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MIT WORLD PEACE UNIVERSITY | PUNE
TECHNOLOGY, RESEARCH, SOCIAL INNOVATION & PARTNERSHIPS

Engineering Physics (FYBTech)

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Diffraction

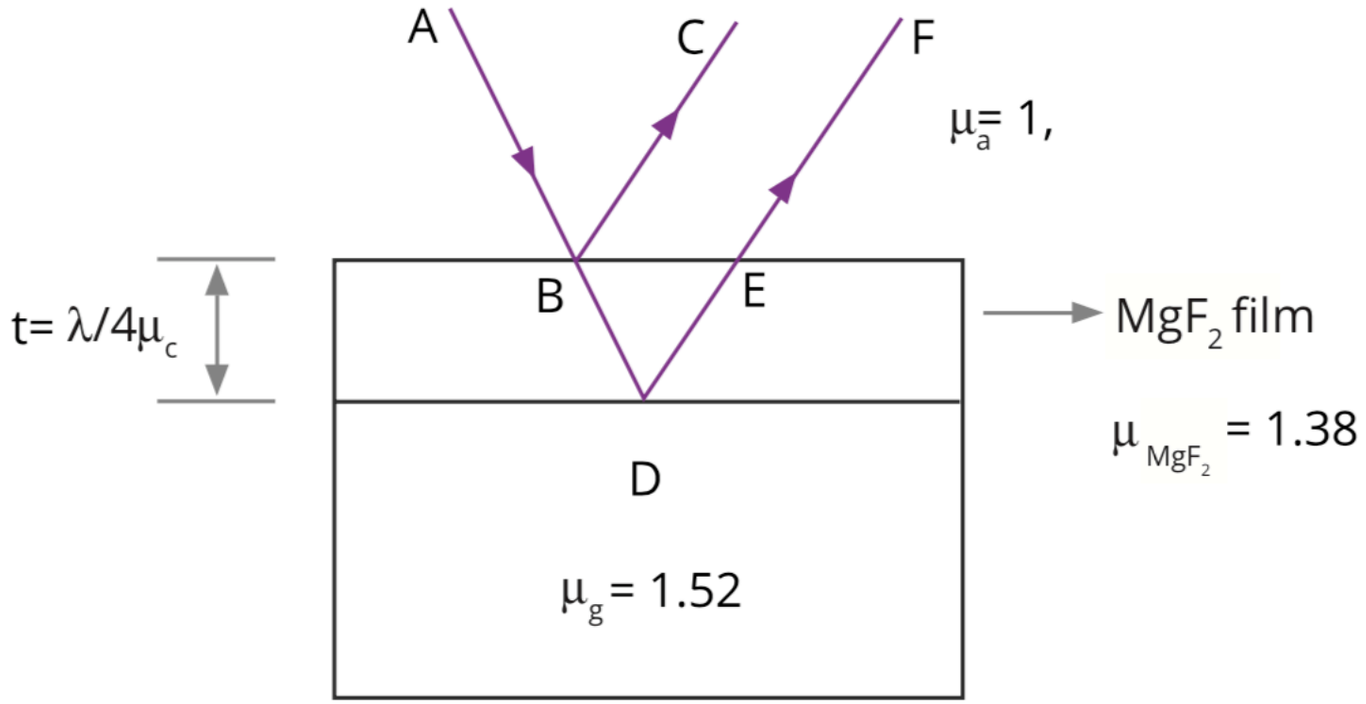
Content:

- Anti Reflection Coating and its Application
- Importance of diffraction in Engineering and Technology
- Fraunhofer diffraction at single slit
- Conditions for maxima and minima
- Diffraction grating, its properties and uses

Reference Books

1. Fundamentals of Physics Extended, David Halliday, Robert Resnick, Jearl Walker,, John Wiley & Sons
2. The Feynman Lectures on Physics (3 Volume Set), by Richard Phillips Feynman (Author), Robert B. Leighton (Contributor), Matthew Sands (Contributor), The New Millennium Edition, Pearson Education India
   - Excellent websites on this book
     i. www.feynmanlectures.caltech.edu/
     ii. www.feynmanlectures.info/
3. A Textbook of Engineering Physics, M N Avadhanulu & P G Kshirsagar, 1oth Edition, S. Chand and Company
4. Fundamentals of Optics, by Francis Jenkins, Harvey White , Tata Mcgraw Hill Publishing Co Ltd
5. Optics, Ajoy K. Ghatak, 5th Edition, McGraw Hill Education,
6. Optics, Eugene Hecht, 4th edition, Addison-Wesley
7. M. Born and E. Wolf, Principles of Optics, Cambridge University Press
8. A Text Book Of Optics, Brijlal, Dr. N. Subrahmanyam, Dr. M. N. Avadhanalu, 25th Edition, S. Chand and Company

