EXPERIMENT 9
CHARACTERISTICS OF THE LIGHT-EMMITTING DIODE

OBJECTIVES:

The objective of this experiment is to measure some of the characteristics of the light emitting diode (LED). The LED characteristics that will be measured in this experiment are the LED linearity (for the output optical power versus input current relationship), I-V characteristics, and the LED angular emission profile.

EQUIPMENT REQUIRED

1- Optical power meter: INFOS, Model # M100.
2- Two laboratory jacks.
3- Two digital multimeters.
4- Infra-red LED. (GaAs Infrared Emitter, Siemens: LD 271L).
5- Power supply.
6- $1K\Omega$ resistor.
7- Rotational stage with adapter plate.
8- Cleaved $62.5\mu m$ GI optical fiber (2-5 meters long, Gray Color).

PRELAB ASSIGNMENT

Read the introduction to this experiment, before you attend the laboratory.

INTRODUCTION:

The LED is an important element in fiber optics communication systems. It is used as a light source in multimode optical fibers. It is inexpensive and has a relatively fast response. The LED can be regarded as an ordinary diode, with the exception that it emits light which is generally proportional to the input current. The LED symbol is shown in Figure 1, which is identical to the symbol of the ordinary LED. The diode voltage V_d is defined with + polarity on the p terminal and the diode current I_d is defined to flow through the diode from the p to the n terminal, which is identical to the standard definitions of the voltage and current of the ordinary diode.

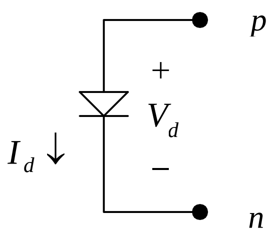

Figure 1: Symbol of the LED, Showing Definition of the Current and Voltage.

The LED must be *forward biased* in order for it to emit light energy. The light power P_o emitted by the LED is generally proportional to current I_d ($P_o \propto I_d$), provided $I_d > 0$. The center wavelength of the LED light emission depends on the bandgap energy of the material used in the fabrication of the LED. The diode used in this experiment emits in the *infrared* region of the spectrum, so you will not be able to see the emitted light without some aid.

The experimental setup used in part A of this experiment is capable only of measuring part of the emitted optical power (see Figure 3). Because we are interested in measuring the diode *linearity* with respect to the diode current, then we need only to detect a fraction of the emitted power, which is obviously proportional to the total power emitted, provide we *fix* the location of the optical power meter relative to the LED. It is thus important in this experiment *not to move* either the power meter or the LED after we start measurements.

The LED emits optical power over a wide range of angles and the output light intensity $I = I(\theta)$ is angle-dependent. Figure 2 shows the basic method used in part B of this experiment to measure $I = I(\theta)$. An optical fiber is first aligned so that its axis is *normal* to the light emitting area of the LED (i.e. $\theta = 0^o$). The fiber is then rotated in such away that its tip remains at a fixed distance d from the center of the light emitting area, while its axis makes angle θ (with respect to the normal). The other end of the fiber is connected to an optical power meter. The variation of the received optical power can then be used to find the angular emission profile of the LED.

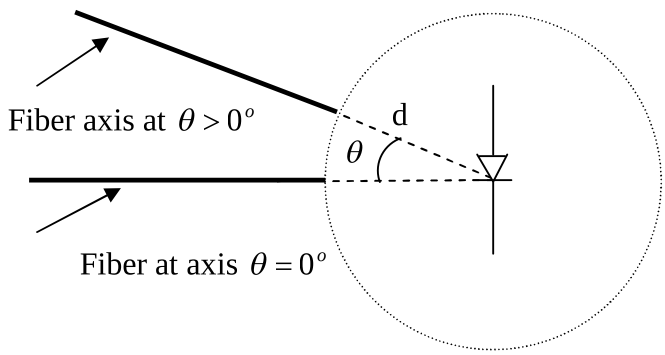

Figure 2: Basic Method for Measuring the Angular Emission Profile of the LED.

The LED used in this experiment has the following specifications:

1- Peak emission wavelength: $950 \pm 20 nm$.
2- Maximum forward current: $100\, mA$.
3- Forward voltage: $1.3V$ (typical).
4- Half angle: $\pm 25^o$.

PROCEDURE:

Part A: LED IV Characteristic and Linearity.

1- Connect the circuit shown in Figure 3. The ammeter should be connected in series with the $1K\Omega$ resistor in order to directly measure the diode current I_d and the voltmeter should be connected across the diode to directly measure the diode voltage V_d.

