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Heat Effects on Data Transmission by Laser Diode and Light Emitted Diode for High Frequency Optical Communication Systems

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ABSTRACT

Laser Diode are vastly used in fields of free space optical and fiber optical communication systems, which become needful devices in the systems and equipment making up the infrastructure of our society. In this paper a laser diode power supply with controller oscillator had be designed and operated with different frequencies (50 kHz – 250 MHz) with tunable pulse width, Different laser diodes with (650 nm) and LED with 650 nm wavelength had be used, An optical spectrum analyzer with spectrum range (200 – 1050 nm) had been used to test the output spectrum, A digital thermometer to measure the temperature and thermo electric cooler (TEC) to controller the device temperature (20 – 50 °C) was also employed. All optical sources had be operated with different frequencies (50 kHz – 250 MHz) and different triggers (10% - 90%) of pulse duration, with high operation frequencies. The device temperature had increased proportionally and the trigger width was the main factor. The best spectrum stability was at a trigger (10%) of pulse duration. With temperature increase, the output spectrums showed Red-shift and expansion in spectrum width, via temperature controller with TEC and metallic heat sink. The instability was controlled in output spectrum. For a laser diode (635 nm) the spectrum shift was (3.21 nm to 4.9 nm). The Light emitter diode (LED) was very stable during the different operating conditions and the change in temperature and operating frequency. The spectrum shift was zero with no change in temperature.

1. Introduction

Laser diode are the generality ubiquitous of all other lasers, which has been used in an large variety of applications, such as telecommunications systems, laser printers, CD players, etc.. A semiconductor lasers in simple are much lighter and smaller, and very rugged than other lasers [1]. In the early 1960s, the first laser diodes has been developed, and it develop in long way from then. This first laser diodes device has required a very high density of current flow to maintain a population inversion also, it quickly effect by the heat generated from the steady-state current [2].

A modern laser diode devices pack the stimulated emission into a small region, this to decrease the heat and current while maintaining a population inversion. Thereby, the current density is large enough to maintain a population inversion, while no overheat will happen to laser by total current. To increase the density of stimulated emission, there are two approaches are used: first by increasing the intracavity optical power density and the other by increasing the density of charge carriers. This techniques invoke the fabrication techniques of sophisticated semiconductor which was developed over the past 30 years that allow grown more complex structures. Nowadays, methods like as metal-organic chemical vapor deposition and the molecular-beam epitaxy allows creation structures of semiconductor that has thickness in several atoms [3].

The center wavelength of a laser diode is directly proportional to its operating temperature. There is a linear relationship between temperature and center wavelength as shown in Fig. 1 [4].

As temperature increases, so does the center wavelength of the laser diode. This characteristic is useful in spectroscopy applications, laser diode pumping of solid state lasers and erbium-doped fiber amplifiers, where the wavelength of emission of the laser diode can be accurately temperature-tuned to the specific properties of the material with which it is interacting [5].

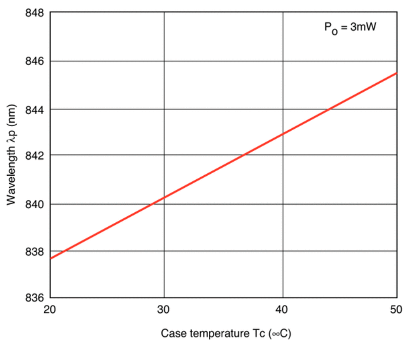

Fig. 1 Effects of temperature on center wavelength [6]

Since many parameters depend on the temperature of the laser diode, it is important to set and maintain a stable temperature using a thermo-electric temperature controller. Most laser diode applications use Thermoelectric (TE) coolers based on the Peltier Effect to maintain a constant temperature. TE modules are semiconductor “heat pumps” that move heat from one side of the device to the other. Depending on the direction the current flows through the TE cooler, you can either heat or cool a laser diode.

Several types of temperature sensors are used: thermistors, I.C. sensors, and platinum resistive temperature devices (RTDs). The most commonly used is the thermistors because of its small size and fast response time. Thermistors and RTDs are nonlinear resistance devices. Both require a small accurate current source to bias them. Changes in temperature result in resistance changes, with the voltage drop across the device proportional to temperature. Each device has a characteristic equation that converts resistance to temperature. The Steinhart-Hart equation is used to convert a thermistors resistance to temperature and uses two or three constants depending on the accuracy required [7].