Anti-Reflection Coating

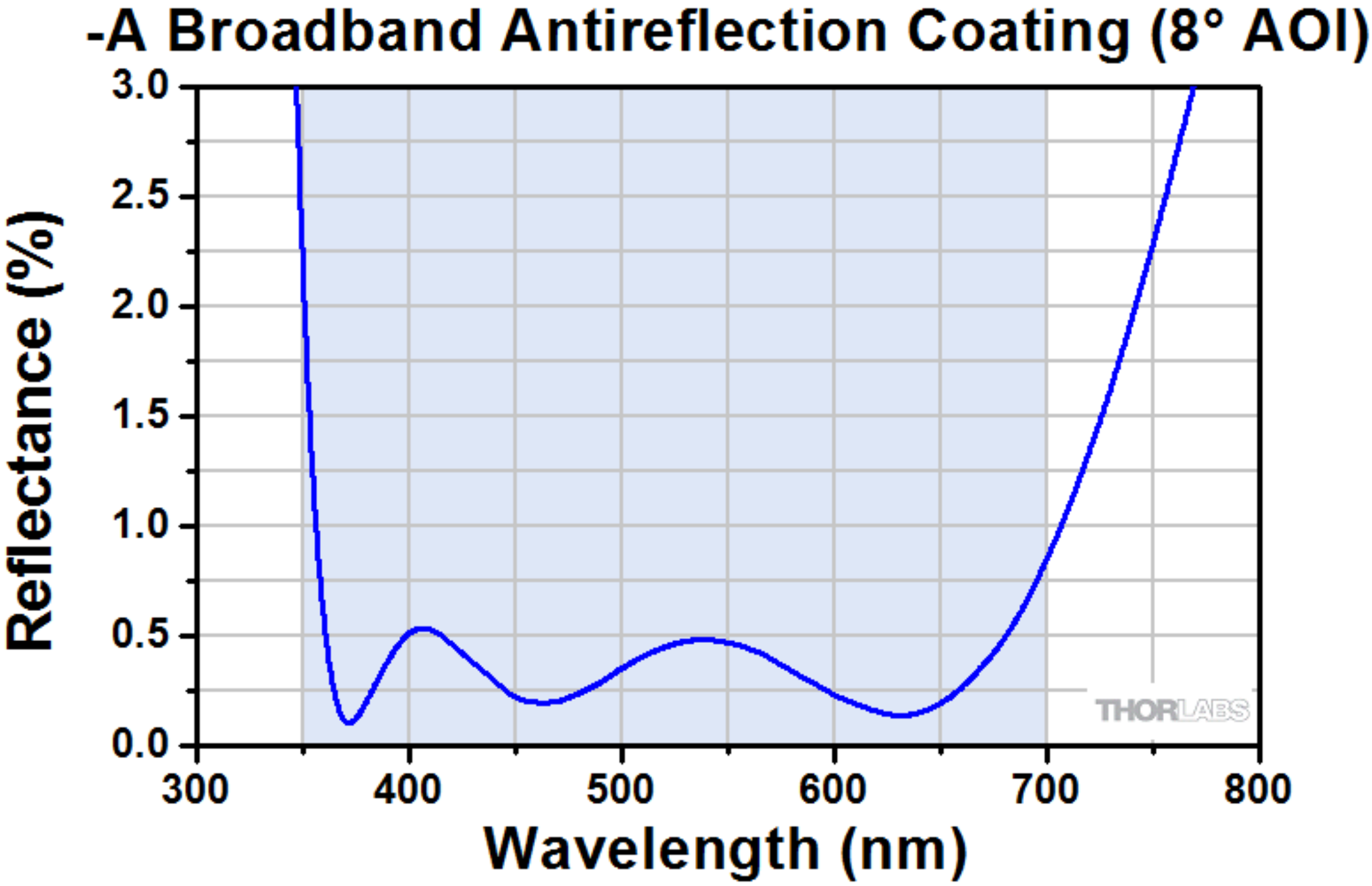


- When light falls on camera then some light gets reflected back it decreases the quality of image.
- Thus, it is necessary to reduce the reflection to improve quality of an image.
- The anti-reflection coating is used in cameras, projector lens, telescopes etc, to reduce loss of light by reflection.

$$t_{ARC} = \frac{\lambda}{4\mu}$$

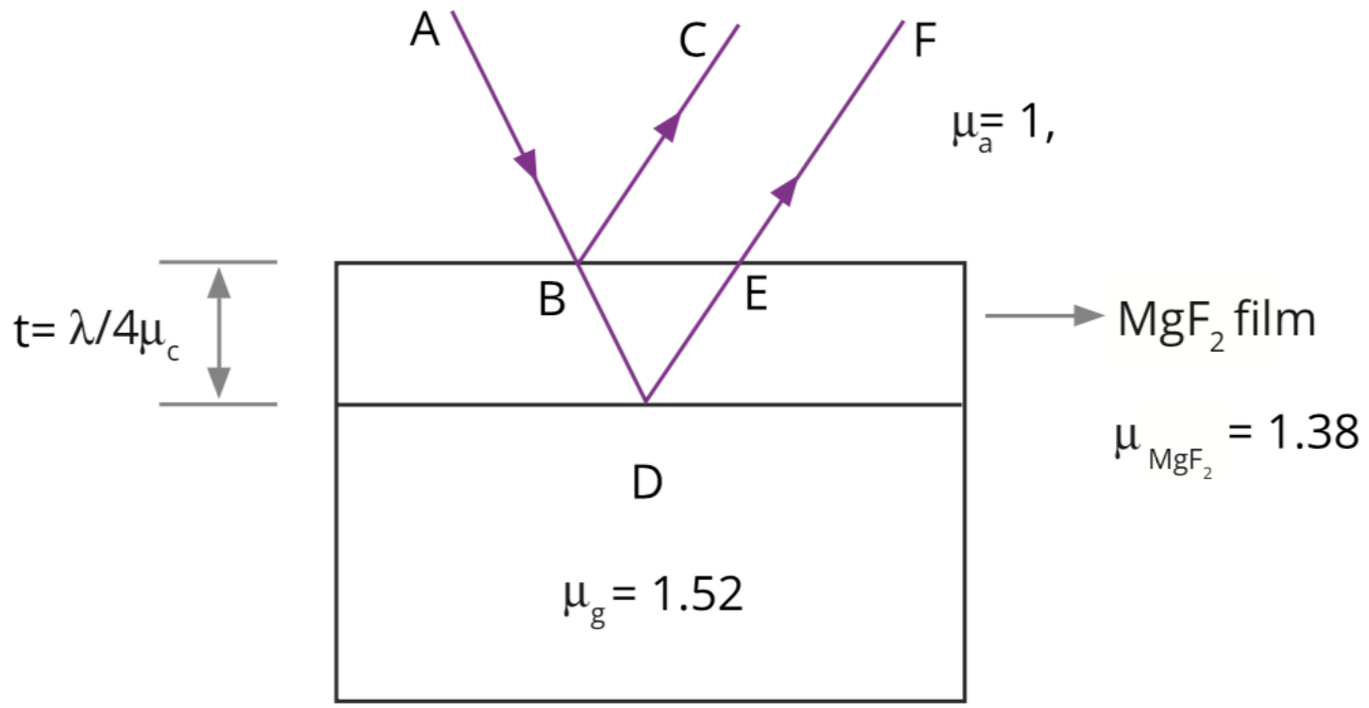
- Thus, the thickness of anti-reflecting coating can be determined by the above formula.

Anti-Reflection Coating



Anti-Reflection Coating

Anti-transmission/High-Reflection Coating



- Reflecting thin film coated on the substrate
- Thin film should be denser than substrate
- Constructive interference between the reflected rays will make the film more reflective
- Thickness of anti transmission coating

$$t_{ATC/HRC} = \frac{\lambda}{4\mu}$$

Diffraction

- The word ‘diffraction’ is derived from the Latin word “diffractus” which means to break into pieces. “The phenomenon of bending of light round the corners of an obstacle and resulting into geometrical shadow (of an object) is called diffraction”.
- Diffraction is the slight bending of light as it passes around the edge of an object.
- The amount of bending depends on the relative size of the wavelength of light to the size of the opening through which the light is passing.
- If the opening is much larger than the light’s wavelength, the bending will be almost un-noticeable. However, if the two are closer in size or equal, the amount of bending is considerable, and easily seen with the naked eye.
- Optical effects resulting from diffraction are produced through the interference of light waves.

