EXPT. NO 01 | NAME SADAT ZUBIN AFTAB SHAH 20CSE1030 | Page No.: 01 | Date: | YOUVA

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

Apparatus: Spectrometer, diffraction grating, sodium light source.

Formula used: Wavelength of the light,

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

where, $(a+b)$ is the grating element, θ is the angle of diffraction corresponding to m^{th} principal maxima on either side of the central slit image.

Theory:

Diffraction of light

When a beam of light falls on obstacles or aperture whose size is comparable to the wavelength of light. It is observed that the light bends round the corners of these narrow obstacles and enters into the geometrical shadow. This bending of light round the corners of obstacles is known as diffraction of light.

The diffraction of light is generally classified into two types as:

1. Fresnel's diffraction: In Fresnel's diffraction either the light source or the screen or both of them kept at finit distance from the aperture causing

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diffraction. In this type of diffraction the incident wavefront is either sperical or cylindrical.

2. Fraunhofer's diffraction: In this type of diffraction, the light source and the screen are effectively at finite distance from the aperture. In Fraunhofer's diffraction the incident wavefront is always a plane wavefront.

Plane Transmission Diffraction Grating

It is simple and most useful instrument for studying spectra. It consists of a grid of fine parallel lines uniformly spaced on a transmitting surface. A diffraction grating makes use of the phenomenon of Fraunhofer's diffraction. The lines are generally ruled with a fine diamond point & generally number several thousand lines per centimeter.

Let 'a' be the width of each slit and 'b' the separation between two adjacent slits then $(a+b)$ is known as the grating element. If n lines are ruled per unit length in a grating then the grating element $a+b = \frac{1}{n}$. The schematic diagram of grating spectrometer is shown in fig (1)

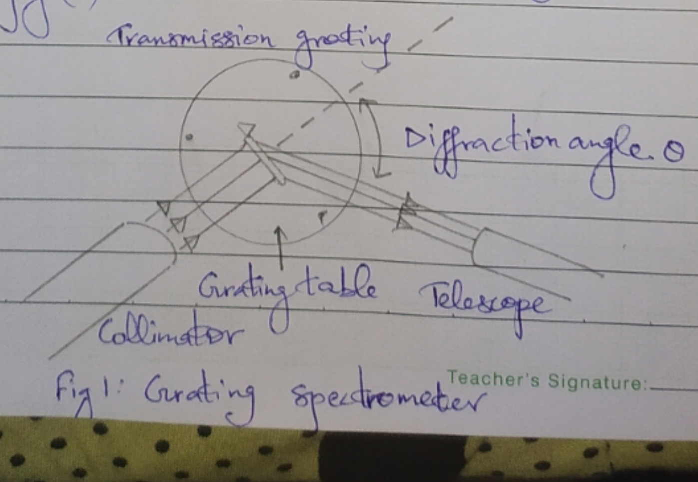

Fig 1: Grating spectrometer

The collimator directs parallel light onto the grating, in turn acting as a dispersive element. It separates the bundles of parallel light of different wavelength and directs them onto the telescope. The observer adjusts the telescope for proper focus and sees the obcaracteristics line or band spectrum.

The diffraction angle θ is unique for each wavelength.

The diffraction angle θ, wavelength λ of the light grating element (a+b) and the order number 'm' are related as

$$m\lambda = (a+b)(\sin i + \sin\theta) \quad \text{——— (1)}$$

where i, is the angle that the incident collimated beam makes with a normal to the grating surface.

The collimator beam, in fig (1) is perpendicular to plane of the grating so that for this orientation angle

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

where, $m = 0, \pm 1, \pm 2 \ldots$ refers to different orders of diffractions.