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The Steinhart–Hart equation is a model of the resistance of a semiconductor at different temperatures. The equation is often used to derive a precise temperature of a thermistors since it provides a closer approximation to actual temperature than simpler equations, and is useful over the entire working temperature range of the sensor. Where Steinhart–Hart coefficients are not available, they can be derived. Three accurate measures of resistance are made at precise temperatures, then the coefficients are derived by solving three simultaneous equations. The equation is [8]

$$1/T = A + Bln(R) + Z\,[ln(R)]^3 \qquad (1)$$

where, T: is the temperature (in Kelvin's); R: is the resistance at T (in ohms); A, B, and Z: are the Steinhart–Hart coefficients which vary depending on the type and model of thermistors and the temperature range of interest. (The most general form of the applied equation contains a $[ln(R)]^2$ term, but this is frequently neglected because it is typically much smaller than the other coefficients, and is therefore not shown above).

I.C. sensors are linear devices whose outputs can easily be converted and displayed in °C. Although they are linear, they are not as accurate as thermistors. RTDs are primarily used where one needs an extremely stable sensor for very long-term and accurate temperature controlled applications. The major drawback of RTDs is their small resistance change, which makes it difficult to measure small absolute temperature changes. Thermistors, on the other hand, have extremely large resistance changes, making it easy to measure small changes in temperature. They are also the smallest of the three types of sensors, which make them ideal candidates for integration into laser diode packages. Laser diode packages with integral TE coolers use a 10 kΩ thermistors as the temperature-sensing device [9].

2. Experimental methods

The experiment includes parts and devices that used to measure the wave shifting for the two type of laser diode and light emitted diode when used with high frequency as a result to increasing its temperature with increasing the frequencies. A circuited has been designed to provide high frequencies for LD or LED with range from (50 KHz up to 250 MHz). Laser diode (LD) has been used with wavelength (650 nm) and a common light emitted diode (LED) as a light source. An oscilloscope has been used to monitor the change of frequencies as a result to changed resistors and capacitor values. A Spectrometer has been used to monitor the wave shifting when increased the frequency of light source. All specification of equipment and devices in addition to circuit design has been described.

2.1 Circuit Design

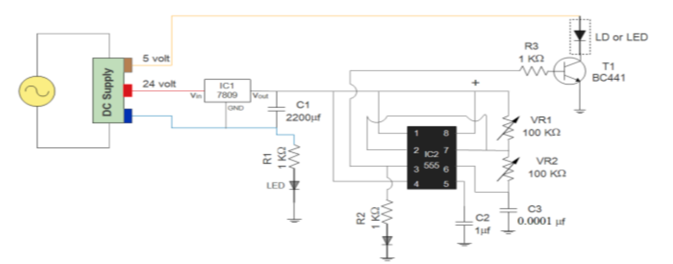

Fig. 2 Transmitter circuit Design

The transmission circuit that used in excrement are illustrated in Fig. 2, and consisted of following parts:

1. DC Power Supply: the type used is switch mode power supply with 220V AC input and two DC output (5, 24) V.
2. Resistors (R): Resistance with values… R1= R2= R3= (1 KΩ).
3. Potentiometer (VR): Potentiometer with value...VR1= VR2 = 100 KΩ.
4. Capacitor (C): Capacitor with values… C1= (2200 µF), C2= (1 µF), C3= (0.0001 µF).
5. Voltage Regulator (IC1): voltage regulator type (7809).
6. Bipolar Transistor (BT1): Magnatec BC441 NPN Bipolar Transistor, 2 A 60 V, 3-pin TO-39.
7. Timer IC: NE555 monolithic timing circuit has been used in transmission circuit which is a very stable controller able to producing accurate oscillation or time delays.
8. Light Sources:

a. Light Emitter Diode: A basic light emitter diode of 5 mm in diameter with a red lens has been used in the experiment. It has a rated (20 mA) forward current and typical (2.0 volt) forward voltage.
b. Laser Diode (635 nm): A red laser module Crosshair diode is used as a light source. This source emits 5mw visible red light at 635 nm wavelength.
c. Light Emitter Diode (780 nm):A Laser Diode (type laser mate LD-780-5 A) is used as a light source. This source emits 5 mw IR light at 785 nm wavelength.
d. Light Emitter Diode (808 nm): A Laser Diode (type laser mate LD-808-5 A) is used as a light source. This source emits 5 mw IR light at 808 nm wavelength.

