PSE605A (Photonics Lab Techniques)

Lab Report: Experiment 2

Diode Laser

Submitted by

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Diode Laser Characterstics

1 Objectives

Measuring:

a) **V-I and L-I characteristics of the diode laser**

b) **Far-field pattern of the laser diode by recording the angular variance/dependence of the radiation;and its variation with distance and power level. This is to be done in two cases, a plane perpendicular and parallel to the junction plane.**

c) **Spectrum of the diode laser.**

2 Apparatus

Diode laser (632 nm), Diode laser power supply, Lock in amplifier, Chopper, Chopper regulator, Si photodiode detector, Biasing circuit, Spectrum Analyzer (with spectrograph software), Multimeter, Fiber optic cable, Connecting cables etc., Rotational stage(position controller software), Desktop computer.

3 Plot

3.1 V-I Characteristics by slope extension method

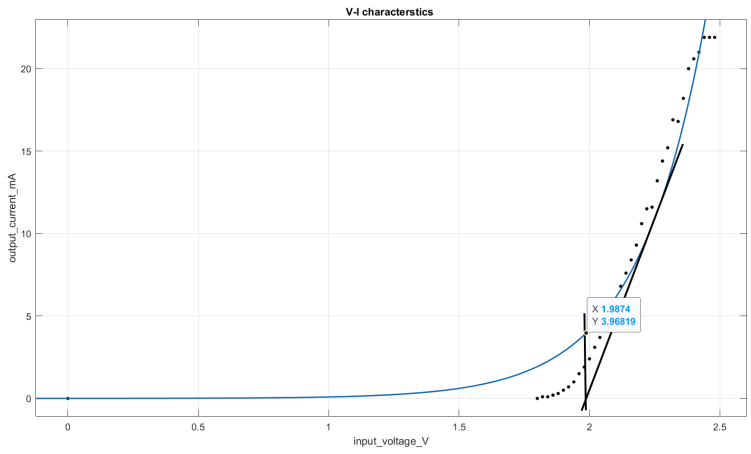

Figure 1: V-I Characteristics by slope extension method

From figure, it is found that the slope is intersecting at a point x=1.9874. Hence, The threshold voltage by slope extension method is 1.9874 volt.

3.2 V-I Characteristics by slope intersection method

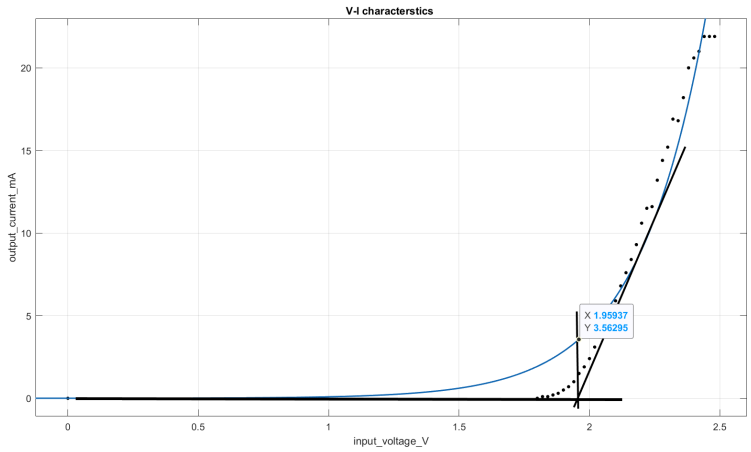

Figure 2: V-I Characteristics by slope intersection method

From figure, it is found that the slope is intersecting at a point x=1.95937. Hence, The threshold voltage by slope intersection method is 1.95937 volt.

