PSE605A (Photonics Lab Techniques)

Lab Report: Experiment 1

He-Ne Laser

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Beam parameter of He-Ne Laser

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To calculate beam parameters of He-Ne laser using:

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- Chopper controller
- Knife edge
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- Iris
- Digital multimeter
- Biasing circuit of PD
- BNC cables.

3 Plots & Tables

3.1 For Chopper method

3.1.1 Plots for Chopper method

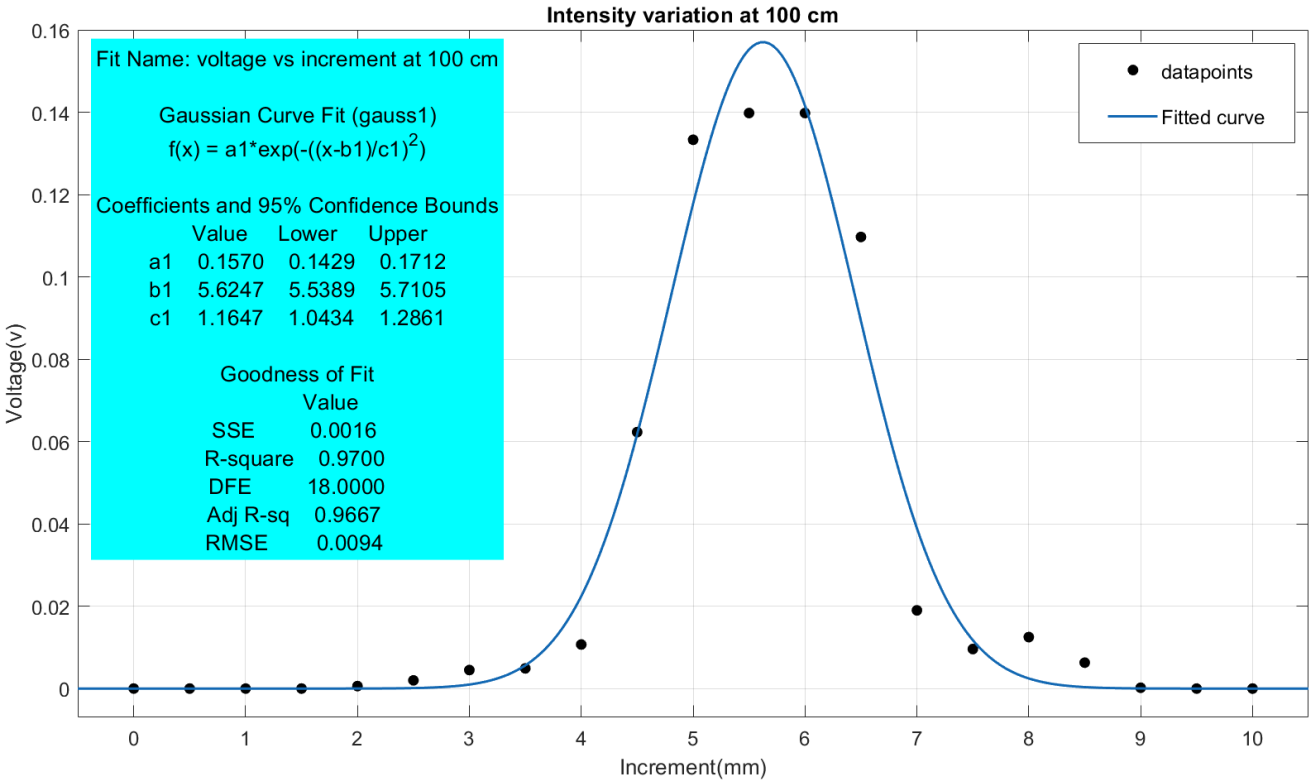

Figure 1: Chopper method: Intensity distribution when detector at 100 cm