2.2 Output Frequency Calculation of Circuit

From Fig. 2, (pins 2 and 6 of IC555 timing circuit are connected), it free runs and triggers itself as a multi-vibrator. VR1 and VR2 charges external capacitor but it only discharges through VR2. By adjusting the two resistors ratio, the duty cycle can be set accurately in the stable mode, the C3 capacitor are charged and discharged in-between (1/3 and 2/3) VCC. The times of charge and discharge (as in triggered mode) are independent of the supply voltage and, so as frequency. It can be calculate the charge time ($t1$) by following equation:

$$t1 = 0.693\,(VR1 + VR2)C3 \qquad (2)$$

and can be calculate the discharge time ($t2$) by following equation:

$$t2 = 0.693\,(VR2)C3 \qquad (3)$$

The total period TP is summation the charging and discharging time which given by:

$$TP = t1 + t2 = 0.693\,(VR1 + 2VR2)\,C3 \qquad (4)$$

The oscillation frequency is then:

$$f = \frac{1}{TP} = \frac{1.44}{(VR1 + 2VR2)C3} \qquad (5)$$

Table 1 illustrated the frequencies can be gained from circuit depending on Eq. 5, which be used in the experiment.

Table 1 The resistors and capacitor values for designed circuit to get the required frequencies

S.No.	Resistor VR1 (KΩ)	Resistor VR2 (KΩ)	Capacitor C3 (μf)	Frequency Gained (KHz)
1	27 KΩ	1 KΩ	1µf	50 KHz
2	100 KΩ	22 KΩ	0. 1µf	100 KHz
3	18 KΩ	39 KΩ	0. 1µf	150 KHz
4	18 KΩ	27 KΩ	0. 1µf	200 KHz
5	56 KΩ	1 KΩ	0. 1µf	250 KHz

The maximum frequency of drive circuit is 250 KHz because of the limitation of monolithic timing circuit (NE555) that it is maximum frequency is circuit 250 KHz.

3. Results and Discussion

3.1 Laser Diode (635 nm)

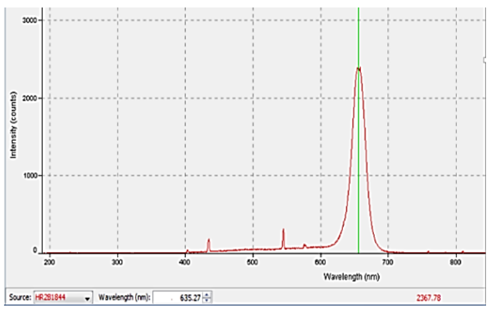

Fig. 3 Laser diode 635 nm spectrum in steady state

The laser diode 635 nm has been connected to oscillation circuit and the optical signal has been measured by spectrometer (HR2000 spectrometer), first we measure the wavelength of laser in steady state (λ_0) then we have been applied a range of high frequencies on it to measure wavelength shifting as a result to increase of frequency. Fig. 3, shows the spectrum of 635 nm laser diode in steady state. Table 2 shows the shifting value for multi frequencies.

As shown in Fig. 3, the steady state wavelength measured by spectrometer are (635 nm), then we calculated the shifting value for each frequency and for five pulse duration (90%, 70%, 50%, 30% and 10%)

$$Shift(\Delta\lambda) = \lambda nm - \lambda_0 nm$$

$\lambda_0 nm$: *thermal wavelength*, λnm: experiment *wavelength and* $Shift(\Delta\lambda$: *shif twavelength*

Table 2 Laser diode 635 nm shifting value as a result to applied multi values of high frequencies

Frequency (kHz)	Pulse duration (%)	λ_0 nm	λ nm	Shift(Δλ)	Spectrum bandwidth
50	90%	635 nm	639.915 nm	4.915 nm	5.42 nm
100		635 nm	639.88 nm	4.88 nm	5.64 nm
150		635 nm	639.74 nm	4.74 nm	6.12 nm
200		635 nm	639.74 nm	4.74 nm	6.12 nm
250		635 nm	639.74 nm	4.74 nm	6.12 nm
50	70%	635 nm	639.719 nm	4.719nm	5.34 nm
100		635 nm	639.61 nm	4.61 nm	6.10 nm
150		635 nm	639.52 nm	4.52 nm	6.25 nm
200		635 nm	639.52 nm	4.52 nm	6.25 nm
250		635 nm	639.52 nm	4.52 nm	6.25 nm
50	50%	635 nm	639.69 nm	4.69 nm	5.23 nm
100		635 nm	639.41 nm	4.41 nm	6.19 nm
150		635 nm	639.37 nm	4.37 nm	6.78 nm
200		635 nm	639.37 nm	4.37 nm	6.78 nm
250		635 nm	639.37 nm	4.37 nm	6.78 nm
50	30%	635 nm	639.22 nm	4.22 nm	5.17 nm
100		635 nm	639.125 nm	4.125nm	5.87 nm
150		635 nm	639.11 nm	4.11 nm	6.34 nm
200		635 nm	639.11 nm	4.11 nm	6.34 nm
250		635 nm	639.11 nm	4.11 nm	6.34 nm
50	10%	635 nm	638.731 nm	3.731nm	5.52 nm
100		635 nm	638.225 nm	3.225 nm	5.86 nm
150		635 nm	638.21 nm	3.21 nm	6.22 nm
200		635 nm	638.21 nm	3.21 nm	6.22 nm
250		635 nm	638.21 nm	3.21 nm	6.22 nm