3.3 V-I characteristics by 1st derivative method

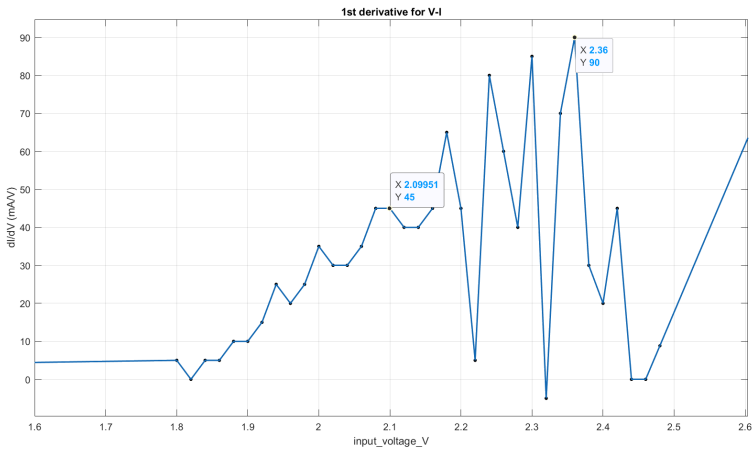

Figure 3: V-I Characteristics by 1st derivative method

In this method, we take the 1st derivative of the V-I curve. Here the maximum is at Y=90.
So, the 50% is at Y=45 and the corresponding X value is 2.09951.
Hence the threshold voltage by the first derivative method is 2.09951 V.

3.4 V-I characteristics by 2nd derivative method

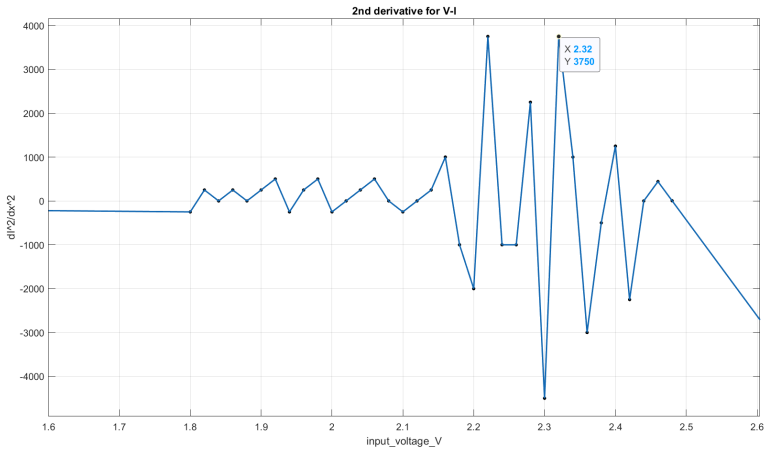

Figure 4: V-I Characteristics by 2nd derivative method

From the plot, we obtain maximum point at Y=3750.
Hence, the Threshold voltage by 2nd derivative approach is 2.32 V.

3.5 L-I Characteristics by slope extension method

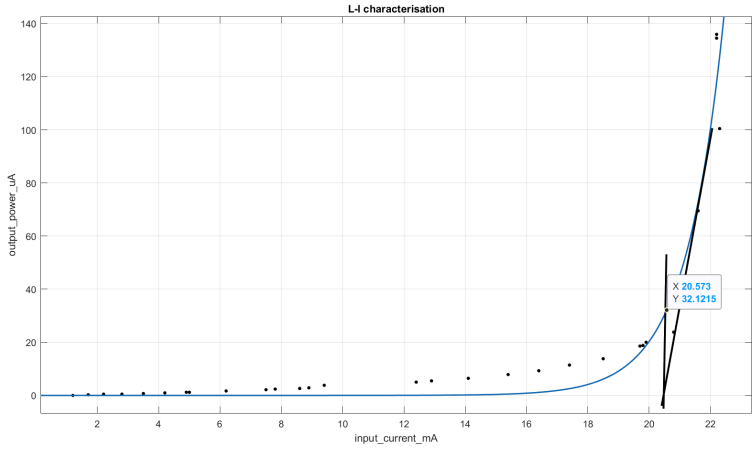

Figure 5: L-I Characteristics by slope extension method

From figure, it is found that the slope is intersecting at a point x=20.573. Hence, The threshold current by slope extension method is 20.573 mA.

3.6 L-I Characteristics by slope intersection method

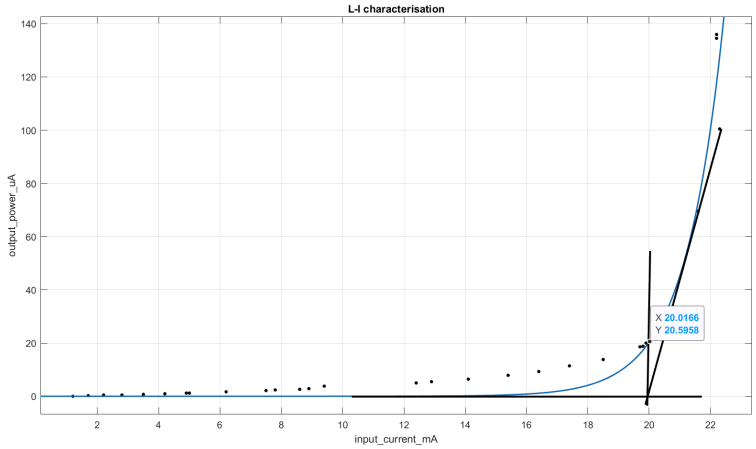

Figure 6: L-I Characteristics by slope intersection method

From figure, it is found that the slope is intersecting at a point x=20.0166. Hence, The threshold voltage by slope intersection method is 20.0166 mA.

