5. HELIUM-NEON LASER

AIM :

To determine the wavelength of He-Ne laser using millimeter scale grating.

APPARATUS :

- He-Ne Laser
- Vernier Callipes
- Meter scale
- Millimeter Graph papes
- Board/ Screen

INTRODUCTION :

This experiment is confirmed by Schawlow in 1965. He performed this experiment to determine the wavelength of laser light by studying the diffraction pattern which is obtained from millimeter scale when light falls on it.

THEORY:

The laser beam is placed in such a way that it incident at an angle of 87° on meter scale placed on table. The diffraction pattern is observed from the scale. Schematic of experiment arrangement and the diffraction stopots obtained are shown in Fig-1.

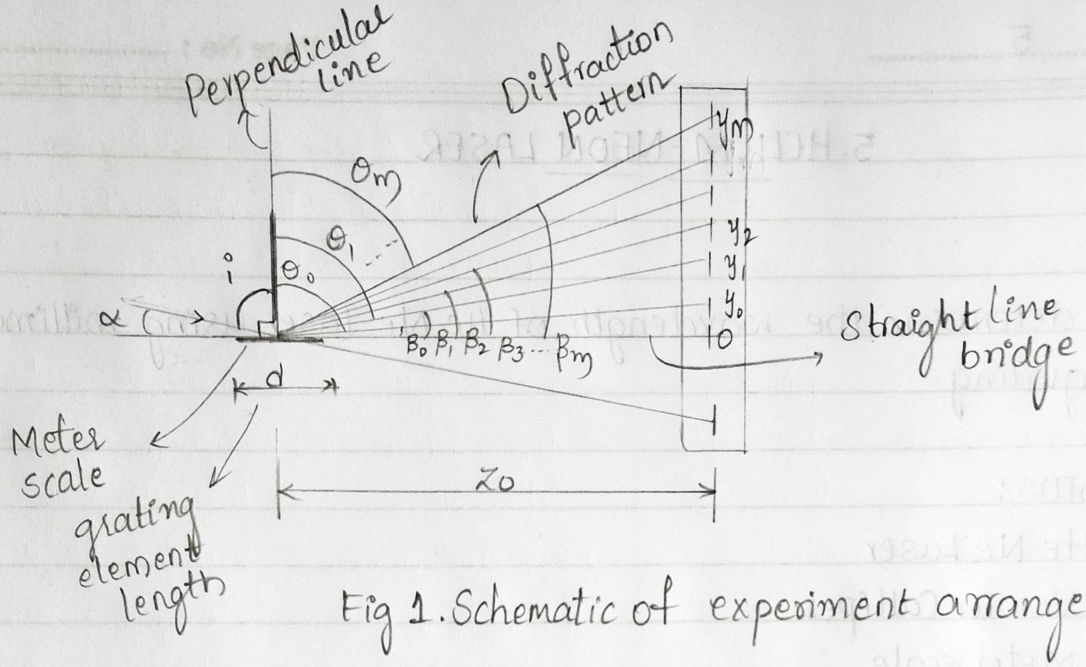

Fig 1. Schematic of experiment arrangement

Bragg's equation,

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

where m is the order of diffraction
d is the grating constant
i is the incident angle
θ_m is the diffracted angle

If $m=0$, then beam undergoes reflection,
In the figure 1, The distance between meterscale and screen is Z_0

$\alpha = \pi/2 - i$, $\beta_m = \pi/2 - \theta_m$

y_m is the position of spots which are taken along Y-axis.
by substituting $i = \pi/2 - \alpha$ and $\theta_m = \pi/2 - \beta_m$ in equation ①,
we get $d(\sin(\pi/2 - \alpha) - \sin(\pi/2 - \beta_m)) = m\lambda$

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

From the figure 1,

$$\cos\beta_m = \left(1 - \left(\frac{y_m}{z_0}\right)^2\right)^{1/2} = 1 - \frac{1}{2}\frac{y_m^2}{z_0^2} \quad \text{—} ③$$

$$\cos\alpha = \cos\beta_0 = 1 - \frac{1}{2}\frac{y_0^2}{z_0^2} \quad \text{—} ④$$

By subtracting equation ③ from equation ④, we get

$$④ - ③ \Rightarrow \cos\alpha - \cos\beta_m = 1 - \frac{1}{2}\frac{y_0^2}{z_0^2} - 1 + \frac{1}{2}\frac{y_m^2}{z_0^2}$$

$$= \frac{1}{2}\left(\frac{y_m^2 - y_0^2}{z_0^2}\right) \quad \text{—} ⑤$$

Substitute equation ⑤ in equation ②,

$$d\left[\frac{y_m^2-y_0^2}{2z_0}\right] = m\lambda$$

$$\lambda = \frac{d(y_m^2-y_0^2)}{2mz_0^2}$$

$$\boxed{\lambda = \frac{d}{2z_0^2}\left[\frac{y_m^2-y_0^2}{m}\right]}$$

where, λ = wavelength of light
d = grating constant
z_0 = distance between meterscale and screen
y_m = position of spots

