Output characteristics of right angle cone mirror cavity laser

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The anti-misalignment stability and output characteristics of the right angle cone cavity laser are experimentally studied. When the misalignment angle of the cone mirror turns to 46.8 minutes, the single-pulse output energy of the plano-cone cavity laser decreases 24% and the near-field beam patterns have little change; as for the beam directional stability, when the measuring place stands 3.12 m in front of the output mirror, the near-field beam patterns of the plano-cone laser are located at the primary places until the misalignment angle of the cone mirror turns to 18 minutes. These results show that the plano-cone cavity laser has better performances in comparison with the plano-concave cavity laser.The analytical results of the mode instrument are also obtained, which show that the near-field beam intensity distribution of the plano-cone mirror cavity laser is near to the plane wave.

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The right angle cone prism cavity lasers have the characteristics of high beam quality and high anti-misalignment stability[1−4]. As the large aperture cone prism has difficulty in cooling, the application of cone prism cavity is restricted. We introduced a new type laser cavity which replaces the cone prism by a right angle cone internal mirror[5]. In this letter, we research into the anti-misalignment stability and the beam directional stability of the cone mirror cavity in comparison with the plano-concave cavity pulse gas laser.

The right angle cone mirror cavity consists of a right angle cone mirror used as the totally reflecting mirror and a parallel flat partially reflecting mirror as the output mirror. The reflecting surface of the right angle cone internal mirror is the inner face of the cone, the conical vertex angle is a right angle, the cone mirror is joined with its mount, the clear aperture is ϕ50 mm. The normal of the output mirror through the vertex point of the cone mirror is the optical axis of the plano-cone mirror cavity.

We put the experiment into practice with TEA CO_2 laser. The gas pressure in the laser cavity is 200 mbar, the discharge voltage is 28 kV, the gas constituent element is H_2:CO_2:N_2=2:3:15, the transmission capability of the output mirror is 70%, the cavity length is 2.4 m.

The output mirror and the cone mirror are fixed in a corrugated pipe and can be adjusted continuously. In the experiment we can adjust the misalignment angle of the output mirror or the cone mirror and test it with the He-Ne laser. Because of the cavity mirrors misalignment, the single-pulse output energy and the beam pattern of the laser change, which are measured by an energy meter that measures the single-pulse energy and by a piece of thermal paper that measures the output beam pattern. The distances from the energy meter and thermal paper to the output mirror are 800 and 550 mm, respectively. The energy meter is the SOLO PE meter manufactured by Gentec-EO Inc. The experiment conditions of the plano-concave cavity laser are the same as the plano-cone cavity laser. We use the same gas discharge laser unit during the experiment, except changing the totally reflecting mirror in laser resonators for composing plano-cone cavity and plano-concave cavity lasers respectively.

Deflecting the output mirror, we can find the relation between the misalignment angle and the single-pulse output energy of the plano-cone cavity or the plano-concave cavity laser (Fig. 1). From the experimental curve we can find that when the misalignment angle approaches 9′, the single-pulse output energy of the plano-cone cavity laser is 21 J, decreasing 17.6% in comparison with its standard state output energy (25.5 J); the single-pulse output energy of the plano-concave cavity laser is 13.4 J, decreasing 54.3% rapidly in comparison with its standard state output energy (29.3 J). The anti-misalignment stability of the plano-cone cavity is better than that of the plano-concave cavity.

In the experiment, we collected the output beam patterns of the plano-cone cavity laser and plano-concave cavity laser on the thermal paper when both lasers were in the state of output mirror misalignment. When the misalignment angles of the output mirror are 2.1′ and 4.2′, the output beam patterns of the plano-concave laser present a state of divergence; when the misalignment angles of the output mirror are 3.9′ and 7.5′, the beam

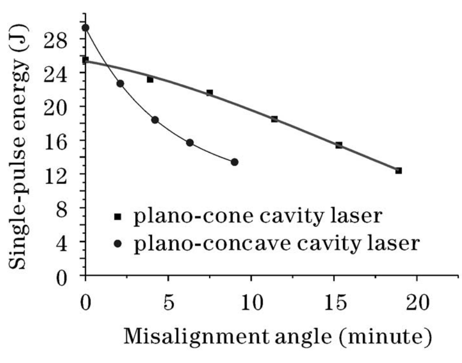

Fig. 1. Relation between the output mirror misalignment angle and the single-pulse energy of the plano-concave cavity and plano-cone cavity lasers.