3.7 L-I characteristics by 1st derivative method

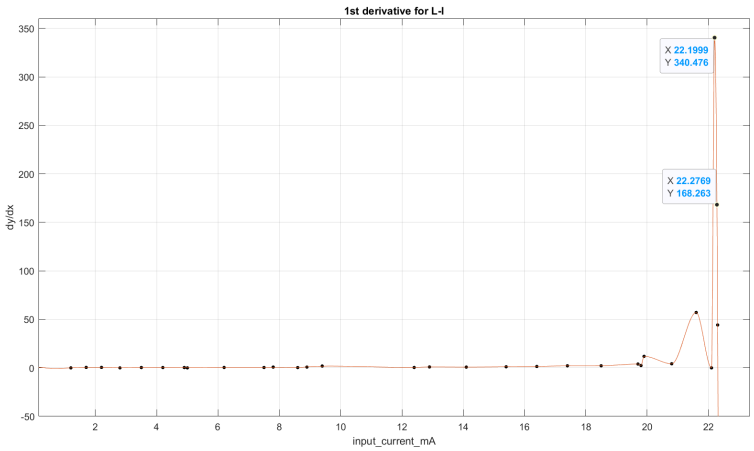

Figure 7: L-I Characteristics by 1st derivative method

We obtain maxima at a point Y=340.476.
So, approximately 50% occur at Y= 168.263 and the corresponding value of x = 22.2769.
Hence, the threshold current is 22.2769 mA.

3.8 L-I characteristics by 2nd derivative method

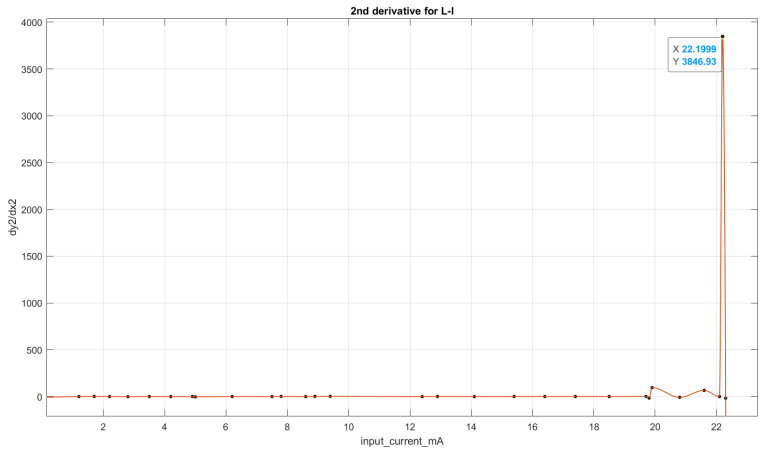

Figure 8: V-I Characteristics by 2nd derivative method

Here the maximum value of y occurs at x = 22.1999.
Hence the threshold current is 22.1999 mA.

3.9 Far field pattern at 26 cm (horizontal)

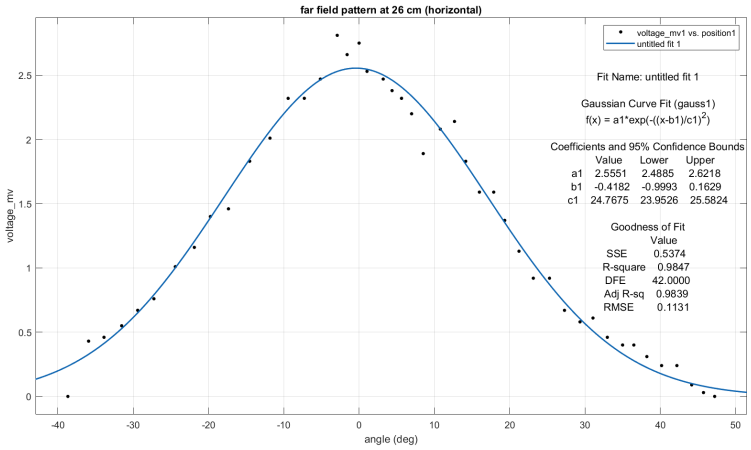

Figure 9: Far field pattern at 26 cm (horizontal)

The value of C1 = 24.7675 (from curve fit).