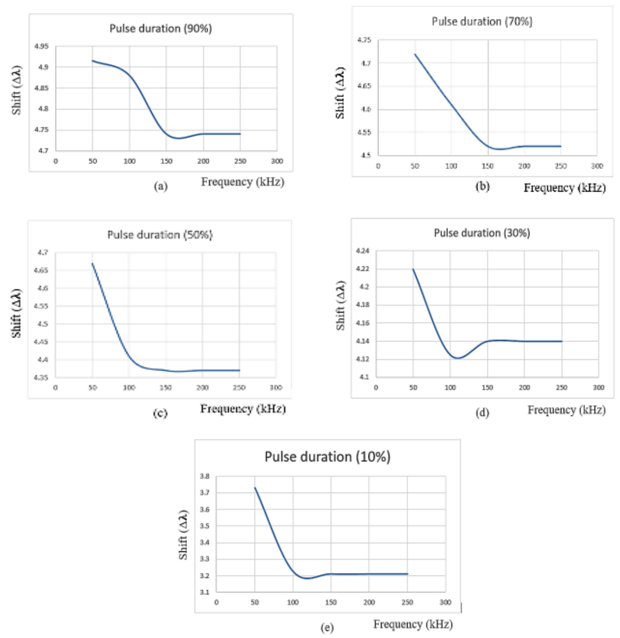

Fig. 4 Laser diode 635 nm shifting for (a) 90% Pulse duration, (b) 70% Pulse duration (c) 50% Pulse duration (d) 30% Pulse duration (e) 10% Pulse duration

3.2 Light Emitted Diode (LED)

The red LED (650 nm) has been connected to waveform function generator (RIGOL "DG1022") and the optical signal has been measured by spectrum analyzer (HR2000spectrometer), first we measure the wavelength of laser in steady state (λ0) then we have been applied a range of high frequencies on it to measure wavelength shifting as a result to increase of frequency. Fig.5 shows the spectrum of LED in steady state. Table 3 shows the shifting value for multi frequencies.

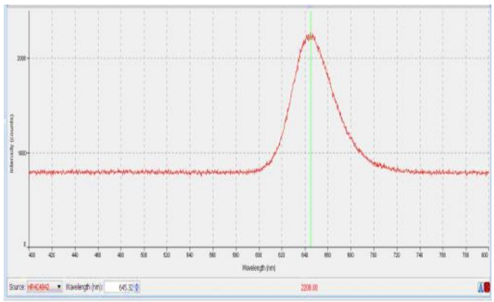

Fig. 5 Light emitted diode (LED) 650 nm spectrum in steady state

As shown in Fig. 5, the steady state wavelength measured by spectrometer are (645 nm), then we calculated the shifting value for each frequency and for 10% pulse duration.

Table 3 Light emitted diode spectrum shifting value as a result to applied multi values of high frequencies

Frequency (kHz)	Pulse duration (%)	λ *nm*	λ_0 nm	Shift(Δλ)	Spectrum bandwidth
50	10%	645 nm	645 nm	0	37 nm
100			645 nm	0	37 nm
200			645 nm	0	37 nm
300			645 nm	0	37 nm
400			645 nm	0	37 nm
500			645 nm	0	37 nm
600			645 nm	0	37 nm
700			645 nm	0	37 nm
800			645 nm	0	37 nm
900			645 nm	0	37 nm
1000			645 nm	0	37 nm
1500			645 nm	0	37 nm
2000			645 nm	0	37 nm

As appeared in Table 3, the LED has no shifting in its wavelength when increased the frequency.

