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TEMPERATURE OPERATING MODE OF THE CuBr+Ne+H_2(HBr)-LASER AT CHANGE OF PUMPING

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The analysis of a temperature mode of the laser on copper bromide vapour using active additives of hydrogen (bromhydrogen) at change of pumping parameters has been carried out. It is shown that introduction of the optimal additive increases the discharge tube wall temperature from 620 up to 720 °C. The increase of wall temperature 50...60 °C more can occur at change of buffer gas pressure from 3,3 to 13,3 kPa, as well as at increase working capacity twice. It is stated that introduction of the additive raises pressure of working substance vapours in the active media of the laser of average diameter 6,7 Pa more due to interaction of bromine, bromhydrogen with copper atoms settled on the tube wall. The peculiarities of laser thermal mode at high frequencies of pulse sequences (up to 100 kHz) have been considered.

Introduction

Among several modifications of gas copper laser known today the lasers on pure copper vapour (LCV) and lasers on copper bromide vapour (LCBV) have found the widest application in science and engineering. It is conditioned by the possibility of active elements of these radiation sources to operate in the sealed off mode [1–3].

In spite of the fact that LCV durability exceeds that of LCBV [3], the latter attract much attention nowadays. First of all it is explained by the fact that the principle of producing working substance vapour in such a system permits to take nearly a third of the temperature in a gas discharge tube (GDT) in comparison with LCV [4]. It significantly simplifies the construction of the active element and reduces the pumping requirements, it resulting in decrease of power supply size. It affects the cost of the device on the whole. Secondly, LCBV do not yield to LCV in their characteristics, but in the capacity the former even surmount them [5]. They can also operate at more high frequencies of pulse sequence (FPS) of generation [6], which is very urgent for some applications.

However LCBV operating mode has some peculiarities. It is basically connected with the fact that one needs to control not only the temperature of working channel, but also that of the containers with CuBr vapours. The difference in these temperatures sufficiently depends on pumping conditions. The change of pumping parameters results in change of GDT wall temperature, that influences the temperature of containers with CuBr, hence, the output characteristics of laser.

In recent years H_2, HBr additives are widely used to increase the LCBV energy characteristics [5–7]. Introduction of such admixture into the laser active media change GDT coordination with pumping generator, that also affects the temperature difference mentioned above.

These additives, as we have assumed before [8], can result in additional formation of working substance that influences notably the radiation power in narrow GDT.

All these problems need a more detailed consideration. The given work is directed to the examination of the thermal conditions of CuBr laser, changes of the concentration of working substance at transition to high FPS at different pressure of buffer gas. The problem is also posed to find out the influence of H_2, HBr active admixtures on the energy input in GDT as well as on the CuBr pressure in LCBV with variable concentration of admixture to verify the assumption about additional production of the working substance.

Experimental technique

The investigation of the thermal conditions of CuBr laser has been performed with three quartz GDTs of 1,6; 2,6; 3,8 sm. diameters and 36; 76; 96 sm. long correspondingly. The similar constructions were presented in [7]. The first GDT presents an element with independent heating of branch containers with CuBr, the rest being self-heating, when the necessary pressure of working substance vapour in the active zone is supported by the energy emitted by the charge. The last two tubes stipulate the joint with differential manometer to measure CuBr and H_2, HBr additive pressure. As a buffer gas Ne is used. All tubes are provided with HBr generator. GDT saturation by hydrogen is made from a balloon through main pipe.

The laser excitation is performed by direct discharge circuit of mutual capacitance on GDT through a commutator-thyratron ТГИ1-1000/25. At frequencies more than 25 kHz a tacitron ТГУ1-1000/25 is used. The wall temperature (T_w) of GDT is controlled by a chromel-aluminium thermocouple. Laser radiating power is measured by power-meter PM-2.

The method of CuBr vapour pressure measurement depending on Ne pressure with an HBr additive and without it consists in the following. The GDT is heated up to the working temperature at definite pressure of the buffer gas. The manometer readings are set on «0», after that the containers with CuBr are heated. The optimal concentration of CuBr vapours is defined by maximum of radiating power. In other case during GDT heating the HBr additive is introduced, T_w of GDT being kept up on the same level. Then in the similar way the measurement of CuBr vapour pressure is performed. The same method permits to determine the pressure of working substance at FPS change. In this case to maintain T_w at FPS increase one has to increase the power consumed from rectifier (P_{cons}).

During the measurement of generation power and T_w at different concentrations of hydrogen pumping the necessary quantity of H_2 is performed into a cold GDT every time, and every time P_{cons} is mounted in the assigned working value.

It should be noted that under the pressure of working substance we imply that part of the pressure, on which the total gas pressure increases at heating the containers with CuBr, in other words, the pressure of CuBr dissociation products in discharge and their further interaction with bromine, hydrogen, etc.

