SRM
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**DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY**
**SRM INSTITUTE OF SCIENCE AND TECHNOLOGY**

**18PYB101J - Electromagnetic Theory, Quantum Mechanics, Waves and Optics**
**Module-IV ( Waves and Optics) Lecture-7**

# *Fraunhofer Diffraction due to N-Slits (Grating) and Concepts of Diffraction grating*

# Fraunhofer Diffraction due to N-Slits (Grating)

- An arrangement consisting of large number of parallel slits of the same width and separated by equal opaque spaces is known as Diffraction grating
- Gratings are constructed by ruling equidistant parallel lines on a transparent material such as glass, with a fine diamond point.
- The ruled lines are opaque to light while the space between any two lines is transparent to light and acts as a slit.
- This is known as plane transmission grating.
- When the spacing between the lines is of the order of the wavelength of light, then an appreciable deviation of the light is produced.

# Fraunhofer Diffraction due to N-Slits (Grating)

## *Theory:*

- A section of a *plane transmission grating MN* placed perpendicular to the plane of the paper is as shown in the figure.

- Let *‘a’* be the width of each slit and *‘b’* the width of each opaque space.

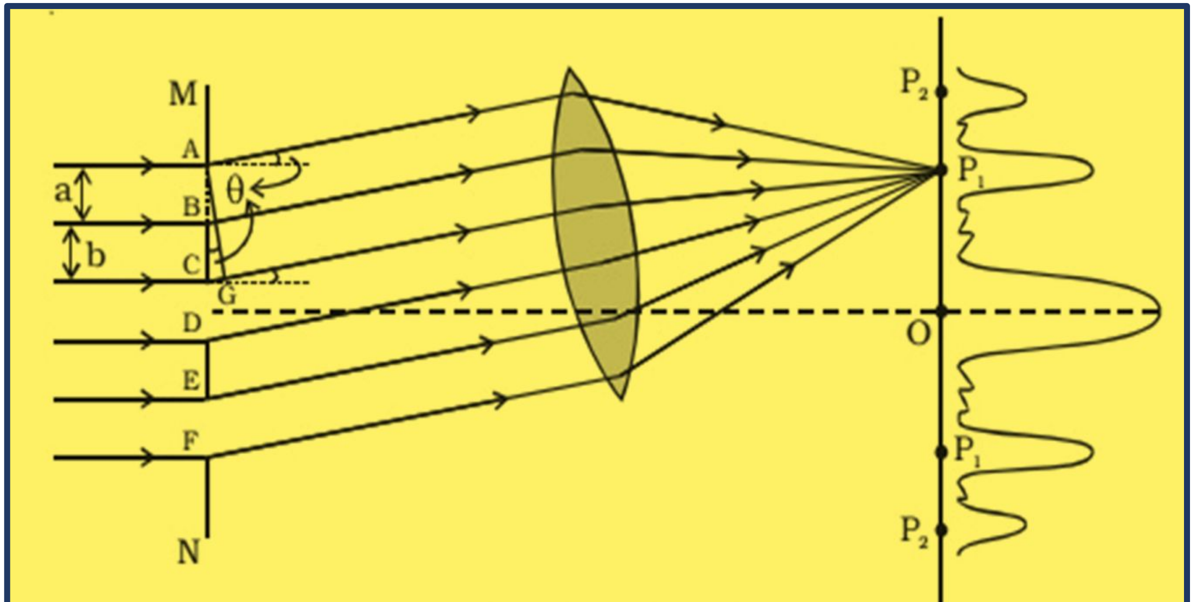



Figure: *Diffraction grating*

# Fraunhofer Diffraction due to N-Slits (Grating)

- MN represents the section of a plane transmission grating. AB, CD, EF … are the successive slits of equal width *a* and BC, DE … be the rulings of equal width b (Fig). Let e = *a*+*b*.

- Let a plane wave front of monochromatic light of wave length λ be incident normally on the grating.

- According to Huygen's principle, the points in the slit AB, CD… etc act as a source of secondary wavelets which spread in all directions on the other side of the grating.

- Let us consider the secondary diffracted wavelets, which makes an angle θ with the normal to the grating.

# Fraunhofer Diffraction due to N-Slits (Grating)

- The path difference between the wavelets from one pair of corresponding points A and C is CG = $(a+b)\sin\theta$. It will be seen that the path difference between waves from any pair of corresponding points is also $(a + b) \sin \theta$

- The point P1 will be bright, when

  $(a+b)\sin\theta = n\lambda$ where n = 0, 1, 2, 3

- $(a+b)\sin\theta = 0$, satisfies the condition for brightness for n=0. Hence the wavelets proceeding in the direction of the incident rays will produce maximum intensity at the centre O of the screen. This is called zero order maximum or central maximum.

