Expt.No.2 Diffraction of a laser light through diffraction grating

Aim:

1. To determine the wavelength of a given laser light using diffraction expt.
2. Determine the wavelength of a given laser source light using diffraction grating by taking equation which follows the Fronhofer diffraction.
3. Show that the wavelength so determined is within the experimental errors with reference to the expected values, inferring that the principle of Fronhofer diffraction is followed and hence the source is coherent and highly directional.

Apparatus:

Laser source, grating screen with graph paper, etc.

Theory:

Diffraction is the deviation of light waves after they pass through small openings (or around the small obstacles).The diffraction of light wave is possible only when the size of the obstacle is of the order of wavelength of incident light. i.e $\lambda \sim d$. the diffraction pattern consists of variation of intensity of the image being formed.

Analysis of diffraction pattern: A typical diffraction pattern consists of a central band called central maxima, and on either side of which will be principal maxima and secondary maxima……

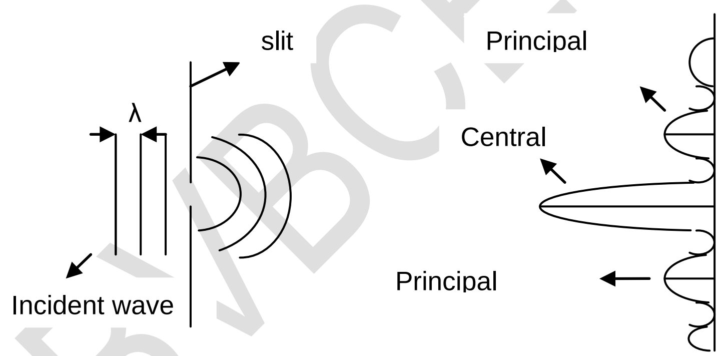


Fig.1 Diffraction at a single slit (with intensity distribution curve)

To diffract the laser light, diffraction gratings are used. **A diffraction grating is an optically plane glass plate on which a number of equidistant parallel lines are ruled.** The region where lines are drawn becomes opaque to light, while the space between two lines is transparent and act as a slit for diffraction of incident light. The number of lines per cm on the grating is called grating constant **'N'** and the slit width $d = \frac{1}{N}$.

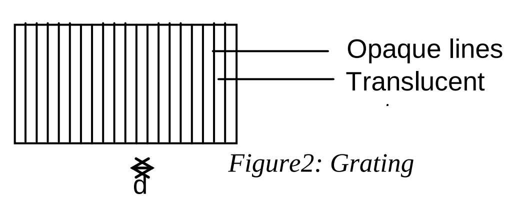


Figure2: Grating

When a parallel beam of laser light falls normally on the grating, it diffracts at every slit and interference between these waves gives rise to diffraction pattern with central maxima, I order and II order diffraction as shown in figure.
The general formula of diffraction pattern is given as, **$n\lambda = d \sin\theta$.**

Where, n – order of the spectrum

d – slit width

λ - wavelength of light source

θ - angle of diffraction.

About laser:

The acronym for Laser stands for "Light Amplification by Stimulated Emission of Radiation". Laser is a special type of light source, which emits a light of highly monochromatic, highly directional, high degree of coherence and highly intensive beam. The emission of laser beam is mainly due stimulated emission process, which was first suggested by Albert Einstein in 1917. The first ever known laser system was built by T H Maiman an American physicist 1960. Based on lasing material, Lasers are broadly classified as, solid state lasers, dye lasers, gas lasers, and semiconductor lasers. In a short span of 40 years, the laser has revolutionized medicine, manufacturing and telecommunications. In addition to it, lasers are being used to monitor pollution, and can be said to have infiltrated our everyday lives.

Procedure:

1. Arrange the experimental set up as shown in the figure, such that the laser source, grating and screen are in the same line.
2. Plane of the grating is placed normal to the incident beam.
3. The diffraction pattern of laser light is observed on the screen
4. The distance between the source and the grating is kept constant.
5. Distance between the plane of the grating and screen can be varied. Note down the distance between the plane of grating and the screen (D_1). For this particular distance, mark the distance between two first order spots on the graph paper attached to the screen, which gives $2x_1$. Similarly for the second order, the distance between the two spots is measured as $2x_2$.
6. The angles of diffraction θ_1 and θ_2 can be calculated using the formula $\tan\theta = x_i / D$. and the respective wavelengths, λ_1 and λ_2 are measured using a well known formula **$n\lambda = d \sin\theta$.** Mean value of λ_1 and λ_2 is taken as λ which gives the wavelength of given source.
7. The experiment is repeated for different grating and screen distances. The mean wavelength is calculated for the different observations. Finally average value of wavelength is calculated using the mean wavelengths for different observations.