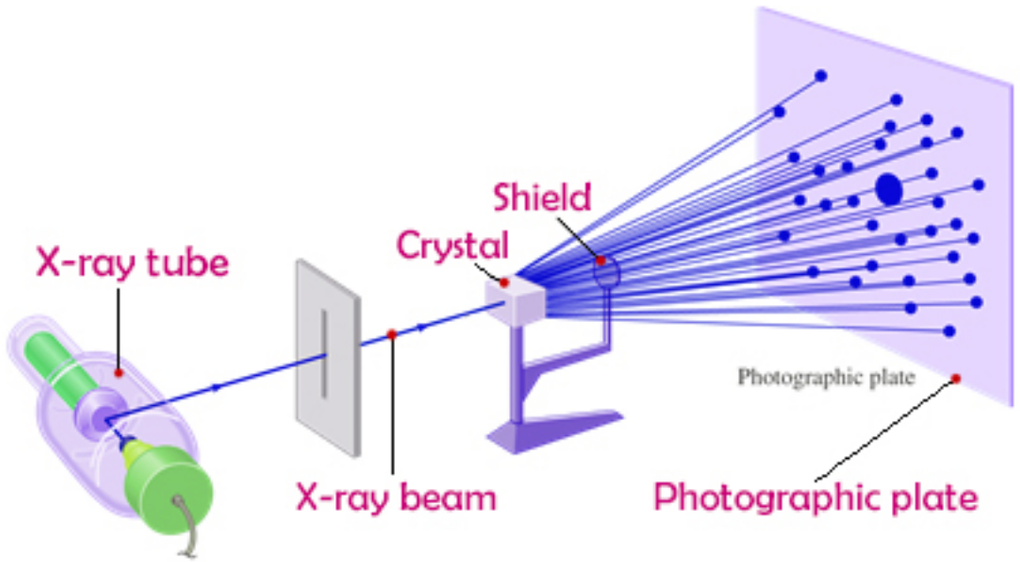
Light at the edges of the door

Red sun during sunset

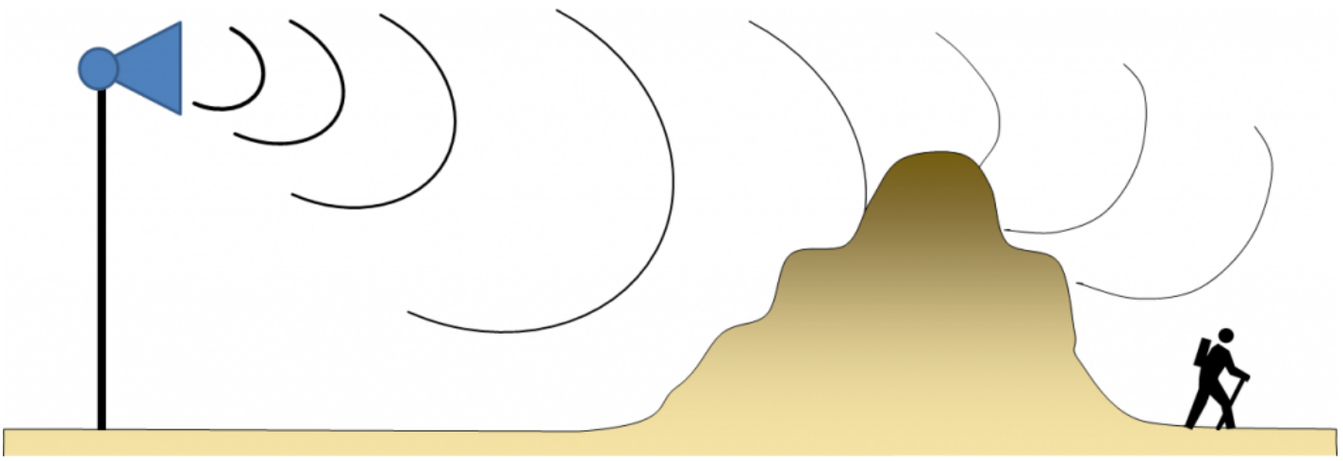
CD Colour

Other examples of Diffraction

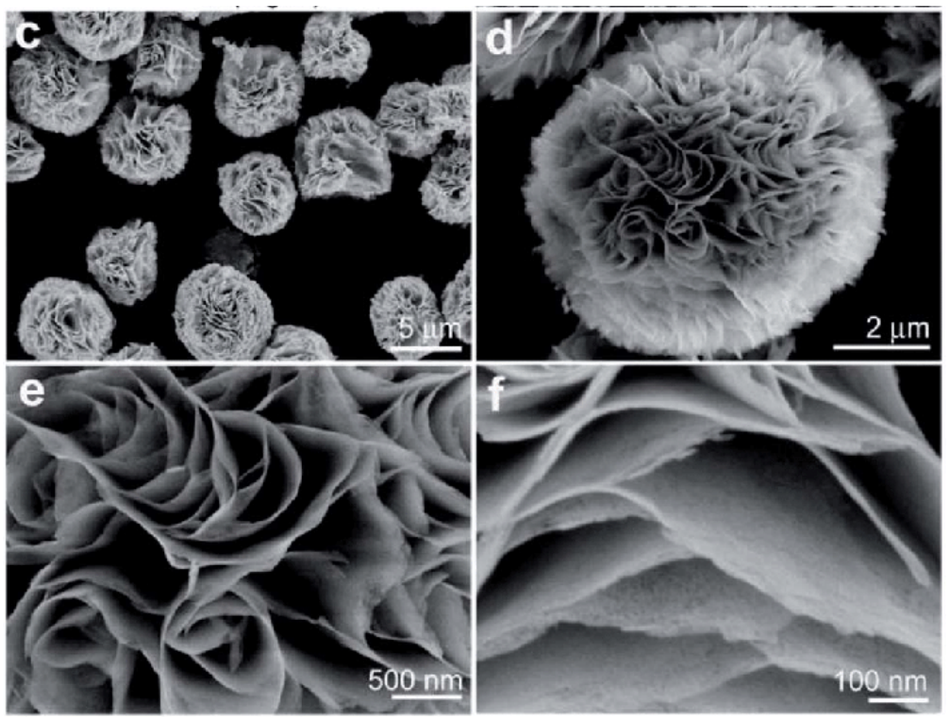
Water diffraction



X-ray Diffraction



Sound diffraction



Electron Diffraction

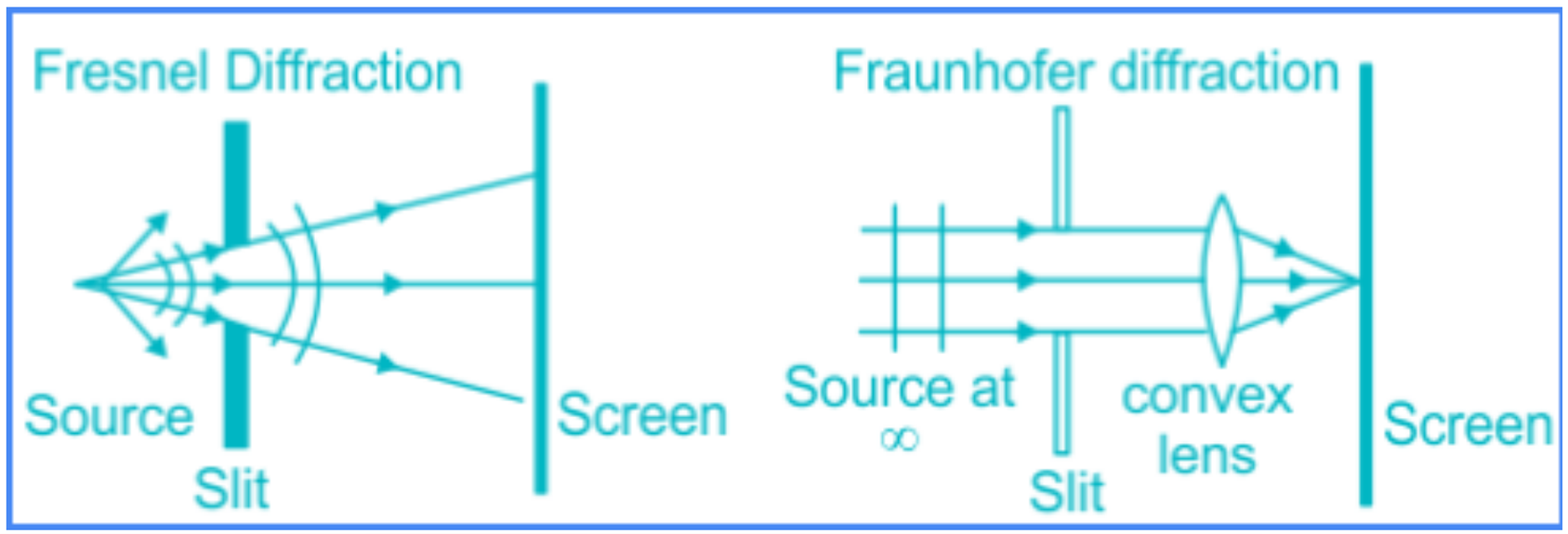
Types of Diffraction

Fraunhofer Diffraction

- The diffraction in which, the distance between source and screen is infinite from the diffracting element is called Fraunhofer diffraction.
- So, a pair of lenses is required in this diffraction. One is to convert that all light into a parallel beam coming from a source to obstacle and other to focus the parallel diffracted rays on a screen.