The essential geometry θ, λ & $(a+b)$ for order m is shown in fig (2)

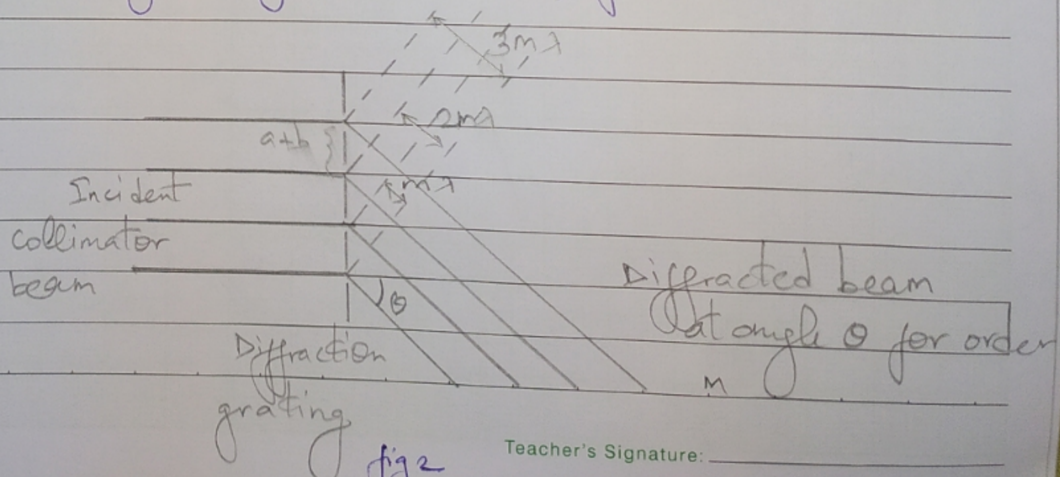

fig 2

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Therefore, the different wavelengths are observed as distinct spectrum.

If a given grating has M slits then between any two principal maxima there are (M-1) secondary minima given by the condition as

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

where, n takes all average values except 0, M, 2M ... because for these values of n we are obtaining the principal maxima.

As in between two consecutive minima there we can say that in between (M-1) minima present between any two principal maxima, there will be M-2 secondary maxima. The pattern obtained on the screen is as shown in fig 3.

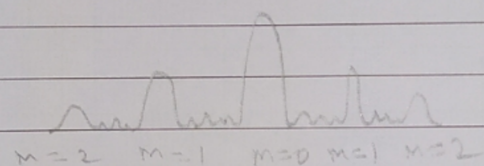

fig 3

Maximum Number of order of spectra.

from equation (2) we can write

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

The maximum value of $\sin\theta$ is 1

∴ maxima numbers of orders available within a given grating is.

$$m_{max} = \frac{a+b}{\lambda}$$

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Determination of λ
To determine the wavelength of light the angle of diffraction θ in the first as well the second order spectra is measured.
The value of λ is calculated using the formula

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

Procedure:
1. Adjustment of spectrometer
The spectrometer with grating is used in a manner which is similar to that in which a prism is used with spectrometer.
See experiment 1 for adjustments. Once these adjustments have been made, they are not to be disturbed for the remainder of measurements. Therefore, different wavelength are observed as a distinct spectrum.
Adjustment of grating
Place the grating on the grating table (ie. Prism Table) of spectrometer in such a way that the plane through the center of the grating table.
(In order to apply equation $m\lambda = (a+b)\sin\theta$ without error to this experiment, the mount & leveling screens must be adjusted such that the grating is in a vertical perpendicular to the axis of the collimator & telescope).

2. Adjust the telescope so that the vertical cross wire lies on the direct image of the slit. Note the reading on the circular scale of spectrometer using any one of the

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two verniers. let this reading be θ.

3. Rotate the telescope through 90°. Thus, the reading of the vernier becomes (θ+90°). Clamp the telescope in this position. In this position the axis of the telescope and collimator are mutually at right angles to each other.