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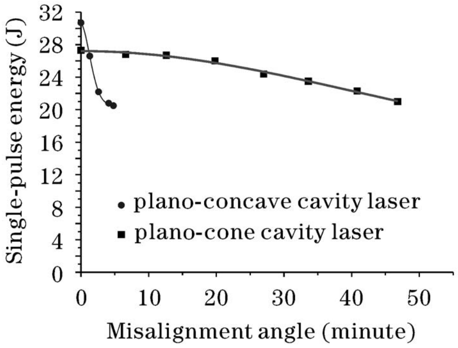

Fig. 2. Relation between the totally reflecting mirror misalignment angle and single-pulse energy of the plano-concave cavity and cone cavity lasers.

patterns of the plano-cone cavity laser have hardly any change. The plano-cone cavity laser has a better output quality than the plano-concave cavity laser when the misalignment angles become larger.

Deflecting the totally reflecting mirror, we can find the relation between the misalignment angle and the single-pulse output energy of the plano-cone cavity or the plano-concave cavity laser (Fig. 2). From the experimental curve we can see that when the misalignment angle approaches 46.8′, the single-pulse output energy of the plano-cone cavity laser is 21 J, decreasing 23.1% in comparison with its standard state output energy (27.3 J); when the misalignment angle is 4.8′, the single-pulse output energy of the plano-concave cavity laser is 20.5 J, decreasing 33.2% rapidly in comparison with its standard state output energy (30.7 J). The anti-misalignment stability of the plano-cone cavity is better than that of the plano-concave cavity.

In the experiment, we collected the output beam patterns of the plano-cone cavity laser and the plano-concave cavity laser on the thermal paper when both lasers were in the state of the totally reflecting mirror misalignment. The beam patterns of the plano-cone cavity laser have little change clearly except that the single-pulse energy falls a little when the misalignment angle of the cone mirror ranges from 0 to 46.8′; when the misalignment angle of the concave mirror is changed from 1.3′ to 2.6′, the beam patterns of the plano-concave laser present a state of divergence, the single-pulse energies are 26.6 and 22.2 J, decreasing 13.4% and 27.7%, respectively. The plano-cone cavity laser has a better output quality than the plano-concave cavity laser when the misalignment angle becomes larger.

In the standard state, the beam distributions of the plano-cone cavity laser and the plano-concave cavity laser are measured by a computer and a charge-coupled device (CCD) infrared imaging system, which is an array detector pulse laser beam distribution measuring apparatus manufactured by Beijing Institute of Optoelectronic Technology. The dynamic beam spot located at a diffuse reflection screen is 1050 mm from the output mirror. We get the beam distributions of both lasers, as shown in Fig. 3. Comparing the beam patterns, we can find that in the standard state, the near-field distributions of the plano-cone cavity and plano-concave cavity lasers are flat-topped pattern, the plano-cone cavity laser patterns are near to the plane wave.

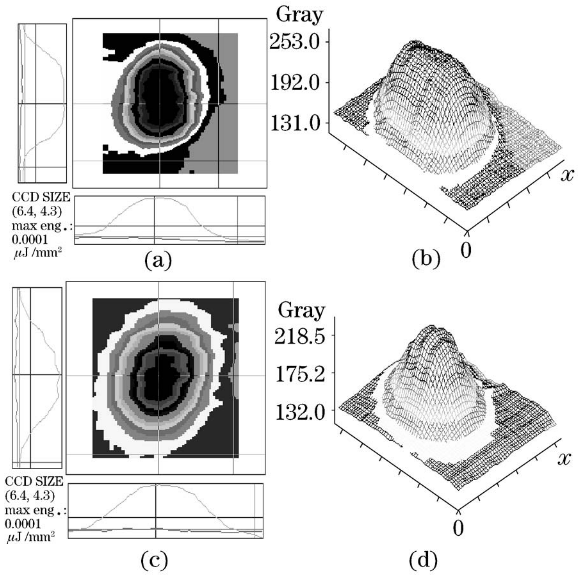

Fig. 3. Near-field beam-intensity distributions of plano-cone cavity laser (a, b) and plano-concave cavity gas laser (c, d).