2- Set the power supply voltage to $V_s = 5V$.

3- Verify that the LED actually emits optical power. [*A mobile phone with camera can be used to view the light emitted by infrared LED's*].

4- Turn on the optical power meter and set it to dBm and $\lambda = 0.85\mu m$.

5- Bring the optical power meter as close as possible to the LED and observe the meter's reading. Try to obtain as much power as you could. [*Do not remove the optical power meter cover*].

6- Set the supply voltage to $V_s = 0V$. Record the values of I_d, V_d and the optical power meter's readings in table 1.

7- Slowly increase V_s until $V_d = 0.1V$. In table 1, record I_d, V_d and the optical power meter reading. [*There is no need to measure and record the value of V_s in this step*].

8- Repeat step 7 for $V_d = 0.2V$, $0.3V$, …., up to $1.0V$. [*Do not record the value of V_s at this point*. *Also, be careful that I_d is initially very small (in the μA range)*].

9- Now, set the supply voltage to $V_s = 2V$. Record the measured values of I_d, V_d, the optical power meter reading and V_s in table 1.

10- Repeat step 9 for $V_s = 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, ...9.0, 9.5, 10.0\, V$ [*Note the change in the step size of V_s*].

11- Covert the measured optical power in dBm (fourth column of table 1) to mW and record the value in column 5 of the same table. Calculate the normalized power P_N and record the values in column 6 of table 1.

12- Plot P_N versus I_d.

13- On the same graph, plot a *straight line* (*you may need more than one separate straight line to fit with the experimental graph*) that best fits the experimental graph. Comment on the linearity of the output optical power versus diode current and the range of linearity.

14- Plot the LED IV characteristic (I_d versus V_d).

15- Comment on the resulting curve.

16- Estimate the turn-on voltage V_T (*forward voltage*) and compare it with the typical LED specification.

17- Discuss the overall experimental results for this part of the experiment and write some conclusions.

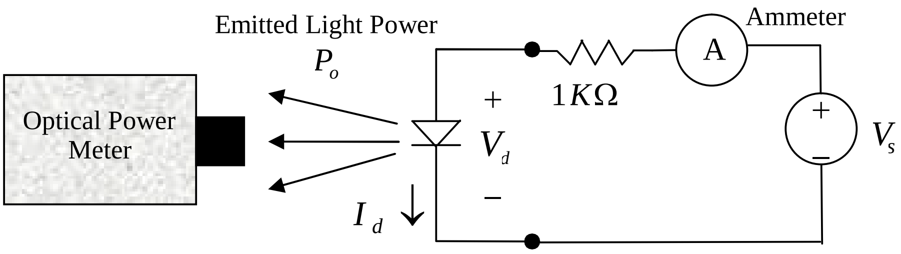

Figure 3: Setup for Measuring Part of the Optical Power Emitted by the LED.

V_s (Volt)	V_d (V)	I_d (mA)	P (dBm)	P (mW)	P_N
0	0				
-	0.1				
-	0.2				
-	0.3				
-	0.4				
-	0.5				
-	0.6				
-	0.7				
-	0.8				
-	0.9				
-	0.95				
-	1.0				
2.0					
2.5					
3.0					
3.5					
4.0					
4.5					
5					
6					
7					
8					
9					
10					

Table 1: Experimental Data for Measuring the LED Linearity and IV Characteristics.

Part B: LED Angular Emission Profile.

1- Use the previous circuit and set the source voltage to $V_s = 25V$ (Figure 3).

2- Refer to the experimental setup shown in Figure 4. Adjust the position of the LED so that the *light emitting surface* is approximately *above* and midway with respect to the center of rotation (COR) of the rotational stage (see Figure 5 for detail).

3- Connect the bare end of the fiber to the fiber holder and connect the other end to the optical power meter.

4- Connect the fiber holder to the rotational stage adapter plate and adjust it, so that there is a gap of approximately $1mm$ separating the fiber's tip is from the LED, as shown in Figure 5.

5- Set the optical power meter to dBm and $\lambda = 0.85\,\mu m$.

