Characterization of Diode Pumped Solid State Laser Beam

Wan Aizuddin Wan Razali
Dr Azman Kasim
Syamsyir Akmal Senawi

ABSTRAK

Diode Pumped Solid State (DPSS) is an optical pumping for Ti:Sapphire laser. The aim of this project is to diagnose the performance of the DPSS. This laser is operating at continuous wave (cw) mode. The fundamental wavelength of the laser is 1064 nm and frequency doubled of KTP crystal to produce a visible green light of 532 nm. The verification of the output is made via the high power laser diode driver. The profile of the beam output was visualized and recorded using Beam Star CCD Profiler. The DPSS laser is started to lase at threshold current of 7 A. The output power of the laser is found to be linearly increased upon the forward current. The slope efficiency was obtained as 0.0576 W/A. The maximum output power is obtained as 1.07 W corresponding to current of 28 A. The output beam produced from DPSS laser was in the form of Gaussian Beam at near field.

Keywords: *Diode Pumped Solid State, Optical pumping, Neodymium Doped Yttrium Orthvanadate (Nd:YO$_4$), Pottasium Titanyl Phosphate (KTP), Gaussian Beam.*

Introduction

Diode Pumped Solid State laser has been recognized as far back as the initial stage of laser development in the late 1960s and early 1970s as a particularly attractive laser excitation scheme [1]. Most solid state lasers are pumped with optical sources. The goal in designing optical pumps for solid state laser is to match the output spectrum of the optical pump with that of the laser pump bands [2]. The DPSS lasers, compared to the traditional flashlamp pumped ones, have the characteristics of being more efficient, compact, versatile, stable and reliable, which allowed them to be used in a wide range of applications with improved performance [3].

The advance of diode laser technology in the past two decades has made low cost, high efficiency, high power and reliable diode lasers commercially available, which provided for the first time a most efficient pump source for the solid state lasers and revolutionized the solid state laser technology. The Nd:YVO4 crystal was identified as a promising gain medium of the DPSS laser because of its many advantages such as a high absorption over a wide pump wavelength bandwidth, a large efficient stimulated emission cross-section, a high allowed doping level and a polarized output. It has been used in high power DPSS laser more and more [4]. Apart from the traditional Nd:YAG and Nd:YVO$_4$ crystals, recently a new type of Nd^{3+} doped vanadate crystal Nd:GdVO$_4$ has also attracted great attention [5]. The DPSS laser also use KTP crystal for frequency doubling to convert 1064 nm infrared into 532 nm green light [6]. To date, extra and intra cavity frequency doubled Nd:lasers using KTP have become a preferred source of pumping visible dye lasers and tunable Ti:sapphire lasers as well as their amplifiers. When applied to diode pumped Nd:laser, KTP has provided the basis for the construction of compact visible solid state laser system.

Laser Diode and Nd:YVO$_4$ are strictly temperature controlled by thermoelectric cooler [7]. Thermoelectric coolers are solid state heat pumps used in applications where temperature stabilization, temperature cycling, or cooling below ambient are required. Thermoelectric are based on the Peltier Effect by which DC current applied across two dissimilar materials causes a temperature differential. DPSS lasers have become extremely useful because of their low-cost, compact size, and high power output. Hence, prior to applying such DPSS as a pumping source, the aim of this project is to characterize its properties and identified its best performance.

Methodology

A Diode Pumped Solid State (DPSS) laser model LYDPG-1 is used as a source of light. The DPSS laser was pumped by a high power diode laser. The wavelength of the diode is 808 nm. The diode is utilized as an end pumping system. The active medium of DPSS laser was Neodymium Doped Yttrium Orthvanadate (Nd:YO$_4$) crystal. After being pumped by the diode laser, it lase infrared (IR) beam of 1064 nm. The frequency of the beam became doubled by passing through Pottasium Titanyl Phosphate (KTP) crystal. In this case the invisible light turned visible, where the wavelength of the original beam became half that is 532 nm. The output beam of DPSS laser is green light. The power of the beam was detected and measured using 3APSH Melles Griott powermeter. The profile of DPSS laser beam was visualized and recorded using a CCD video camera of the BeamStar System. The schematic of the whole experiment setup is depicted in Figure 1.

