20CSE1030 Zubin Shah

Aim: To measure wavelength using a millimetre scale as a grating.

Apparatus: A He-Ne laser, a vernier calliper, a meter scale, millimeter graph paper, etc.

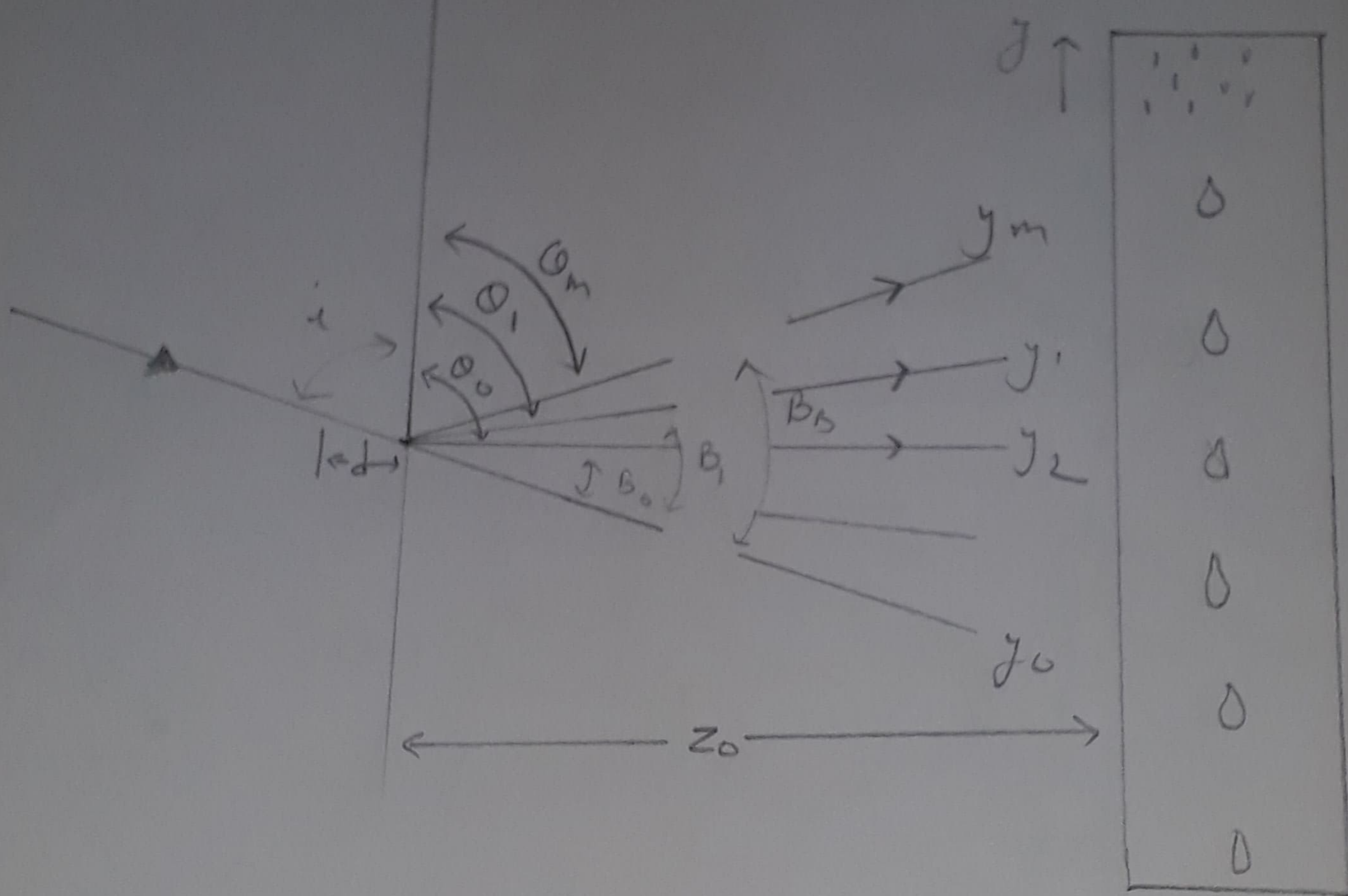
Introduction:
Schawlow in 1965 performed the experiment using a vernier calliper and He-Ne laser to determine the wavelength of laser light by studying the diffraction pattern obtained from millimeter scale of a ruler when laser light is made to fall on it. This is done here using the main scale of the vernier calliper in which the scale is engraved.

Theory:
The unexpected laser beam is allowed to fall at the grating angle ($i = 87°$) on the vernier calliper placed on a horizontal table and the diffraction pattern is observed at a distance of 3 to 4 meters from the scale. The beam is suitably aligned so that a well defined diffraction pattern is obtained.