6- If necessary readjust the height and orientation of the LED so that it directly faces the fiber's tip (the fiber's *axis* should be approximately normal to and passing through the center of the *light emitting surface* of the LED).
7- Record the power meter reading in dBm in the second column of table 2 (and the row corresponding to $\theta = 0^o$.
8- Rotate the stage clockwise (negative angles) using a step of -4^o and record the meter's readings in table 2.
9- Set the stage back to the position corresponding to step 7 and repeat step 8 by rotating the stage counterclockwise (positive angles) using a step of $+4^o$.
10- Covert the power in dBm to mW, then compute the normalized power P_N. Record the values in table 2.
11- Since P_N is normalized, it is exactly the same as the normalized intensity I_N. Plot I_N versus θ.
12- Comment on the resulting plot including symmetry and the general behavior of I_N with θ.
13- Use the above graph to calculate the half power beam width (HPBW). HPBW is defined as the angular width in degrees at which the power is 50% of the maximum power. [Draw a horizontal line at $P_N = I_N = 0.5$ and use it to find the beam width in degrees]. Compare the result with the typical LED specifications.
14- Discuss the results and write some conclusions.

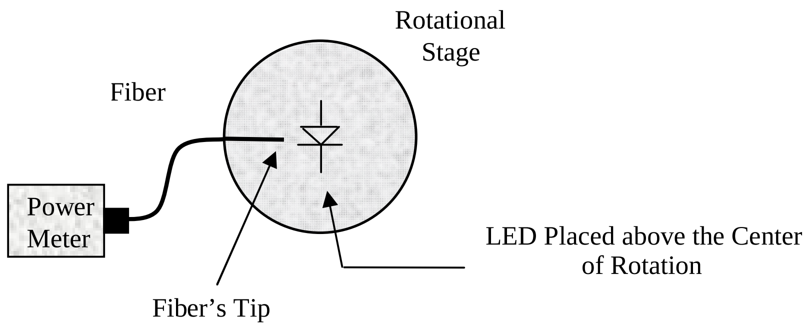

Figure 4: Experimental Setup for Measuring the Angular Emission Profile of the LED.

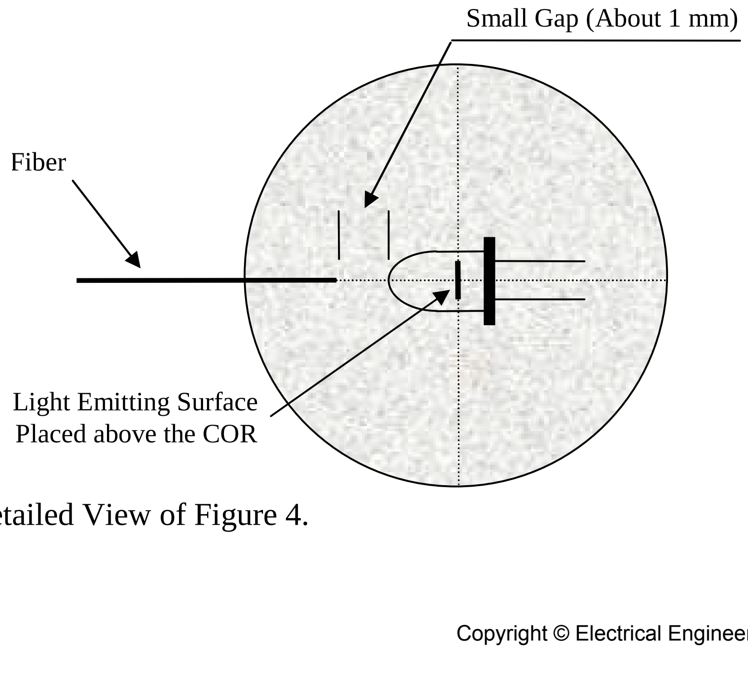

Figure 5: Detailed View of Figure 4.

θ (Degrees)	P (dBm)	P (mW)	$P_N = I_N$
-60			
-56			
-52			
-48			
-44			
-40			
-36			
-32			
-28			
-24			
-20			
-16			
-12			
-8			
-4			
0			
4			
8			
12			
16			
20			
24			
28			
32			
36			
40			
44			
48			
52			
56			
60			

Table 2: Experimental Data for Measuring the LED Angular Emission Profile.

QUESTIONS:

1- Why is it important for the LED to have a linear response? Is the linearity property more important for analog or digital systems?

2- If we keep on increasing I_d, do you think there is a point beyond which the LED response becomes nonlinear? Explain.

3- For part A of the experiment, use a straight line fit to estimate the optical power meter's reading in dBm when $V_s = 20V$.

4- Ordinary semiconductor diodes have a typical forward voltage of about $0.7V$. However, the LED used in this experiment clearly has a higher value of forward voltage (substantially larger than $0.7V$). Briefly explain why this is so.

5- Briefly explain why it is important to know the angular emission profile of the LED.