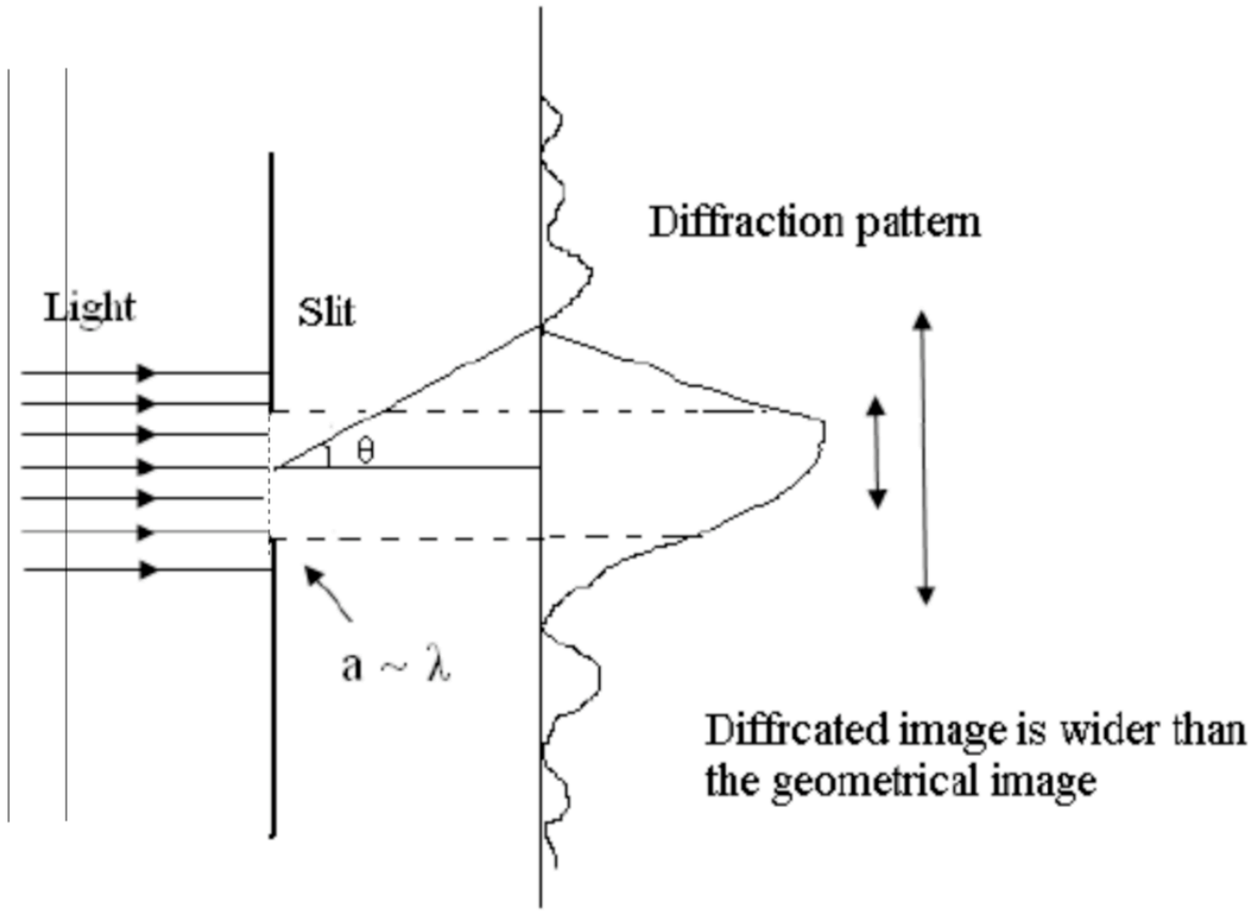
Fresnel Diffraction

- The diffraction in which, the distance between source and screen is finite from a diffracting element is called Fresnel diffraction.
- Due to finite distance, lenses are not required in this diffraction.



Diffraction due to Single Slit

When a wavefront is obstructed by a slit, diffraction takes place and a diffraction is produced .