PROCEDURE :

1. Keep the meter scale on the table at an appropriate distance (3-4 meters) from the screen.
2. Switch on the He-Ne laser that placed on the stand and adjust the position such that it incident at grazing angle (87°)
3. Place a millimeter graph paper on the screen.
4. Mark the position of the direct beam on the screen to measure the distances (in absence of meter scale).
5. Replace back the meter scale and observe the diffraction patter on the screen.
6. Now measure the distances of diffraction spots from direct beam position between direct beam and reflected beam. These distances are measured from graph paper.
7. Note down the value of z_0 (i.e distance between meter scale and screen).

OBSERVATION TABLE :

S.No	Positions of spots (cm)	Reduced positions y_m (cm)	y_m^2 (cm^2)	$y_m^2 - y_0^2$ (cm^2)
1	$y_0 = 5.8$	$y_0/2 = 2.9$	$A_0 = 8.41$	
2	$y_1 = 8.3$	$y_1 - y_0/2 = 5.4$	$A_1 = 29.16$	$A_1 - A_0 = 20.75$
3	$y_2 = 10.1$	$y_2 - y_0/2 = 7.2$	$A_2 = 51.84$	$A_2 - A_0 = 43.43$
4	$y_3 = 11.5$	$y_3 - y_0/2 = 8.6$	$A_3 = 73.96$	$A_3 - A_0 = 65.55$
5	$y_4 = 12.5$	$y_4 - y_0/2 = 9.6$	$A_4 = 92.16$	$A_4 - A_0 = 83.75$
6	$y_5 = 13.8$	$y_5 - y_0/2 = 10.9$	$A_5 = 118.81$	$A_5 - A_0 = 110.4$
7	$y_6 = 14.7$	$y_6 - y_0/2 = 11.8$	$A_6 = 139.24$	$A_6 - A_0 = 130.83$
8	$y_7 = 15.6$	$y_7 - y_0/2 = 12.7$	$A_7 = 161.29$	$A_7 - A_0 = 152.88$
9	$y_8 = 16.4$	$y_8 - y_0/2 = 13.5$	$A_8 = 182.25$	$A_8 - A_0 = 173.84$

CALCULATIONS:

$$d = \frac{2.54\,cm}{64} = \frac{2.54}{64} \times 10^{-2}\,m$$

$$z_0 = 820\,mm = 820 \times 10^{-3}\,m$$

$$\lambda_m = \frac{d}{2z_0^2} \cdot \frac{y_m^2 - y_0^2}{m} \qquad y_m^2 - y_0^2 \rightarrow cm^2 \Rightarrow 10^{-4}\,m$$

$$\lambda_1 = \frac{2.54 \times 10^{-2} \times 20.75 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 1}$$

$$= 6123.703\,A^\circ$$

$$\lambda_2 = \frac{2.54 \times 10^{-2} \times 43.43 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 2}$$

$$= 6408.492 A^0$$

$$\lambda_3 = \frac{2.54 \times 10^{-2} \times 65.55 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 3}$$

$$= 6448.33 A^0$$

$$\lambda_4 = \frac{2.54 \times 10^{-2} \times 83.75 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 4}$$

$$= 6179.038 A^0$$

$$\lambda_5 = \frac{2.54 \times 10^{-2} \times 110.4 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 5}$$

$$= 6516.211 A^0$$

$$\lambda_6 = \frac{2.54 \times 10^{-2} \times 130.83 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 6}$$

$$= 6435.053 A^0$$

$$\lambda_7 = \frac{2.54 \times 10^{-2} \times 152.88 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 7}$$

$$= 6445.382 A^0$$

$$\lambda_8 = \frac{2.54 \times 10^{-2} \times 173.84 \times 10^{-4}}{64 \times 2 \times (820)^2 \times 10^{-6} \times 8}$$

$$= 6412.919 A^0$$

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

$$= 6371.141 A^0$$

ERROR CALCULATION:

$$\text{Error}(\%) = \left| \frac{6371.141-6328}{6328} \right| \times 100$$

$$\text{Error} = 0.68\%$$

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RESULT:

Wavelength of He-Ne laser, $\lambda = 6371.141\ A^{\circ}$

CONCLUSION:

From the experiment, the wavelength of He-Ne Laser was found to be $6371.141\ A^{\circ}$ with an error of 0.68 % with the exact value of $6328\ A^{\circ}$.

PRECAUTIONS:

1. Make sure that laser light should not enter ~~wi~~ into the eyes.
2. While taking the measurements, we have to reduce them to the midway position between direct beam and reflected beam.
3. Make sure that laser light should not fall on the body for long time.

Teacher's Signature : ____________________