RF excited diffusively cooled all-metal slab waveguide CO_2 laser

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In this paper, a new type of radio frequency (RF) excited diffusively cooled all-metal slab waveguide CO_2 laser is presented, in which the waveguide channel is constructed by two aluminum side walls and two aluminum electrodes, the discharge is confined in the slab waveguide channel in terms of the voltage division structure. From this type of structure, 127-W laser power is obtained.

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Since 1989, Denis Hall has first presented the radio frequency (RF) excited diffusively cooled area scaling waveguide CO_2 laser technique[1], which employs a RF gas discharge excited slab hollow waveguide and an off-axis unstable optical resonator combined with a diffusive cooling technique to obtain a compact high power laser, the area scaling technique with the advantages of simplicity and easy achieving compact high power lasers have been well developed and applied in the field of RF excited waveguide CO_2 laser[2-5], because of its advantages of high beam quality and excellent performance over traditional direct current (DC) excited CO_2 lasers.

In the past decade, RF excited single channel waveguide CO_2 lasers have experienced a shift from all-ceramic waveguide channel structures to ceramic and metal sandwich waveguide channel structures to achieve better cooling. In 1991, Xin *et al.* reported a RF excited single channel all-metal waveguide CO_2 laser[6], in order to obtain the improved cooling and low cost. In this paper, we present the results of extending the all-metal single channel waveguide CO_2 laser coupled with a computer-aided software engineering (CASEI) resonator[7] to an all-metal slab waveguide CO_2 laser coupled with an off-axis unstable resonator, in which the waveguide channel is constructed by two aluminum side walls and two aluminum electrodes. For a single channel waveguide laser, scaling the laser power output is achieved by increasing the gain length of the waveguide in order to maintain the good quality of laser mode which is called linear scaling, however for the slab waveguide laser, scaling the laser power output is achieved by increasing the gain area of the slab waveguide and coupling an off-axis unstable resonator with the gain area in order to obtain the good quality of laser mode which is called area scaling. In the past ten years, the area scaling technique has been often employed to achieve a compact high power laser. In the current area scaling techniques, the ceramic and metal sandwich slab waveguide channel structure is widely used. In comparison with the ceramic slab waveguide channel structure or the ceramic and metal sandwich slab waveguide channel structures, the all-metal slab waveguide has the advantages of low cost, easy manufacturing, and high thermo conductance. By using this type of structure, we have obtained 127-W laser power from a discharge region length of 386 mm.

The schematic diagram of the all-metal slab waveguide channel CO_2 laser is shown in Figs. 1(a) and (b). The all-metal slab waveguide channel consists of two aluminum electrodes and two aluminum side walls, the surfaces of the electrodes towards to the waveguide are polished to an optical surface to obtain a high reflectivity for the light wave propagation in the waveguide. The top electrode, the bottom electrode and the two supporting side walls compose a gas discharge region of the slab waveguide with a height of 2 mm,

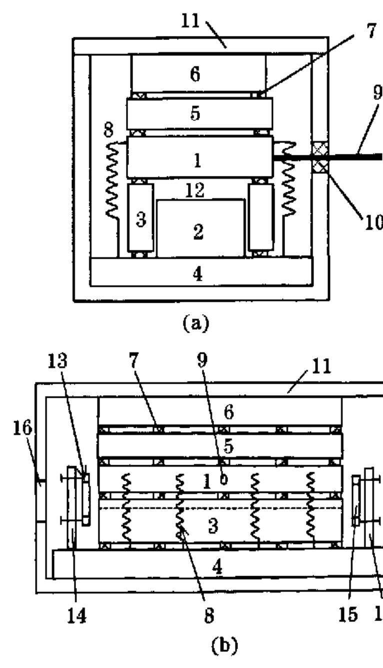

Fig. 1. Transverse (a) and longitudinal (b) cross section diagrams of the slab waveguide laser head. 1: top electrode; 2: bottom electrode; 3: side wall; 4: bearing plate; 5: liner plate; 6: clamp plate; 7: insulating plate; 8: matching inductors; 9: copper electrode link pin; 10: vacuum separation insulation bush; 11: vacuum box; 12: slab waveguide discharge region; 13: convex reflection mirror; 14: mirror mount and adjusting setup; 15: concave reflection mirror; 16: output window.

a width of 20 mm, and a length of 386 mm. The bottom electrode is disposed on an aluminum bearing plate, which is tightly connected with the inner wall of aluminum vacuum chamber. The two supporting side walls are disposed between the top electrode and the bearing plate. Electric insulation separations are formed respectively between the top electrode and the supporting side walls, and between the bearing plate and the supporting side walls by using a plurality of small ceramic insulating plates with a diameter of 6 mm and a thickness of 0.3 mm along longitudinal direction of the electrodes. The electric insulation separations are formed respectively between the aluminum liner plate and the top electrode, and the aluminum clamp plate by the same ceramic insulating plates along longitudinal direction of electrodes. Eight matching inductors with different periodical values are connected longitudinally between the top electrode and the bottom electrode to achieve the longitudinal uniformity of the RF power disposition[8]. The top electrode is connected with a copper electrode link pin, which passes through a vacuum separation insulation bush to connect with the high frequency power supply outside the vacuum chamber. With this structure, when a high frequency electric field is applied between the top electrode and the bottom electrode, a stable gas discharge can be confined in the slab waveguide, no gas discharge phenomenon is found outside the waveguide.

The top and the bottom electrodes were cooled with tap water to maintain the aluminum electrodes at room temperature. A kilowatts RF power with a frequency of 92 MHz was employed in the experiments. A virtual focus point telescope optical resonator was designed to couple with the slab waveguide gain medium, which consists of a concave spherical copper mirror with a curvature radius of 4100 mm and a copper convex spherical mirror with a curvature radius of 3280 mm. The resonator separation is 410 mm. The output aperture size is 2×4 mm^2 on the convex mirror. By combining this resonator with the RF discharge excited slab waveguide gain medium, at a gas mixture pressure of 12 kPa, a maximum laser power output of 127 W was obtained at an efficiency of 12.5%. The laser output mode is EH_{11} mode distribution at the direction of waveguide height and unstable resonator mode distribution at the direction of waveguide width. The laser power output against RF power input is shown in Fig. 2.

In our experiments, the whole setup of electrodes and optical resonator was enclosed in the aluminum vacuum chamber, which was sealed with "O" rings and square shaped rings. The output window of the laser beam is

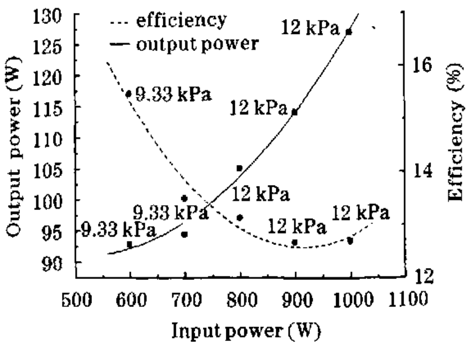

Fig. 2. Laser power output against RF power input.

a 2-inch diameter of ZnSe window with a transitivity of 99%, which is sealed with an "O" ring on the vacuum box. A gas composition of $CO_2 : N_2 : He + Xe = 1 : 1 : 3 + 5\%$ with gas pressures between 6.5 and 13.5 kPa was used.

In conclusion, we have presented a new type of RF excited diffusively cooled all-metal slab waveguide CO_2 laser, by which we have obtained a maximum laser power output of 127 W and an efficiency of 12.5% at a gas mixture pressure of 12 kPa.

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