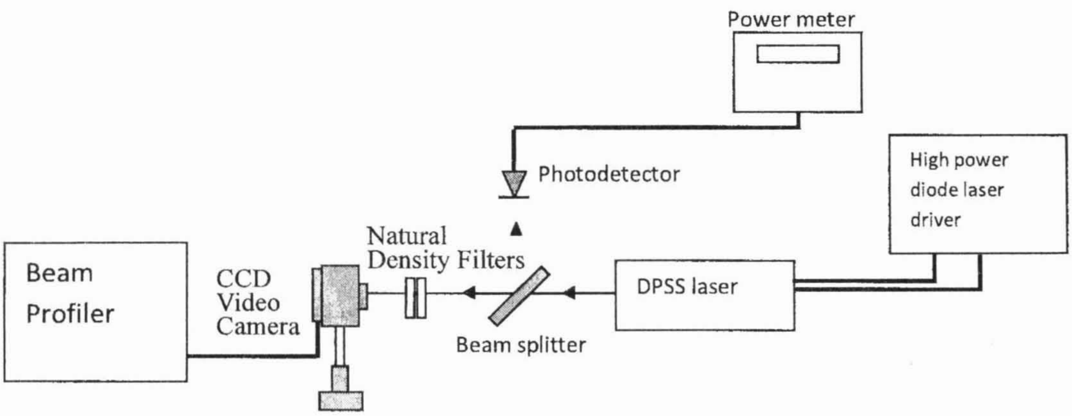

Figure 1: Block diagram of the experimental setup

Results and Discussion

The output of Diode Pumped Solid State laser was diagnosed by measuring the power and recording the beam profile. The pumping current of the power supply was increased until the DPSS was lased, begining from zero till a certain pumping current, where the power was just started to be traced. Such pumping current is known as a threshold current. In this particular experiment, the threshold current was found to be at 7 A.

The pumping current was continuously increased and the corresponding power of the laser beam was measured. The power was measured 3 times for each increment of the current. The average of power was then calculated. The collected data were used to plot a graph of power against current. The plotted graph is shown in Figure 2. Initially no power was detected although the current was increased. The curve remained at zero power. In other word, the given pumping current was not enough to initiate the combination process between hole and electron in the diode laser. As a result no light emitted, as well as no lasing occured. Soon after enough energy was given to the diode, green light was observed and detected by the power meter. However, the power was gradually increased within 7 - 16 A. After the pumping current exceeded 16 A, the power was found to be drastically increased.

The slope efficiency of the linear part was obtained as 0.0576 W/A. The value of the slope tells us the efficiency of the conversion factor which is how much the input current has been used to convert into light. The nearer value to one, means the better conversion factor. However, the conversion factor found in this experiment is relatively low. A lot of energy given to the system was lost either by absorption, scattering, reflection and other possibilities. Hence, only little energy was involved in the production of laser output. The maximum power obtained from this experiment was 1.07 W corresponding to the pumping current of 28 A.

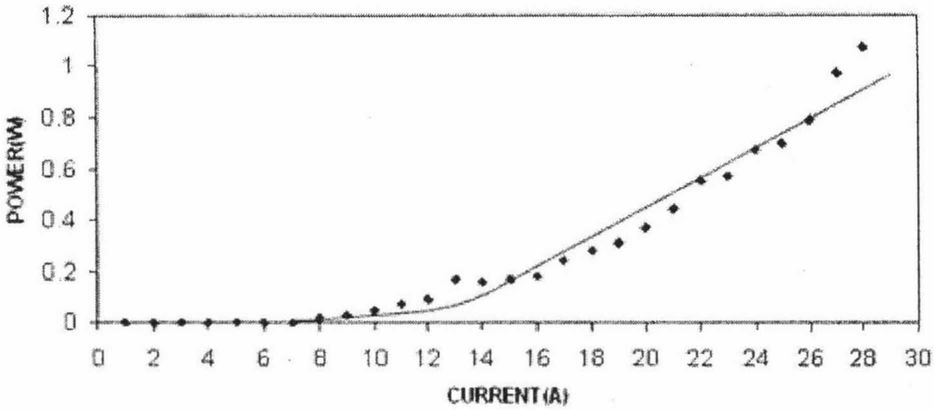

Figure 2: Output power of DPSS laser as a function of pumping current.

The output of the DPSS laser was observed and recorded by using a beam profiler. Prior to record the beam by the CCD camera, various neutral density filters were provided to avoid over exposure. If the brightness of beam is high, this not only would damage the sensitivity of the CCD camera but also pose danger to the end user. So this laser should be operated with an appropriate goggle and other safety precautions. In order to overcome the luminosity of the beam, various types of filters were manipulated until the image of the beam managed to be captured. Otherwise, without the association of the filter, only white image due to over exposure was monitored from the computer screen. Finally, with a good combination of several filters, the beam at last could be visualized. The typical result obtained from this observation is shown in Figure 3.

The beam profile was visualized in 3D. The DPSS was producing a Gaussian beam profile. The beam was also observed in topographic view. The result is illustrated in Figure 4. The picture was taken at the near field. The beam spot was not in uniphase mode TEM_{00}. This is due to a wider aperture of the laser head. The beam needs to be cleaned up either by using a spatial filter or pinhole. The horizontal and vertical cursor profiles of the beam are illustrated in Figure 5. Frame (a) of Figure 5 indicated that the near field beam was not really overlapping with the normal distribution of theoretical Gaussian beam. The beam spot was run off from the center of the cross line of the cursor. The intensity of the beam or the amplitude achieved 100 %. This indicated the degree of the beam brightness. The frame was also accompanied with two small amplitude of the laser beam. This meant that although the spot of the beam was considered spreading, the intensity of both side of the beam was relatively quite low. In contrast, the vertical cursor profile of the near field beam was perfectly overlapping with the theoretical Gaussian beam.