Experimental results and discussion

The experience of using LCBV GDT with independent heating of branch containers with CuBr shows that energy produced in pulse-periodic discharge contributes into heating of the containers. Before it, in [9] it was pointed out that the temperature of the containers becomes 25...70 °C less at disconnection of discharge.

The output characteristics of laser are often necessary to change especially in laboratory conditions. The simplest way to do this is to change P_{cons}. In this case to avoid overheating or overcooling of the active medium one needs to support the temperature difference provided by the discharge on the one hand (in the GDT working temperature range) and by the container furnace on the other hand.

In the self-heating installations the GDT T_w change results in the change of CuBr container temperature. To maintain it on the same level one has to change the thickness of heat insulator. It produces some inconveniences in laser attendance. One of the variants to solve this problem in self-heating lasers was proposed by us before [10] and consisted in using heat shield with the temperature stabilization within it.

It is evidently that the change of output characteristics can occur not only due to direct variations of voltage and supply current, but also due to other parameters closely connected with them, e.g. mutual capacitance, FPS.

Thus, working at FPS of kHz with mutual capacitance of 170 pF, GDT of diameter 2,6 sm consumes 2232 W (voltage – 6,2 kV, current – 360 mA). This corresponds to T_w – 650 °C. Replacing one capacity by the other – 340 pF, we provide approximately the same P_{cons} at voltage of 4,5 kV and current of 500 mA. Because of the loss enhancement in the commutator T_w increases up to 700 °C.

It is also known that at the increase of buffer gas pressure the GDT resistance rises and its accordance with pumping generator gets better. By an example of GDT of diameter 3,8 sm one can observe the change of GDT T_w at Ne pressure change. At Ne pressure of 2,7 kPa and frequency of 18 kHz P_{cons} amounts to 2520 W, and T_w=640 °C. Having increased the pressure up to 13,3 kPa, T_w increases up to 700 °C at the same power extracted from rectifier. To maintain it at the same level one has to decrease P_{cons} by nearly 300 W.

These examples show that it is necessary to reduce the thickness of CuBr container heat insulator or decrease P_{cons} to keep up the essential concentration of working substance in the working zone of self-heating laser.

GDT temperature mode is sufficiently influenced by H_2, HBr additives which increase the output radiation power and laser capacity twice and more. They also increase the active resistance of GDT [1] and improve its accordance with pumping generator. In our case the introduction of optimal H_2 additive equal to 46,7 Pa into GDT of diameter 2,6 sm increases T_w by 95 °C. In fig. 1 the dependence of generation power and T_w on hydrogen pressure is shown. It is seen that T_w sharply rises near optimum of additive – 33,3...46,7 Pa. Further increase of hydrogen concentration results in decrease of generation power, but wall temperature remains the same. The similar behavior of power and T_w is observed in the presence of HBr.

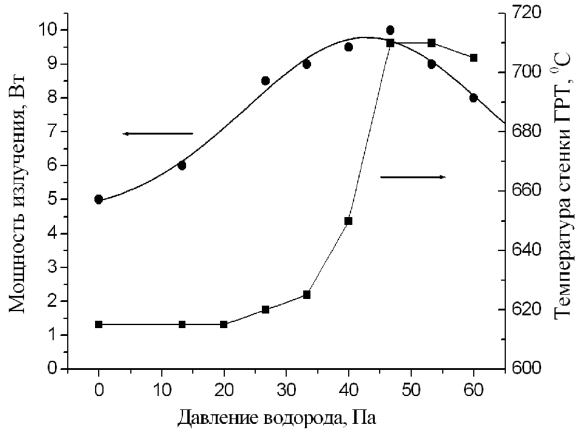

Рис. 1. *Dependence of radiation power as well as GDT T_w of diameter 2,6 sm on the pressure of added hydrogen*

Besides, the temperature mode of LCBV active elements of less than 2 sm with H_2 or HBr additives has an additional feature which, as we assume [8], consists in the additional generation of CuBr due to the interaction of bromine and bromhydrogen with metal copper left on GDT walls. Let us consider this feature in details by the example of GDT if diameter 1,6 sm.

The gradual supply of optimal quantity of HBr (that was set up before) into GDT working with maximum power of 0,5 W increased the radiation power first, but then decreased it due to the excess of working substance vapour. One can judge about it by ejection of working substance into subelectrode and front zones. Further ejection of HBr resulted in discharge stop, therefore there appeared the necessity to decrease the temperature of container heater with CuBr. Only after doing it the output laser power reached the maximum – 2,5 W.

In GDT of average diameter this phenomenon is less pronounced, but in large ones of more than 4 sm it is practically insignificant. In the work [8] we assumed that it is explained by, firstly, the increase of length of HBr molecule diffusion towards the wall of GDT. Secondly, it is conditioned by the fact that the input energy per unit of volume of larger GDT is sufficiently less and, hence, the molecule dissociation is lower, therefore, the concentration of active bromine is lower too.