3.10 Far field pattern at 26 cm (vertical)

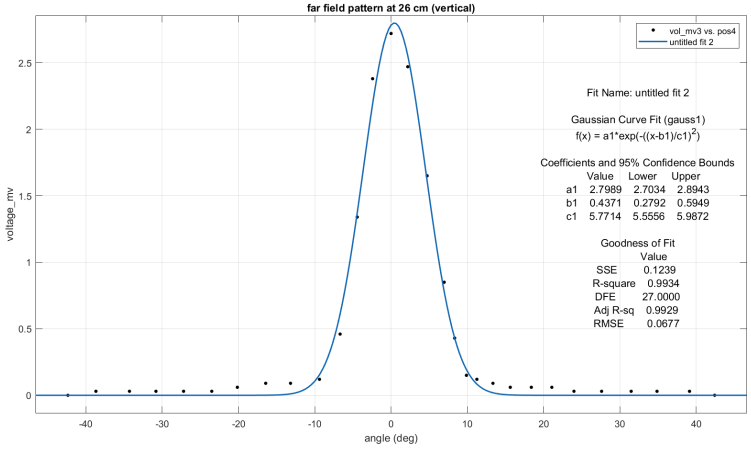

Figure 10: Far field pattern at 26 cm (vertical)

The value of C1 = 5.7714 (from curve fit).

3.11 Far field pattern at 28.5 cm (horizontal)

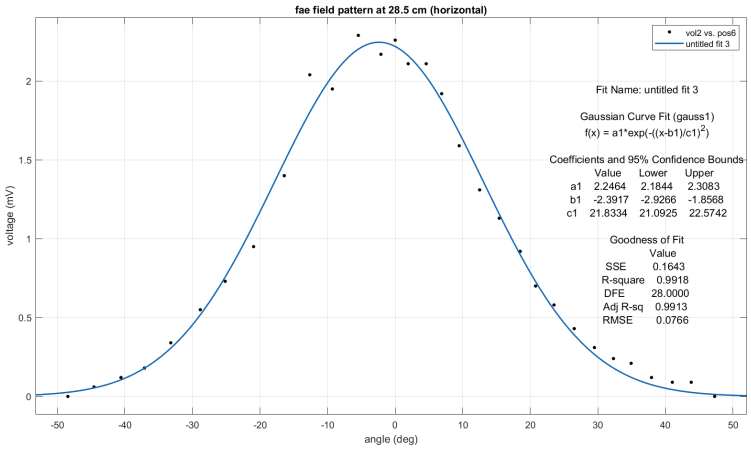

Figure 11: Far field pattern at 28.5 cm (horizontal)

The value of C1 = 21.8334 (from curve fit).

3.12 Far field pattern at 28.5 cm (vertical)

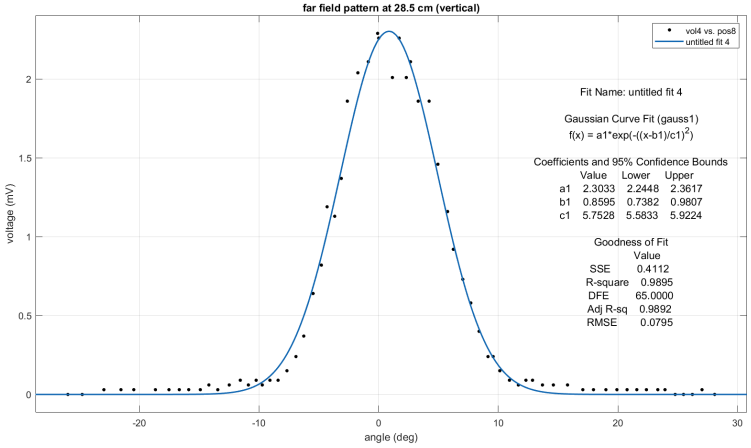

Figure 12: Far field pattern at 28.5 cm (vertical)

The value of C1 = 5.7528(from curve fit).

