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CHARACTERIZATION OF THE OUTPUT OF DEVELOPED Nd:YAG LASER

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ABSTRACT

The characterization of a developed Nd:YAG laser is reported. Nd:YAG rod was employed as gain medium and pumped by a single xenon flashlamp. The output of the laser was characterized by using phosphor card, spectrum analyzer and burn paper. The spectrum of Nd:YAG laser was dominated at line of 1064 nm. The infrared beam was made visible by using phosphor card. The spot of light started appearing at 1.83 mJ and the intensity of light was proportionally increased after threshold value. Burn paper was used to record the laser beam permanently. The diameter of the beam spot on burn paper remains constant to rod diameter (4 mm) at high energy but linearly increases at low energy. One dimensional energy density for developed Nd:YAG laser is 10.73 $x10^3$ $(A.U)^2$/ J.

Keywords: Nd:YAG laser, flashlamp, phosphor card , burn paper and beam spot.

INTRODUCTION

The Nd:YAG laser is the most commonly used type of solid-state laser in many fields at present because of its good thermal and mechanical properties, easy maintenance and low threshold [1,2]. The output energy of a single flashlamp pumped Nd:YAG laser in free-running is usually in range 50- 300 mJ. The beam quality of the laser is depending on its applications for which the beam is intended [3]. There are many ways to measure beam quality.

Siegmen suggested the use of second moment, M^2 to measure indirectly the beam quality [3] from the calculation. Amial *et al* used CCD cameras and Spiricon Laser Beam Analyzer for beam profile and intensity distributions [4]. A systematic theoretical and experimental work on the unstable resonator with super-Gaussian mirror was investigated by Silvestri *et al* [5]. They used the Nd:YAG laser for testing their fabricated mirror and the intensity profile of near-field and far-field were recorded. Strozyk used the photographic technique to measure the beam quality for investigation of concentric spherical cavities of ruby laser. The photographs show a uniform intensity distribution across the beam [6].

In this present paper, we are reporting the characterization of a developed Nd:YAG which operates in free-running mode using phosphor card and the burn paper. This includes the measurement of intensity distribution and energy density of the developed Nd:YAG laser.

THEORY

The intensity of fundamental TEM_{00} single Gaussian mode emitted by a stable resonator is given by [1, 5];

$$I(r) = I_0 \exp\left(-2\left(\frac{r}{w}\right)^2\right) \tag{1}$$

where *r* is the radial coordinate, I_0 is the peak intensity, and *w* is the spot size.

The characterization of laser beam depends on the laser resonator. Plano-concave resonator is the simplest resonator and very easy to align. The equations of the beam sizes w_1 and w_2 at the mirrors as given by Kogelnik et al [7] are;

$$w_1^2 = w_0^2 = \left(\frac{\lambda}{\pi}\right)\left[d(R_2 - d)\right]^{1/2} \tag{2}$$

$$w_2^2 = \left(\frac{\lambda}{\pi}\right)R_2\left(\frac{d}{R_2 - d}\right)^{1/2} \tag{3}$$

where w_0 is the size of the beam waist, R_1 and R_2 are the radii of curvature of the mirrors. The mode parameters obtained with a plane mirror and concave mirror of radius 5 m.

EXPERIMENTAL

In the present work a developed flashlamp-pumped Nd:YAG laser was characterized using spectrum analyzer, phosphor card and burn paper. Figure 1 shows the schematics diagram of the developed Nd:YAG laser. The Nd:YAG laser was designed for free-running mode with maximum frequency of 5 Hz. The active medium comprises Nd:YAG rod with dimension of 4 × 60 mm and both ends of the rod are cut at angel of 0.5 ‘ (in opposite direction) polished and coated one with antireflection, thin film of 1064 nm. Both a Nd:YAG rod and a single xenon flashlamp were placed in a ceramic reflector.

