INVESTIGATION OF A CO_2-LASER GAS MIXTURE REGENERATING SYSTEM WITH A SOLID STATE CATALYST

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Closed-cycle transversely excited CO_2*-laser with a system for the gas mixture regeneration using relatively inexpensive low-temperature catalysts of* IK–12–11 *and* IKT–12–9 *types is described. The use of these catalysts allows one to stabilize the output laser emission power. Time behavior of the output emission power obtained at different catalyst temperatures and pumping pulse repetition rates is studied.*

Stability of the output emission power of the TEA closed-cycle CO_2-lasers is very important for their practical applications. As was shown in Ref. 1, CO_2 content in the gas mixture of a TEA CO_2 laser progressively decreases and then stabilizes at a certain value. The output emission power falls in a similar manner. Gaseous and solid-state catalysts are used to compensate for the CO_2 content decrease. Up to now, known solid-state catalysts with high catalytic properties made from expensive materials require heating to high temperature (up to 400°C).

In the present paper, the possibility of using relatively inexpensive and low-temperature catalysts of IKT–12–9 and IK–12–11 types for the gas mixture regeneration base in closed-cycle TEA CO_2 laser is considered. The catalysts are the oxide compositions containing aluminium, copper, and cobalt oxides. The IK–12–11 catalyst containing 15% of cobalt oxide is manufactured by mixing the basic cobalt carbonate with the oversettled aluminium hydroxide. Then the mixture was molded dry and fired at 500°C. The catalyst IKT–12–9 is made by mixing the copper oxide powder (the product of thermal decomposition of the basic carbonate of copper), after its mechanical activation in a power ball mill, with the aluminium hydroxide. Then the mixture was molded, dried and fired at 500°C. Aluminium oxide content in the catalyst is no higher than 10%. Specific surfaces of copper and cobalt oxide catalysts are 30 and 180 m^2/g for the copper oxide and cobalt oxide, respectively. When the catalysts (weight 1 g, fraction 1–2 mm) were tested in a flow-circulation device (gas circulation velocity 10 l/h) under standard conditions and at a load of about 10000 inverse hours the temperatures of 50% CO conversion in a mixture of 1% CO with air in the reaction of catalytic oxidation were found to be 119°C and 84°C for IKT–12–9 and IK–12–11, respectively.

Block-diagram of the experimental set-up is shown in Fig. 1. It consists of CO_2-laser *1* (see Ref. 2), regenerating cartridge with a heater *5*, cooler *6*, compressor *7*, and a system of independent water cooling. The laser discharge gap is formed by two electrodes from stainless steel. The active volume size is $1.2\times1.2\times72$ cm^3. High-voltage pulsed generator is made according to a conventional electrical circuitry based on the Extra–2 thyratron (see Ref. 2). The gap breakdown voltage was 20 kV, specific deposited energy was as high as 84.9 J/l. Twelve small-size fans of DVO–1–400 type provide gas circulation. Working pressure was 0.8 Bar. The laser chamber volume was 50 l. The internal optical cavity consists of a total reflection copper mirror with the radius of curvature $R = 11$ m and an output copper mirror 6 mm in diameter and $R = 6$ m. The regenerator contains about 100 g of the catalyst made from CuO and Al_2O_3 (granules 3 mm in diameter and 4 mm in length). The catalyst temperature varied from 20 to 200°C. Before returning into the laser chamber the restored gas mixture was cooled to room temperature in the cooler *6*. Gas circulation through the regenerating cartridge was provided by a compressor of UK–25–1.6M type. The valves *8* and *10* were used to cut off the laser chamber from the regenerating system. The output laser emission power was measured with a calorimeter IMO–2N *3* (the radiation was attenuated using a KCl plate *2*, placed at ~7° to the optical axis) and recorded with a plotter LKS 4–300 *4*.

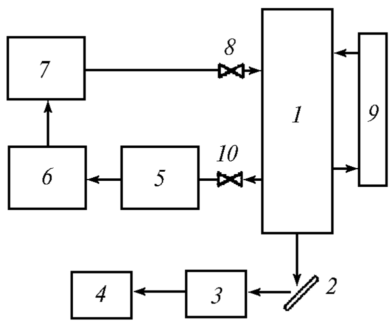

*FIG. 1. Block-diagram of the experimental set-up: laser (1), beam-splitting plate (*KCl*) (2), calorimeter IMO-2N (3), plotter LKS-4-300 (4), compressor UK-25-1,6M (5), regenerating cartridge (6), cooler (7), valves (8, 10), system of independent water cooling (9).*

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Time dependences of the output laser emission power in mixtures $CO_2:N_2:He = 1:1:4$; $1:4:8$ and $1:10:25$ obtained when the regenerator is switched on (*a*) and switched off (*b*) are presented in Fig. 2 (the catalyst temperature is 180°C, pulse repetition rate is 50 Hz). As is seen from Fig. 2, a nonlinear decrease in the power is observed. During 15 min after the laser switching rapid fall in the power occurs then the fall slows down. After ~2 hours operation it either stabilizes at a level of 0.55 of the initial power (in the mixture $CO_2:N_2:He = 1:1:4$) or slowly decreases (in the mixture $CO_2:N_2:He = 1:4:8$).