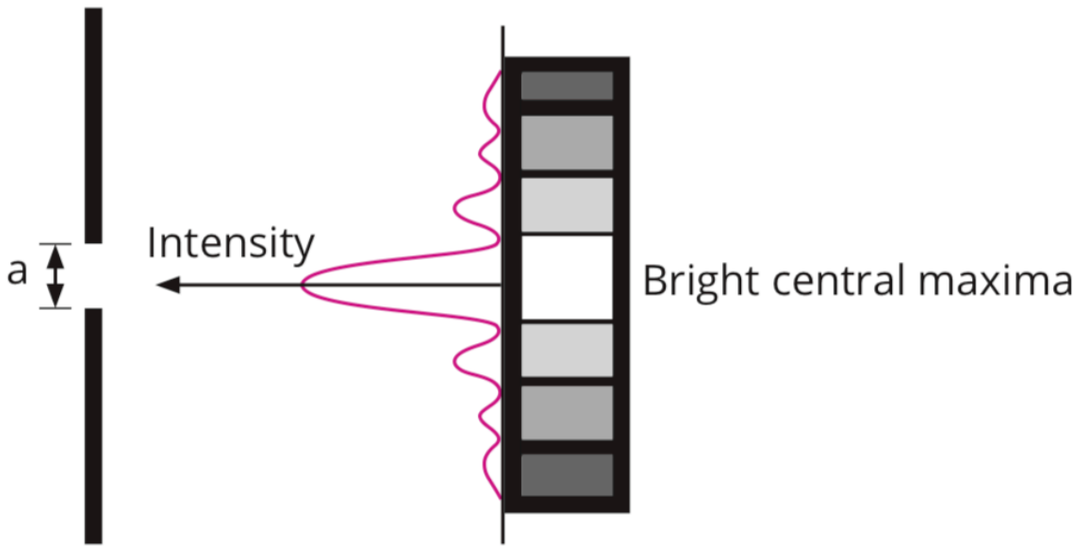


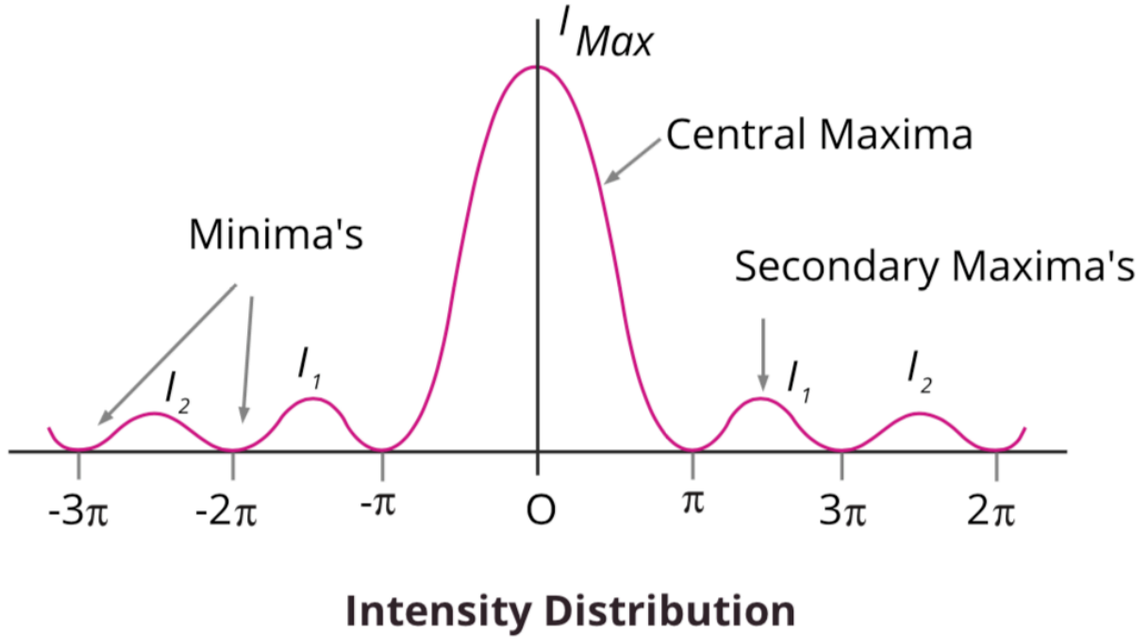
Huygen's Explanation:

- When a wavefront passes through a slit every point in the slit becomes a source of secondary wavelets
- These wavelets generates waves which propagate in all directions.
- The waves originating from secondary wavelets, undergo superposition and result in a pattern of maxima and minima called diffraction

Diffraction due to Single Slit

When a wavefront is obstructed by a slit, diffraction takes place and a diffraction is produced .