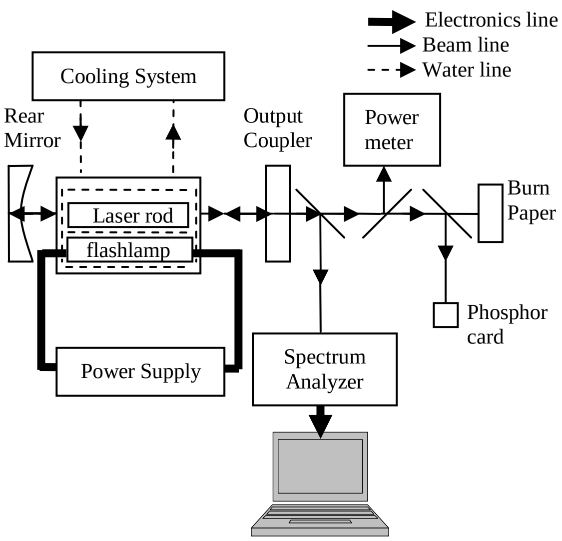

Figure 1: Experimental setup for characterization a new developed Nd:YAG laser

The plano-concave resonator consisted of a plane mirror and concave 100 % reflecting mirror of 5 m radius of curvature placed 400 mm apart. The laser head was placed close to plane mirror with 50 % reflectivity. Since the measurements were performed at a 1 Hz repetition rate, the thermal lens of the rod is negligible. The rod and flashlamp are cooled using distilled water to maintain the temperature gradient. The laser will be operated in free running mode and the capacitor voltage was varied for different input energies.

A Ophir Spectrum analyzer was utilized to measure the output profile of developed Nd:YAG laser range rom 500 nm to 1100 nm. The output signal was sent to a personal computer for further analysis. The output energies were measured using Melles Griot powermeter with maximum energy 3000 mJ.

Intensity of the developed laser has been detected using phosphor card as detector for infrared beam. The card was placed 5 cm from the output coupler and a digital camera was used to record the event. A red spot will be produced on the phosphor card when the infrared beam appears. The beam spot was capture using video player for various laser energies and analyze using the Maxtrox Inspector 2.1 software. Intensity of the laser beam on the phosphor card was measured in arbitrary unit (A.U).

The beam quality was measured using a burn paper which absorbs the laser beam and produce a spot on the burn paper due this interaction. The mechanisms of laser interaction involve are absorption, scattering and reflection. The pattern and size of the beam spot on the burn paper are directly proportional to the laser output after threshold input energy. By scanning the burn paper using scanner, the image of the beam spot will be analyzed using Matrox software and VideoTest 5. The depth, area density and diameter of the beam will be measured and the graph will be plotted.

RESULT AND DISCUSSION

The output of a developed Nd:YAG laser was first detected using Ophir Spectrum analyzer which was connected to computer. The typical result is shown in Figure 2. The dominant line of the spectrum is 1064 nm.

Figure 2: Spectrum of Nd:YAG laser with dominant line of 1064nm

The fundamental wavelength of Nd:YAG laser emission is 1064 nm [1, 13] with the highest cross section of 2.8 x 10^{-19} cm^2. At room temperature, the 1064 nm is dominant hence the cooling process is very important to maintain the laser output. Besides that, Nd:YAG crystal also emits the 946 nm and 1338 nm. In this experiment, the 1338 nm line is out of the range of the Ophir Spectrum analyzer which only detects the spectrum in range of 400-1100 nm.

The brightness and intensity of the laser produced is quantified using the phosphor card. The use of the card is to turn the invisible light of infrared signal into visible of red color. The typical visible red spot on phosphor card is shown in Figure 3. The beam intensity are arranged in the increasing order of the input energy accompanied with the corresponding intensity profile captured using Matrox Inspector 2.1 software.

Furthermore the diameter and the brightness of the spot on phosphor card increase when the energy is increased. For further analysis, the intensity versus laser energy was plotted as shown in Figure 4. Magnitude of the laser intensity was measured by subtracting the peak value. The noise level is 2800 AU which corresponding to the environment and sensitivity of instruments. The intensity of the beam is proportionally increased with the laser output energy after threshold. The slope of the graph is 412.93 AU/mJ.

The Nd:YAG laser beam was further characterized by using burn paper. The typical observation results are shown in Figure 5. The pictures are arranged in the increasing order of charging voltage. The beam spot was first appeared at capacitor voltage of 400 V which is corresponding to output energy of 67 mJ. Each beam spot is associated with its own line profile. The line profile of spot indicates the absorption of the photons on the burn paper. If more photons absorbed by burn paper, it shows that more laser energy interact with burn paper. It also shows the damage area on the burn paper.