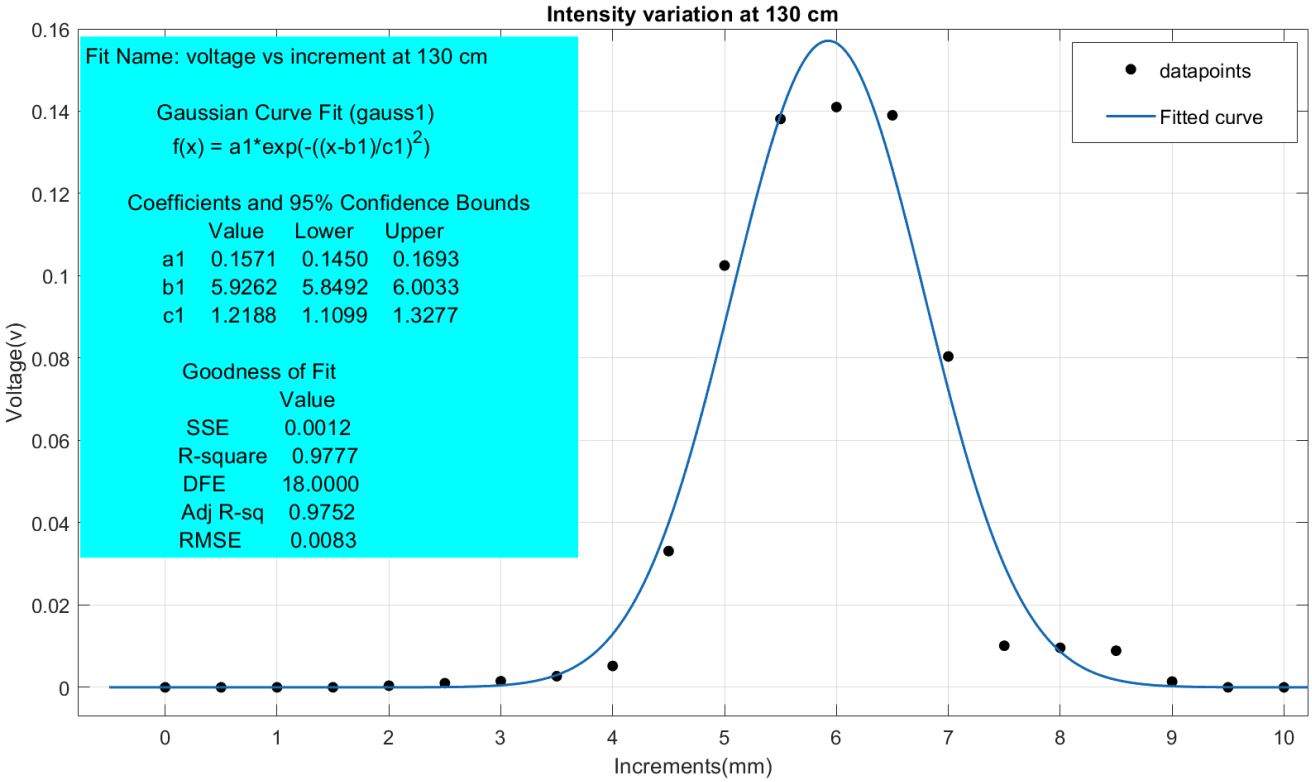

Figure 2: Chopper method: Intensity distribution when detector at 130 cm

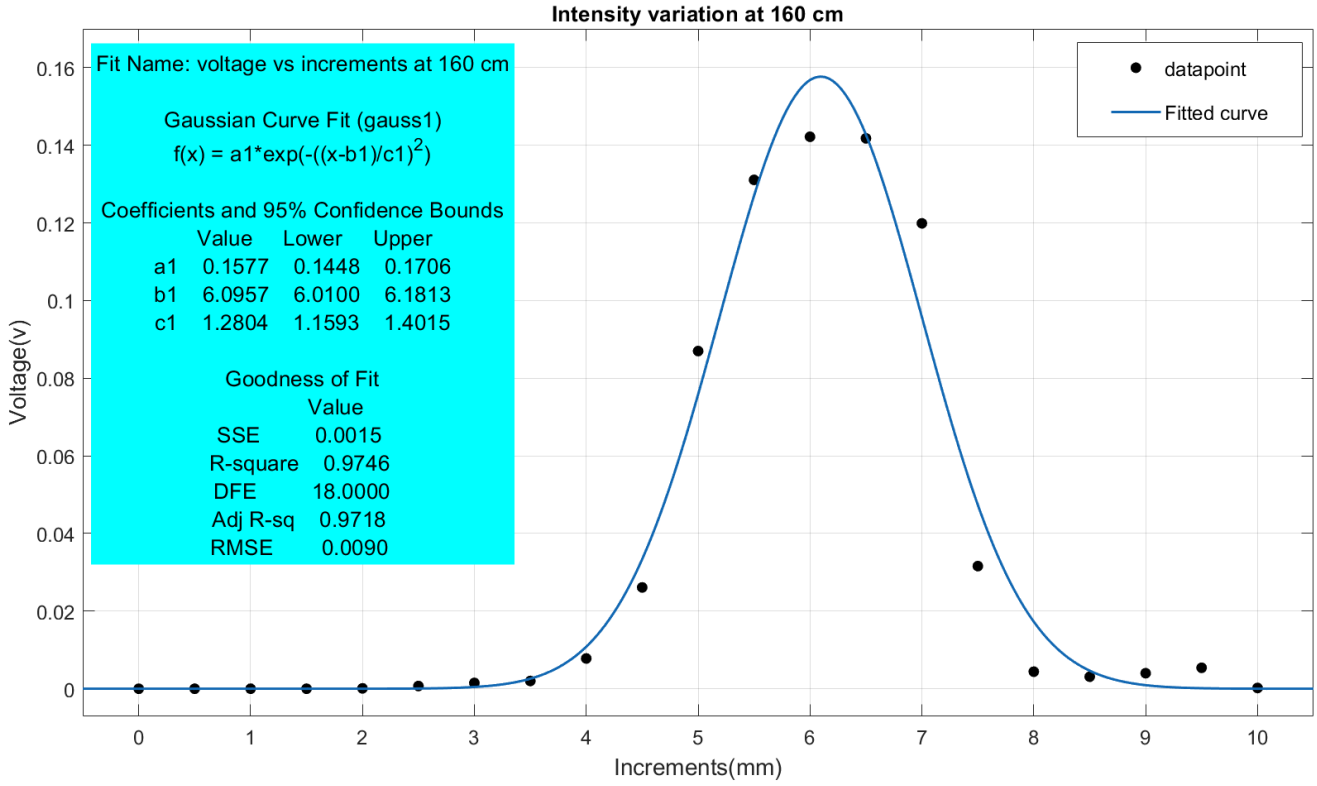

Figure 3: Chopper method: Intensity distribution when detector at 160 cm

3.1.2 Tables for Chopper method

Table 1: Chopper method: beam width value

Distance (cm)	C1 from curve fit (mm)	Beam width (mm) $w = \sqrt{2}C1$
100	1.1647	1.6471
130	1.2188	1.7236
160	1.2804	1.8108

Table 2: Chopper method: Calculation of various parameter

Distance (cm) L	Lower bound for C1 (mm)	Upper bound for C1 (mm)	Beam width (mm) $w = \sqrt{2}C1$	Δw (mm)	Lower bound for θ (mrad)	Upper bound for θ (mrad)	$\Delta\theta$ (mrad)
100	1.0434	1.2861	1.6471	0.3432	0.1365	0.1107	0.0258
130	1.1099	1.3277	1.7236	0.3080	0.1283	0.1073	0.0210
160	1.1593	1.4015	1.8108	0.3425	0.1229	0.1016	0.0213

From Table 1 we get,
W1 = 1.6471 mm as beam width at a distance of 100cm
W2 = 1.7236 mm as beam width at a distance of 130cm
W3 = 1.8106 mm as beam width at a distance of 160cm

From the above data, we calculate the following parameters:

- The divergence angle is found to be $\theta_0 = 0.8762$ mrad
- The Beam Spot size(radius) is found out to be $w_0 = 0.2299$ mm
- The Rayleigh range is $Z_r = 0.2624$ m

