Tuning a Laser Diode[*]

Alamdar Hussain, Rabiya Salman and Muhammad Sabieh Anwar
Syed Babar Ali School of Science and Engineering, LUMS

Version 2018-1; June 19, 2018

The output of a laser diode can be modulated by varying its temperature and current. In this experiment, we will develop an understanding of how a laser diode's optical power and wavelength can be varied by controlling its temperature and operating current. Furthermore, we will use the proportional integral (PI) feedback control system to stabilize and tune the temperature of the diode laser.

Essential pre-lab reading: "*Laser Diode (L785P100) Specifications*" by Thorlabs.

"*Laser Diode Mount (TCLDM9) Manual*" by Thorlabs (Understand the internal configuration of the mount).

"*Laser Diode Driver Manual*" by Thorlabs.

Optional Reading: "*Feedback control of Dynamic Systems*" by Frankline, Powell and E-Naeini, Pearson (Section 4.3).

1 Overview of the Experiment

In this experiment, we will control the temperature and the current through the laser diode and observe the effects on the light output. The schematic of the control system is shown in Figure 1. Now follow this discussion closely.

The setup is divided into four different blocks. The laser diode is placed in a laser diode mount; the mount is shown as block A in the figure. The laser diode package contains a laser diode and a photodiode for monitoring its output. These two components are then connected to a *laser diode current driver* depicted overall as block B. Within block A, the laser diode package is in thermal contact with a thermistor and a Peltier heater. Using these two components, the temperature controlling system, comprising boxes C and D, is designed to control the temperature. Block C contains a current source to drive the temperature sensor (thermistor) and a transistor (50N06) which acts as a switch for operating the Peltier heater. The output

---

[*] No part of this document can be used without the explicit permission of Dr. Muhammad Sabieh Anwar. We like to thank Muhammad Hamza Waseem, Faizan e Ilahi, Zahra Tariq and Mahpara Iqbal for improving this experiment and the associated write-up in 2018.

of the temperature sensor, $y(t)$, is fed into block D where it is compared with the desired temperature y_s. The difference $e(t)$ is then used to create a control signal $u(t)$ which is then converted to a voltage signal $z(t)$. Block D is implemented through the data acquisition system (DAQ). Finally this voltage signal is fed to the transistor in block C which accordingly switches the current through the Peltier heater.

