BEAM SPOT OF Q-SWITCHED ND: YAG LASER BASED ON RASTER GRAPHIC

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ABSTRACT

The quality of beam produced by a Q-switched Nd:YAG laser was investigated. A photographic technique associated with image processing system was utilized to determine the beam quality. The invisible light was detected using burn paper at various operation voltages of flashlamp driver in the range of 450 V to 900 V. The permanent record of the beam spots were made via a scanner and analyze using raster graphic or bitmap from a Matrox Inspector version 2.1 software. The line profile each of the beam spot produced an absorption spectrum. The amplitude of the spectrum indicates the depthness of the hole created after laser interaction with photographic paper. Meanwhile the width shows the beam size as well as the surface roughness. Thus the beam quality is illustrated by the depthness and the flatness of the beam spot. The flatter the surface the more uniform the laser beam distribution and the deeper the hole the more energetic the laser beam interacted with burn paper.

Keywords: *Laser beam quality, burnt paper, Raster graphic and infrared laser.*

INTRODUCTION

Nd:YAG lasers can be operated in both pulsed and continuous mode. The pulsed lasers are typically operated using Q-switching mechanism: In Q-switched mode, the laser output powers of 20 megawatts scale and pulse durations of less than 100 nanoseconds are commonly available. The high-intensity pulses may be required to convert light from 1064 to become 532 nm through the process of frequency doubler, or even higher order harmonics generation can be achieved at 355 and 266 nm [1]. A high quality beam is desired to pump another high power laser such terawatt class Ti:Sapphire amplifiers [2].

The M^2 factor usually uses to characterize the quality of the laser beam [2-3]. However the M^2 factor being a single number and cannot be considered as a complete characterization of beam quality. The actual quality of a beam could be estimated by using beam profiler or CCD camera [4] and phosphor material [5]. However, the low cost, fast and simple technique to measure the beam quality could be achieved by using photographic paper or burn paper [5]. When the unfocused laser beam interacts with this material, the vaporization occurred; particles remove and the contamination was observed. By using this technique, the beam spot of the laser could permanently record.

In this paper, the beam quality of Q-switched Nd:YAG laser was characterized based on the absorption on burn paper. The line profiles of the beam spot at different energies were analyzed using raster graphic or bitmap.

A RASTER GRAPHIC

Assumed that the laser beam propagates in the Gaussian's beam profile. After laser interacts with a target material (in this case photographic paper) the beam spot was considered to be in the form of airy disk. The intensity profile of such airy disk will be transform into Gaussian beam as illustrate in the *raster graphic* or *bitmap* such as shown in Figure 1. A bitmap is technically characterized by the width and height of the image in pixels and by the number of bits per pixel.

Signing or indicator related to the effect of absorption on the burn paper. The amplitude or the height of the Gaussian profile in Figure 1 is also indicated the depthness of the hole created on the burn paper. The beam size can be determined based on the width of the Gaussian beam profile. Raster graphics are resolution dependent. In this work, the resolution can be achieved up to 1 cm:

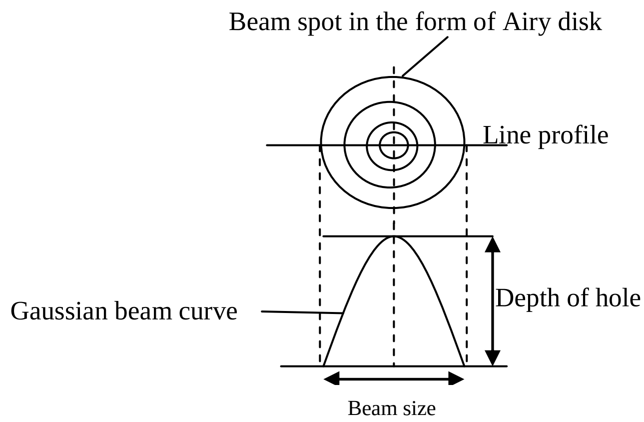

Figure 1: The relationship between depth and beam size of the beam spot.

EXPERIMENTAL SETUP

In this experiment a developed Q-switched Nd:YAG laser was employed as source of light. The fundamental wavelength of the laser is 1064 nm. The laser was Q-switched Nd:YAG using KD*P as a Pockels cell. The quarter-wave voltage of the q-switched driver was 3.0 kV. The pulse duration of the Q-switched laser was 10 ns. The laser was operated in a single pulse operation. The power of the laser was regulated by changing the capacitor voltage between 500 V and 900 V.

