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ScienceDirect

Procedia Computer Science 86 (2016) 67 – 70

Procedia Computer Science

2016 International Electrical Engineering Congress, iEECON2016, 2-4 March 2016, Chiang Mai, Thailand

Study and Experiment of Parameters Related to Small Beam Diameter of High Power Nd:YAG Laser

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Abstract

This paper presents the study and experiment of parameters related to small beam diameter of high power Nd:YAG laser that greater than 50 W in continuous wave mode (CW) at wavelength 1064 nm. In this paper, two mirror conditions of optical cavity such as R_1:750 mm, R_2:1000000 mm and R_1:508 mm, R_2:1000000 mm are used to compare the laser performances of each Nd:YAG laser system. Here, using mirrors curvature radius of R_1: 750 mm, R_2: 1000000 mm obtains a smallest beam diameter at aperture diameter 1 mm, the maximum output power of 56.88 W at optical cavity length 260 mm and the small beam diameter is maintained about 1 mm at optical cavity length 260 − 450 mm. Furthermore, compared with using mirrors curvature radius of R_1: 508 mm, R_2: 1000000 mm, the optimum current to achieve the maximum output power is lower, the optimized temperature to achieve the diode-pumped wavelength 805.5 nm is higher, the beam propagation has smaller beam diameter of 1.71 mm, and it has better circularity of 91%. And the beam quality is also better. Therefore, it can be concluded that R_1:750 mm, R_2:1000000 mm is the appropriate mirror condition to achieve the small beam diameter of high power Nd:YAG laser for this research.

Peer-review under responsibility of the Organizing Committee of iEECON2016

Keywords: High power Nd:YAG laser; Continuous wave mode; Small beam diameter.

1. Introduction

Nowadays, Nd:YAG crystal has been the most widely used solid-state active medium due to their excellent optical and mechanical properties [1-3]. Therefore, Nd:YAG laser system is very useful for the industrial applications. The high power laser that higher than 50W is used for guiding the machine, cutting wafer & PCB including cutting the automotive part. However, if the laser generates distortion beam then the drill position is not circle. Or when the unstable beam is used for cutting process, the unshaped on the cutting area is produced.

Peer-review under responsibility of the Organizing Committee of iEECON2016
doi:10.1016/j.procs.2016.05.017

Moreover, the cutting area is lost, if it is cut with a big beam diameter. In recent years, the beam diameter for cutting is about 6 mm. Therefore, the study and experiment of parameters related to small beam diameter is very significant to be considered.

In this paper, the study and experiment of the parameters related to small beam diameter of the high power Nd:YAG laser is reported. It is the further experiment of our previous work [4]. We selected only 2 conditions mirror curvature of R_1: 750 mm, R_2: 1000000 and R_1: 508 mm, R_2: 1000000 mm for the experiment setup of Nd:YAG laser in this research. The cavity length adjustment, changing the aperture diameter, optimum current and optimized diode temperature are demonstrated to achieve the maximum power and the smallest beam diameter. In additional, the beam quality (M^2) and beam divergence are measured to verify the symmetric of the laser performance. After that, the appropriate mirror condition is selected. We have expected that this experiment can be adapted for the actual work in the related institute, especially in the industrial sector.

2. Experiment setup

The optical cavity of a high power Nd:YAG laser for this research is depicted in Figure 1. The active medium is placed between high reflection (HR) mirror and output couple (OC) mirror. The optical axis is a line perpendicular to both mirror surfaces at the center of an optical cavity. The aperture is located an element within the cavity that limits the size of a beam. In most cases, the aperture is at the end of the active medium. The laser contains an amplifying medium and an optical cavity. Here, the beam is reflected backward and forward between both mirrors. During each round trip of the cavity, the beam passes through the active medium twice and is amplified. Some of the light passes through the output coupler to be the output beam, and some of the light is removed from the beam due to losses in the cavity. The remaining portion of the light energy is reflected back into the optical cavity. Moreover, the optical resonator composes with the mirrors coating the dielectric film M_1 and M_2 which has reflectivity of r_1 and r_2, respectively [5].

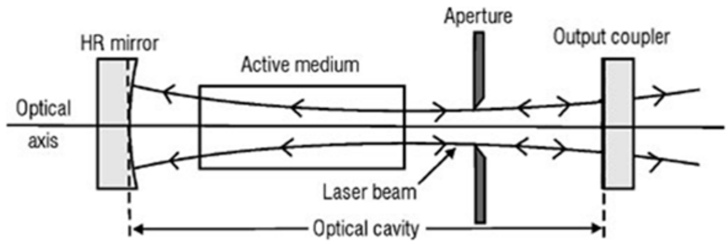

Fig. 1. Schematic of the optical resonator

The experimental setup of high power Nd:YAG laser are shown in Fig.2. The blue laser with power 1 mW wavelength 488 nm is used to align the guiding in the laser system, and the pinhole is used to reduce a scattering beam. Then the visible flat mirrors (item 3, 4) are installed to align the beam in X-Y-Z axis. The pump source is laser diode with the pump wavelength of 805.5 nm.

In this paper, the active medium is Nd:YAG with a diameter 2 mm length of 60 mm and it has the net gain coefficient (g-γ) of 0.0126 cm^{-1}[6]. From equation $1 = r_1 r_2 e^{2(g-\gamma)L}$, where r_1 is the reflectivity of 0.8, r_2 is the reflectivity of 0.9. Therefore, the optical cavity length (L) is equal to 260 mm. Here, the pump source system is called as “Module”. It is inserted between 2 mirrors and is also used to convert the output wavelength from 805.5 to 1064 nm. In order to prevent the thermal fracture, the Nd:YAG is mounted in the water-cooled which temperature is controlled at about 22-30 °C. Moreover, the laser has a simple linear concave-plane cavity configuration. The HR mirror is a concave mirror with the curvature radius of R_1:750 or 508 mm. The OC mirror is a plan mirror, i.e. R_2:1000000 mm, with transmission coefficient of 10% at wavelength 1064 nm. And, the beam tube is the attenuator to adjust an appropriate optical beam intensity. Lastly, the power meter has a distance 500 mm from the OC mirror.