Diffraction takes place at the engraving on the scale and is governed by the equation.

$$d(\sin i - \sin \theta_m) = m\lambda \quad \text{—— (1)}$$

where, m is the order & d is the grating constant, i the angle is incidence & θ_m is the angle corresponding to m order.



Schematic of Experiment arrangement and diffraction spots

If $m=0$, then beam is reflected.
In the figure

$$\alpha = \frac{\pi}{2} - I \quad \& \quad \beta_m = \frac{\pi}{2} - \theta_m$$

and z_0 is the distance between the region of incidence at the ruler and the screen.
y_m is the position of m^{th} spot where the diffraction spots are taken to lie along y-axis.
∴ Equation(1) becomes:

$$d(\cos\alpha - \cos\beta_m) = m\lambda \quad \text{--- (2)}$$

for zeroth order $\alpha = \beta_0$

from the figure.

$$\cos\beta_m = \left(1 - \frac{y_m^2}{z_0}\right)^{1/2}$$

$$\cos\beta_m = 1 - \frac{y_m^2}{2z_0} + \cdots \quad \text{--- (3)}$$

similarly: $\cos\alpha = \cos\beta_0 = 1 - \frac{y_0^2}{2z_0^2} + \dots$ — (4)

subtracting eq 3 from eq 4 we get:

$$\cos\alpha = \cos\beta_0 = \frac{y_n^2 - y_0^2}{2z_0^2} \quad — 5$$

from eq 2

$$\lambda = \frac{d}{m}(\cos\alpha = \cos\beta_m)$$

substituting eq 5 in eq 2 we get:

$$\lambda = \frac{d}{m}\frac{(y_m^2 - y_0^2)}{2z_0^2}$$

∴ wavelength of light is given by

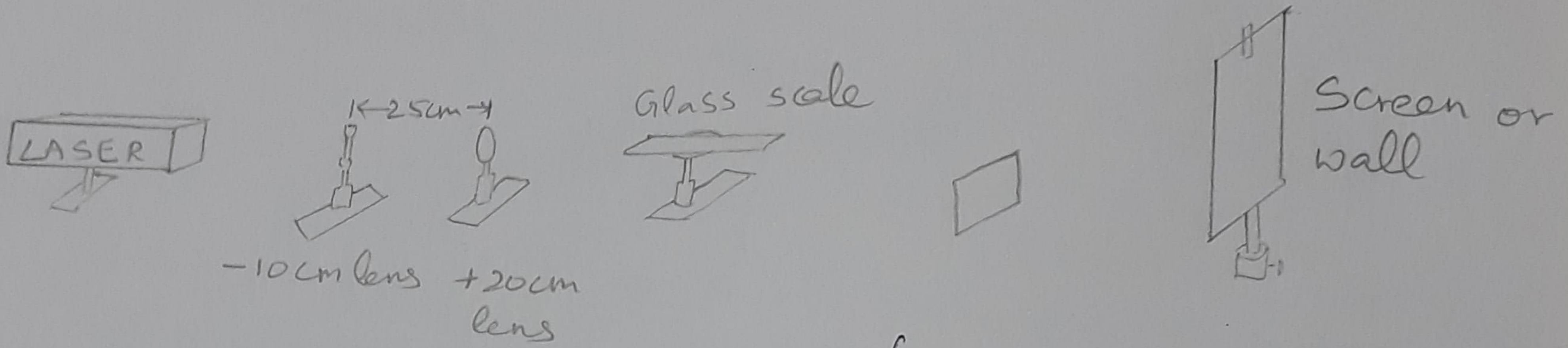
$$\lambda = \frac{d}{2z^2}\left(\frac{y_n^2 - y_0^2}{m}\right) \quad (6)$$

Procedure:

1. ~~Place the~~ Clamp the He Ne laser in its stand. Switch on the helium-neon laser and adjust its position so that unexpanded laser beam is incident at grazing angle on the engraving on the scale as shown in the figure 1a.
2. Paste a millimeter graph paper.
3. For measuring the distances from the horizontal, marking the position of the direct beam on the screen.
4. Observe the diffraction pattern on the screen.
5. Measure the distances of various diffraction spots from the position of the direct beam on the screen

and reduce them to the position midway between the direct beam and specularly reflected beam positions. These distance can be measured on a millimeter graph paper pasted on the screen.