Intensity Distribution

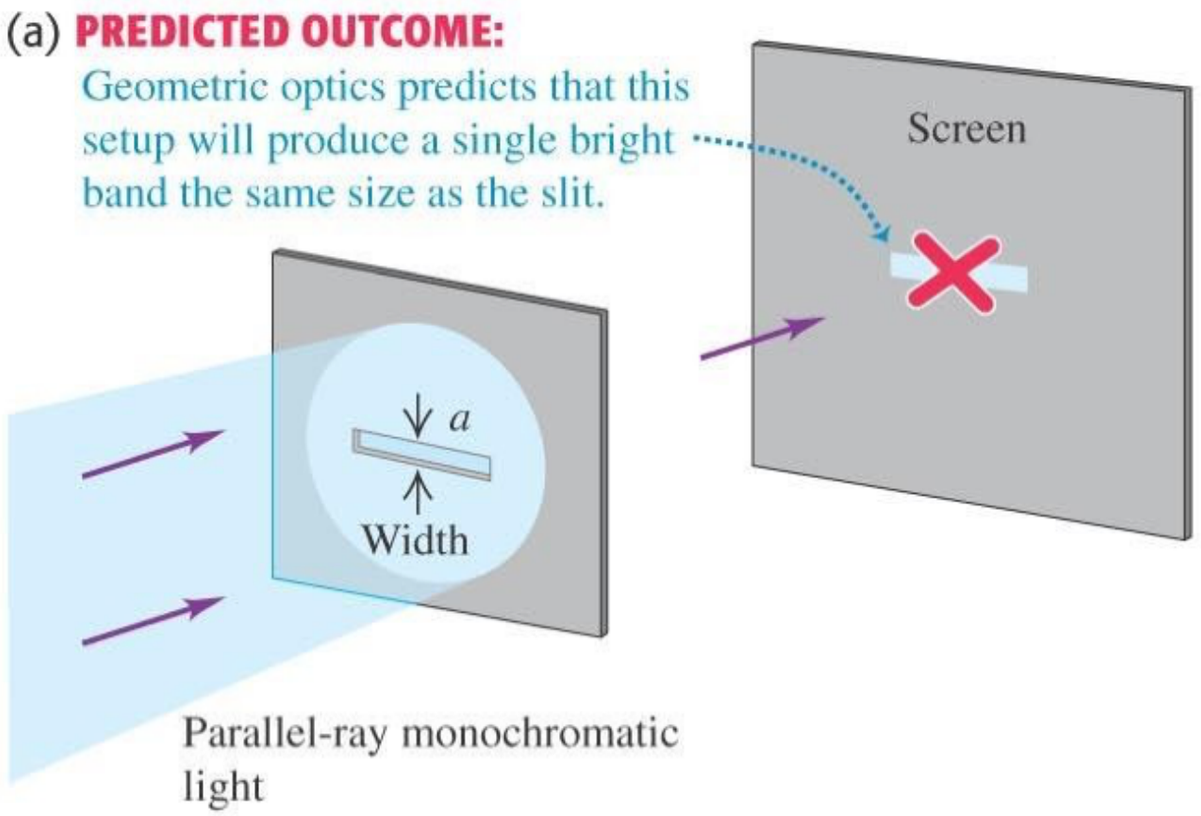
Condition for Maxima and Minima

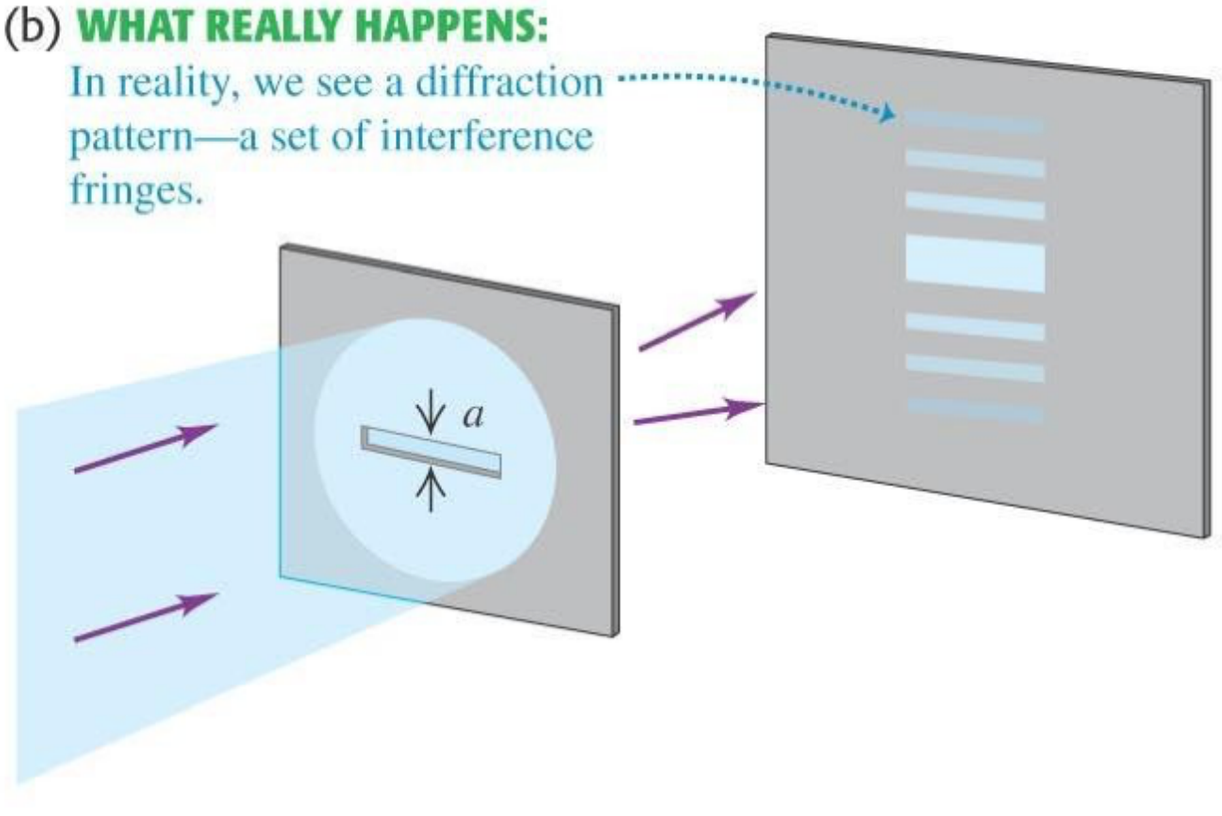
Type of maxima/minima	Intensity	α	θ
Central maximum,	$I_\theta = I_m,$	$\alpha = 0^o,$	$\theta = 0^o$
Minima,	$I_\theta = 0,$	$\alpha = m\pi,$	$asin\theta = m\lambda$
Secondary maxima	I_θ : very small,	$\alpha = \left(m + \frac{1}{2}\right)\pi,$	$asin\theta = \left(m + \frac{1}{2}\right)\lambda$

$$I_\theta = I_m \left(\frac{sin\alpha}{\alpha}\right)^2$$

$$\alpha = \pi \frac{a}{\lambda} sin\theta$$

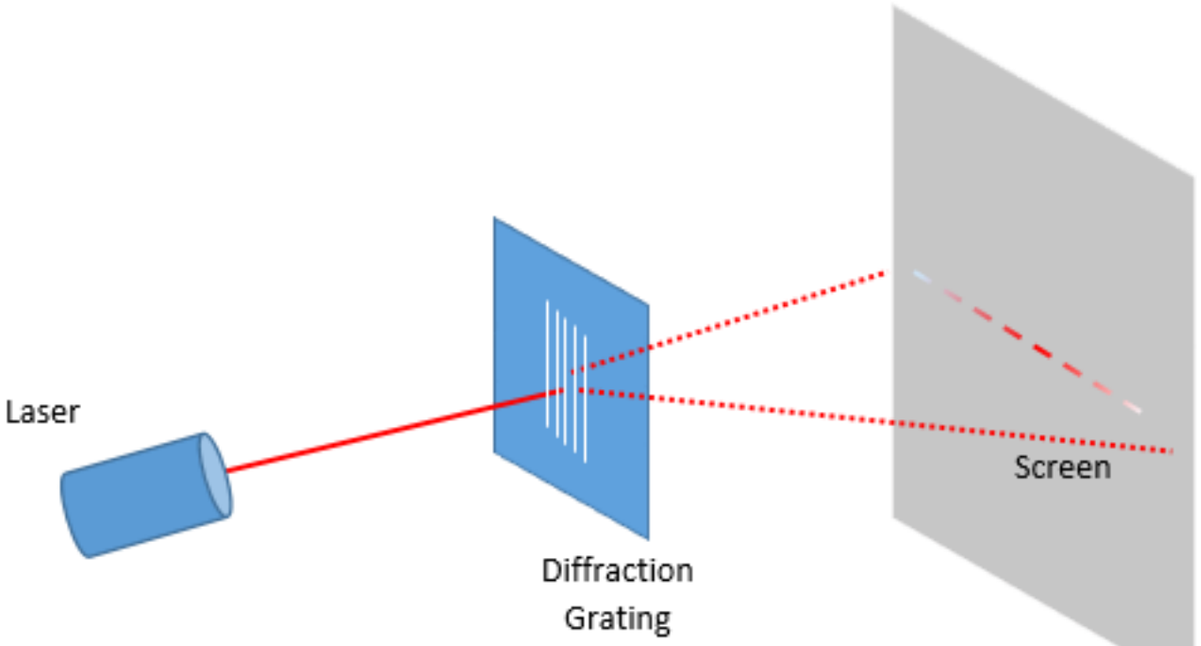
Realisation of Diffraction in Single Slit