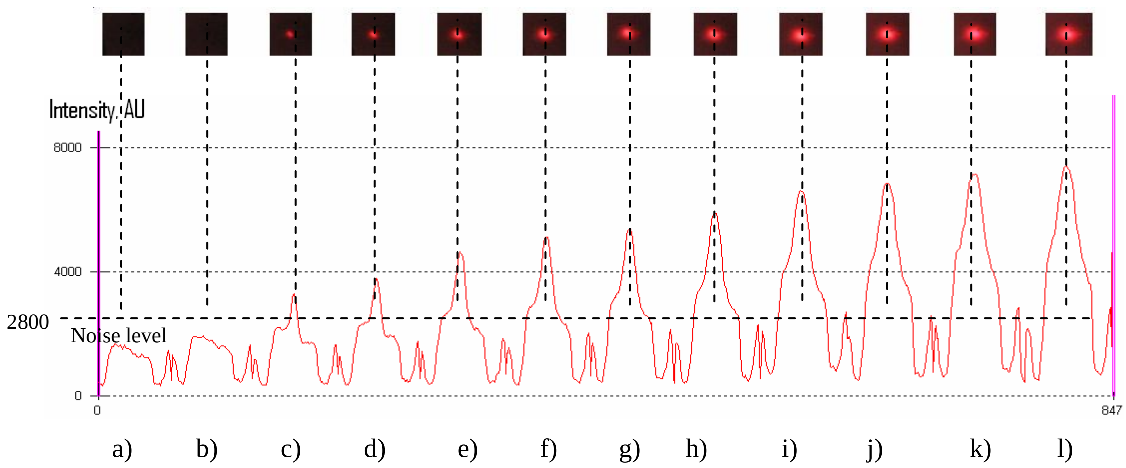

Figure 3: Laser beam on phosphor card and the profile of the beam was measured using Matrox 2.1 for various of capacitor voltage, a) 0.50 mJ , b) 1.00 mJ, c) 1.83 mJ, d) 2.73 mJ, e) 3.60 mJ, f) 4.85 mJ, g) 5.85 mJ, h) 7.18 mJ, i) 8.63 mJ, j) 9.52 mJ, k) 11.14 mJ and l) 12.44 mJ.

The diameter of damage area can be measured using VideoTest 5 software. The typical result of measurement is shown in Figure 6. At low energy, the diameter of the damage area increases linearly with laser energy. Meanwhile at high energy, the diameter remains constant for certain values of diameter of the laser rod. The slope of the graph is 0.005 mm/mJ. Moreover the pattern of beam spot indicates the effect of the diffraction either from the inside of the rod or the cleanness of the mirror. The defect on the rod and the cleanliness of the mirror affect the quality of the beam produced. Since laser crystal is a rod, the laser beam produced should be in circular shape. Otherwise, the beam quality is very bad and the shape is not circular.

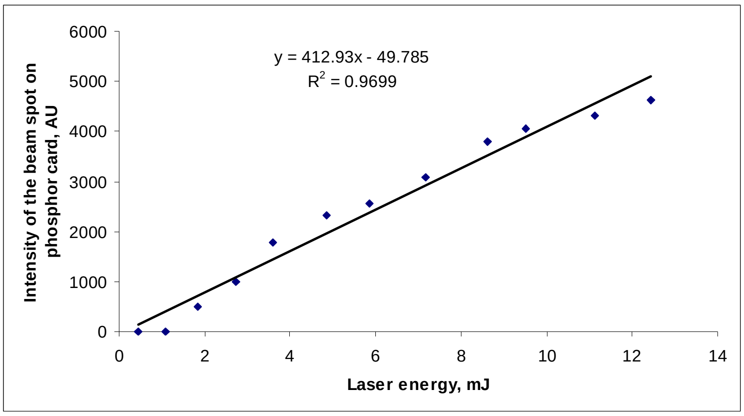

Figure 4: Intensity of the beam spot on phosphor card in AU versus laser output.