To verify these assumptions the CuBr vapour pressure in the GDT of average diameter 2,6 sm with a HBr additive and without it at different pressures of buffer gas was measured. To eliminate the effect of additional heating of GDT channel at HBr introduction T_w was maintained constant. In fig. 2 the dependencies of CuBr pressure on Ne pressure for LCBV with and without additive are presented. A general tendency of decrease of the working substance concentration at the increase of Ne pressure is most likely conditioned by the stabilization of discharge voltage in the inetrelectrode interval. It is clearly seen that in the given GDT bromhydrogen increases the concentration of CuBr on the average by 6,7 Pa. It is not so few with respect to optimal value of additive – 40...46 Pa. Therefore, using the active admixtures it is necessary to take into consideration not only increase of GDT temperature, which influences the container heating, and hence, the CuBr concentration, but also additional CuBr formation due to the reactions of the following type:

Cu(sol)+Br(gas)→CuBr(gas);
Cu(sol)+HBr(gas)→CuBr(gas)+H(gas).

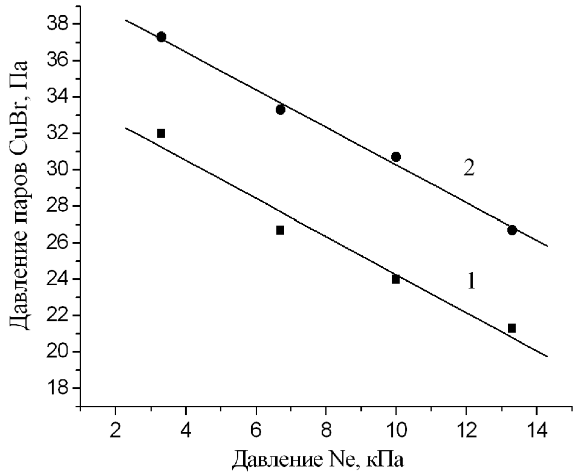

Рис. 2. *Pressure of CuBr working substance at different pressure of Ne buffer gas during the operation of GDT of diameter 2,6 sm: 1) without HBr additive, 2) with HBr additive*

The peculiarities of heating conditions of CuBr laser are also displayed at high FPS. They were investigated with the same GDT in which the change of CuBr vapour pressure at FPS of 20...100 kHz occurred. The feature of the condition consists in the necessity to reduce the concentration of working substance by means of decrease of thickness of container heat insulator with CuBr with the increase of FPS to achieve the maximum radiation power. In this case T_w at all frequencies maintained on the same level. The results of the experiments are presented in fig. 3.

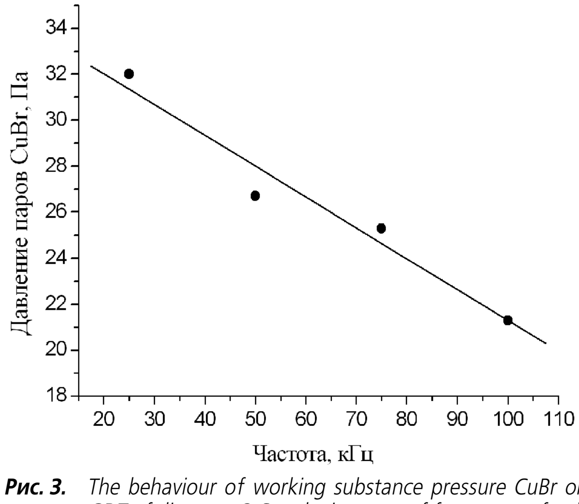

Рис. 3. *The behaviour of working substance pressure CuBr on GDT of diameter 2,6 at the increase of frequency of pulse sequence*

The difference in CuBr pressure at 20 and 100 kHz frequencies amounts 10,7 Pa. It is evidently connected with the fact that with the increase of pulse-to-pulse interval not all atoms of copper connect with CuBr and there is an accumulation of free copper atoms.

Conclusion

The temperature mode of CuBr laser in dependence on pumping conditions has been investigated. It is shown that the change of mutual capacitance twice as well as the pressure of buffer gas from 3,3 to 13,3 kPa (when keeping up the power extracted from rectifier) improves the agreement of gas discharge tube of diameter 2,6...3,8 sm with pumping generator and increase the wall temperature from 640 °C by 50...60 °C. Introduction of optimal additive of H_2 or HBr increases the wall temperature even more – by 100 °C due to essential rise of tube resistance. In the gas discharge tubes of small and average diameter the additional formation of working substance due to interaction of bromine and bromhydrogen with copper atoms settled on the tube wall takes place. In the gas discharge tube of diameter 2,6 sm with HBr additive the CuBr pressure increases by 6,7 Pa. At high frequencies of pulse sequence one needs to decrease the concentration of CuBr to obtain the maximum output characteristics of laser because of the accumulation of free atoms of copper. For the tube of diameter 2,6 sm operating at frequency of pulse sequence 100 kHz the CuBr vapour pressure is less by 10,7 Pa at typical frequencies of sequence (20 kHz).

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