Date : 24-06-2021

Expt. No : 4 Page No :

4. TRANSPARENT DIFFRACTION GRATING

AIM:

To determine the wavelength of sodium light using a plane diffraction grating.

APPARATUS:

1. Spectometer
2. Diffraction Grating
3. Sodium Light source
4. Single slit

THEORY:

Deviation of the light from its straight path by passing close to edges of opaque obstacles and narrow slits is known as Diffraction.

Diffraction of light is classified into two types.

1. Frensel Diffraction
2. Fraunhoffer Diffraction

Frensel Diffraction :- In this case, the source of light or screen or both are at a finite distance from the obstacle and the incident light/wavefront is either spherical or cylindrical.

Fraunhoffer Diffraction :- In this case, the source of light and the screen are effectively at infinite distance from the obstacle (or aperture) causing diffraction and the incident wavefront is

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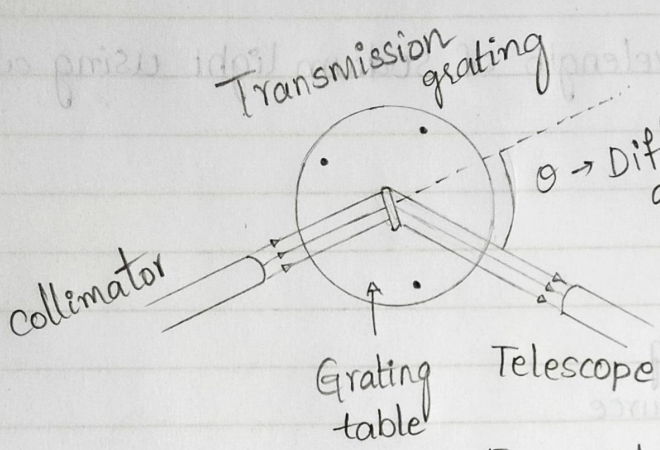

Fig 1. Schematic Diagram of grating.

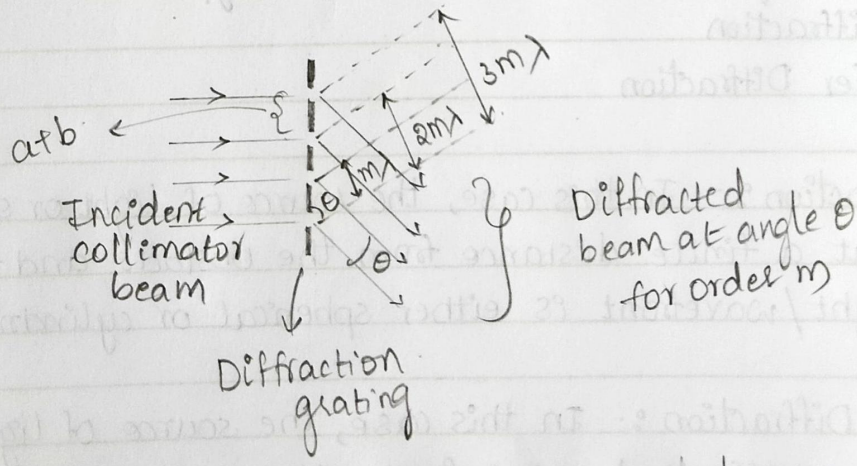

Fig 2. Geometry related to equation (2)

always a plane wavefront.

Diffraction grating :-

It is the instrument which is used to study spectra. It consists of series of opaque and transparent spaces which are uniformly spaced. Diffraction grating use of the phenomenon of Fraunhofer diffraction.

The width of the each slit is 'a', the seperation between slits is 'b' and 'a+b' is known as grating element.

If n lines are ruled per unit length in a grating then $a+b = 1/n$. The schematic diagram is shown in Fig-1.

The collimator directs parallel light on the grating. It seperates bundles of parallel light of different wavelengths and directs them into the telescope. with the help of telescope we observe the band spectrum of the source.

The wavelength (λ), diffraction angle (θ), incident angle (i), grating element ($a+b$) and the order 'm' are related as

$$m\lambda = (a+b)(\sin i + \sin\theta) \quad -①$$

As the light is coming perpendiculas to grating, Thus incident angle $i=0$, then equation ① becomes

$$m\lambda = (a+b)\sin\theta \quad -②$$

where m is the order of diffraction (0, 1, 2, ...)

The geometry related to equation ② is shown in Fig-2.

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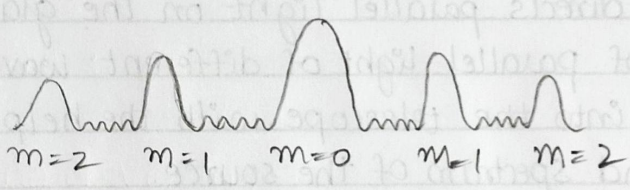

Fig 3. Pattern

Date : .....

Expt. No : ..... Page No : .....

In the equation ②,

a+b, m are constants for given order

θ changes with wavelength

Thus, different wavelengths are observed as distinct spectrum.

The given grating has M slits, then (M-1) minima will form between any two principal maxima

$$(a+b)\sin\theta = \pm \frac{n\lambda}{M}$$

where n = integer except 0, M, 2M ...

because for these values (0, M, 2M ..) there is principal maxima.

We know that there is a maxima between two consecutive minima. Thuse there are (M-1) minima and (M-2) Secondary maxima in between any two principal maxima.

The patterns is shown in Fig-3.