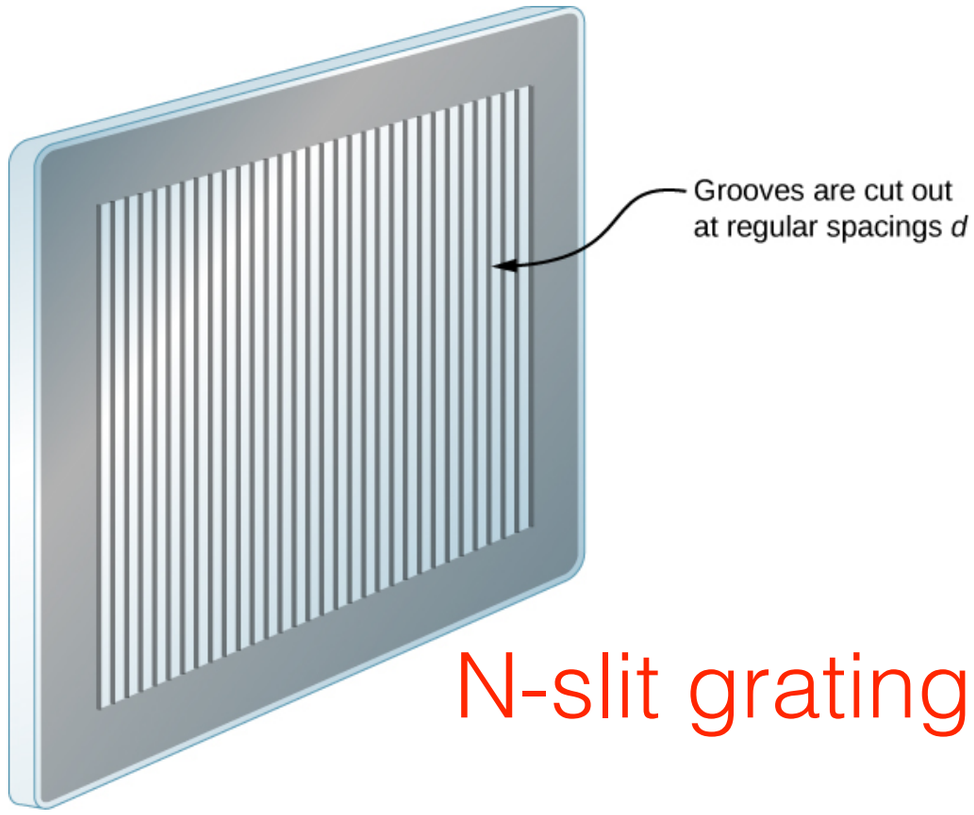


Diffraction shows/confirms that the light have a wave nature

Diffraction in Grating



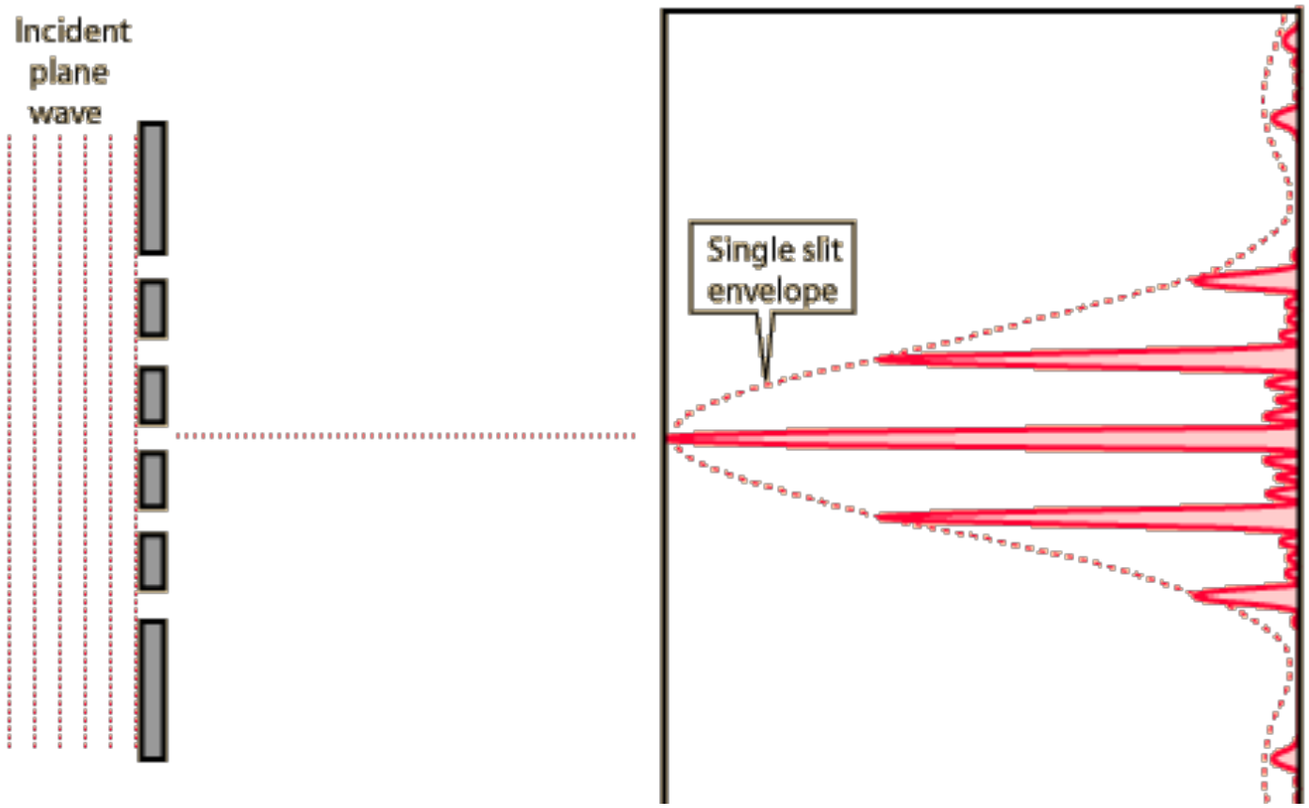
N-slit grating



N-slit grating

- Instead of using a single slit, we can used N no of equally placed slit.
- It is used to overcome demerits of single slit.
- Due to this, Maxima becomes more sharp and bright.
- Several secondary maxima are introduced between the consecutive maxima
- In a system of N slits, at (N-1) minima and at (N-2) Secondary maxima were formed

Diffraction in N-slit Grating

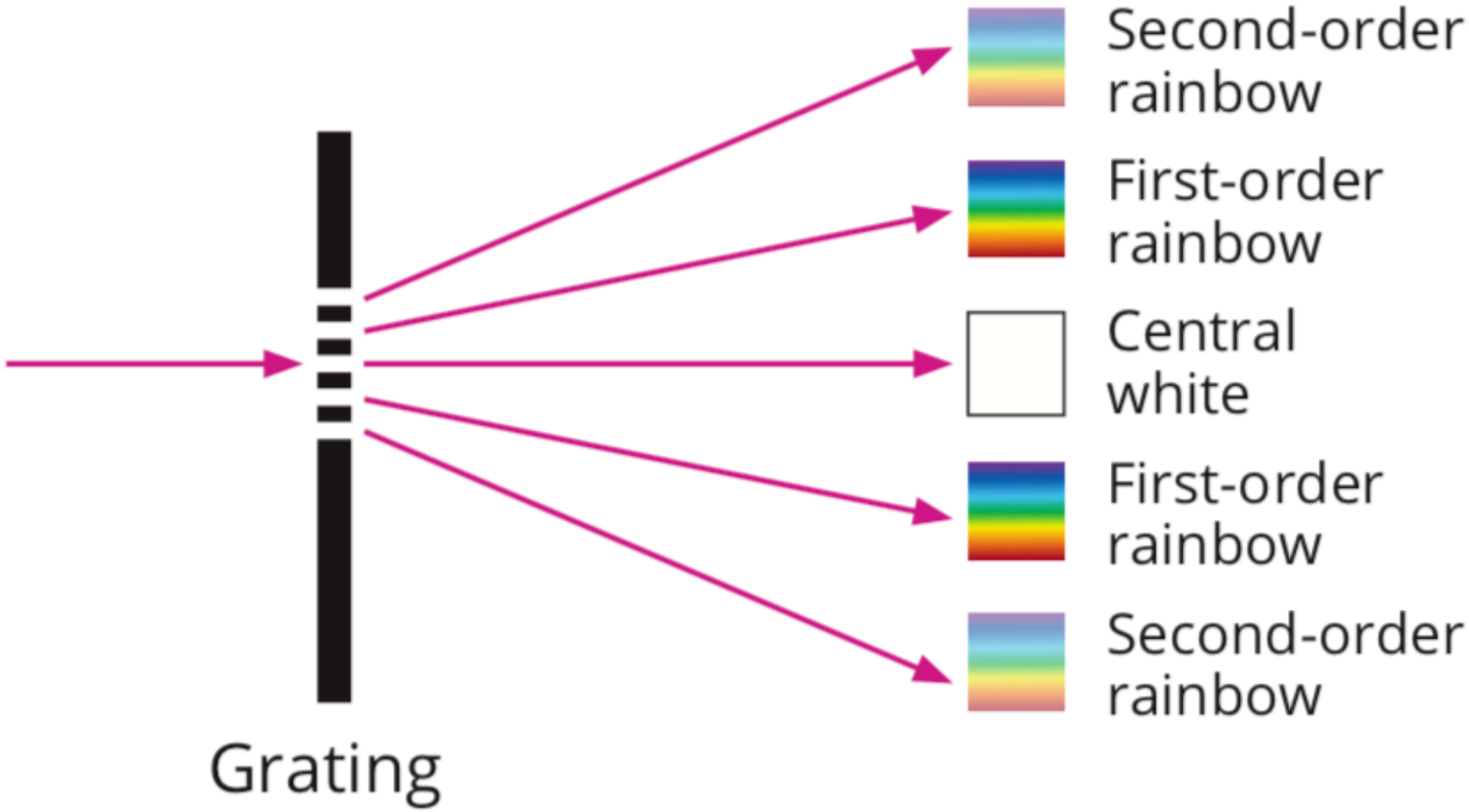


d=grating element
N=total no of slit
m=order of the spectrum
θ=Diffracted angle
$\beta=(\Pi/\lambda).d.\sin\theta$

