LD Longitudinally Pumped Nd:YAG 946nm Lasers Optimization Analysis

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***Abstract*—In this paper, the best crystal length and transmission of quasi-three-level 946nm Nd:YAG laser is analyzed and optimized. Under the different condition of pump power loss of cavity and mode matching the analysis show that one should select different length of laser crystal and different transmission if one wants to make the lasers output power is maximum.**

Keywords-quasi-three-level; crystal length; transmission

I. INTRODUCTION

Nd:YAG is a good crystal, currently found in the laser transition can be achieved more than 20 lines, one of the most commonly used three spectrum lines are ${}^4F_{3/2} \to {}^4I_{9/2}$ ${}^4F_{3/2} \to {}^4I_{11/2}$ ${}^4F_{3/2} \to {}^4I_{13/2}$ transition, produce 946nm, 1064nm, 1319nm infrared radiation, which the latter belong to the fourth-level system, easy to form the laser oscillation, and the 946nm transition is quasi-three-level system[1], the threshold is higher, therefore in the select of laser parameters from lower threshold consideration, namely, how to choose parameters in order to make the minimum threshold. Such as Nd:YAG crystal length usually select between the 3-4mm[2-4], laser transmittance is generally less than 3%, because there is no good pumping source in the past, but the most recent years due to the rapid development of semiconductor laser technology for providing high-quality solid-state lasers pump source, such as a single LD output has reached more than 5W, fiber coupling output has reached kw. So for 946nm quasi-three-level laser system threshold level is not the main problem, more importantly, how to improve the power and the optical-to-optical efficiency. In this paper, abandoned the departure from the traditional threshold to select the parameters of the laser, but proceed from the perspective of the output power of laser parameters were optimized to make the most efficiency.

II. THEORETICAL ANALYSIS

It can be derived from the rate equation when Laser pumped by a diode laser Nd: YAG which is in steady state that[5]:

$$F = \frac{1 + \dfrac{B}{fS} In(1 + fS)}{f \displaystyle\int_0^\infty \frac{\exp\left[-(a^2+1)x\right]}{1 + fS\exp(a^2 x)} dx} \tag{1}$$

The parameters are as follow：

$$a = \frac{w_p}{w_l}, \quad x = \frac{2r^2}{w_p^2}, \quad B = \frac{2\sigma N_1^0}{(L+T_3)}, F = \frac{4P_p\tau_f\sigma_3\eta_a}{\pi h v_p w_l^2 l},$$

$$f = f_1 + f_2, \quad \phi = \frac{2nlp_l}{chv_l}, \quad P_{out} = P_L + T_3, S = \frac{2c\sigma\tau_f\phi}{n\pi w_l^2(L+T)}$$

P_L is one-way intracavity laser power, P_{out} is the laser output power, T_3 is 946nm transmittance, L is in addition to transmission loss for the return trip loss rate, F is the normalized pumping rate, S is the normalized cavity photon number, By formula (1) the laser output power can be derived.

Let S = 0, then

$$F_{th} = \frac{(1+a^2)(1+B)}{f} \tag{2}$$

Have the above parameters into:

$$F_{th3} = \frac{\pi h v_p (w_l^2 + w_p^2)(L + T_3 + 2N_1^0\sigma l)}{4\sigma\tau_f\eta_a(f + f_2)_1} \tag{3}$$

P_{th3} is pumped quasi-three-level threshold, w_p and w_l were pumped laser beam waist spot radius and the radius of the waist spot.

III. NUMERICAL CALCULATION AND ANALYSIS

Make $w_P = w_L = 150\mu m$, $L = 1\%$,have the parameters into formula(3), we can obtain the relationship between the different transmission and threshold as shown in Figure 1,in order to obtain the minimum threshold, we choose Nd:YAG crystal with the specification between 0.2-0.4cm, the same conditions as above, when $T_3 = 3\%$ by the formula (1) can be calculated in the output power under different pump power and crystal length as shown in Figure 2, figure 1 shows that, when $T_3 = 3\%$,in order to make the minimum threshold, laser crystal length should be about 0.3-0.4cm. Figure 2 shows when the pump power is increased to obtain high output power should increase the length of the crystal, as $P_P = 3.5W$, laser length should be 0.4-0.5cm，obtain the maximum laser output power.

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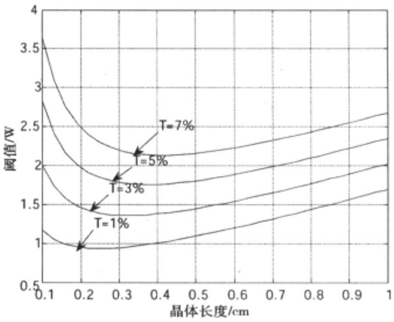

Figure1 Relationship between threshold and crystal length

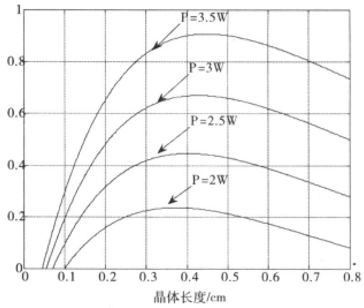

Figure2 Relationship between laser crystal length and output power with different pump power when $w_P = w_L = 150\mu m$