→ As we know that, $m\lambda = (a+b)\sin\theta$

we can get maximum number of order of spectra when $\sin\theta$ is maximum, i.e when $\theta = 90^\circ$

Thus $m_{max} = \frac{(a+b)}{\lambda}$ $(\sin\theta = 1)$

↓ maximum no. of orders of spectra

Formula for determination of λ,

$$\lambda = \frac{(a+b)\sin\theta}{m}$$

θ → diffraction angle corresponding to m^{th} principal

Teacher's Signature : _____

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maxima on either side of the central image.

(a+b) → grating element.

PROCEDURE:

1. First we have to adjust the spectometer such that they should not disturb the remainder of measurements. Therefore different wavelengths are observed as a distinct spectrum.

2. Adjustment of grating -

Grating should be placed on top of the turn table which is present on spectrometer

We have to make sure the light coming from the sodium lamp is incident exactly perpendicular to the grating so that the angle of incidence becomes zero.

In order to make incident angle zero we have to do the following :-

(i) Make the telescope paallel to the incident light. Look at the source from telescope and make sure that crosswire is aligned to the source.

Once the telescope is aligned, note the readings on the circular scale. Let the reading be θ.

(ii) Then rotate the telescope 90° with the help of scale on turn table. Thus reading becomes (θ+90) and clamp the telescope at this position. In this position, the axis of telescope and collimator are mutually perpendicular.

(iii) Adjust the grating such that the diffracted light is visible on telescope. We have to make sure the diffracted angle is 45°.

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OBSERVATION TABLE:

Green/ Yellow	Reading of Vernier, V_1			Reading of Vernier, V_2			Avg
	Image on right hand side (θ_R)	Image on left hand side (θ_L)	$\theta = \frac{\theta_L - \theta_R}{2}$	Image on right hand side (θ_R)	Image on left hand side (θ_L)	$\theta = \frac{\theta_L - \theta_R}{2}$	$\frac{\theta_{V_1} + \theta_{V_2}}{2}$
Green	149° 38 min	191° 32 min	20.95°	329° 38 min	371° 53 min	21.125°	21.0375° (θ_{green})
yellow	149° 5 min	192° 25 min	21.667°	329° 5 min	372° 25 min	21.667°	21.667° (θ_{yellow})

CALCULATIONS:

Green,

Reading of Vernier, V_1

$\theta_R = 149°38\ min = 149.63°$

$\theta_L = 191°32\ min = 191.53°$

$\theta = \frac{\theta_L - \theta_R}{2} = 20.95°$

Reading of Vernier, V_2

$\theta_R = 329°38\ min = 329.63°$

$\theta_L = 371°53\ min = 371.88°$

$\theta = \frac{\theta_L - \theta_R}{2} = 21.125°$

$\theta_{green} = \frac{20.95 + 21.125}{2} = 21.0375°$

Yellow,

Reading of Vernier V_1,

$\theta_R = 149°5\,min = 149.083°$

$\theta_L = 192°25\,min = 192.417°$

$\theta = \frac{\theta_L - \theta_R}{2} = 21.667°$

Reading of Vernier V_2,

$\theta_R = 329°5\,min = 329.083°$

$\theta_L = 372°25\,min = 372.417°$

$\theta = \frac{\theta_{PL} - \theta_R}{2} = 21.667°$

$\theta_{yellow} = \frac{21.667° + 21.667°}{2}$

$= 21.667°$

Wavelength,

$\lambda_{green} = \frac{(a+b)\sin\theta_{green}}{m}$

As it is first order, $m = 1$

$a+b = \frac{2.54}{15000}\,cm$

$= \frac{2.54}{15000} \times 10^{-2}\,m$

$\lambda_{green} = \frac{2.54}{15000} \times 10^{-2} \times \sin(21.0375°)$

$= 6078.71\,A°$

$\lambda_{yellow} = \frac{2.54 \times 10^{-2}}{15000} \sin(21.667°)$

$= 6251.982\,A°$

$\lambda_{avg} = 6165.346\ A^\circ$

Error Calculation :

Exact value of λ (for sodium light) = $5893\ A^\circ$

Calculated, $\lambda = 6165.346\ A^\circ$

$$\text{Error \%} = \frac{6165.346 - 5893}{5893} \times 100$$

$$= 4.62\%$$

(iv) Now, note the readings and turn the grating exactly 45° such that the grating is normal to the axis of collimator and then clamp the turn table.

Now, we exactly know that, i=0

3. Rotate the telescope to see first as well as second order spectrum on either side of slit image by undamping it.
4. Rotate the telescope to see the first order image on right hand side till the vertical cross wire just falls on first order image. Note the readings of both veniers.
5. Now rotate the telescope to see the first order image on left hand side and note the readings.
6. Repeat the same for second order image on both left and right hand side and note the readings.

RESULTS:

Wavelength of incident light, $\lambda = 6165.346\ A^\circ$

CONCLUSION:

From the experiment, the wavelength of sodium light was found to be $6165.346\ A^\circ$ with an error of 4.62% with the exact value of $5893\ A^\circ$

PRECAUTIONS:

1. The experiment must perform in a dark room.
2. The Grating should be mounted such that its ruled surface faces the telescope.

Teacher's Signature : _____

Date : .....

Expt. No : .....

Page No : .....

3. The Telescope and the collimator must be set for parallel rays.
4. Never touch the ruled surface of grating.
5. The grating table should be levelled.

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