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THE EFFECT OF TEMPERATURE ON HIGH POWER DIODE LASER

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ABSTRACT

In this paper, the effects of temperature on semiconductor laser output are studied. High power diode laser was employed as a source. LM35 was used to detect the temperature and spectrum analyzer to measure the intensity. Fan and heat sink were incorporated to assist the dissipation of heat during current pumping. The temperature was found to be higher without the fan in the system which reduced the intensity of the laser diode.

INTRODUCTION

The diode laser possessed the characteristics of being small in size , together with high efficiency and the longest lifetime of all the existing laser today. This characteristics, enables the fields of semiconductor laser to draw the attention and resources that are necessary for its development [1].Diode laser such as 808 nm wavelength is the key component in the development of Diode pumped Solid State (DPSS) laser [2]. Laser diode can efficiently pump Q-switched solid state laser, which in turn support the development of even better and more versatile lasers [1]. Stimulated emission in semiconductor laser is more intense compared to other types of laser. This will contribute to high rates of energy generation but also leads to high amount of heat dissipation [3]. The effects of temperature on diode laser output should be paid much attention as the variation of temperature results in change the of spectrum intensity.

THEORY

In diode laser, the heat generation per unit area at threshold is sufficient for it to be necessary to pay careful attention to heat sinking to obtain CW operation. The most important source of heat is that generated by non-radiative recombination within the thickness of the active layer.

There are two additional sources of heat generation in the diode laser. The first is the Joule heat generated across the resistance of the contacts. The second additional source of heat generation arises because the injected carriers in the active layer lose their recombination energy not only by non-radiative processes but also by spontaneous emission of photons. The spontaneous photons generate heat when they are re-absorbed, which takes place either in substrate or the contact layers. In either case the energy is spread over a greater volume than that for the heat generated directly in the active layer.

The threshold current density of semiconductor laser increases with temperature. The thermal dissipation in the active layer at threshold therefore also rises with temperature. Lasing occurs where the current, I is greater than the threshold current, I_{th}. The intensity of the lasing is then proportional to $I - I_{th}$ [3],[4].

METHODOLOGY

A diode laser model C35-808-0 from Apollo instruments was employed as a source. The system comprised of high power diode laser which is used as a pumping source. The wavelength of the diode laser is 808 nm. This diode laser is operated using forward biased current as a pumping energy. The heat liberated during pumping process was measured by a LM35 and displayed on the LCD.

In order to stabilize the laser output, the laser head need to be provided with a cooling system. In this experiment the reduction of heat was controlled by using two techniques. First, the laser beam was measured with only heat sink as a stabilizer. Secondly, the laser head was cooled via both the heat sink and fan.

The diode laser was pumped by forward-bias current. Variable forward-bias currents were injected into the active medium in order to characterize the output.

The photodetector was located very closed to the laser head to avoid the loss of laser energy. It is well known that due to the size of the active medium, normally in the region of micron, the output tends to diverge as it propagates in the space.

Figure 1 illustrates the schematic diagram of the experimental setup to investigate the effects of temperature to the spectrum intensity. The diode laser radiation was measured via the aid of Wavestar CCD Spectrometer. The data were directly transferred to a personal computer. The results were processed then interpreted by using Wavestar version 1.05 software.