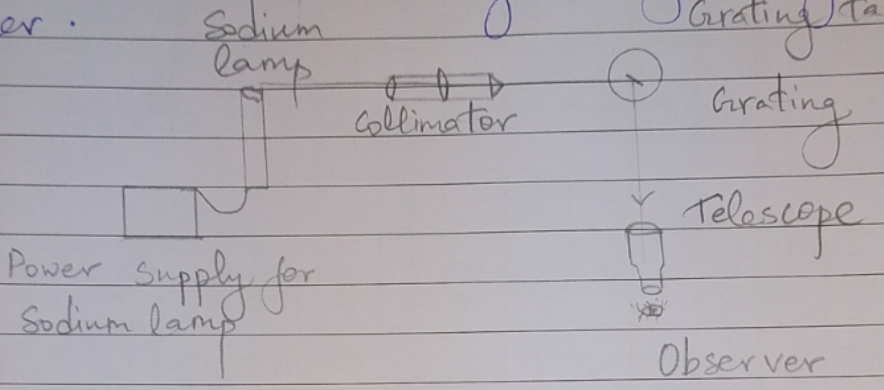

Fig 4

4. Rotate the turn table containing the grating till the reflected image of the slit is clearly obtained on the cross wire of the telescope. (In this position the grating is inclined at 45° to the incident light beam as shown in fig 4.

5. Note down the reading on circular scale and then turn the table from this position through 45° in a direction such that the grating is normal to the axis of the collimator and the ruled surface of grating is facing the telescope. Clamp the turn table in this position.

6. Unclamp and rotate the telescope to see first order as well as second order spectrum on either side of the direct slit image.

7. Rotate the telescope to see the first order image on the right hand side using the fine adjustment screw and move the telescope till the verticle cross wire just falls on first order image. Note the readings of the both verniers.

8. Set the telescope on first order image on the left hand side & note down the readings of both verniers.

9. The difference between corresponding readings on left and right side gives 2θ. Divide this reading in half to obtain the value of θ.

10. Repeat step no (vii) to (ix) for the second order image & find the angle of diffraction for second order image.

Observations:

Least count of spectrometer = 0.001 cm.

Number of lines per inch of grating, $n' = 15000$

Grating element $a+b = \frac{2.54}{n'} = 1.693 \times 10^{-4}$ cm

Observation table:

Readings of the V_1			Readings of V_2			Mean value of the θ
Image on the right hand side (θ_R)	Image on the left hand side (θ_L)	$\theta = \frac{\theta_R - \theta_L}{2}$	Image on the right hand side θ_R	Image on the LHS θ_L	$\theta = \frac{\theta_L - \theta_R}{2}$	
348°4'	304°7'	21°33'	168°8'	124°45'	21°41'	21°37'
347°10'	305°31'	20°49'	167°9'	125°39'	20°45'	20°47'

Calculations:

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

$$a+b = 1.693 \times 10^{-4}$$

$$\lambda_y = \frac{1.693 \times 10^{-4} \times 0.3683 \text{ cm}}{1}$$

$$\lambda_y = 0.6162 \times 10^{-6} \text{ m}$$

$$\lambda_y = 6162 \text{ Å m}$$

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$\lambda_y = 1.693 \times 10^{-4} \times 0.349$ cm

$= 0.5908 \times 10^{-4}$ cm

$\lambda_y = 5908\ \mathring{A}$ m

$\lambda_{avg} = 6035\ \mathring{A}$ m

Percentage error $= \left(\dfrac{6035-5893}{5893}\right) \times 100$

$= 2.4\%$

Precautions:

1. The telescope and the collimator must be set for parallel rays
2. The grating table should be leveled.
3. The experiment must be performed in a dark room.
4. The slit should be perfectly vertical and it should be made as narrow as possible.
5. The reading of both verniers should be read carefully (one can use and magnify and a lamp)
6. Never touch the ruled surface of gratings.
7. Grating should be adjusted such that the grating is in a vertical plane perpendicular to the axis of the collimator and telescope.
8. The grating should be mounted such that its ruled surface faces the telescope.

Result: The wavelength ~~det~~ of Sodium light determined using plane diffraction grating turns out to be $6035\ \mathring{A}$ m which is close to the true wavelength $5893\ \mathring{A}$ m by percentage error of 2.4%