3.13 Intensity plot

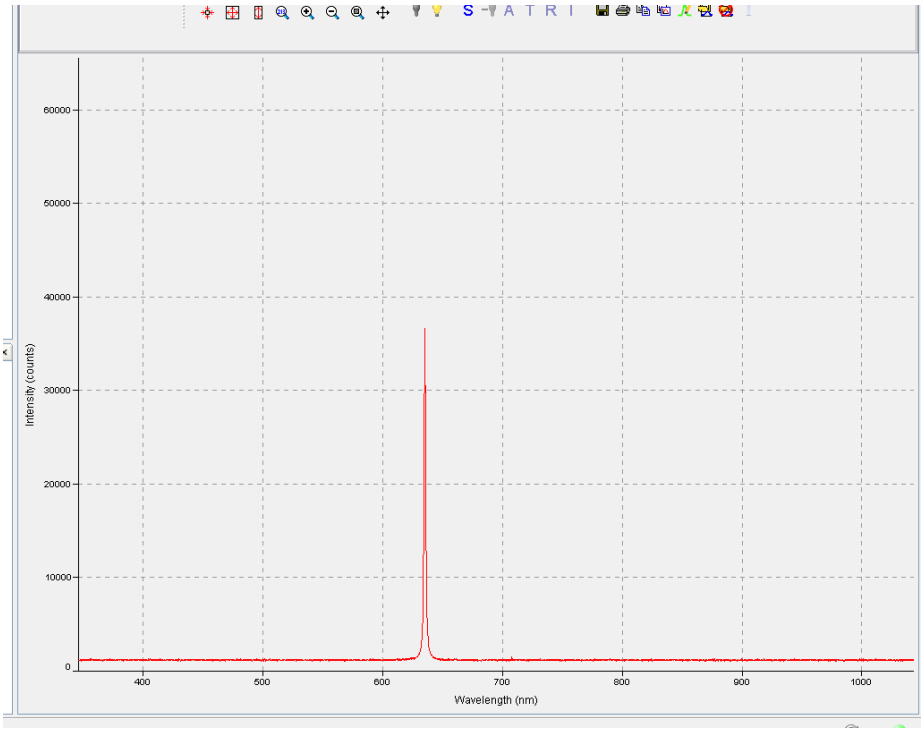

Figure 13: Intensity plot

Maximum intensity 37000 at wavelength of 635.58 nm.

4 Calculations

4.1 Sample calculation

Laser output voltage = 8mV
Resistance(R)=1kΩ
$I_p = \frac{8\ mv}{10^3} = 8\ \mu A$
$Power(P) = \frac{I_p}{Responsivity} = \frac{8*10^{-6}}{0.42} = 19.047\ \mu W$

4.2 Threshold Voltage

To get the threshold voltage of the diode laser, We calculate the average of all four threshold voltage

$$V_{th} = \frac{1.9874 + 1.95937 + 2.09951 + 2.32}{4} = 2.09157\ V$$

4.3 Threshold Current

To get the threshold current of the diode laser, We calculate the average of all the four threshold current

$$I_{th} = \frac{20.573 + 20.0166 + 22.2769 + 22.1999}{4} = 21.2666\ mA$$

4.4 Differential efficiency (Watt/Amp)

From L-I char curve, we can find out the differential power efficiency which is equal to the slope of the curve since it is define by $\frac{dP}{dI}$.
We get 2 coordinate (21.5,70) and (22,100).
Therefore,

$$\frac{dP}{dI} = \frac{100 - 70}{22 - 21.5} = 60\ \mu W/mA$$

4.5 The threshold power conversion efficiency

Threshold current =21.2666 mA
Corresponding threshold voltage =2.09157V
The output power at the threshold current = 60 µW
Threshold Power conversion efficiency:

$$\frac{P_{out}}{V_{th}I_{th}} = \frac{60\ \mu W}{2.09157\ V * 21.2666\ mA} = 1.358 * 10^{-3}$$