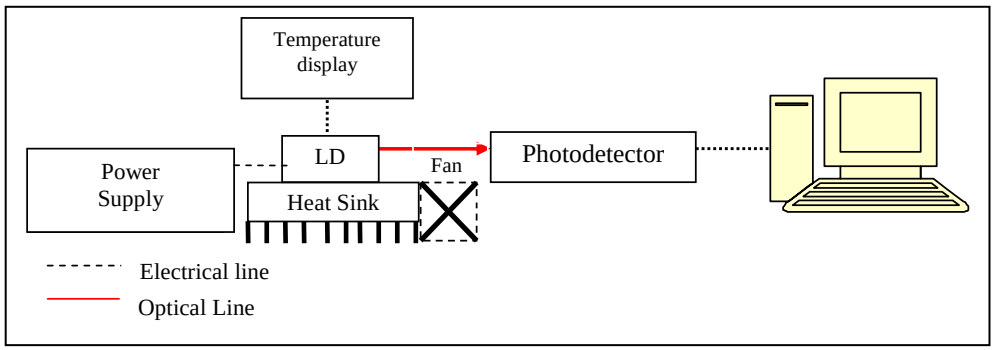
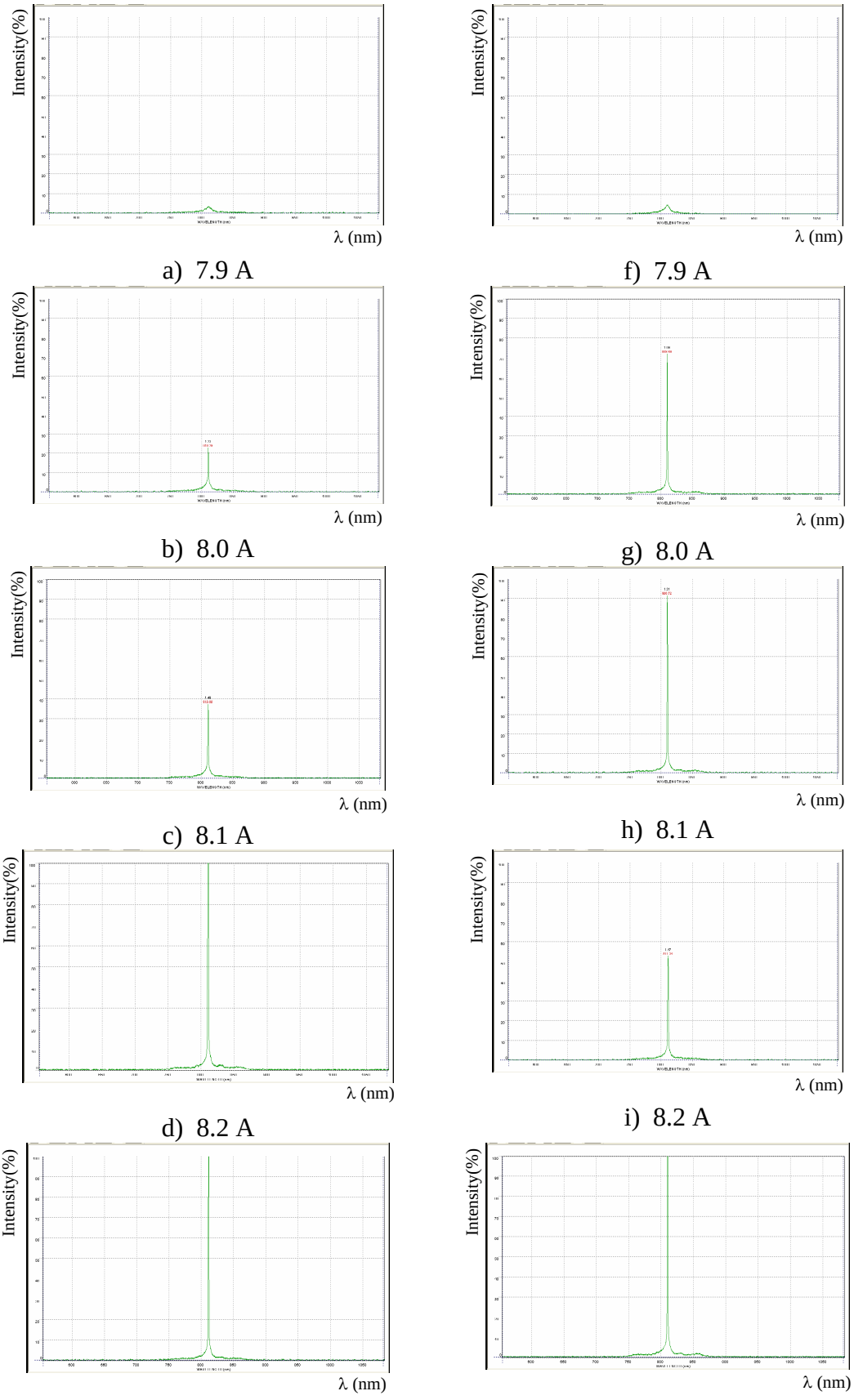


Figure 1: Schematic diagram of the whole experiment setup.