## Fraunhofer Diffraction due to N-Slits (Grating)

- If $(a + b)\sin\theta_1 = \lambda$, the diffracted wavelets inclined at an angle $\theta_1$ to the incident direction, reinforce and the first order maximum is obtained.

- Similarly, for second order maximum, $(a+b)\sin\theta_2 = 2\lambda$

- On either side of central maxima different orders of secondary maxima are formed at the point P1, P2.

# Fraunhofer Diffraction due to N-Slits (Grating)

- In general, $(a+b)\sin\theta = n\lambda$ is the condition for maximum intensity, where n is an integer, the order of the maximum intensity.

$$Sin\theta = \frac{n\lambda}{a+b} \quad or \quad Sin\theta = Nn\lambda$$

- where N = 1/a+b , gives the number of grating element or number of lines per unit width of the grating
- In the undiffracted position, $\theta = 0$ and hence $\sin\theta = 0$.
- Therefore $\sin\theta = Nm\lambda$ is satisfied for m= 0 for all values of $\lambda$.

# Fraunhofer Diffraction due to N-Slits (Grating)

- Hence, at O all the wavelengths reinforce each other producing maximum intensity for all wave lengths. Hence an undispersed white image is obtained.

- As $\theta$ increases, $(a + b) \sin\theta$ first passes through $\lambda/2$ values for all colours from violet to red and hence darkness results.

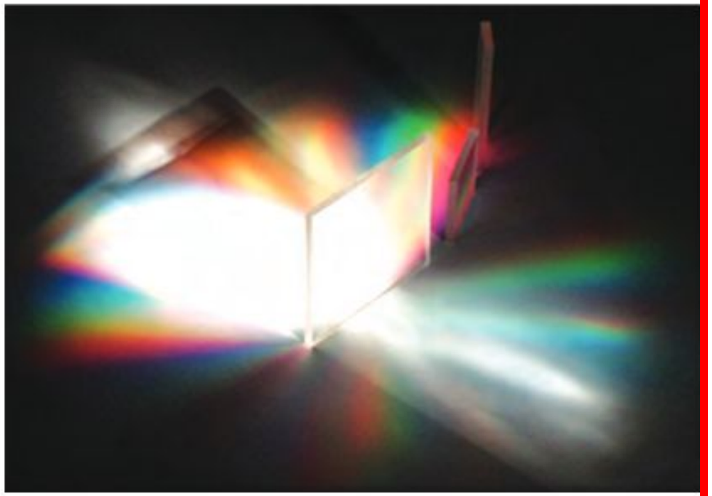
- As $\theta$ further increases, $(a + b) \sin \theta$ passes through $\lambda$ values of all colours resulting in the formation of bright images producing a spectrum from violet to red.

- These spectra are formed on either side of white, the central maximum.

# Concepts of Diffraction grating

A diffraction grating is an extremely useful device and in one of its forms it consists of a very large number of narrow slits side by side. The slits are separated by opaque spaces. When a wave front is incident on a grating surface, light is transmitted through the slits and obstructed by the opaque portions. Such a grating is called a **transmission grating**. The secondary waves from the

positions of the slits interfere with one another, similar to the interference of waves in Young's experiment. Joseph Fraunhoffer used the first grating which consisted of a large number of parallel fine wires stretched on a frame. Now, gratings are prepared by ruling equidistant parallel lines on a glass surface. The lines are drawn with a fine diamond point. The space in between any two lines is transparent to light and the lined portion is opaque to light. Such surfaces act as transmission gratings. If, on the other hand, the lines are drawn on a silvered surface (plane or concave) then light is reflected from the positions of the mirror in between any two lines and such surfaces act as *reflection gratings*.



Transmission grating.

# Concepts of Diffraction grating

If the spacing between the lines is of the order of the wavelength of light, then an appreciable deviation of the light is produced. Gratings used for the study of the visible region of the spectrum contain 10,000 lines per cm. Gratings, with originally ruled surfaces are only few. For practical purposes, replicas of the original grating are prepared. On the original grating surface a thin layer of collodion solution is poured and the solution is allowed to harden. Then, the film of collodion is removed from the grating surface and then fixed between two glass plates. This serves as a plane transmission grating. A large number of replicas are prepared in this way from a single original ruled surface.

Reflection grating images.