4.6 To find Horizontal beam spot size

- **At distance 26cm**
  from figure 9 we get, C1 = 24.7675
  Angular beam width(θ):

$$\theta = \sqrt{2} * C_1 = 35.026^0$$

  Beam spot size(W_0):

$$W_0 = \frac{2\pi L}{360}\theta = 15.89\ cm$$

- **At distance 28.5cm**
  from figure 11 we get, C1 = 21.8334
  Angular beam width(θ):

$$\theta = \sqrt{2} * C_1 = 30.8771^0$$

  Beam spot size(W_0):

$$W_0 = \frac{2\pi L}{360}\theta = 15.3588\ cm$$

4.7 To find Vertical beam spot size

At distance 26cm
from figure 10 we get, C1 = 5.7714
Angular beam width(θ):

$$\theta = \sqrt{2} * C_1 = 8.1620^0$$

Beam spot size(W_0):

$$W_0 = \frac{2\pi L}{360}\theta = 3.7038\ cm$$

At distance 28.5cm
from figure 12 we get, C1 = 5.7528 Angular beam width(θ):

$$\theta = \sqrt{2} * C_1 = 8.1357^0$$

Beam spot size(W_0):

$$W_0 = \frac{2\pi L}{360}\theta = 4.0468\ cm$$

5 Error calculation

5.1 Threshold voltage

Obtained value from the experiment= 2.09157 V
Actual value from the data sheet = 2.2 V

$$Percentileerror = \left| \frac{2.2 - 2.09157}{2.2} * 100\% \right| = 4.93\ \%$$

5.2 Threshold current

Obtained value from the experiment= 21.2666 mA
Actual value from the data sheet = 20 mA

$$Percentileerror = \left| \frac{20 - 21.2666}{20} * 100\% \right| = 6.33\ \%$$

6 Results

6.1 From V-I graph

1) The threshold voltage obtained by slope extension method =1.9874 V
2) The threshold voltage obtained by slope intersection method = 1.95937 V
3) The threshold voltage obtained by first derivative approach = 2.09951 V
4) The threshold voltage obtained by the second derivative approach = 2.32 V
The threshold voltage of the diode laser Vth = 2.09157 V

6.2 From L-I graph

1) The threshold current obtained by slope extension method =20.573 mA
2) The threshold current obtained by the slope intersection method = 20.0166 mA
3) The threshold current obtained by the first derivative approach = 22.2769 mA
4) The threshold current obtained by the second derivative approach = 22.1999 mA
The threshold current of the diode laser Vth = 21.2666 mA

6.3 Threshold Power conversion efficiency

Threshold Power conversion efficiency= $1.358 * 10^{-3}$

6.4 Differential efficiency of laser

Differential efficiency of laser 0.06 mW/mA

6.5 far field pattern

Horizontal beam spot size at 26 cm =15.89 cm
Horizontal beam spot size at 28.5 cm = 15.3588 cm
Vertical beam spot size at 26 cm = 3.7038 cm
Vertical beam spot size at 28.5 cm =4.0468 cm

7 Discussion & Conclusions

- We can see from the V-I characteristics, that there is a voltage after that the current starts increasing which is called threshold voltage. Here we got 2.09157 V experimentally.
- In measuring threshold voltage the error is 4.93 %. The error is not so much.
- From the L-I characterstics, measured threshold current is 21.2666 mA. The percentile error is 6.33 %. It is also moderate error.
- The diode must only be handled with grounded tweezers to avoid reverse bias breakdown from static electric charges.
- Sudden electrical spikes have the potential to damage the laser. Therefore, one should always exercise caution when increasing or decreasing power to the diode. Additionally, cables should never be connected or disconnected without proper grounding.

8 Appendix

8.1 Source of Error

- Diode laser output is temperature dependent. So, temperature of diode laser leads to error.
- Vibration of optical bench.
- Least count of voltmeter.
- Least count of photodetector.
- Saturation of output (intensity) on photodetector

8.2 Frequency Chopper

- Frequency chopper switches frequency of the input signal from high to low frequency and vice-versa, fixed chopping frequency.
- Common applications are in control systems, where it is necessary to periodically change the frequency of a signal to eliminate unwanted components or to improve measurement accuracy.
- This can be implemented using a switch, such as a transistor, that is controlled by a square wave signal at the chopping frequency.
- The output of the frequency chopper is a signal that has been modulated by the chopping frequency, and it can be demodulated to recover the original input signal using a synchronous detector.
- There are several types: 1. Amplitude choppers, These choppers change the amplitude of the input signal, 2. Phase choppers, They change the phase of the input signal.

8.3 Locking Amplifier

A locking amplifier is a type of electronic circuit that is used to lock the frequency of an 20 oscillator to a reference frequency. It is commonly used in applications such as frequency synthesis and frequency stabilization of lasers Operation:

- It compares the frequency of the oscillator to the reference frequency and generate an error signal.
- This error signal is then used to adjust the frequency of the oscillator until it is locked to the reference frequency.