RESULTS AND DISCUSSION

The typical results obtained from this experimental work are shown in Figure 2. The figure indicates the results obtained from the measurement of the working temperature of laser head which was cooled by using heat sink only and by using fan and heat sink.



a) 7.9 A

f) 7.9 A

b) 8.0 A

g) 8.0 A

c) 8.1 A

h) 8.1 A

d) 8.2 A

i) 8.2 A

e) 8.3 A

j) 8.3 A

Figure. 2: (a – e) show the series of intensity spectum when the diode laser operated with only heat sink., (f - g) indicate the series of intensity when the diode laser was accompanied by heat sink and fan extractor

Figure 2(a – e) show the series of intensity spectrum when the diode laser operated with only heat sink. Meanwhile, Figure 2(f - g) indicate the series of intensity when the laser diode was accompanied by heat sink and fan extractor. For each series, the intensity spectrums are arranged in the increasing order of the pumping currents.

The line in the center of each frame represents the amplitude of intensity. Initially, only small signal was observed at both Figure 2 (a) and (f) which taken at the source pumping of 7.9A. This indicate the absence of laser at this pumping current. As the current increase up to 8 A such as shown in Figure 2 (b) and (g) a line appeared in each spectrum. This current is known as threshold current.

The intensity or the line, kept on increasing as the pumping current increased. It was obviously clear that, the line in the picture obtained from laser conducted with fan and heat sink is much higher compared with the intensity induce by the laser operated with heat sink only.

However, as the pumping current achieve up to 8.3A, both operation of diode laser indicate the same intensity. At is pumping current, the photodetector is said to be over saturated. The intensity of laser diode radiation at that pumping current is too bright. The intensity of both operations gives the same results.

The data measurement is tabulated in Table 1.The temperature of laser head was measured at variable pumping current. The laser output was detected and analyzed by Wavestar version 1.05 software.

Table 1: Temperature and Intensity upon pumping currents.

	With Fan		**Wihtout Fan**	
Input current (A) ± 0.1 A	Temperature ± 0.1 °C	Intensity (%)	Temperature ± 0.1 °C	Intensity (%)
7.9	27.7	4.48	28.2	3.39
8.0	28.1	80.27	29.6	30.47
8.1	29.7	86.01	31.1	38.41
8.2	30.5	112.66	32.9	67.25
8.3	31.9	112.02	33.3	111.72

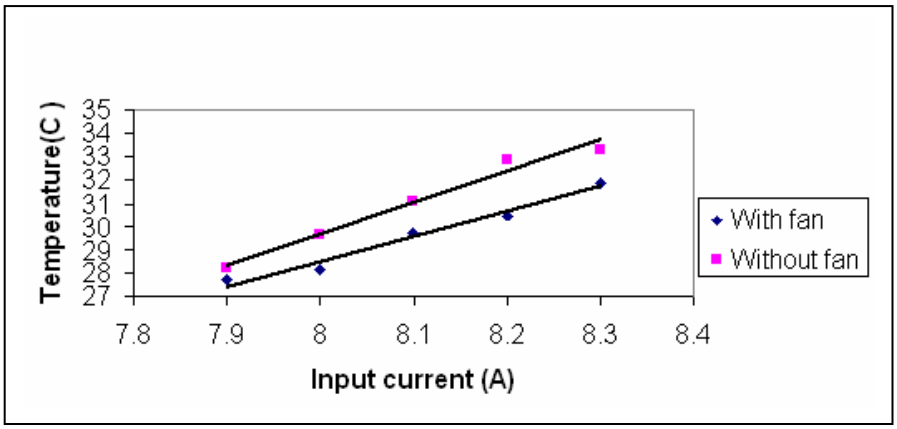


Figure 3: Temperature versus input current

From Table 1, the temps are plotted against its pumping current. The graph is shown in Figure 3. The temperature of the laser head, linearly increase with respect to pumping currents, indicates the measurement of heat dissipated from the laser medium. Obviously seen that the heat liberated from the laser head with fan is larger compared to the laser head without fan. The temperature produced from the laser is proportional with the pumping current. This means, more energy are lost as the current increased. With the present of fan, the heat liberated from the laser head can be reduced. Hence more recombination occurs and produces more coherent photon as laser output.