3.2 For Knife Edge method

3.2.1 Plots for Knife Edge method

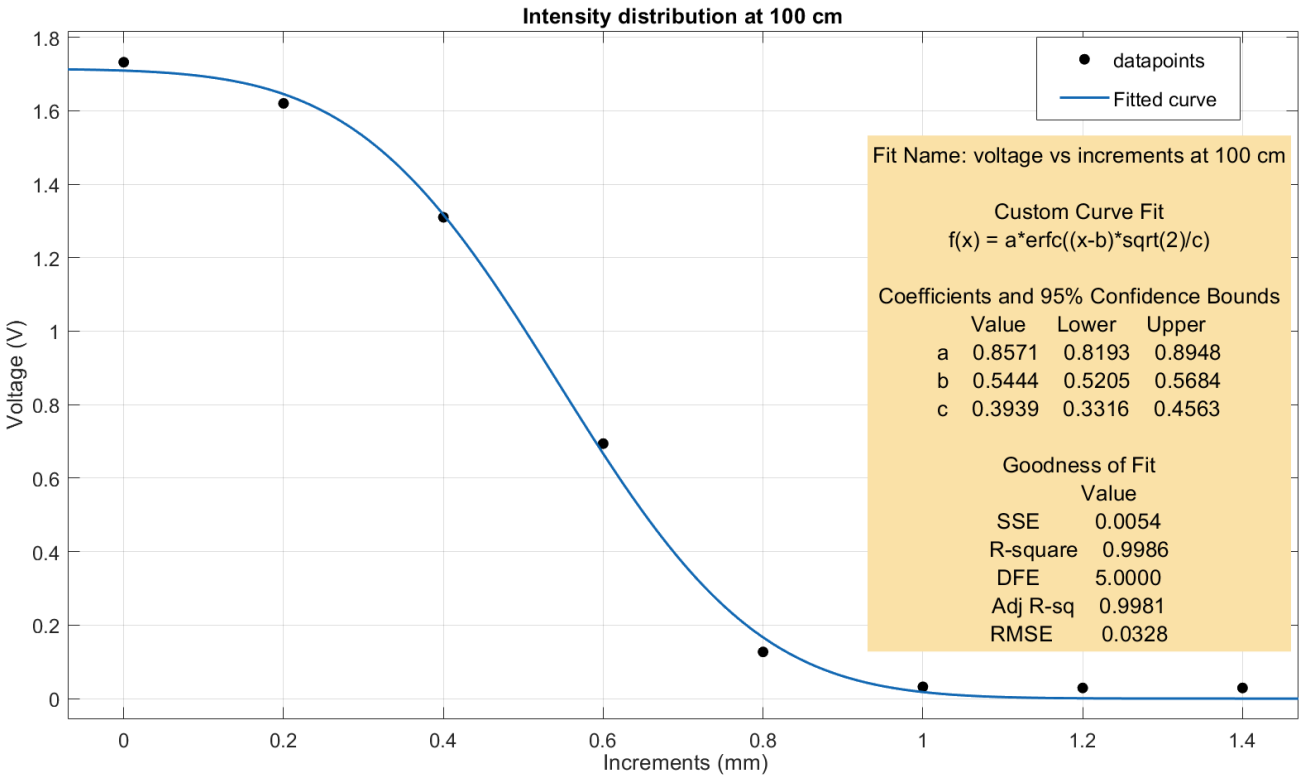

Figure 4: Knife Edge method: Intensity distribution when detector at 100 cm

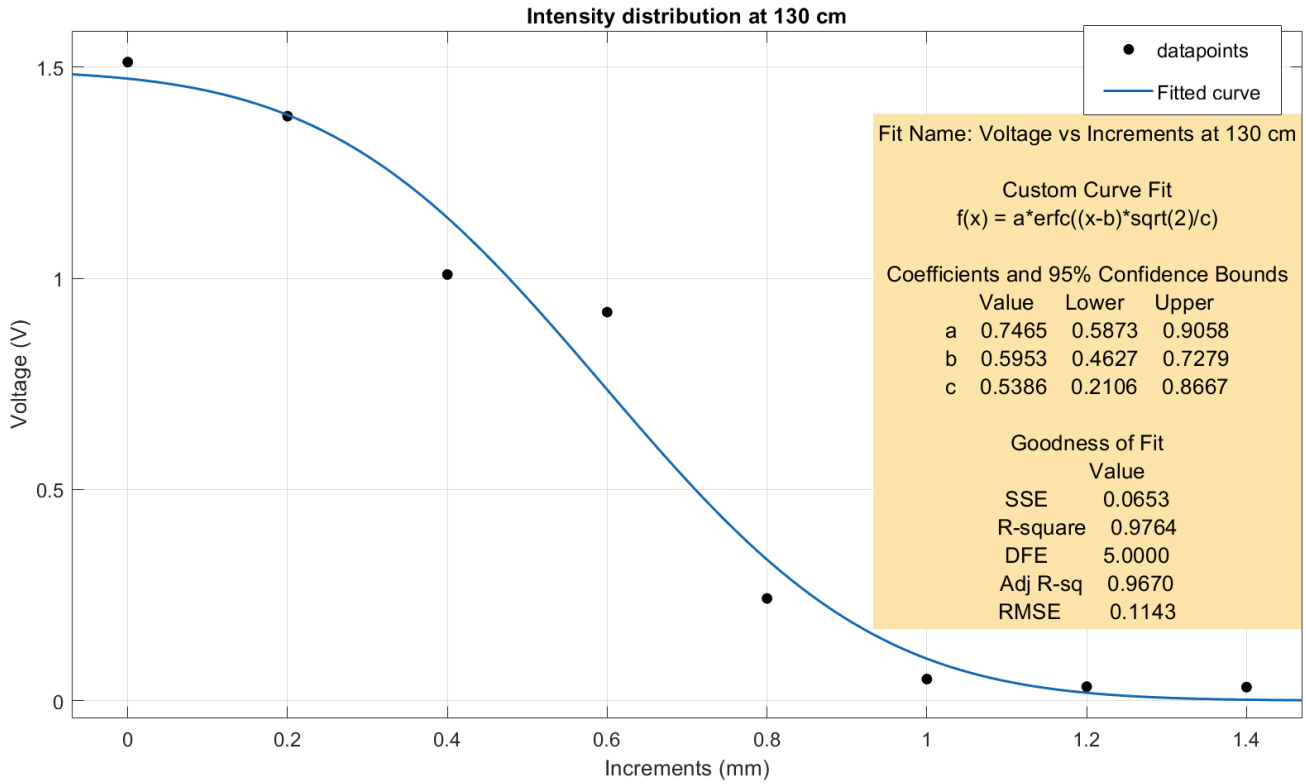

Figure 5: Knife Edge method: Intensity distribution when detector at 130 cm

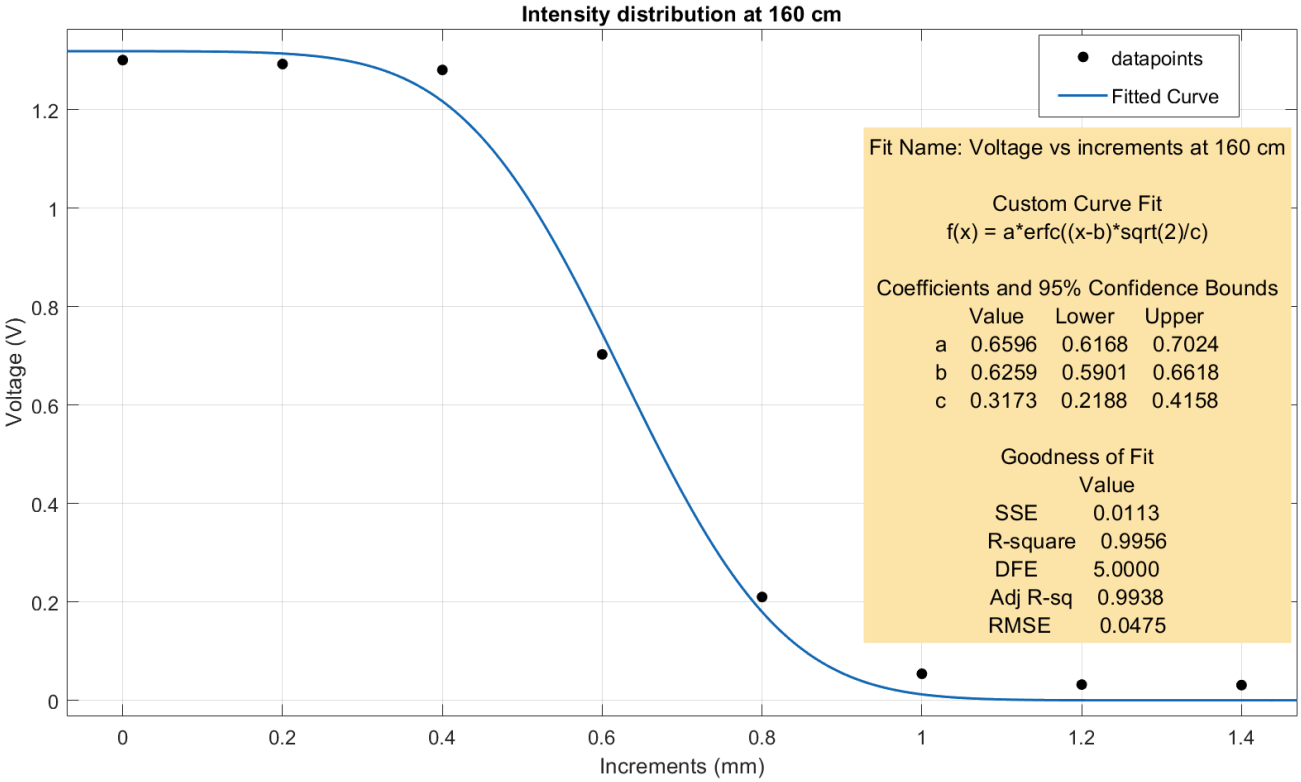

Figure 6: Knife Edge method: Intensity distribution when detector at 160 cm

3.2.2 Tables for Knife Edge method

Distance (cm)	C from curve fit (mm)	Beam width (mm) $w = \sqrt{2}C$
100	0.3939	0.5571
130	0.5386	0.7617
160	0.3173	0.4487

Table 3: Knife Edge method: beam width value

Table 4: Knife Edge method: Calculation of various parameter

Distance (cm) L	Lower bound for C (mm)	Upper bound for C1 (mm)	Beam width (mm) $w = \sqrt{2}C$	Δw (mm)	Lower bound for θ (mrad)	Upper bound for θ (mrad)	$\Delta\theta$ (mrad)
100	0.3316	0.4563	0.5571	0.1763	0.4295	0.3121	0.1174
130	0.2106	0.8667	0.7617	0.9279	0.6763	0.1643	0.5120
160	0.2188	0.4158	0.4487	0.2786	0.6510	0.3425	0.3085