There are several types:

- Phase-locked loops (PLLs): They use the phase difference between the oscillator and reference frequency to generate the error signal.
- Frequency-locked loops (FLLs): They use the frequency difference between the oscillator and reference frequency to generate the error signal.

9 Observation Table

9.1 V-I characterstics

Table 1: V-I characterstics

input voltage (V)	output current (mA)
0.000000	0.000000
1.800000	0.000000
1.820000	0.100000
1.840000	0.100000
1.860000	0.200000
1.880000	0.300000
1.900000	0.500000
1.920000	0.700000
1.940000	1.000000
1.960000	1.500000
1.980000	1.900000
2.000000	2.400000
2.020000	3.100000
2.040000	3.700000
2.060000	4.300000
2.080000	5.000000
2.100000	5.900000
2.120000	6.800000
2.140000	7.600000
2.160000	8.400000
2.180000	9.300000
2.200000	10.600000
2.220000	11.500000
2.240000	11.600000
2.260000	13.200000
2.280000	14.400000
2.300000	15.200000
2.320000	16.900000
2.340000	16.800000
2.360000	18.200000
2.380000	20.000000
2.400000	20.600000
2.420000	21.000000
2.440000	21.900000
2.460000	21.900000
2.480000	21.900000

9.2 L-I characterstics

Table 2: L-I characterstics

input$_v oltage(V)$	input current (mA)	output current (μA)	output voltage (V)	output power (μW)
2.500000	22.200000	57.100000	57.100000	135.952381
2.480000	22.200000	56.500000	56.500000	134.523809
2.460000	22.300000	42.200000	42.200000	100.476191
2.440000	21.600000	29.200000	29.200000	69.523810
2.420000	20.800000	10.000000	10.000000	23.809524
2.400000	19.900000	8.400000	8.400000	20.000000
2.380000	19.800000	7.900000	7.900000	18.809524
2.360000	19.700000	7.800000	7.800000	18.571429
2.340000	18.500000	5.800000	5.800000	13.809524
2.320000	17.400000	4.800000	4.800000	11.428571
2.300000	16.400000	3.900000	3.900000	9.285714
2.280000	15.400000	3.300000	3.300000	7.857143
2.260000	14.100000	2.700000	2.700000	6.428571
2.240000	12.900000	2.300000	2.300000	5.476190
2.220000	12.400000	2.100000	2.100000	5.000000
2.200000	9.400000	1.600000	1.600000	3.809524
2.180000	8.900000	1.200000	1.200000	2.857143
2.160000	8.600000	1.100000	1.100000	2.619048
2.140000	7.800000	1.000000	1.000000	2.380952
2.120000	7.500000	0.900000	0.900000	2.142857
2.100000	6.200000	0.700000	0.700000	1.666667
2.080000	5.000000	0.500000	0.500000	1.190476
2.060000	4.900000	0.500000	0.500000	1.190476
2.040000	4.200000	0.400000	0.400000	0.952381
2.020000	3.500000	0.300000	0.300000	0.714286
2.000000	2.800000	0.200000	0.200000	0.476190
1.980000	2.200000	0.200000	0.200000	0.476190
1.960000	1.700000	0.100000	0.100000	0.238095
1.940000	1.200000	0.000000	0.000000	0.000000

9.3 Beam parameter

Table 3: Far field at 26 cm (horizontal)

Clockwise		Anti-clockwise	
angle (deg)	voltage (mV)	angle (deg)	voltage (mV)
0.000000	2.750000	0.000000	2.810000
1.046000	2.530000	-1.590000	2.660000
3.198100	2.470000	-2.905600	2.810000
4.375600	2.380000	-5.138100	2.470000
5.635600	2.320000	-7.271300	2.320000
6.970000	2.200000	-9.418800	2.320000
8.515000	1.890000	-11.828100	2.010000
10.784400	2.080000	-14.527500	1.830000
12.665000	2.140000	-17.341200	1.460000
14.156900	1.830000	-19.740000	1.400000
15.971900	1.590000	-21.867500	1.160000
17.868800	1.590000	-24.403100	1.010000
19.331900	1.370000	-27.241300	0.760000
21.232500	1.130000	-29.393100	0.670000
23.125600	0.920000	-31.521300	0.550000
25.275000	0.920000	-33.863100	0.460000
27.266200	0.670000	-35.909400	0.430000
29.326900	0.580000	-38.660000	0.000000
31.046300	0.610000		
32.955000	0.460000		
34.978100	0.400000		
36.468800	0.400000		
38.198800	0.310000		
40.160000	0.240000		
42.188100	0.240000		
44.151900	0.090000		
45.721200	0.030000		
47.199400	0.000000		

