage power supply is 5.5 kV, and for Fig. 3b and Fig. 3c – 4.7 kV and 4.0 kV, respectively.

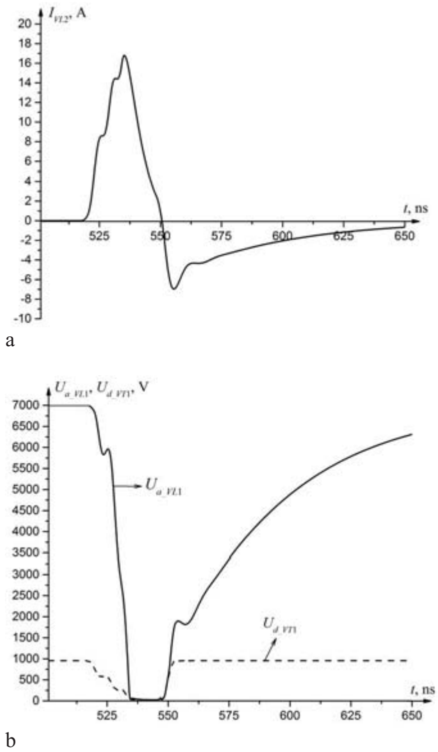
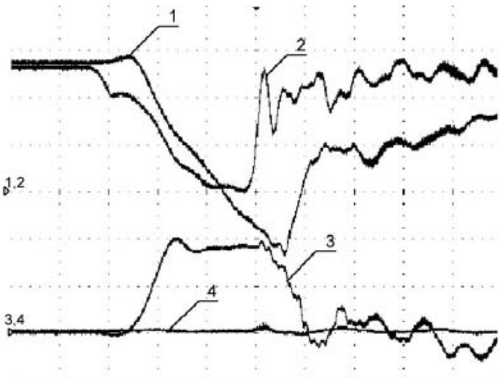


Fig. 2. The simulation waveforms of a pumping source for GDT with capacitive electrodes: a – current of the GDT electrode connected to the VL1 lamp; b – the anode voltage of the VL1 lamp (solid line), the drain voltage of the VT1 transistor (dashed line).

With a decrease in the voltage value of the high-voltage power source, and, consequently, in the amplitude of the pump pulse, a noticeable improvement in the generation characteristics of the medium occurred in the experiment. This is due to the fact that at high repetition rates in small volume GDTs, as noted above, generation and amplification is possible only when operating in conditions of reduced energy deposition into the discharge. However, a further decrease in voltage is impossible, since this negatively affects the breakdown of the gas-discharge gap and leads to a generation failure.

Figure 4 presents waveforms of the operation of an active medium with a reduced pump pulse duration, which also makes it possible to operate in a reduced energy deposition mode. Reducing the pulse duration makes it possible to increase the level of the power supply voltage. The pumping of the active medium by pulses with higher amplitude made it possible to obtain a more stable discharge in the GDT and to improve the lasing characteristics.

The generation pulse is seen to shift to the end of the current pulse. Also, unlike the simulation results, there is a significant reverse voltage surge at the anode of the modulator lamp in the experiment.



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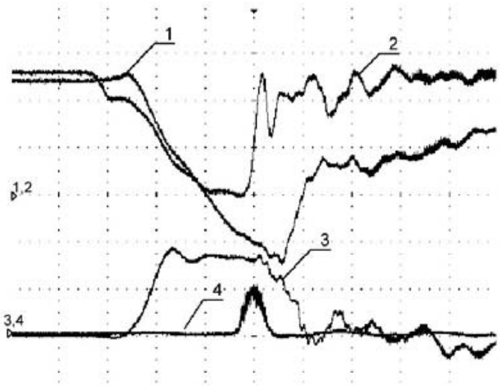

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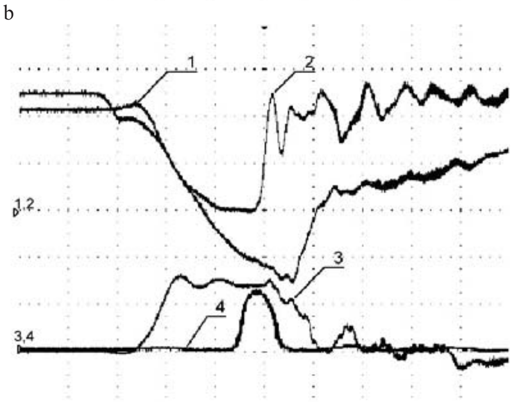
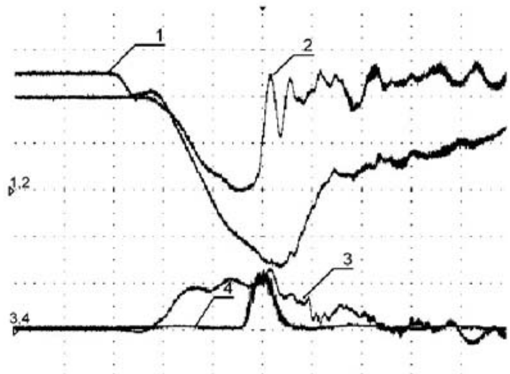


c

Fig. 3. The experimental waveforms of a pumping source for GDT with capacitive electrodes at the duration of a GDT current pulse of 64 ns: 1 – the anode voltage of the VL1 lamp (2 kV/div.), 2 – the VT1 drain-source voltage (200 V/div.), 3 – the GDT current measured on an electrode connected to the ground (5 A/div.), 4 – generation pulse. Time base: 20 ns/div.



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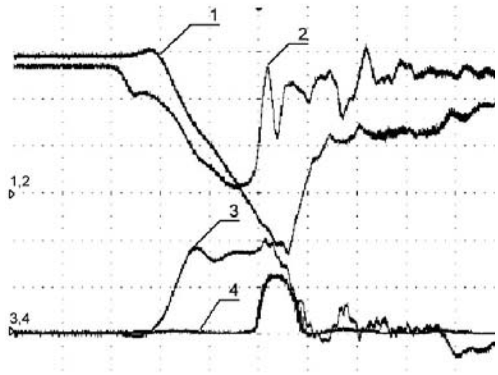

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Fig. 4. The experimental waveforms of a pumping source for GDT with capacitive electrodes at the duration of a GDT current pulse of 56 ns: 1 – the anode voltage of the VL1 lamp (2 kV/div.), 2 – the VT1 drain-source voltage (200 V/div.), 3 – the GDT current measured on an electrode connected to the ground (5 A/div.), 4 – generation pulse. Time base: 20 ns/div.

IV. Conclusion

As a result, the simulation of the operation of a pumping source on a GDT with capacitive electrodes was carried out, which showed the possibility of using the previously developed source in the tasks of capacitive pumping of active media on metal vapors.

Experimental studies show that when an active medium of a small volume is operated at a high frequency, it is necessary to provide conditions of a reduced energy deposition into the discharge. Moreover, it is advisable in this case to obtain this mode by reducing the pump pulse duration. The experimental results are in good agreement with the data obtained in the pumping source simulation. However, there is the need to adjust the model, in particular by adding the parasitic parameters in the circuit. Subsequently, a similar experiment with GDT of various geometries is planned.

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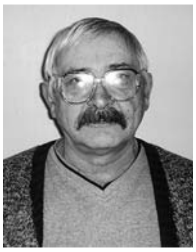

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