Exposed IFord Photographic paper was used as a burn paper. The burn papers were cut into hundreds pieces. Each piece was used to detect a single exposure from invisible infrared laser beam. The unfocused laser beam was exposed on the burn paper. The paper was placed at an identical location. Various exposures were produced by adjusting the capacitor voltage of the flashlamp driver. For each constant voltage, the beam spot will be obtained 10 times. The average of ten read out will represent the size of beam spot.

The image of the beam spot for each voltage was permanently recorded by scanning using HP Scan Jet 2300. The file was saved and transfer into personal computer for further analysis. Matrox Inspectors version 2.1 was utilized to analyze the raster graphic of the beam spot. The height and the width are measured in arbitrary units (arb. unit). The whole experimental set-up is shown in Figure 2.

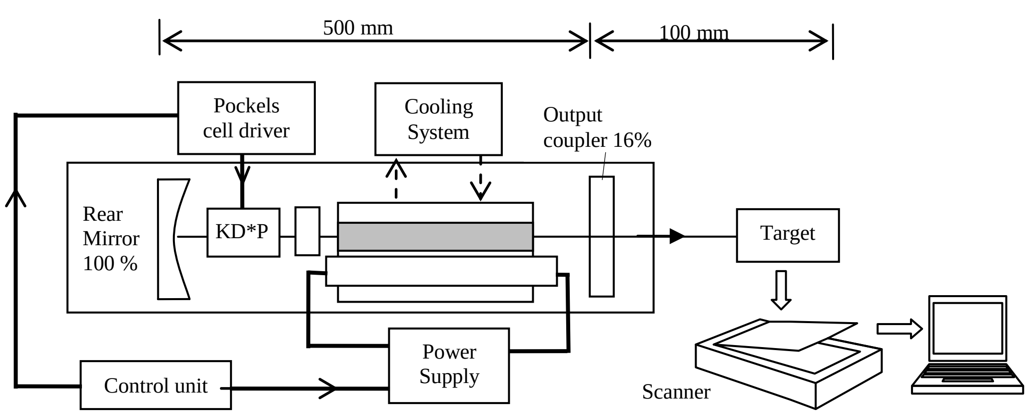

Figure 2: Experimental Setup of beam quality measurement.

RESULT AND DISCUSSION

The unfocused beam of infrared (IR) laser (1064 nm) was detected using burn paper. The paper was immediately damaged when interacted with an energetic laser beam. Figure 3 shows the typical beam spots for both Q-switched and pulsed Nd:YAG laser at 700 V of voltage operation. From the experiment, for pulsed laser operation (without Q-switched), the threshold energy to produce the beam spot on the burn paper is 50 mJ. Meanwhile the threshold energy for Q-switched laser is 10 mJ. The difference between pulsed and Q-switched laser beam spot could be recognized using naked eyes. For Q-switched pulse, the color of the beam spot is brighter, uniform and solid round pattern as compared to pulsed laser such as depicted in Figure 3.

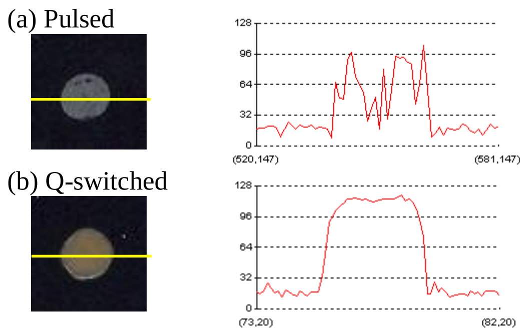

Figure 3: Beam spot on burn paper at 700 V of operation voltage (a) free running laser, (b) Q-switched Nd:YAG laser.

