PHYF214 PHYSICS LAB REPORT SEM1 2018-2019
Lab 2 Group 7: Laser Characteristics [LC]

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1 Experimental Tasks

1. To measure the transverse beam profile of He-Ne laser and to determine the divergence.
2. To construct a beam extender and measure the divergence of the beam having larger cross-sectional area and to study how the divergence depends on the beam size.

2 Apparatus

He-Ne Laser, photo-detector, Photo amplifier, Multimeter/Voltmeter.

3 Theory

LASER which is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation, is a source for highly coherent and culminated light source. It can be theoretically derived that the LASER intensity varies vertically and forms a Gaussian. The light emitted by a laser is confined to a rather narrow cone, but as the beam propagates outward, it slowly diverges or fans out. At the output aperture of the laser, the beam diameter is d. Its beam divergence angle θ. In traversing a distance l, the beam diverges to a circle of diameter d'. Thus the beam divergence is an angular measure of increase in beam diameter with distance. So we can calculate the divergence θ as

$$\tan\theta = \frac{d - d'}{l} = \frac{w(z_1) - w(z_2)}{z_1 - z_2} \tag{1}$$

The laser beam is scanned horizontally in incremental steps and intensity is recorded using a photo-detector and amplifier.

4 Observations and Analysis

4.1 Part 1: Without beam expander

Least count of micrometer= 0.01 mm.
The data of three trial is presented here among the 4 trials performed without a beam expander system.

Table 1: Data for detector position at 105cm

Photo-detector position(in mm)	Intensity (in V)
0	0.059
0.1	0.0658
0.2	0.0746
0.3	0.085
0.4	0.114
0.5	0.192
0.6	0.341
0.7	0.65
0.8	1.5
0.9	2.79
1	4.61
1.1	6.43
1.2	7.3
1.3	7.95
1.4	7.053
1.5	6.15
1.6	4.2
1.7	3
1.8	1.7
1.9	0.94
2	0.55
2.1	0.305
2.2	0.215
2.3	0.175

Figure 1: Detector position at 105cm

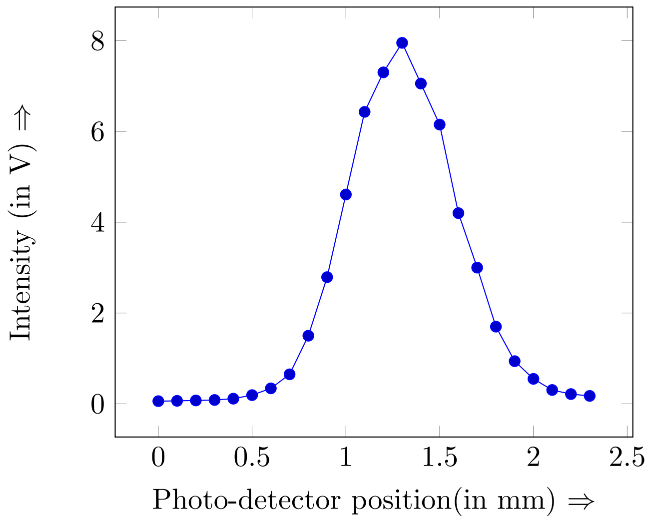


Table 2: Data for detector position at 115cm

Photo-detector position(in mm)	Intensity (in V)
0	0.0052
0.1	0.0056
0.2	0.006
0.3	0.0069
0.4	0.0086
0.5	0.0111
0.6	0.0152
0.7	0.0208
0.8	0.0275
0.9	0.0362
1	0.048
1.1	0.06
1.2	0.0735
1.3	0.0856
1.4	0.0967
1.5	0.106
1.6	0.114
1.7	0.118
1.8	0.1187
1.9	0.116
2	0.11
2.1	0.103
2.2	0.093
2.3	0.0808
2.4	0.0605
2.5	0.0565
2.6	0.0452
2.7	0.0361
2.8	0.0292
2.9	0.022
3	0.0174
3.1	0.0123
3.2	0.011
3.3	0.0096
3.4	0.0087
3.5	0.0076
3.6	0.0066
3.7	0.0064
3.8	0.0062