From Table 3 we get,
W1 = 0.5571 mm as beam width at a distance of 100cm
W2 = 0.7617 mm as beam width at a distance of 130cm
W3 = 0.4487 mm as beam width at a distance of 160cm

From the above data, we calculate the following parameters:

- The divergence angle is found to be $\theta_0 = 0.9148$ mrad
- The Beam Spot size(radius) is found out to be $w_0 = 0.2202$ mm
- The Rayleigh range is $Z_r = 0.2407$ m

4 Calculations

4.1 For Chopper method

We know, D=30 cm, λ=632.8 nm. From Table 1,
$w_1 = 1.6471\ mm$, $w_2 = 1.7236\ mm$, $w_3 = 1.8106\ mm$

- **Divergence Angle** (θ_0)**:**

$$\theta_0 = \frac{1}{\sqrt{2D}}\sqrt{w_3^2 - 2w_2^2 + w_1^2}$$
$$\theta_0 = 0.8762\ mrad$$

- **Beam Spot size** (w_0)**:**

$$w_0 = \frac{\lambda}{\pi\theta_0}$$
$$w_0 = \frac{632.8 * 10^{-9}}{\pi * 0.8762 * 10^{-3}} = 0.2299\ mm$$

- **Rayleigh range** (Z_r)**:**

$$Z_r = \frac{\pi w_0^2}{\lambda}$$
$$Z_r = \frac{\pi * (0.2299 * 10^{-3})^2}{632.8 * 10^{-9}} = 0.2624\ m$$