For further analysis of beam quality, the line profile option from matrox inspector version 2.1 software was performed. On the right hand side of Figure 3 shows the profile of beam absorption for both free running pulsed and Q-switched laser. The spectrum of free running pulsed and Q-switched laser is obviously different. For free running pulse laser, the spectrum comprising several sharp peaks. The various peaks represent the irregular roughness of the surface. In average the depth of the hole created on the burn paper is quantified to be as 60 arbitrary units (Figure 3a). In contrast, the absorption spectrum of beam spot for Q-switched laser shows only a single peak with a flat top. This indicates that the surface of the beam spot is smooth due to the impact of uniform light distribution on the burn paper. The height of the peak is equivalent with the depth of hole drilled by the Q-switched laser. In average the depth is 100 arbitrary units which is 40 % better than produced by pulsed laser. From this observation, the beam quality is measured base on the absorption spectrum. The flatness of the spectrum peak becomes the measurement of the beam quality. The best beam quality is based on the uniformity and the energetic of the light. This is transformed on the beam spot pattern. The flatness of the peak means the smoothness of the surface, indirectly indicates that uniformity of the laser beam distribution. The strength or the energetic of the laser beam is illustrated by the depth or the height of the peak. The higher the peak means the deeper the drilled hole on the burn paper.

The previous speculation was confirmed by investigating various operation voltage of the flashlamp power supply. The typical results obtained from these experiments are depicted in Figure 4. The beam spots are arranged in the increasing order of the operation voltage. Each beam spot, associated with its own line profile. Irregular peaks are observed in Figure 4 (a) and Figure 4 (e) indicate that the non-uniformity of light distribution impact on the burn paper. The absorption spectrum as shown in Figure 4 (b) almost similar to the Gaussian beam profile. This is occurred at operation voltage of 600 V. The beam quality of the laser is almost similar as uniphase of transverse electromagnet TEM_{oo}. The beam spot almost like an airy disk, having deep part in the center and shallow part upward. This translates that the density of beam image whereby the brightest at the center and getting blurred as it propagates outward. This quality is merged with M^2 definition, whereupon it depends on the quality of the beam to be focused. To meet the definition, mean this laser need to be operated at 600 V.

As the laser operated with higher operation voltages, the beam spot becomes solid and saturated. This is demonstrated such as shown in Figure 4(c) and Figure 4 (d) corresponding to operation voltage of 700 V and 800 V. The image of beam spot is manifested in solid circular configuration. The line profile of such solid surface demonstrated the saturated spectrum of absorption. The saturation is demonstrated by the flat top of the peak, similar as if the beam directed detected by the photodiode. Due to the super-radiation of the light, the photodiode become overexposure, and display a saturated signal. Similar configuration is observed on the burn paper, no more airy disk pattern, but the smoothness surface as shown with the flat top. In contrast, this can be as an indicator that the homogenous distribution of photon impact on the burn paper. As a result the quality of beam produce at this high end of the operation voltage is very energetic and uniformity. Hence, with high power operation laser, the best beam quality is represented by the solid circular configuration of beam spot associated with homogenous flat top of absorption spectrum. Meanwhile at the low end operation voltage, the beam quality can maintain as airy disk formation which indicated the Gaussian beam profile.

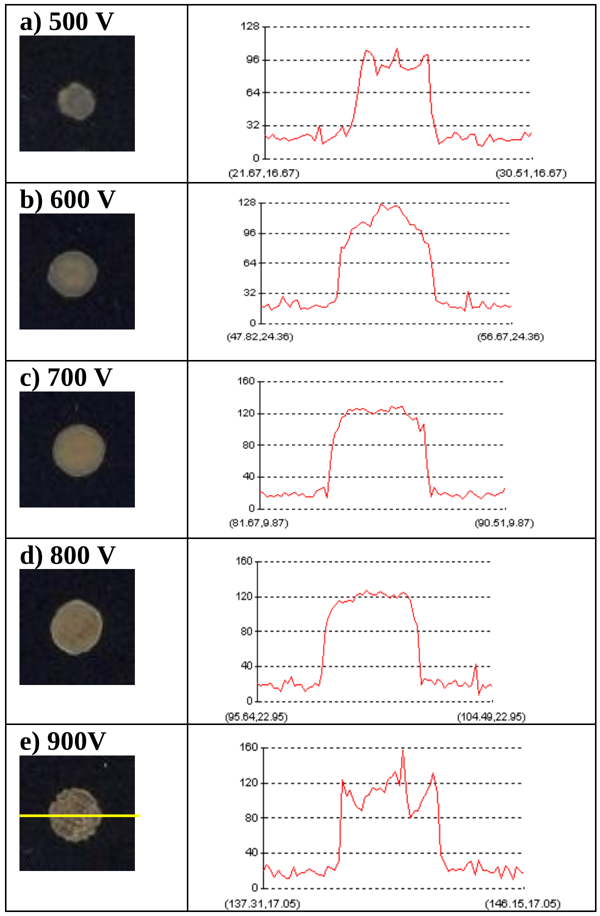

Figure 4: Typical beam spots and line profile of Q-switched Nd:YAG laser at different operation voltage of power supply.