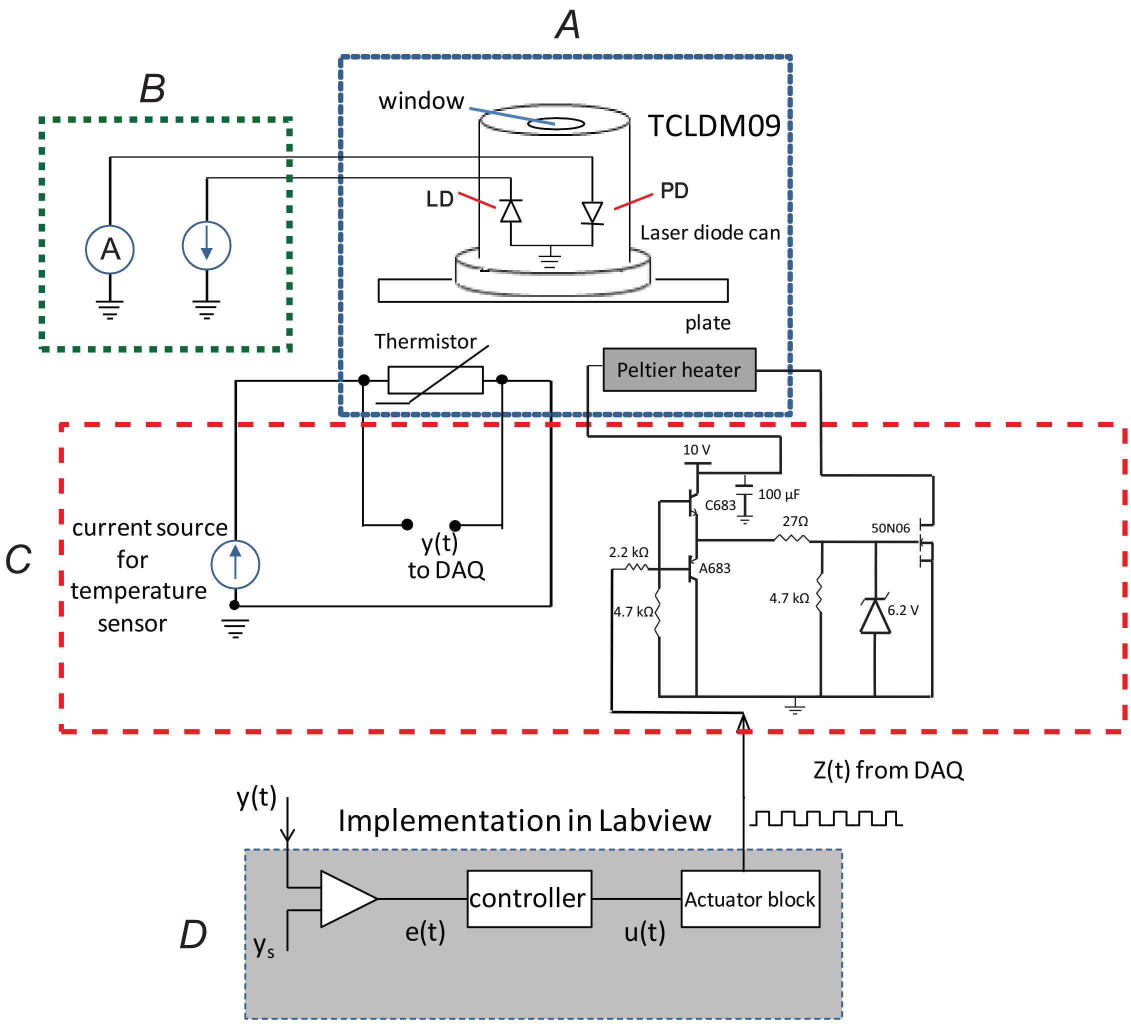

Figure 1: Schematic for the tuning experiment. A represents the laser diode mount, B is the laser diode current controller, C is the temperature controller box and D represents the control algorithm implemented in LabView. This figure is seen best in color. LD = laser diode and PD = monitor photodiode.

2 Procedure

A 785 nm laser diode (Thorlabs L785P100) has already been mounted for you inside the mount. The laser diode package contains two diodes as shown in Figure 1, where LD is the laser diode whose characteristics we will analyze while PD is a monitor photodiode placed in close proximity to the LD. The PD acts as a monitor, directly measuring the optical power emitted from the LD. The laser diode current controller drives the laser diode and the in-built (monitor) photodiode independently.

Connect the laser diode controller to the laser diode mount. Before switching on the laser diode make sure the limiting current I_{lim} is within the safe operating range as mentioned in the data sheet of the laser diode. Furthermore check that **the laser diode polarity switches on the laser diode controller and the laser diode mount are according to the laser diode's pin configuration**. The laser diode will ideally produce a collimated beam of 785 nm wavelength. The collimation is done and can be adjusted by the aspheric lens mounted on the laser mount in front of the laser diode. This lens has already been mounted for you.

Connect the temperature control box with the laser diode mount and other components according to the printed labels (Figure 2a). Run the Labview file "`laser modulation.vi`" which implements the PI based temperature controller. The front panel of PI control is shown in Figure 2b. Assign the weights $P = 20$ and $I = 0.025$ to proportional and integral controls respectively. These values are chosen such that temperature rises rapidly when the error is large and then changes slowly when the error diminishes.