3.3 Measurement the Laser Diode Temperature

3.3.1 Laser Diode (635 nm)

The laser diode 635 nm has been connected to oscillation circuit and the optical signal has been measured by spectrometer (HR2000 spectrometer), first we measure the wavelength of laser in the laser diode 635 nm has been connected to Digital Multimeter (Pro'sKit"MT-1232") to measure LD temperature at each frequencies. Table 4 shows the temperature readings for LD for each applied frequency.

$$\Delta T = T(°C) - T_0(°C)$$

T_0(°C) : is the thermal temperature
T(°C): is the experiment temperature
ΔT : *is the* difference temperature

Table 4 Laser diode 635 nm temperature as a result to applied multi values of high Frequencies

Frequency (kHz)	Pulse duration (%)	T_0 (°C)	T(°C)	ΔT
50	10%	27	27,6	0,6
100			28,2	1,2
200			29,4	2,4
300			30,7	3,7
400			33,1	6,1
500			37	10
600			39,3	12,3
700			41,2	14,2
800			43,5	16,5
900			45,4	18,4
1000			47,8	20,8
1500			49,2	22,2
2000			50,1	23,1

In second part we have been used thermoelectric cooler to control temperature for laser diode in rang (from 25 to 50 °C). Table 5 shows the shifting of laser diodes 635 nm, respectively. Operating voltage 5 Volt and frequency 1000 kHz pulse width (10%) of the wave time.

Table 5 Laser diode 635 nm shifting as an increased of temperature

T (°C)	λ_0 nm	λ nm	Shift(Δ**λ**)nm	Spectrum bandwidth
25	635	635.66 nm	0. 66 nm	4.34 nm
30	635	636.02 nm	1.02 nm	4.65 nm
35	635	636.44 nm	1.44 nm	4.98 nm
40	635	637.23 nm	2.23 nm	5.05 nm
45	635	638.77 nm	3.77 nm	5. 18 nm
50	635	639.915 nm	4.915 nm	5.42 nm

From the results, the spectrum laser diode shown unstable behavior with high frequency. At higher operating frequency, as frequency increased it leads to a rise in device temperature that is the main reason to spectrum shift and expansion. Fig. 6 laser diode 635 nm shifting as an increased of temperature.

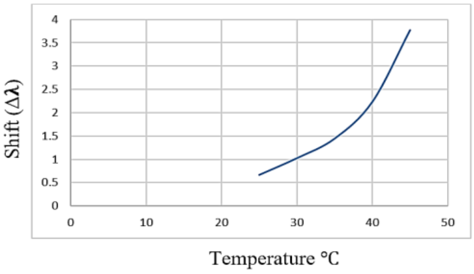

Fig. 6 Laser diode 635 nm shifting as an increased of temperature

4. Conclusion

The emphasis of this paper is to steady the effects of heat on data transmission by laser diode and light emitted diode at high frequency. From the results, the spectrum laser diode shown unstable behavior with high frequency. At higher operating frequency, as frequency increased it leads to a rise in device temperature that is the main reason to spectrum shift and expansion. At the same operation frequency the short pulse was better than the longer pulse. By used cooling techniques, the laser diode give the system more stability but add more cost. Furthermore, the result appeared that lasers diode with metallic case has a higher heat capacity and lead to increases the temperature. The result of Light emitted diode (LED) shown that it got a better result than Laser diode with all frequencies, which means it is better to use for data transition in high frequency.

References

[1] C.B. Hitz, J.J. Ewing, J. Hecht, Introduction to laser technology, 4th Ed., Wiley-IEEE Press, USA, 2012,

[2] A. Halina, Introduction to laser spectroscopy, Vol. 1, Elsevier Inc., USA, 2005.

[3] C. Mark, Introduction to laser technology, John Wiley & Sons Inc., USA, 2004. .

[4] Z. Nurkhaizan, B. Noriah, The Effect of temperature on high power diode laser, Vol. 3, Jabatan Fizik UTM, Japan, 2008, pp. 84-89.

[5] E. Farsad, S.P. Abbasi, A. Goodarzi, M.S. Zabihi, Experimental parametric investigation of temperature effects on 60W-QCW Diode Laser, Int. J. Electric. Comp. Energ. Electro. Comm. Eng. 5(11) (2011) 1462-1467.

[6] Stanford Research Systems, Laser diode controllers, LDC500 Series, Stanford Research Systems, Inc., Document number 9-01640-903, USA, 2008.

[7] A.J. Lawrence, Controlling temperatures of diode lasers thermoelectrically, ILX Light Wave Corporation, USA, 2003.

[8] T. Alessio, Laser sources and nonlinear optics based on self-assembled quantum dots, PHD Thesis, Department of Physics and SUPA, University of Strathclyde, UK, 2010.

[9] H. Tyll, Measuring diode laser characteristics, ILX Light wave Corporation, USA, 2003.

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