The bitmap of the absorption spectrum were quantified based on the height and the width of the peak. The height represents the depth of the hole created on the burn paper. Meanwhile the width is representing the beam spot diameter. Figure 5, shows the relationship between the depth and width with respect to the operation voltage. Both curves have non-linear relationship. Initially change occurs drastically, the depth and the beam diameter increase abruptly upon the operation voltage. The burn paper immediately contaminate after interacted with Q-switched laser. The sensitivity of the paper allows the burning following the contour of the incoming beam. In additional, the shortest pulse duration induced local heating without affected neighboring areas. As a result, the beam spot follow exactly the cross section of beam radiation. Although the heat is not conduct laterally, but the beam does penetrated through the papers. The photographic paper relatively thicker as compared to the normal A4 paper, so the penetration is allowable depends on the energetic of the incoming beam. The higher the energy the deeper the beam penetrated under the paper. In general the depth of beam spot due to operation voltage in between 400 V to 500 V, is found to be 90 arbitrary unit. The depth is then increased gradually against the operation voltage. The optimum depth of 120 arbitrary is obtained at operation voltage of 750 V. At higher operation voltage of 900 V, the depth is found to be 100 arb. units. The possible reason for the decreasing is due to the fluctuation or un-stability of the laser output at higher operation voltages. The beam diameter profile is similar trend as depth profile. Except that no significant beam size is realized, since the size is almost consistent.

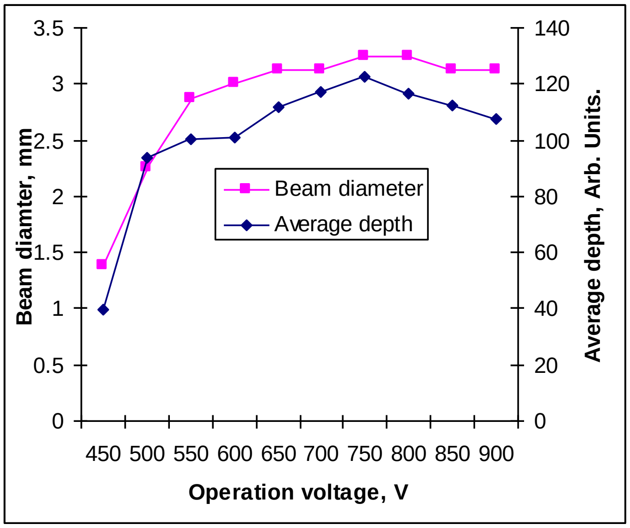

Figure 5: The average of depth of hole created on photographic paper for operation voltage from 450 to 900 V

CONCLUSION

The beam quality of infrared laser is determined based on the absorption spectrum of photographic paper. Burn paper is the easiest way to detect the existence of invisible light of Nd:YAG laser. Furthermore the detector can also extended to become as a tester for the beam quality of high power laser. The effect of immediate absorption on burn paper is analyzed based on raster graphic or bitmap. As a result the beam quality is found to be similar as Gaussian beam profile for low operation voltage (600V). Smoothen flat top and deep penetration due to saturated absorption is identified as the best beam quality for high operation voltage of 700V.

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REFERENCES

[1] W. Koechner, Solid State laser Engineering (Springer Series in optical science), New York, 2006
[2] Isao Matsushima, HidehikoYashiro, and ToshihisaTomie, (2006) Optics Letters, Vol.31, No.13
[3] A. E. Seigman, " How to (Maybe) Measure laser beam quality, "Tutorial presented at Optical Society of America Annual Meeting long Beach, California, 1997
[4] A. A Amial, N. Davidson, and G Machavariani, (2003), *IEEE J. Quantum Electron*, 39, 74,
[5] A. R Tamuri, N. Bidin, and Y. M Daud, (2008), Laser Physics, Vol. 18, No. 1, pp 18-21