Self-heating CuBr laser

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A CuBr laser has been studied experimentally. The design of a gas discharge tube of this laser allowed its steady self-heating operation. Experiments with discharge tubes having different active volume showed that this design could be easily scaled to the output power from 1 to 50 W. Sealed-off operation of active elements has been obtained.

Introduction

In contrast to metal-vapor lasers, lasers using metal halogenides as active media are capable of providing the same output power and efficiency, but at lower temperature of an active body.[1] The development of such lasers started after lasing in vapors of copper, lead, and manganese halogenides was obtained in the case of pumping by doubled pulses.[2–5]

Further research into lasing in vapors of metal compounds allowed the operation with regular pulses repeating with the frequency from several kilohertzs to some tens kilohertzs to be obtained.[1,6–9] In this case, self-heating conditions were provided for. An active substance was distributed, as a rule, uniformly over the length of the gas-discharge tube. Unfortunately, uncontrolled fluctuations of the pressure of halogenide vapor in this case are significant, thus leading to instability of discharge and degradation of laser output parameters down to contraction of lasing.

To overcome this drawback and to obtain a steady state discharge, specialized limiting diaphragms were inserted in a gas discharge tube (GDT). Thus, quartz and ceramic rings served as such diaphragms in Refs. 5 and 7, and rings from chamotte were used for this purpose in Ref. 8. However, even such modernized self-heating modifications of metal halogenide lasers did not receive wide acceptance in practice. Gas discharge tubes, in which a working substance is housed in specialized heated containers, are now widely used in the research practice.[6,10] Thanks to such a method of halogenide vapor bleeding-in, the vapor pressure can be controlled and limiting values of the output power and efficiency can be achieved for a short time. For the long-term operation of the active element, the temperature difference (ΔT) between the GDT channel and containers should be kept with high accuracy, since even small fluctuation of ΔT can lead to an intense income of halogenide vapor to cold near-electrode zones and cause dusting of the GDT entrance windows. This is especially significant for small-volume tubes. It should also be noted that high voltage is needed for efficient pumping of the mixture of metal atoms with halogenide vapor. However, currents through the containers are significant at such high voltage. This leads to uncontrolled extra heating of the containers and, in some cases, to quartz breakdown.

Having analyzed the literature data, we formulated our task – to develop, design, and test a modification of a sealed-off self-heating GDT capable of providing long-term (500 h and longer) operation of metal halogenide lasers. In this class of lasers, the CuBr laser is most promising for practical applications.[11–13] Therefore, the results given below apply just to this laser.

Experimental results and discussion

The sealed-off active element was made as a quartz tube with a number of ring chambers along the generating line. Some of the chambers situated above the active zone were filled with CuBr powder, and CuBr vapor came to the discharge through the special holes with the onset of the GDT self-heating. The required working temperatures in the active zone and the chambers filled with CuBr were kept by use of layers of thermal insulator. To prevent the ingress of the working substance to the electrodes and GDT windows, specialized traps (damper rings) were installed in front of them. The electrodes were made as a cup filled with copper chips. The current was fed to them through the electrodes of IFP-200 (1200) flash lamps. Such a design of the CuBr laser is technically simple and convenient in use in contrast to the earlier designs. The required ΔT is automatically kept in the laser (if the outer thermal insulator keeps its thermal insulating properties). The problem of electric decoupling between the discharge channel and heated containers with CuBr is lifted, since the latter are absent.

We have made and tested several sealed-off GDTs having this design. Their dimensions and the results of tentative tests are given in the Table.

Typical oscillograms of current, voltage, and lasing are shown in Figure 1. These oscillograms were recorded in the GDT having the following parameters: buffer gas (neon without hydrogen) pressure of 25 mm Hg, input voltage from a rectifier 8.8 kV, discharge current of

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0.5 A, pulse repetition frequency of 10 kHz, and mean output power of 20 W; t is time. The consumed power is given here as applied to the rectifier, and the output power is summed over both lines with a plane-parallel resonator installed.

Table

No.	Diameter, cm	Length, cm	Frequency, kHz	Output power, W	Consumed power, kW
1	1.4	36	8 – 10	0.5 – 1.0	0.5 – 0.8
2	2.5	100	8 – 10	5.0 – 10.0	1.2 – 1.4
			16	20*	2.0
3	5.8	150	10	20	4.4
			10	35**	4.8
4	5.8	2* 120	10	35	7.5
(bi-section GDT)	–	–	9.2	64**	8.0

* Pumping from Altek lamp generator (Moscow; in co-operation with A.I. Moshkunov).

** 0.2 mm Hg hydrogen was added to Ne buffer gas (25 mm Hg).

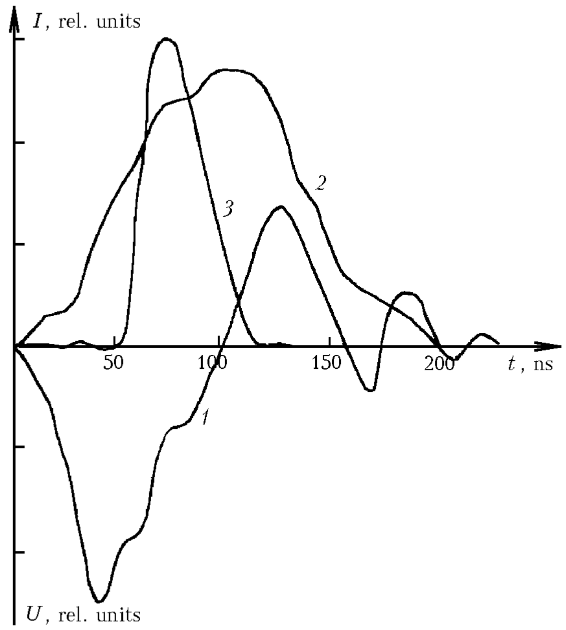

Fig. 1. Oscillograms of voltage (*1*), current (*2*), and lasing pulse (*3*) for GDT No. 3.

GDTs Nos. 1 and 2 were excited by the direct discharge of a working capacitor through a TGI 1–1000/25 thyratron. GDTs Nos. 3 and 4 were pumped using a magnetic compression line and a TGI 1–2500/50 switch similarly to Ref. 14. Results obtained when pumping GDT No. 2 by a modulator lamp (GMI–29) power supply and the data of Refs. 1, 11, 15–18 indicate that the working frequencies (~ 10 kHz) preset in our experiment and determined by the switch and the compression line are much lower than the optimal values. The increase of the pump pulse repetition rate must lead to, at least, doubling of the output power. The addition of hydrogen also leads to the 1.5–2 times increase of the optimal frequency and the laser output power. However, we still cannot keep hydrogen (as a controlled minor admixture) in a sealed-off GDT. This will be the subject of our further research.

Conclusion

The main result of this work is the proposed design of the GDT that allows a long-term (hundreds of hours) steady lasing and scaling of the output characteristics of the CuBr laser.

The tentative tests of the CuBr lasers in scientific research and light graphics systems showed that the operation time of the sealed-off active elements made under laboratory conditions can achieve 500 h.

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