Figure 2: Detector position at 115cm

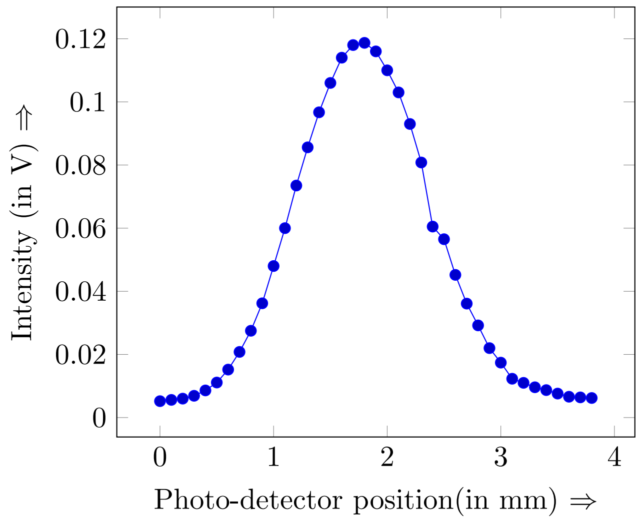
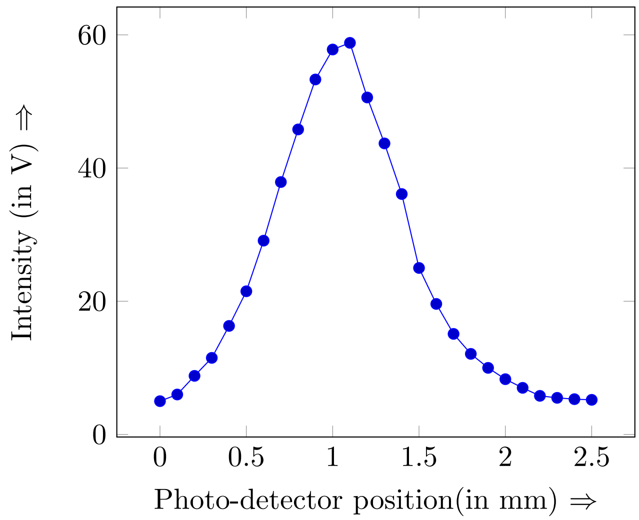


Table 3: Data for detector position at 75cm

Photo-detector position(in mm)	Intensity (in V)
0	5
0.1	6
0.2	8.8
0.3	11.5
0.4	16.3
0.5	21.5
0.6	29.1
0.7	37.9
0.8	45.8
0.9	53.3
1	57.8
1.1	58.8
1.2	50.6
1.3	43.7
1.4	36.1
1.5	25
1.6	19.6
1.7	15.1
1.8	12.1
1.9	10
2	8.3
2.1	7
2.2	5.8
2.3	5.5
2.4	5.3
2.5	5.2

Figure 3: Detector position at 75cm



Analysis:

Since we find that Graph of Intensity verses x (the position across the beam) is a symmetric bell-shaped curve , the Gaussian nature of the graph's are easily inferred.
In order to calculate the divergence of the beam we use the equation 1 as mentioned above.
We find the divergence $\alpha = 0.00375$ rad by taking $z_1 = 75cm$ and $z_2 = 115cm$ which gives us $w_1 = 2.3mm$ and $w_2 = 3.8mm$.
The expected error can be calculated as follows:
$\frac{\Delta A}{A} = \frac{\Delta w}{w} + \frac{\Delta z}{z}$
By considering the values for $w = 0.01mm$ (which is also the least count of the micrometer) and $\Delta z = 0.1cm$ (which is also the least count of the scale attached to the bench) we find that the expected error range is $\pm 16e - 6$ rad.

4.2 Part 2: With beam expander

Least count of micrometer= 0.01 mm.

Table 4: Data for detector position at 80cm with beam expander

Photo-detector position(in mm)	Intensity (in V)
0	6.9
0.1	7.4
0.2	8.7
0.3	9.3
0.4	13
0.5	15.3
0.6	21.7
0.7	26.3
0.8	33
0.9	39.9
1	42.4
1.1	45.6
1.2	55.5
1.3	63.2
1.4	72.7
1.5	87.9
1.6	109
1.7	126
1.8	135
1.9	146
2	148.9
2.1	146
2.2	132
2.3	120
2.4	97
2.5	77
2.6	65.5
2.7	64.1
2.8	44.2
2.9	34.9
3	29.3
3.1	21.4
3.2	17.4
3.3	12.7
3.4	9
3.5	6.9