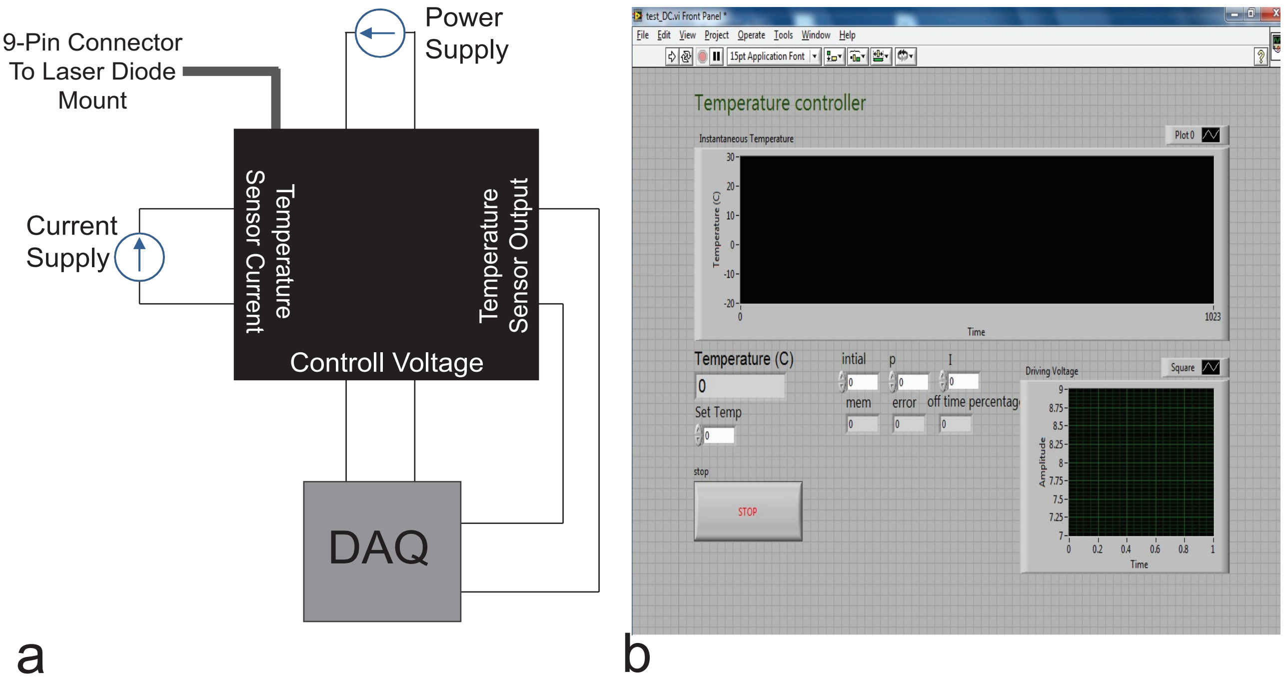

Figure 2: (a) The temperature control box and (b)the front panel of PI based temperature controller. These were represented by blocks C and D in Figure 1 respectively.

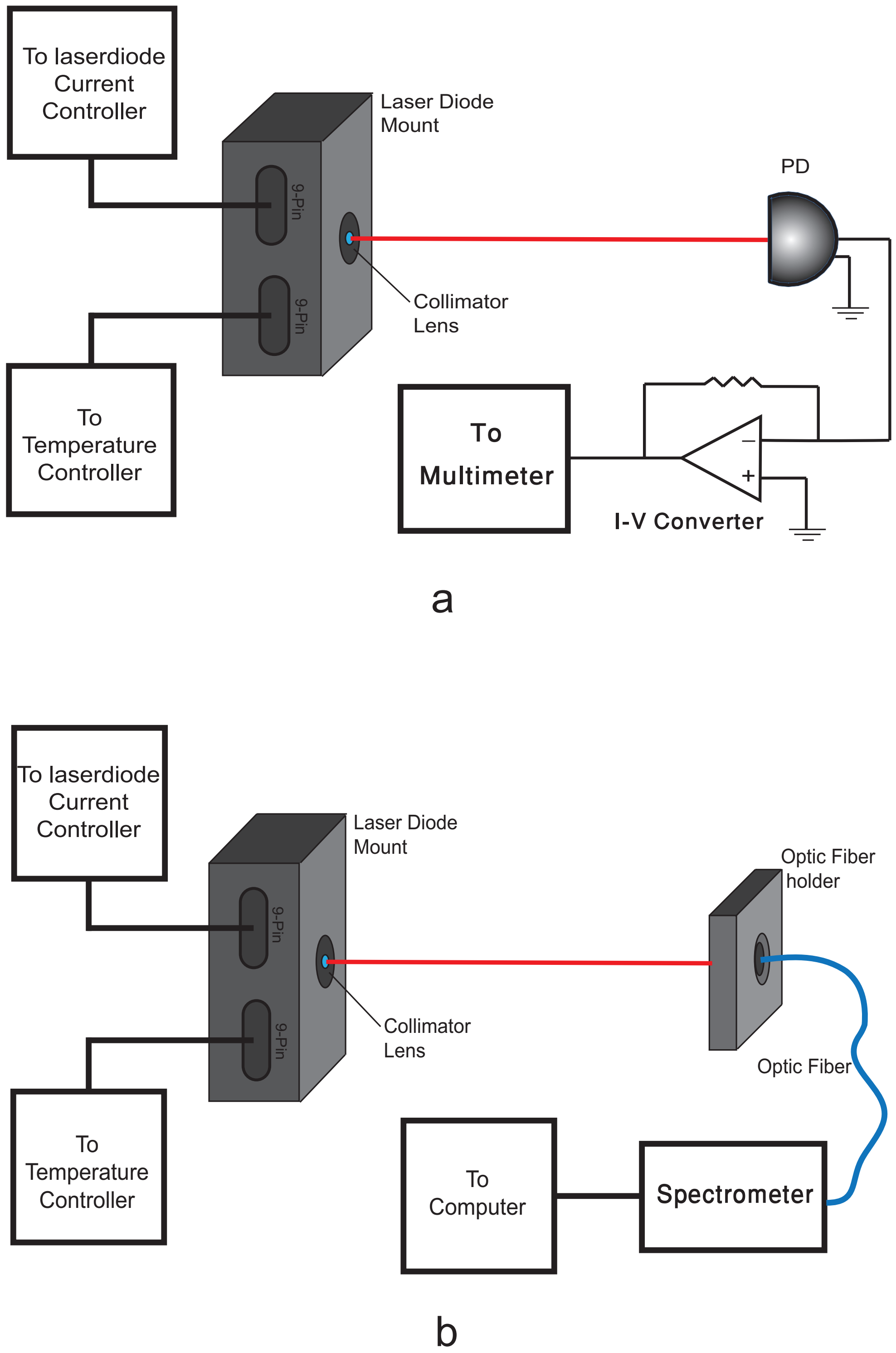

Figure 3: Schematic for measuring (a) the output intensity of the laser diode and (b) the wavelength of laser diode. The red line shows the perceived path of laser (the picture is seen best in color).