4.2 For Knife Edge method

From Table 3,
$w_1 = 0.5571\ mm$, $w_2 = 0.7617\ mm$, $w_3 = 0.4487\ mm$

- **Divergence Angle** (θ_0)**:**

$$\theta_0 = \frac{1}{\sqrt{2D}}\sqrt{w_3^2 - 2w_2^2 + w_1^2}$$
$$\theta_0 = 0.9148\ mrad$$

- **Beam Spot size** (w_0)**:**

$$w_0 = \frac{\lambda}{\pi\theta_0}$$
$$w_0 = \frac{632.8 * 10^{-9}}{\pi * 0.9148 * 10^{-3}} = 0.2202\ mm$$

- **Rayleigh range** (Z_r)**:**

$$Z_r = \frac{\pi w_0^2}{\lambda}$$
$$Z_r = \frac{\pi * (0.2202 * 10^{-3})^2}{632.8 * 10^{-9}} = 0.2407\ m$$

5 Comparisons between Manufacturing data and Experimental data

Table 5: Comparisons between Manufacturing data and Experimental data

Parameter	Manufacturing data	Experimental data	
		Chopper method	Knife Edge method
Divergence angle (mrad)	1	0.8762	0.9148
Beam spot size (mm)	0.2014	0.2299	0.2202
Rayleigh range (m)	0.2013	0.2624	0.2407

6 Error Analysis

- **Manufacturing Data:**
  Divergence angle (θ_t)= 1 mrad.
  Beam radius (w_t) = 0.2014 mm.
  Rayleigh range (Z_{rt})= 0.2013 m.