Formula: The condition for maximum intensity is

$$n\lambda = d\sin\theta$$

i.e, $$n\lambda = \frac{\sin\theta}{N}$$

where n is order of spectrum,

λ is wavelength of laser light,

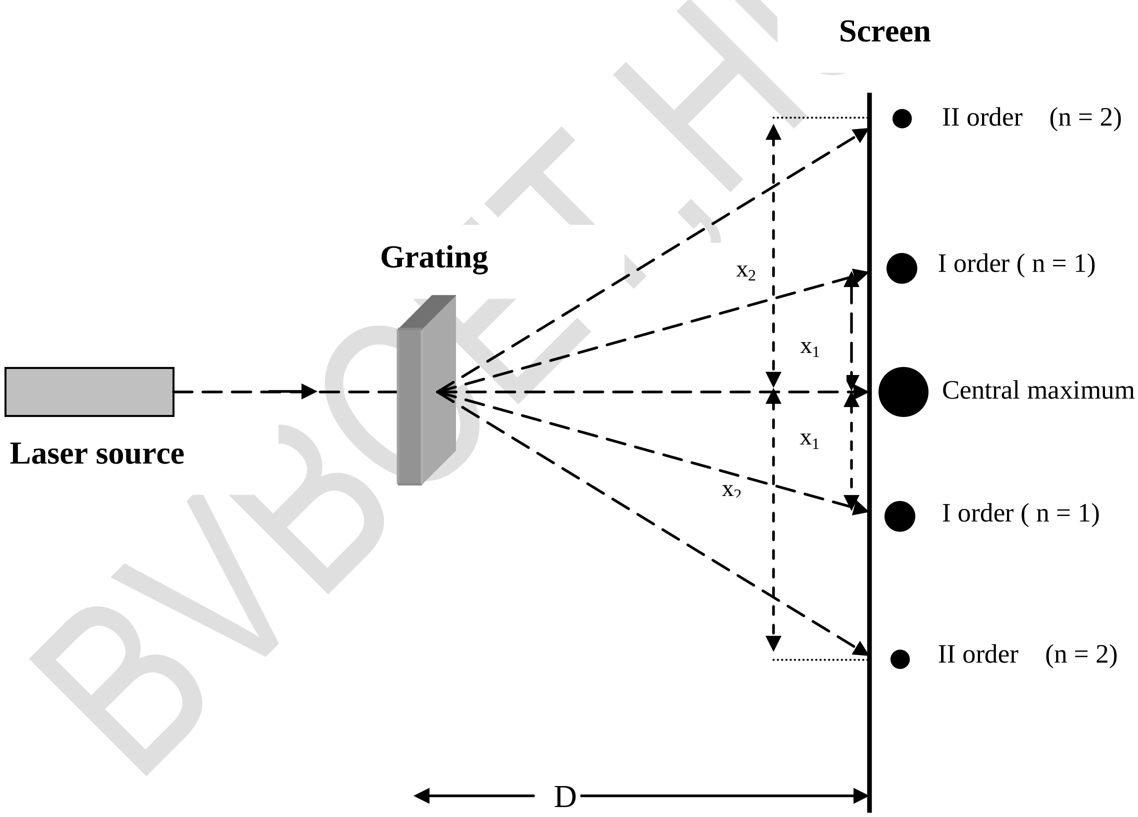
N = 1/d = number of lines/cm on grating

Where'd' is the slit width,

θ = angle of diffraction.

= $\tan^{-1}(x_i / D)$ (refer figure)

Ray diagram:



Record of observations:

1. d = 1 / N = 1 / 5906 = --------------± _______ cm

Tabular column:

SL. NO	DISTANCE BETWEEN GRATING & SCREEN 'D' IN CM	$2X_I$		$\tan(\Theta_I)=X_I / D$		ANGLE OF DIFFRACTION θ IN DEG	
		I order $2x_1$ in cms	II order $2x_2$ in cms	I order $\tan\theta_1 = x_1 / D$	II order $\tan\theta_2 = x_2 / D$	I order θ_1	II order θ_2
Errror	±_______						
1							
2							
3							

Calculation: **individual for all θ**

Trial 1:

$\lambda_1 = d \sin\theta_1$

= -------- cm = **--------- A^0**

$\lambda_2 = (d \sin\theta_2)/2$

= ----------cm = -------------**A^0**

Mean $\lambda'_1 = (\lambda_1 + \lambda_2)/2$

=----------cm=-------------**A^0**

Trial 2:

$\lambda_{11} = d \sin\theta_1$

= -------- cm = **--------- A^0**

$\lambda_{22} = (d \sin\theta_2)/2$

= ----------cm = -------------**A^0**

Mean $\lambda'_2 = (\lambda_{11} + \lambda_{22})/2$

=----------cm=-------------**A^0**

Trial 3:

$\lambda_{111} = d \sin\theta_1$

= -------- cm = **--------- A^0**

$\lambda_{222} = (d \sin\theta_2)/2$

= ----------cm = -------------**A^0**

Mean $\lambda'_3 = (\lambda_{111} + \lambda_{222})/2$

=----------cm=-------------**A^0**

Mean $\lambda = (\lambda'_1 + \lambda'_2 + \lambda'_3) / 3$

=----------cm=-------------**A^0**

Result: The wavelength of the given laser source = ---------- A^0

Estimation of percentage error:

Standard value: 6300 ^{0}A

% percentage of error = (standard value – experimental value) x100 / standard value

Viva questions:

1) What is the principle of this experiment?
2) What is diffraction?
3) What is the condition for diffraction?
4) How many types of diffraction are there? What are they?
5) Mention few differences between interference and diffraction.
6) What is grating?
7) What is grating constant?
8) What is a laser?
9) What are the principles of laser?
10) What is the condition foe lasing action?
11) What do you mean by population of an energy state?
12) What is Boltzmann factor?
13) What are the different methods of pumping?
14) What kind of an energy source is used in He-Ne laser?
15) What is semiconductor laser?