Make $w_P = w_L = 100\mu m$, $L = 0.01$, $T_3 = 3\%$,can be Figure 3, figure 3 shows when $P_P = 3.5W$, the best crystal length should be 0.5-0.6cm. When $P_P = 5W$, $w_P = w_L = 200\mu m$, $T_3 = 3\%$, different cavity loss when the output power and the crystal length relationship, as shown in figure 4, shows that when L is increased to make the maximum output power, laser crystal length should be increased.In the laser output mirror transmission rate, the traditional choice of laser cavity transmission rate of less than 3% , this is because, as shown in Figure 1, when the transmission rate increases the laser threshold is increased, and the mirror plating increased requirements, but in recent years due to plating technology progress. this is not main

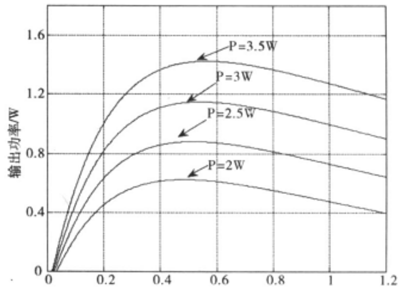

Figure3 Relationship between laser crystal length and output power with different pump power when $w_P = w_L = 100\mu m$

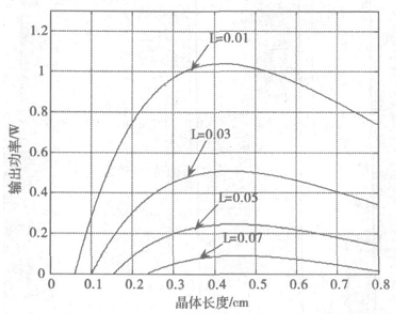

Figure4 Relationship between laser crystal length and output power with different pump power when $w_P = w_L = 200\mu m$

Problem for quasi-third-level laser system should select the appropriate transmission to make the maximum laser output power. By formula(1), when the laser crystal length of 0.3cm, $w_P = w_L = 100\mu m$, $L = 1\%$, Fig 5 can be obtained, It can be seen that when the pump power is 2-3.5W, the laser should be in the best transmission between $3\% - 5\%$,and with increasing pump power corresponding increase in the output mirror transmittance. When $L = 1\%$,laser crystal length of 0.3cm, when the pump power of 3.5W to take a different pump spot radius, transmission and output power relationship shown in Figure 6.

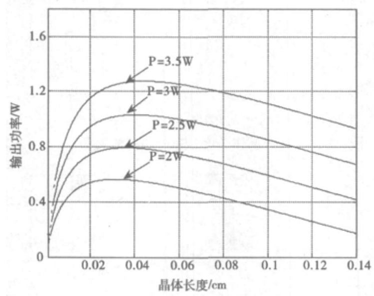

Figure5 Output transmission versus output power with different pump power when $w_P = w_L = 100\mu m$

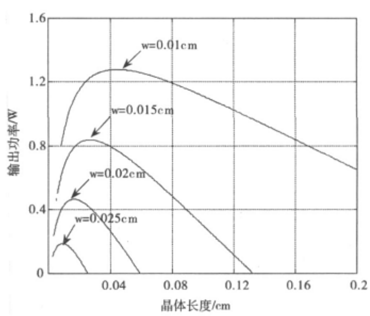

Figure6 Relationship between transmission and output power with different pattern match

In a certain pump power, the greater the pump beam and laser spot, then the smaller the laser output power, the best transmission rate is lower, so the heat capacity of the laser under the conditions allowed by the pump beam and laser spot should be reduced to obtain a high laser power output, when the pump power of 3.5W, the laser crystal length of

0.3cm, $w_P = w_L = 100\mu m$ could be obtained at different cavity loss between laser transmittance and power output relationship as shown in figure 7.

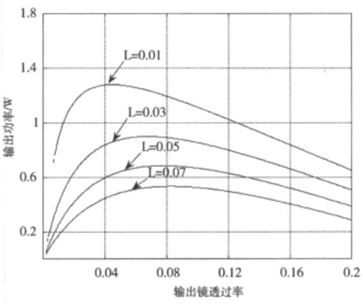

Figure7 relationship between laser transmittance and power output with different cavity loss

It can be seen when the cavity loss increases, to get the highest output power, optimal transmissivity should also be increased, so we should minimize the laser cavity loss, which can increase the output power, but also can reduce the mirror plating requirements.

IV. CONCLUSION

In this paper, by the Nd :YAG 946nm quasi-third-level laser rate equation, based on the different pump power, different cavity loss, the different pattern matching situation to make the corresponding numerical analysis, abandoned the traditional method of departure from the threshold to select the parameters of the laser, for the first time in the power output as a standard of LD pumped quasi-third-level of Nd:YAG laser was used to optimize the parameters, it is pointed out that the traditional to threshold minimum standard parameter selection can not make the maximum laser output power. This paper has a certain reference value in the selection of Nd:YAG quasi-third-level laser parameters.

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