6.1 Error analysis for Chopper method

- **Error in Divergence Angle** (θ_0)**:**
  Percentile error in calculating divergence angle,

$$\frac{\delta\theta}{\theta} * 100\% = \left|\frac{\theta_t - \theta_0}{\theta_t}\right| * 100\%$$

$$\frac{\delta\theta}{\theta} * 100\% = \left|\frac{1 - 0.8762}{1}\right| * 100\% = 12.38\ \%$$

- **Error in Beam Radius** (w_0)**:**
  Percentile error in calculating beam radius,

$$\frac{\delta w}{w} * 100\% = \left|\frac{w_t - w_0}{\theta_t}\right| * 100\%$$

$$\frac{\delta w}{w} * 100\% = \left|\frac{0.2014 - 0.2299}{0.2014}\right| * 100\% = 14.15\ \%$$

- **Error in Rayleigh range** (Z_r)**:**
  Percentile error in calculating Rayleigh range,

$$\frac{\delta Z_r}{Z_r} * 100\% = \left|\frac{Z_{rt} - Z_r}{Z_{rt}}\right| * 100\%$$

$$\frac{\delta Z_r}{Z_r} * 100\% = \left|\frac{0.2013 - 0.2624}{0.2013}\right| * 100\% = 30.35\ \%$$

6.2 Error analysis for Knife Edge method

- **Error in Divergence Angle** (θ_0)**:**
  Percentile error in calculating divergence angle,

$$\frac{\delta\theta}{\theta} * 100\% = \left|\frac{\theta_t - \theta_0}{\theta_t}\right| * 100\%$$

$$\frac{\delta\theta}{\theta} * 100\% = \left|\frac{1 - 0.9148}{1}\right| * 100\% = 8.52\ \%$$

- **Error in Beam Radius** (w_0)**:**
  Percentile error in calculating beam radius,

$$\frac{\delta w}{w} * 100\% = \left|\frac{w_t - w_0}{\theta_t}\right| * 100\%$$

$$\frac{\delta w}{w} * 100\% = \left|\frac{0.2014 - 0.2202}{0.2014}\right| * 100\% = 9.33\ \%$$

- **Error in Rayleigh range** (Z_r)**:**
  Percentile error in calculating Rayleigh range,

$$\frac{\delta Z_r}{Z_r} * 100\% = \left|\frac{Z_{rt} - Z_r}{Z_{rt}}\right| * 100\%$$

$$\frac{\delta Z_r}{Z_r} * 100\% = \left|\frac{0.2013 - 0.2407}{0.2013}\right| * 100\% = 19.57\ \%$$

7 Source of Error

- The position of the scale in the knife edge is in an odd position. That's why there is a possibility of error of perpendicularity.
- The smallest division of the scale is in order of the beam spot of the gaussian beam. That's why errors arise when taking a reading between the smallest division.
- There is a noise in the detector due to the unavailability of the completely dark room.

8 Discussions & Conclusions

- **divergence Angle:**
  Errors in calculating the divergence angle in the chopper and the knife edge methods are 12.38% and 8.52%. These errors are not negligible. But in our case knife edge method is more suitable than chopper method.

- **Beam radius:**
  Errors in calculating the divergence angle in the chopper and knife edge methods are 14.15% and 9.33%. The percentile error is higher than the percentile error in the divergence angle.

- **Rayleigh range:**
  Errors in calculating the divergence angle in the chopper and knife edge methods are 30.35% and 19.57%. Errors in calculating the rayleigh range are too high for both methods. It will affect the work where we use this He-Ne laser.

- We can see here errors are gradually increasing. That's why the errors in calculating divergence have to be negligible. Otherwise we will be in trouble while using this He-Ne laser.

9 References

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