On Output Power of Fast-Flow CO_2-Laser

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The role of the selectivity of pumping, excitation rate of the upper and relaxation time of the lower laser levels in obtaining the maximal output power of fast-flow CO_2-lasers are discussed. The much higher output power of fast-flow CO_2-laser compared with laser without a gas flow is caused by the larger excitation rate and saturation parameter and not by the gas cooling is shown. There is the own optimal temperature of the active medium to achieve the maximal output power of fast-flow CO_2-laser is concluded.

The expression for estimation of the output power P_{out} of the fast-flow (FF) CO_2-lasers is usually written in the form [1, 2]:

$$P_{out} = \frac{\eta_L}{1-\eta_L} c_p \left(\frac{dM}{dt}\right)\left(T_{in} - T_{out}\right), \qquad (1)$$

where $\eta_L = P_{out}/P_{in}$, is the laser efficiency, P_{in} is the pumping energy, c_p and dM/dt are the specific heat and the mass flow rate of the gas mixture, T_{in} and T_{out} are the gas temperatures inside and outside of the laser cavity, respectively. It follows from (1) that $P_{out} \sim T_{in}$, but such dependence contradicts to the generally accepted point of view that namely the temperature of the active medium of electric-discharge CO_2-laser limits its output power because of the grow of the thermal population of the lower laser level and the acceleration of the upper laser level relaxation [1]. It is also known that the cooling of the active media of FF CO_2-laser happens outside the resonator and so the gas temperature T_{out} does not influence directly on the characteristics of generated radiation. The work of power FF CO_2-lasers without closed cycle confirms this statement. In addition, the product $c_p \frac{dM}{dt}\left(T_{in} - T_{out}\right)$ does not define the thermal energy of the active media of CO_2-laser as it still remains the vibrational-nonequilibrium media and after emission of laser radiation. The energy stored in CO_2 and N_2 molecules is defined mainly by the vibrational temperatures and not by the gas temperature. Thus we can conclude that the expression (1), used in the literature to estimate the output power of FF CO_2-lasers, is incorrect and contradicts to the physical reality.

The aim of the present work is to determine the main physical processes that really influence on the output power of FF electric-discharge CO_2-lasers. The kinetic model of the CW electric-discharge FF CO_2-laser is analyzed. The expressions linking the small-signal gain, saturation intensity and output power of the laser with the excitation rates and relaxation times of laser levels are obtained. It is shown that the selectivity of pumping and excitation rate of the upper and relaxation time of the lower laser levels are the main parameters defining the output power of the FF CO_2-lasers. The role of the active media fast flow is consisted in replacement of vibrational-nonequilibrium CO_2 molecules after emission of laser radiation on new vibrational-equilibrium molecules, in which the high excitation rates can be realized. The dependences of P_{out} and η_L of FF CO_2-lasers on P_{in} are considered at different ratio between the gas mixture flow rates and the relaxation rates of laser levels. The much higher output power of FF CO_2-lasers compared with lasers without a gas fast-flow is caused by the larger saturation parameter and not by the grater efficiency of the gas cooling is shown. There is the own optimal temperature of the active medium for every laser cavity parameters, discharge conditions, gas mixture composition and velocity of gas flow to achieve the maximal output power of FF CO_2-laser is concluded.

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