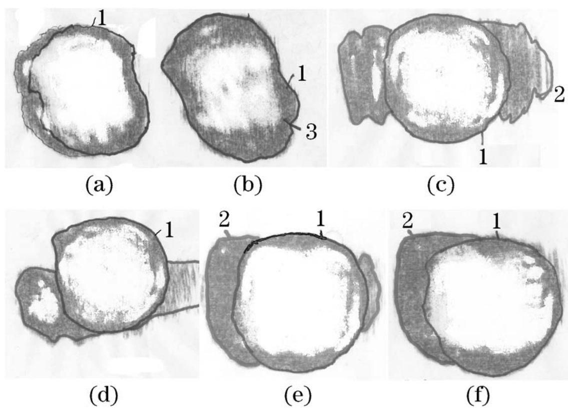

Fig. 4. Beam displacements of the plano-cone cavity and plano-concave cavity lasers when the cavity mirrors are misaligned.

The beam direction stability is the beam drift relative to its standard direction when a laser shoots. There are many factors affecting the beam direction stability of the laser, the main factor is the cavity mirror misalignment. In course of the experiment, we compared the plano-cone cavity laser with the plano-concave cavity laser on the beam direction deflection owing to the cavity mirror misalignment.

The experimental method is as follows. First we irradiate the thermal paper in front of the output mirror with the good alignment laser, then deflecting the cavity mirrors, we irradiate the same thermal paper again and measure the beam pattern displacement. The sign ‘1’ represents the first pattern in Fig. 4. The less movement of the pattern, the more beam direction stability of the laser. Furthermore, we can find the beam deflection angle according to the displacement.

Placing the thermal paper at 3.12 m in front of the output mirror, when the misalignment angle of the output mirror of the plano-cone cavity laser is 3.9′, we can find the displacement of the new beam pattern is 6.5 mm, the beam deflection angle is 7.2′ (Fig. 4(a)). When the misalignment angle of the cone mirror is 18′, we cannot find the displacement of the beam pattern (Fig. 4(b)). When the output mirror of the plano-concave cavity laser is deflected 4.5′ (Fig. 4(c)) or the concave mirror is deflected 2.4′ (Fig. 4(d)), both output beams of the laser diverge. When the misalignment angle of the output mirror of the plano-concave cavity laser is 1.8′, the displacement of the new beam pattern is 10 mm (Fig. 4(e)), the beam deflection angle is 11.4′; when the misalignment angle of the concave mirror is 1.3′, the displacement of the new beam pattern is 10 mm (Fig. 4(f)), the beam deflection angle is 11.4′. The beam direction stability of the plano-cone cavity laser is better.

The experimental results show that: 1) The plano-cone cavity laser has the great advantage of the anti-misalignment stability. When the totally reflecting mirror is misaligned, the plano-concave cavity laser has hardly any output energy, while the plano-cone cavity laser runs correctly, the single pulse output energy has hardly any decrease, and the near-field patterns have hardly any change. 2) When the cone mirror is deflected badly, the output beam of the plano-cone cavity laser has hardly any deflection, the beam direction is very stable. 3) The output beam of the plano-cone cavity laser is flat-topped, and the near-field distribution is uniform. 4) The single pulse output energy of the plano-cone cavity laser is close to the plano-concave cavity laser, but the basic mode volume of the plano-cone cavity is larger.

The output characteristics of the plano-cone cavity laser depend on the optical property of the plano-cone cavity and the right angle cone mirror. The right angle cone mirror has the property of spatial directed reflection. For a right angle internal cone mirror, an incident ray is reflected back parallel to its propagation direction, independent of the angle of incidence, in other words, a low misalignment sensitivity is with respect to arbitrary tilted axes of the mirror. According to the property, the plano-cone cavity laser has the better characteristics of anti-misalignment stability and beam directional stability.

A planar wave front remains planar after the reflection by a right angle cone mirror. The oscillatory beams in the plano-cone cavity are parallel with each other. The plano-cone cavity laser has the large basic mode volume, the uniform near-field distribution, and the plane wave output beam. When the basal plane of the cone mirror is perpendicular to the optical axis of the cavity, the cavity has the maximal mode volume, and the plano-cone cavity laser has the maximal single-pulse output energy at the same time.

The right angle cone mirror cavity lasers have the great advantages in the anti-misalignment stability and beam directional stability. With the simple structure, they are easy to install and adjust, especially suitable for applications in the high power laser system in a bad condition.

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