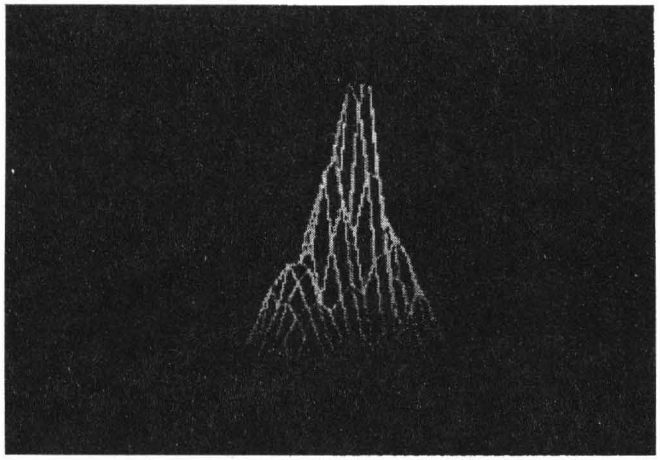

Figure 3: Gaussian beam of DPSS in 3D

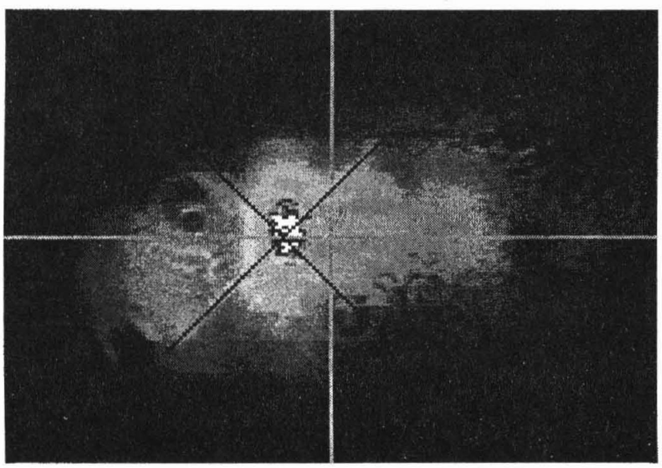

Figure 4: Beam profile in near field

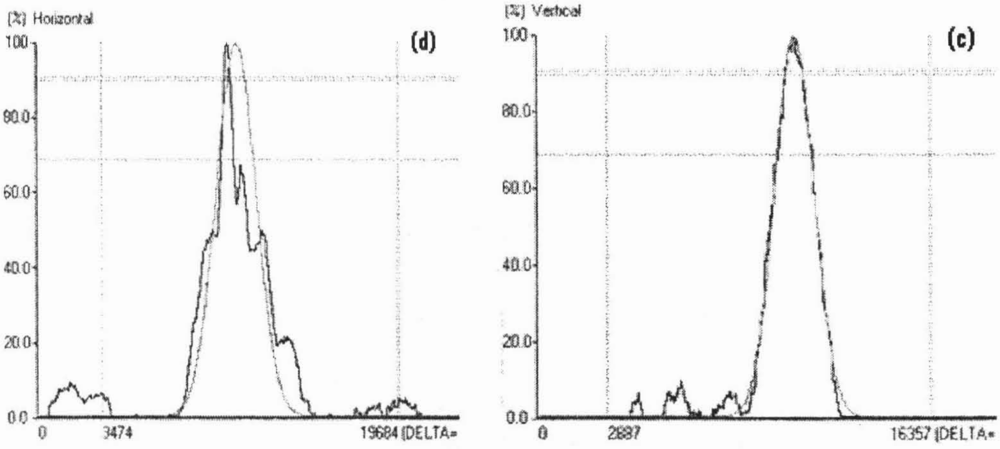

Figure 5: a) Horizontal cursor profile of near field b) Vertical cursor profile of near field

On the other hand, when the beam was observed from the far field as shown in Figure 6, various spots were noticed. This is due to the beam disperses when the detector was located at a higher distance from the laser head. As a result we can see 3 or 4 spots produced.

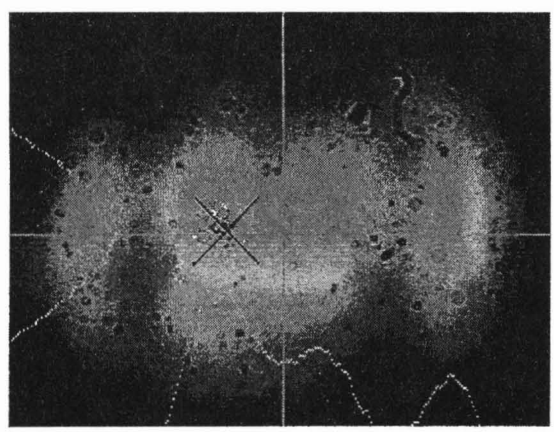

Figure 6: Beam profile in far field

Conclusion

A diode pumped solid state laser behavior was successfully studied. The output power of the DPSS laser was initially detected at threshold current of 7A. Beyond that point, the power was found to be proportionally increasing with the pumping current. The beam profile of the DPSS was found in the Gaussian form at near field.

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WAN AIZUDDIN WAN RAZALI, Pensyarah Fizik, UiTM Pahang. wanaizuddin@pahang.uitm.edu.my