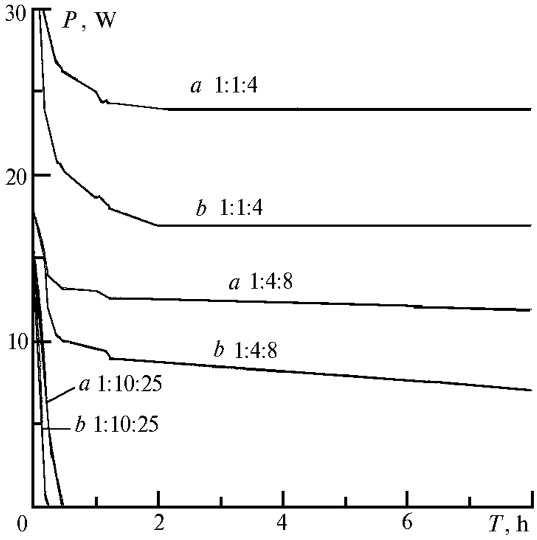

FIG. 2. The laser output power versus time of operation. Gas mixtures are $CO_2:N_2:He = 1:1:4$; $1:4:8$ *and* $1:10:25$. *The regenerator is switched on (a) and switched off (b).*

The use of a regenerator makes it possible to provide for a long-term laser operation on the mixture $CO_2:N_2:He = 1:1:4$ at a level of 0.85 of the initial output emission power. Figure 3 depicts time dependence of the laser emission power obtained at different catalyst temperature in the mixtures $CO_2:N_2:He = 1:1:4$ and $CO_2:N_2:He = 1:4:8$. It should be noted that if the catalyst temperature is below 100°C the effect of CO_2 regeneration becomes insufficient. The catalyst regenerating ability reaches its peak at 180°C and keeps constant when the temperature is increased up to 400°C. The output laser emission power versus time obtained in mixtures $CO_2:N_2:He = 1:1:4$ and $1:4:8$ at the pulse repetition rates of 80 and 30 Hz is shown in Fig. 4. Gas flow through the regenerating cartridge was 5 l/m. One can see that the output power does not vary over an extended time of operation at 30 Hz repetition rate. It is apparent that for similar result to be obtained at higher pulse repetition rates one should increase either the catalyst amount in the regenerating cartridge or the gas flow velocity through the cartridge.

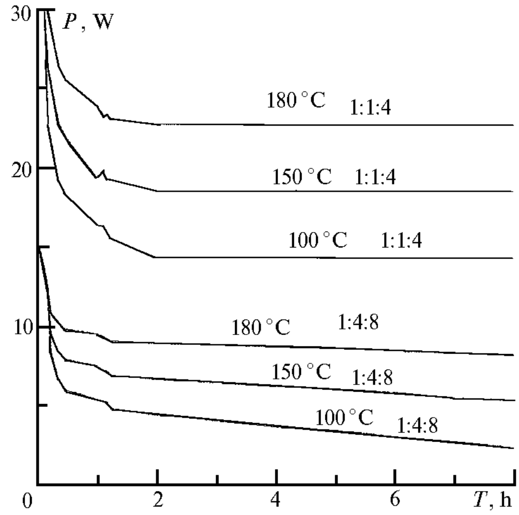

FIG. 3. The output laser emission power versus time at different catalyst temperatures. The laser operates on gas mixtures $CO_2:N_2:He = 1:1:4$ *and* $1:4:8$, *regenerating system is switched on.*

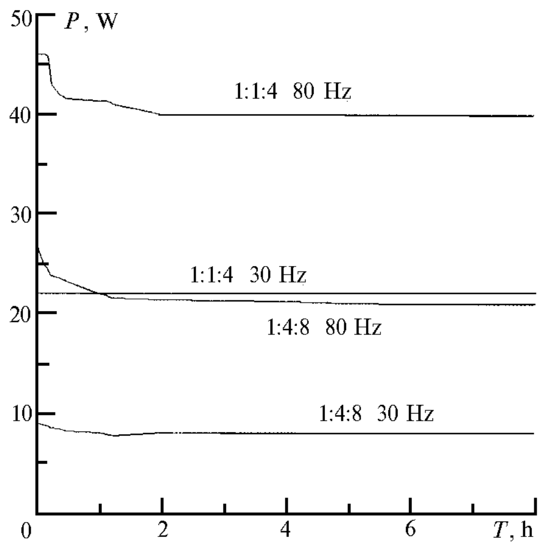

FIG. 4. The output laser emission power as a function of time. Gas mixtures $CO_2:N_2:He = 1:1:4$ *and* $1:4:8$; *pulse repetition rates are* 80 *and* 30 Hz, *respectively.*

Similar results were obtained using a catalyst of IK–12–11 type. Its regenerating ability saturates at 150°C.

The experiments conducted demonstrate high efficiency of the solid-state catalysts of IKT–12–9 and IK–12–11 types. Their application provides for better stability of CO_2 output laser emission power.

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