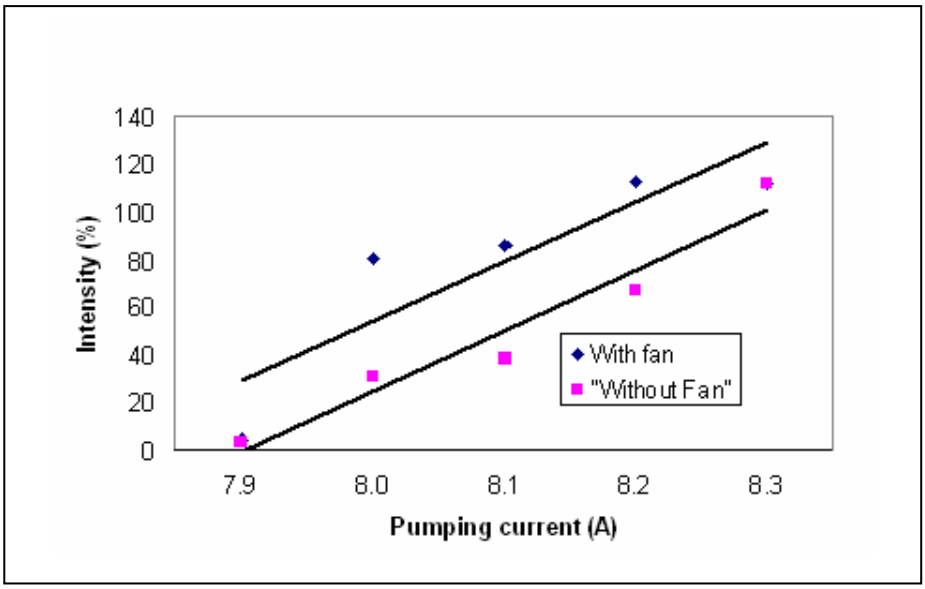


Figure 4: The intensity versus pumping current

In order to examine the effect of pumping current upon the intensity of the diode laser, Figure 4 is plotted. The diode laser started to lase after receiving pumping current of 8.0 A. The result obtained showed that the threshold current for this laser diode is 8.0A. Referring to Figure 4, the intensity of laser head equipped with fan is higher than laser head without fan after given the same amount of pumping current. The intensity produced by the laser diode is proportional with the pumping current. This result is in good agreement with result obtained by previous researcher [3, 4].

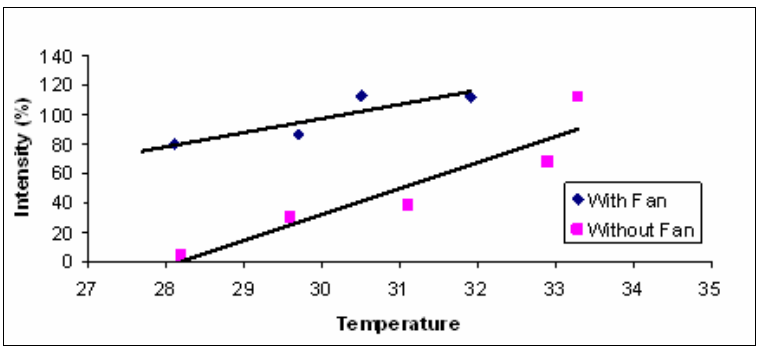


Figure 5: Intensity versus temperature

The data of intensity in Table 1 was plotted against temperature. The graph is shown in Figure 5.The intensity of laser diode was found to increase linearly with respect to the temperature .This indicates that the intensity is proportional to the temperature as well as the pumping current .For laser head equipped with fan, it started to lase at 28.1°C with 80.27% of intensity. However, for laser head without fan, it started to lase at 29.6°C with 30.47% of intensity. The working temperature of laser head equipped with fan found to be lower than laser head without fan. Consequently the magnitude of intensity is much higher for laser head equipped with fan than laser head without fan.

This is an indicator that the present of fan assist the dissipation of heat during current pumping. The heat is taken away from the laser head which reduced distortion in the recombination process and allows the increase of the stimulation of radiation process.

The amplitude of intensity represents the power of the laser. Meaning the higher the intensity the greater the power of laser, because the relationship of the intensity and power well known as I= P/A, where A is the beam area. If the beam area assumed to be constant, the intensity is directly proportional to the power of laser. Hence, if the temperature affects the intensity, meaning the power of laser output is also affected.

CONCLUSION

From the experiment, we found that the higher the current, the more heat was produced. Heat sink and fan were used to reduce the heat. Heat as measured by temperature affected the intensity. The higher the working temperature the lower the intensity of the laser radiation hence the power of the laser diode also decrease. Therefore it is necessary to control the working temperature of laser diode to obtain the most efficient output.

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