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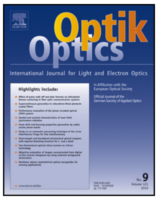

Theoretical analysis of the multi-pumped light intensity distribution of laser system with different pumping parameters

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ABSTRACT

By approaching of the Gaussian function, the intensity distribution of multi-pumped light with different pumping parameters such as pumping structure, pumping beam waist, gain medium radius and absorption coefficient has been simulated, and the impact of the different pumping parameters on the pumping homogeneity has also been discussed. The conclusion is that the pumping intensity distribution can be strengthened by increasing pumping direction and pumping beam waist, and it can also be strengthened by decreasing the gain medium radius. It also indicates that the absorption coefficient should be moderate.

1. Introduction

The thermal effect is the important influence factor of the LD pumped high power solid state lasers, which including the thermal lens effect, the thermally induced stress birefringence effect and the end effect [1]. The thermal lens effect aspects the laser system seriously, such as the system stability, the efficiency, the mode size, the output beam quality, etc. The study of the thermal lens effect and the compensation methods of the end pumped laser system are deep and wide both at home and abroad, while, the side-pumped thermal lens effect are more complex, and it is necessary to increase the pump uniformity to improve the laser performance.

The light intensity distribution of multi-pumped light with different pumping parameters such as pumping structure, pumping beam waist, gain medium radius and absorption coefficient has been simulated, and the impact of the different pumping parameters on the pumping homogeneity has also been discussed.

2. Theoretical analysis and calculation

The conventional method of describing the pumping light intensity distribution of side-pumped laser system is the ray tracing method [2,3], while, the computation is too heavy and the light way will changes when the actual light enters the crystal, so it will cost too much time to design the program and brings too much trouble to achieve it. The pumping light performances as Gauss distribution emitted from laser diode, therefore, it is more consistent with the actual situation and simpler by taking Gauss approximation, which has been taken in this article to carry on the simulated calculation.

In order to make the problem simpler, a few assumptions have been introduced [4]:

1. The energy distribution is uniform in crystal axis direction of the diode bar (Z-axis).
2. The pumping light in the crystal is considered, and the true beam can be obtained by the ray tracing method.
3. The pumping light single pass the crystal, and the reflected light is ignored.

Taking the single side pumping as example, which shown in Fig. 1, the center of laser diode is in the origin of coordinate, and the pumping intensity of single side pumping is

$$I(x, y) = \sqrt{\frac{2}{\pi}\frac{I_0}{\omega_p}} \exp\left[-\frac{2x^2}{\omega_p^2} - \alpha d(x, y)\right] \quad (1)$$

where $\omega_p = \omega_{p0}[1 + (\lambda y/\pi\omega_{p0}^2)^2]^{\frac{1}{2}}$, $d(x, y) = \sqrt{r_0^2 - x^2} + y$, ω_p represents the pumping beam radius in y position of crystal, ω_{p0} is the pumping beam waist, d is the distance, I_0 is the pumping light intensity of unit length in Z-axis, λ is the pumping wave length, α is the absorption coefficient, and r_0 is the crystal radius.

In multi-pumped condition, the laser diode bars arrange equally round the laser crystal by different pumping direction, so the light intensity on a certain point is the stack of intensity in every

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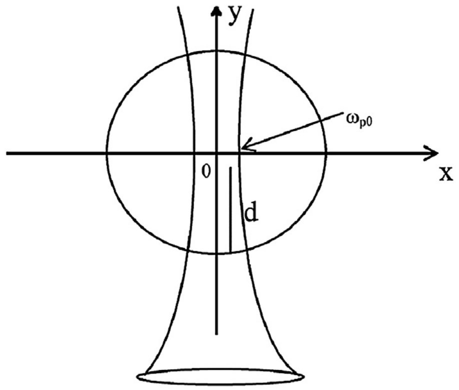


Fig. 1. Schematic diagram of one-side pumped structure.

pumping direction, and the pumping light intensity can be obtained by the coordinate transformation, which shows in Fig. 2(a)–(c). For the three-side pumping condition, let bar1 along the y axis direction, the light intensity can be described as

$$I_1(x,y)=\sqrt{\frac{2}{\pi}}\frac{I_0}{\omega_p(y)}\exp\left[-\frac{2x^2}{\omega_p^2(y)}-\alpha d_1(x,y)\right] \tag{2}$$

$$I_2(x_2,y_2)=\sqrt{\frac{2}{\pi}}\frac{I_0}{\omega_p(y_2)}\exp\left[-\frac{2{x_2}^2}{\omega_p^2(y_2)}-\alpha d_2(x_2,y_2)\right] \tag{3}$$

$$I_3(x_3,y_3)=\sqrt{\frac{2}{\pi}}\frac{I_0}{\omega_p(y_3)}\exp\left[-\frac{2{x_3}^2}{\omega_p^2(y_3)}-\alpha d_3(x_3,y_3)\right] \tag{4}$$

