3W average power 4.3 μm CO₂ laser

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A 3W average power CO₂ laser oscillating in the range of 4.3 μm (10⁰ to 10⁰ transition) is described. At the same time, the laser can emit 100 W in the sequence band 00² to 10⁰ (10.6 μm). It is based on a commercial system with continuous-wave discharge of 12 m length and a slow gas flow. It operates in the Q-switched mode at pulse repetition rates up to 15 kHz. The pulse peak power is 1 kW and the pulse duration is 200 ns. The deviation from the theoretical efficiency limit has been decreased by a factor 2.5 in our device, due to saturation of the pumping (sequence band) radiation. We predict an improvement by another factor of 5 (possible average power of 10 to 20 W), if one avoids the absorption in the discharge-free zones.

1. Introduction

Electric discharge CO₂ lasers oscillating on the 4.3 μm bands are of interest for various applications such as atmospheric monitoring [1], laser photochemistry [2] and optical pumping. Besides, as shown in [3, 4] mixing of this laser radiation with the 9 or 10 μm radiation of conventional CO₂ lasers in nonlinear crystals permits to cover the 7 to 9 and 2.95 to 3.15 μm bands with a stepwidth of 0.02 cm⁻¹ and to extend their application for spectroscopic purposes.

Lasing in the above systems occurs on the 10⁰ to 10⁰ (02⁰ to 02⁰ transition of CO₂ (Fig. 1) using combined electrical and optical excitation. Sufficiently strong excitation of asymmetric vibrations of CO₂ and simultaneous action of short powerful 'dumping' radiation pulse on the sequence band 00² to 10⁰ (02¹) are required to obtain inversion on the mentioned transition [5]. Therefore, and because the upper laser level (10⁰) is more rapidly deactivated than the lower one (10⁰), these lasers operate in pulsed mode only. A detailed theoretical and experimental study of the characteristic properties of similar systems with both pulsed transverse electric discharge and longitudinal d.c. discharge is given in [6-9]. To date, specific energy output of 15 to 50 mJ⁻¹ was obtained in TE discharge systems [10-11] at active medium pressure of 80 to 150 mbar and a pulse energy of 15 mJ was achieved [10]. Specific energy output of 0.1 mJ⁻¹ was realized in a system with longitudinal d.c. discharge at pressure 15 to 25 mbar and an average power of about 100 mW was obtained at a pulse repetition rate of about 6 kHz [12, 13]. Further practical use of such lasers requires to increase their pulse energy.
The specific output energy in the TE system is close to the theoretical limit [10]. Therefore higher output energy in these lasers may be reached only by volume scaling. According to the vibrational temperature measurements in the diffusion cooled systems with longitudinal d.c. discharge, the limit of specific energy output at about 20 mbar total pressure is 5 mJ l⁻¹ [14]. This is approximately 50 times more than the value presently obtained. One of the principal reasons of this discrepancy is insufficient intensity of the dumping radiation.

In [12, 13], for example, the peak intensity in the sequence band inside the cavity was about 1 kW cm⁻², that is by an order of magnitude lower than the saturation intensity [7] at which all available energy of the 4.3 μm radiation is extracted from the active medium.

In our work we increased the intensity of the dumping radiation to above the saturation value, using a laser with longitudinal d.c. discharge with very long active medium. Thus the pulse energy increased by more than a factor of 10 compared to similar devices. We demonstrated an average output power of 3 W at 4.3 μm. This is however still far from the theoretical limit. An estimation of the absorption in the discharge-free zones shows that avoiding these dead space would promise 5 times more energy and power.

2. Experimental
No special installation was built up to carry out this work. We made use of part of the device designed for obtaining powerful radiation pulses on the lines of the regular band of CO₂ at high repetition rate. The entire setup consisting of a Q-switched oscillator and an amplifier is described in detail elsewhere [15-16]. We used the oscillator section only (Fig. 2). It is based on a commercial laser (Ferranti MFK, U.K.). Conventional longitudinal discharge of direct current is used to excite the gas mixture at 15 to 25 mbar. The oscillator has six sections. Each of them consists of two discharge tubes with 11 mm inner diameter and 1 m length. The walls of the tubes are water cooled. The gas is circulated between the discharge tubes and a gas regenerator, and fresh gas is slowly fed into the system. The total