Table 4: Far field at 26 cm (vertical)

Clockwise		Anti-clockwise	
angle (deg)	voltage (mV)	angle (deg)	voltage (mV)
0.000000	2.720000	0.000000	2.660000
2.184400	2.470000	-2.423100	2.380000
4.722500	1.650000	-4.438100	1.340000
6.958100	0.850000	-6.684400	0.460000
8.338100	0.430000	-9.384400	0.120000
9.879400	0.150000	-13.180600	0.090000
11.242500	0.120000	-16.436900	0.090000
13.351300	0.090000	-20.153700	0.060000
15.625600	0.060000	-23.510000	0.030000
18.383100	0.060000	-27.197500	0.030000
21.071200	0.060000	-30.819400	0.030000
23.973700	0.030000	-34.293800	0.030000
27.593800	0.030000	-38.689400	0.030000
31.471900	0.030000	-42.365600	0.000000
34.860600	0.030000		
39.120600	0.030000		
42.412500	0.000000		

Table 5: Far field at 28.5 cm (horizontal)

Clockwise		Anti-clockwise	
angle (deg)	voltage (mV)	angle (deg)	voltage (mV)
0.000000	2.260000	0.000000	2.290000
1.923800	2.110000	-2.113100	2.170000
4.588800	2.110000	-5.464400	2.290000
6.876100	1.920000	-9.299400	1.950000
9.471200	1.590000	-12.645600	2.040000
12.496300	1.310000	-16.416300	1.400000
15.392500	1.130000	-20.962500	0.950000
18.508700	0.920000	-25.165600	0.730000
20.772500	0.700000	-28.842500	0.550000
23.506300	0.580000	-33.219500	0.340000
26.503100	0.430000	-37.103700	0.180000
29.486300	0.310000	-40.589400	0.120000
32.300000	0.240000	-44.576900	0.060000
34.921300	0.210000	-48.445600	0.000000
37.933100	0.120000		
41.015600	0.090000		
43.815600	0.090000		
47.278800	0.000000		

Table 6: Far field at 28.5 cm (vertical)

Clockwise		Anti-clockwise	
angle (deg)	voltage (mV)	angle (deg)	voltage (mV)
0.000000	2.260000	-0.090000	2.290000
1.146900	2.010000	-0.868100	2.110000
1.712200	2.260000	-1.742500	2.040000
2.309000	2.010000	-2.620600	1.860000
2.660000	2.110000	-3.125000	1.370000
3.300000	1.860000	-3.676800	1.130000
4.215000	1.860000	-4.316400	1.190000
4.948800	1.460000	-4.790000	0.820000
5.758800	1.160000	-5.485600	0.640000
6.238800	0.920000	-6.261900	0.370000
7.030600	0.730000	-6.916200	0.240000
7.699000	0.580000	-7.670000	0.150000
8.393800	0.400000	-8.409400	0.090000
9.135600	0.240000	-9.090000	0.090000
9.566000	0.240000	-9.729000	0.060000
10.121900	0.150000	-10.240000	0.090000
10.930000	0.090000	-10.890000	0.060000
11.672500	0.060000	-11.570000	0.090000
12.303800	0.090000	-12.491900	0.060000
12.860000	0.090000	-13.450600	0.030000
13.690000	0.060000	-14.195000	0.060000
14.599000	0.060000	-14.910000	0.030000
15.782500	0.060000	-15.880000	0.030000
17.063100	0.030000	-16.670000	0.030000
17.950000	0.030000	-17.530000	0.030000
18.990000	0.030000	-18.660000	0.030000
19.910000	0.030000	-20.470000	0.030000
20.759400	0.030000	-21.544000	0.030000
21.573800	0.030000	-22.970000	0.030000
22.380000	0.030000	-24.780000	0.000000
23.326800	0.030000	-25.980000	0.000000
23.930000	0.030000		
24.780000	0.000000		
25.478000	0.000000		
26.220000	0.000000		
27.022000	0.030000		
28.080000	0.000000		

9.4 References

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