7. Measure the distance (Z_0) between the point of incidence of laser light and the laser screen using the meter scale.



setup of the experiment

Observations:

Spacing of the engravings on main scale of vernier calliper

$d = 0.004\,mm$

Horizontal distance of screen from the point of incidence of laser beam on the vernier main scale

$z_0 = 820\,mm$

Camlin Page
Date / /

Observations:

Sr. No.	Position of spot (mm)	Reduced Positions y_m	y_m^2	$y_m^2 - y_0^2$
1	0	0	0	
2	$y_0 = 5.8$	$y_0/2 = 2.9$	$A_0 = 8.4$	$A_1 - A_0 = 20.7$
3	$y_1 = 8.3$	$y_1 - y_0/2 = 5.4$	$A_1 = 29.1$	$A_2 - A_0 = 43.4$
4	$y_2 = 10.1$	$y_2 - y_0/2 = 7.2$	$A_2 = 51.8$	$A_3 - A_0 = 65.6$
5	$y_3 = 11.5$	$y_3 - y_0/2 = 8.6$	$A_3 = 73.96$	$A_4 - A_0 = 83.7$
6	$y_4 = 12.5$	$y_4 - y_0/2 = 9.6$	$A_4 = 92.1$	$A_5 - A_0 = 110.4$
7	$y_5 = 13.8$	$y_5 - y_0/2 = 10.9$	$A_5 = 118.8$	$A_6 - A_0 = 130.8$
8	$y_6 = 14.7$	$y_6 - y_0/2 = 11.8$	$A_6 = 139.2$	$A_7 - A_0 = 152.9$
9	$y_7 = 15.6$	$y_7 - y_0/2 = 12.7$	$A_7 = 161.3$	$A_8 - A_0 = 1783.8$
10	$y_8 = 16.4$	$y_8 - y_0/2 = 13.5$	$A_8 = 182.2$	

$z = 820\,mm$ $d = 0.004\,mm$

Calculations:

$$\lambda_1 = \frac{D}{2Z_0^2}\left(\frac{y_1^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times 20.7$$

$$= 6.157 \times 10^{-7}\ cm$$

$$\lambda_1 = 615.7\ nm$$

$$\lambda_2 = \frac{D}{2Z_0^2}\left(\frac{y_2^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times \frac{43.4}{2}$$

$$= 6.454 \times 10^{-7}\ cm$$

$$\lambda_2 = 645.4\ nm$$

$$\lambda_3 = \frac{D}{2Z_0^2}\left(\frac{y_3^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times \frac{65.6}{3}$$

$$\lambda_3 = 6.504 \times 10^{-7}\ cm$$

$$\lambda_3 = 650.4\ nm$$

$$\lambda_4 = \frac{D}{2Z_0^2}\left(\frac{y_4^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times \frac{83.7}{4}$$

$$= 6.224 \times 10^{-7}\ cm$$

$$\lambda_4 = 622.4\ nm$$

Camlin Page

Date / /

$$\lambda_5 = \frac{D}{2Z_0^2} \times \left(\frac{y_5^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times \left(\frac{110.4}{5}\right)$$

$$= 6.568 \times 10^{-7}\ cm$$

$$\lambda_5 = 656.8\ nm$$

$$\lambda_6 = \frac{D}{2Z_0^2}\left(\frac{y_6^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times \left(\frac{130.8}{6}\right)$$

$$= 6.4842 \times 10^{-7}\ cm$$

$$\lambda_6 = 648.42\ nm$$

$$\lambda_7 = \frac{D}{2Z_0^2}\left(\frac{y_7^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2} \times \left(\frac{152.9}{7}\right)$$

$$= 6.4969 \times 10^{-7}\ cm$$

$$\lambda_7 = 649.69\ nm$$

$$\lambda_8 = \frac{D}{2Z_0^2}\left(\frac{y_8^2 - y_0^2}{m}\right)$$

$$= \frac{0.04}{2\times(820)^2}\left(\frac{173.8}{8}\right)$$

$$= 6.4619 \times 10^{-7}\ cm$$

$$\lambda_8 = 646.19\ nm$$

$$\lambda_{avg} = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_8}{8}$$

$$= \left(\frac{615.7 + 645.4 + 650.4 + 622.4 + 656.8 + 648.4 + 649.7 + 646.19}{8}\right) \times 10^{-9}$$

$$= 641.87\ nm$$

$$\lambda_{avg} = 641.9\ nm$$

$$\text{Percentage error} = \frac{641.9 - 632.8}{632.8} \times 100$$

$$\%\ \text{error} = 1.438\ \%$$

Conclusion:

The wavelength of HeNe laser determined via diffraction ~~t~~through millimetre scale was found to be 641.9nm with a percentage error of 1.438%

Result: Wavelength of He Ne laser is 641.9nm

Precautions:

- Avoid contacts with the laser light. No laser light should enter the eyes.
- The distance should be measured from horizontal plane.
- In the absence of vernier calliper, the position of the direct beam should be marked on the screen and the distances of various diffraction spots are measured from the position and later reduced to the position midway between the direct beam and secularly reflected be a positions.