2.1 Optical power versus injection current

Arrange the apparatus as shown in Figure 3a. Using the *temperature controller*, implemented in LabView, set the temperature to 25°C. Increase the injection current of the laser diode in regular intervals from zero to 150 mA (since the maximum operation current is 160 mA). Note down the output of the external photodiode and the current produced by the internal photodiode at each step. The monitor photodiode outputs current proportional to the power incident on it.

Q 1. Using proper conversion factor plot the external photodiode current as a function of the injection current. Find the *threshold current* and explain the shape of graph.

Q 2. Similarly plot the internal photodiode's photo-current and confirm the value of the *threshold current.*

Q 3. Utilize the external photodiode current to plot the power emitted by the laser diode using the proper conversion factor. The responsivity of the external photodiode is 0.48 A/W.

2.2 Optical power versus temperature

Now set the injection current to 115 mA and increase the temperature in regular steps from 25°C to 50°C. Measure the output power using the external photodiode at each step.

Q 4. Plot the optical power as a function of the temperature.

2.3 Wavelength versus temperature

Finally let the laser diode cool down to room temperature and then set the apparatus as shown in Figure 3B . Connect the fiber optic spectrometer (StellarNet Blue Wave Spectrometer) to the computer and open its software named *SpectraWiz*. It will immediately start acquiring the spectrum. To measure the wavelength of the laser, right click on the spectrum peak and press the *peak wavelength* button indicated by 📊. Increase the temperature up to 50°C in regular steps and measure the wavelength of the laser. You may need to change the value of injection current at each step so that the peak is identifiable as well as the observable within the software window. You can also change the limits of the y-axis scale.

Q 5. Plot the wavelength as a function of temperature. What is the best estimate of $\frac{d\lambda}{dT}$? What's the uncertainty?

Appendix on Feedback Control

In a feedback control system the variable that is to be controlled is measured. This measurement is compared with a set point. The controller takes the difference between the current value of the parameter and the set point and decides what action should be taken to compensate for, and hence remove, the error. The ultimate goal is to train or steer the control variable to the desired set point.

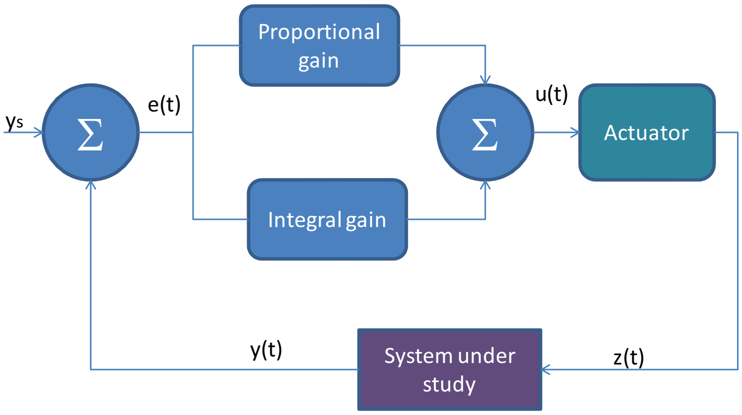

Figure 4: Block diagram of a typical PI Controller.

A PI controller, implemented in the current experiment, is special kind of controller. A PI controller works by summing the current controller error and the integral of all previous errors. If we define the error as

$$\begin{aligned} e(t) &= \text{(set point)} - \text{(current measured variable)}, \\ &= y_s - y(t), \end{aligned}$$

then the output of the PI controller would be,

$$u(t) = K_p\, e(t) + K_I \int_{\tau=0}^{t} e(\tau) d\tau,$$

where K_P= proportional gain and K_I= integral gain are approximately chosen weighting factors.

PI controllers work in a closed-loop feedback system as shown in Figure 4. A sensor measures the parameter, the measurand being $y(t)$ is then fed back into the comparator, and compared against the set point y_s. This signal $u(t)$ is then sent to the actuator, and the output $z(t)$ is obtained. The signal $z(t)$ actuates some mechanism enabling the system to restore its parameters.

This control loop is ultimately an iterative process. In each iteration, the controller takes this new error signal and computes integral. In this experiment, the PI controller is implemented in the LabView program, while $y(t)$ is the measured temperature, y_s is the set temperature and $z(t)$ is the signal that is fed into the heater.