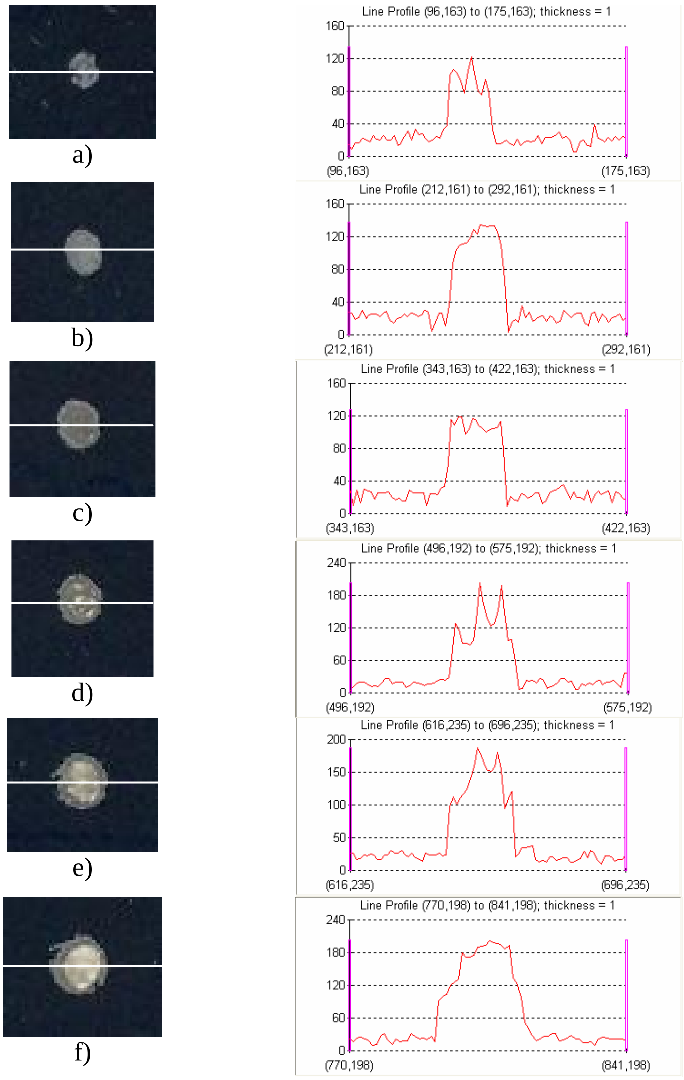

Figure 5: The beam spot on burn paper and the spot profile in Matrox Inspector at different laser energy a) 67 mJ, b) 104mJ, c) 142 mJ, d) 179 mJ , e) 216 mJ and f) 253 mJ.

Besides that, we also can measure the area under the line profile using Matrox software. The area under the line profile indicates the density of the damage area. If we plot the graph of area under line profile versus laser energy as in Figure 7, we will get the linear graph with slope of 10.728 AU/mJ. If we assume that the area under the line profile as an energy density in one dimensional, we can measure the energy density from the slope of the graph. The slope of the graph is the energy density of the laser beam and the value is $10.73 \times 10^3 (AU)^2/J$.

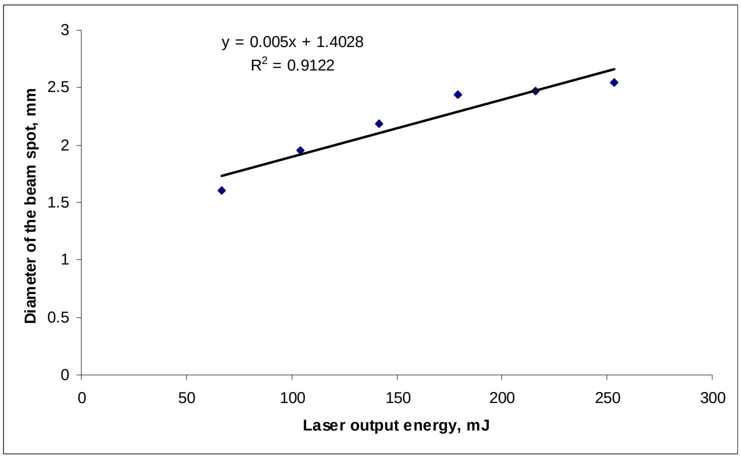

Figure 6: Diameter of the beam spot on burn paper versus laser energy.

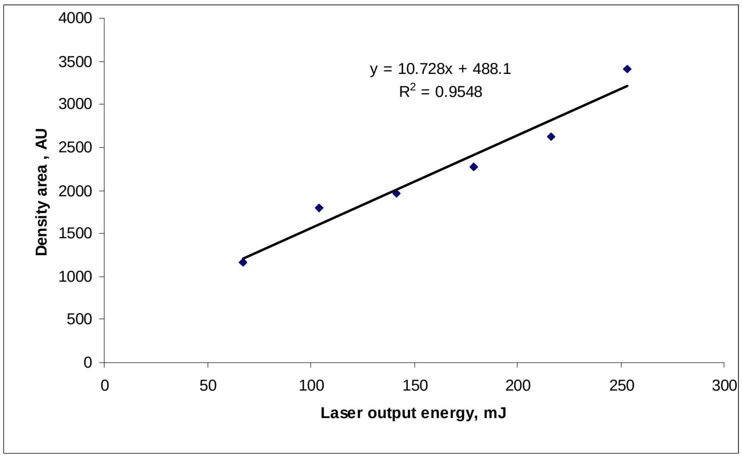

Figure 7: Density area under line profile of the beam spot on burn paper at different energy.

CONCLUSION

As the conclusion, a developed Nd:YAG laser was successfully characterized using basic parameters. The Nd:YAG laser beam was dominated at 1064 nm line. Intensity of the laser beam was detected using phosphor card and it is proportionally increases with laser energy after the threshold value. The pattern on the burn paper was analyzed using Matrox software to a measure diameter of damage area and area under line profile. Diameter of the damage remains constant at high energy and it increases linearly at low energy. The one dimensional energy density of developed Nd:YAG laser is 10.73 $x10^3$ $(A.U)^2$/ J.

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