$$x_1=x\cos(120^\circ)+y\sin(120^\circ) \tag{5}$$

$$y_2=-x\sin(120^\circ)+y\cos(120^\circ) \tag{6}$$

$$x_3=x\cos(-120^\circ)+y\sin(-120^\circ) \tag{7}$$

$$y_3=-x\sin(-120^\circ)+y\cos(-120^\circ) \tag{8}$$

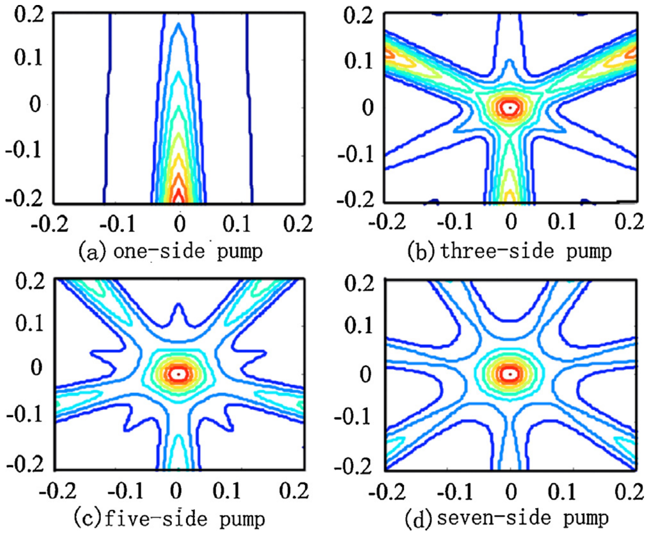
$$d_1(x,y)=\sqrt{r_0^2-x^2}+y \tag{9}$$

$$d_2(x_2,y_2)=\sqrt{r_0^2-{x_2}^2}+y_2 \tag{10}$$

$$d_3(x_3,y_3)=\sqrt{r_0^2-{x_3}^2}+y_3 \tag{11}$$

$$I(x,y)=I_1(x,y)+I_2(x,y)+I_3(x,y) \tag{12}$$

For the five and seven side-pumped condition, the angle of the adjacent bar are 72° and 51.4°, respectively, the light intensity in each direction and the total light intensity can be obtained. When $I_0=50\,\mathrm{W/cm^2}$, $\omega_{p0}=300\,\mu\mathrm{m}$, $\lambda=808\,\mathrm{nm}$, $r_0=0.2\,\mathrm{cm}$, the intensity distribution of multi-pumped light and the contour map can be gotten.



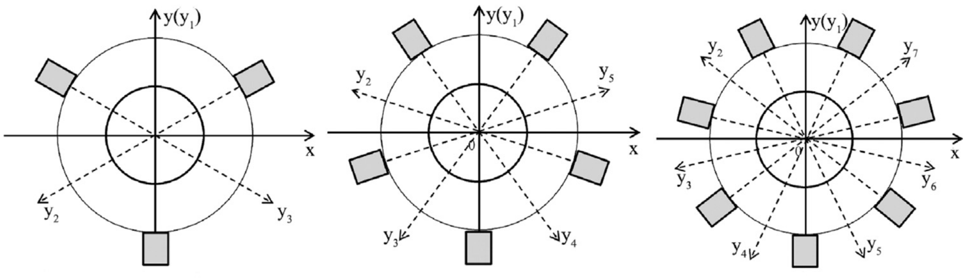
(a) one-side pump (b) three-side pump (c) five-side pump (d) seven-side pump

Fig. 3. Pumping intensity distribution with different pumping structure.

Fig. 3 shows the sectional view of the intensity distribution of multi-pumped light, and we can get that the intensity distribution is not uniform. In the single pumped condition, the pumping light intensity distribution is not the symmetric distribution as the axis of the crystal axis, actually, it distributes on both sides of the pumping light direction symmetrically, the energy near to the laser diode bar is high, and it decays when passing the laser crystal because of the absorption. With the increasing of the pumping group number, the pumping energy distribution becomes more uniform and the output beam quality is also improved.

The laser system performance is decided by the distribution of the pumping energy in crystal, and we can get that the pumping uniformity can be improved by increasing the pumping group number which be mentioned above, while, it will make the system more complex and expensive, so other configuration parameters should be taken into account. Taking the three-side pumping condition as example, by changing the pumping beam waist ω_{p0}, the crystal radius r_0 and the absorption coefficient, the two-dimensional graph of pumping light distribution and the isotherm profile can be obtained.

Fig. 4(a) and (b) shows the pumping light distribution and the isotherm profile in Y-axis with different pumping beam waist ω_{p0}. It can be seen from the figures that the common feature is the light intensity near to the laser diode bar greater than the one far away from the LD bar, and the light intensity is strongest in the center of the crystal because of the stack effect. With the increasing of the pumping spot size, though the distribution uniformity of pumping light is enhanced, the light weakens in the center of crystal, so the large size of pumping beam is not good for the fundamental mode operation.



(a) 3-side pumped structure (b) 5-side pumped structure (c) 7-side pumped structure

Fig. 2. (a) Three-side pumped structure. (b) Five-side pumped structure. (c) Seven-side pumped structure.