Figure 4: Detector position at 80cm with beam expander

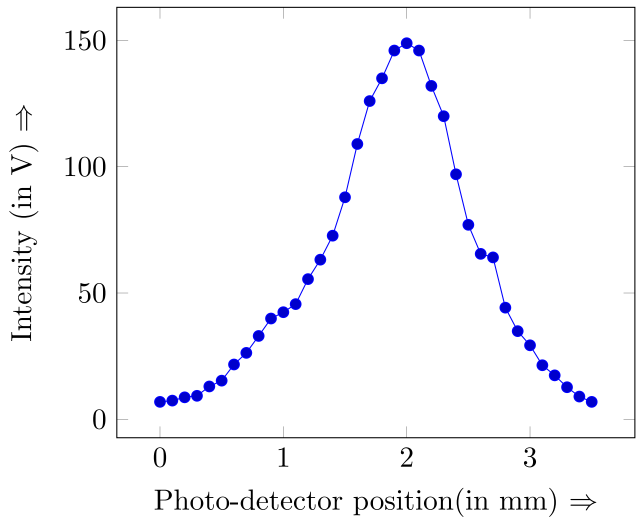
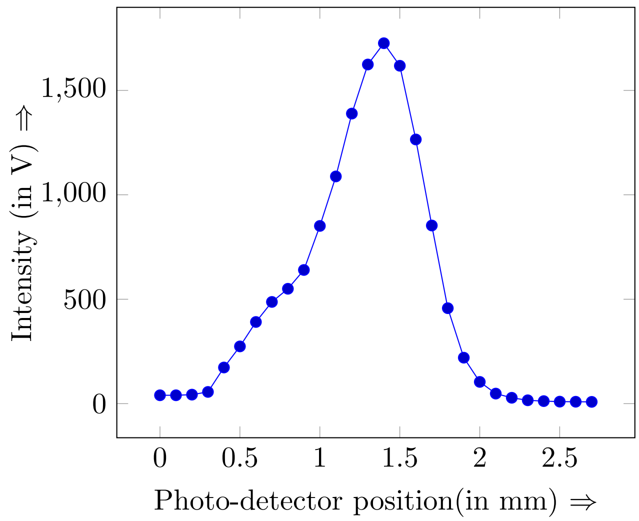


Table 5: Data for detector position at 100cm with beam expander

Photo-detector position(in mm)	Intensity (in V)
0	40
0.1	40
0.2	43
0.3	56
0.4	173
0.5	274
0.6	391
0.7	487
0.8	550
0.9	640
1	851
1.1	1088
1.2	1389
1.3	1624
1.4	1726
1.5	1618
1.6	1265
1.7	853
1.8	457
1.9	220
2	104
2.1	48
2.2	28
2.3	16
2.4	12
2.5	9.5
2.6	9
2.7	8.4

Figure 5: Detector position at 100cm with beam expander



Analysis:

The shape of the curve was again of the form of a Gaussian.
In order to calculate the divergence of the beam we use the equation 1 as mentioned above. We find the divergence $\alpha = -.0065$ rad (the negative sign indicates that we have convergence rather than divergence) by taking $z_1 = 80cm$ and $z_2 = 100cm$ which gives us $w_1 = 3.5mm$ and $w_2 = 2.2mm$.
The expected error can be calculated as follows:
$\frac{\Delta A}{A} = \frac{\Delta w}{w} + \frac{\Delta z}{z}$
By considering the values for $w = 0.01mm$ (which is also the least count of the micrometer), $< z >= 9.5cm$, $< w >= 2.95mm$ and $\Delta z = 0.1cm$ (which is also the least count of the scale attached to the bench) we find that the expected error range is $\pm 29e - 6$ rad.

5 Precautions

- Ensure that eye-level is always higher than the laser beam.
- Ensure that beam is propagating parallel to the base plane.
- Never look into the laser beam directly or even reflected from an optical surface.
- Always use wooden blockers while working with laser beam.

6 Conclusions and Results

- All the plots of the obtained data verify that intensity plot of a LASER light is Gaussian in nature.

- From the values of the angle of divergence calculated in the two different experimental setup, we can infer that we have built a beam condenser rather than a beam expander.
- The divergence angle for the two experimental setups were found to be 0.00375 $\pm 16e-$ 06 rad in the case without a beam expander and -0.0065 $\pm 29e6$ rad in the case with a beam expander.