Position of Maxima and Minima in Multiple slits

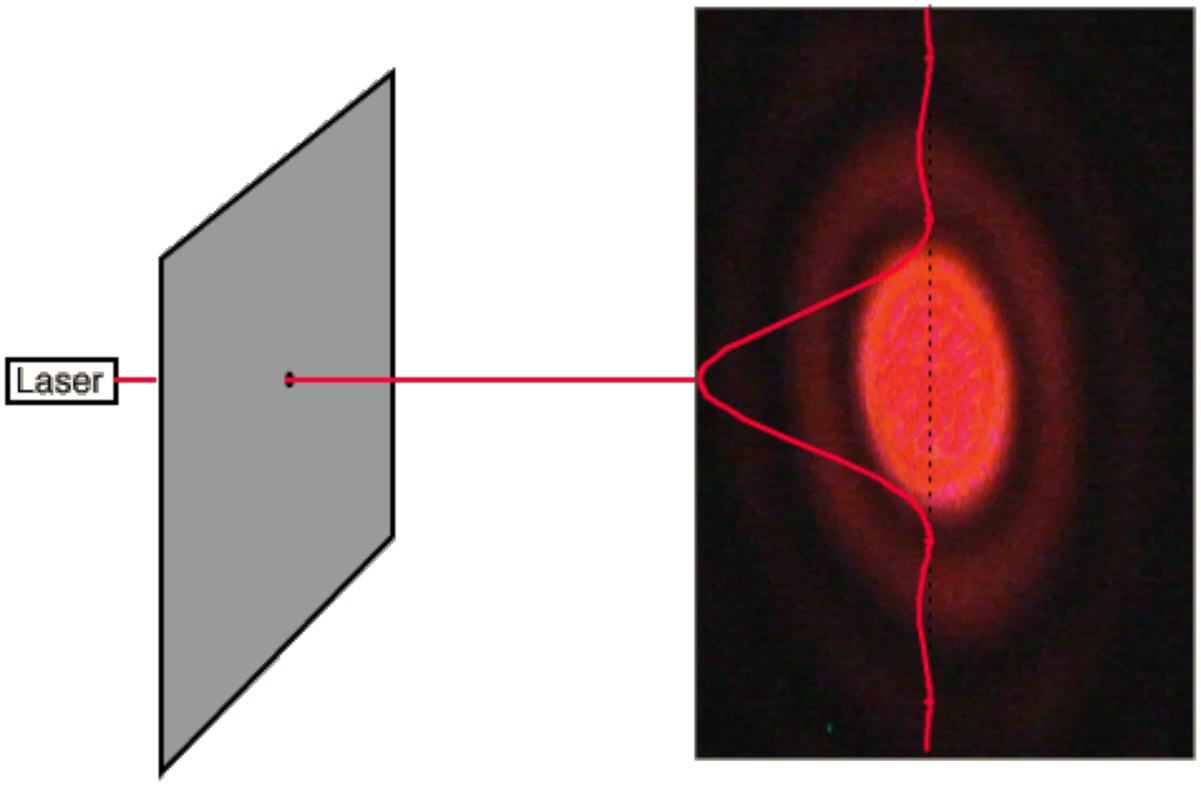
Type of maxima/minima	Intensity	β	θ
Principle maxima	$I_\theta = N^2 I_m \left(\frac{sin\alpha}{\alpha}\right)^2$	$\beta = m\pi$	$dsin\theta = m\lambda$
Minima,	$I_\theta = 0$	$N\beta = m'\pi$	$dsin\theta = \frac{m'}{N}\lambda, (m' \neq mN)$

N-Grating Diffraction with White Light

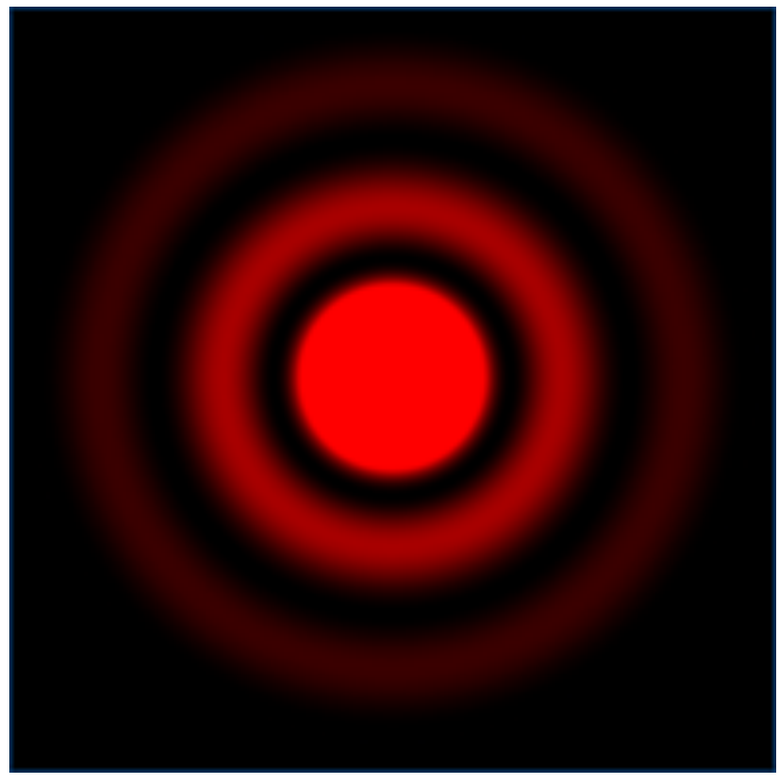


White light is having rainbow, and we will have several set of rai

Diffraction by Circular Aperture



Circular Aperture Diffraction



Airy's Discs

- This diffraction pattern is just like rotating the intensity distribution graph of single slit diffraction above central axis passing through P which traces the circular aperture perfectly symmetrical.
- This produces a diffraction pattern due to circular aperture produces central bright disc's (Airy's disc) surrounded by alternate dark and bright Airy rings.
- The diffraction pattern consisting of a central bright disc surrounded by bright and dark rings. The central bright disc is often called Airy's Disc.

Resolving Power of Grating

- The ability of the instrument to produce just separate diffraction pattern of two close objects is known as its resolving power.

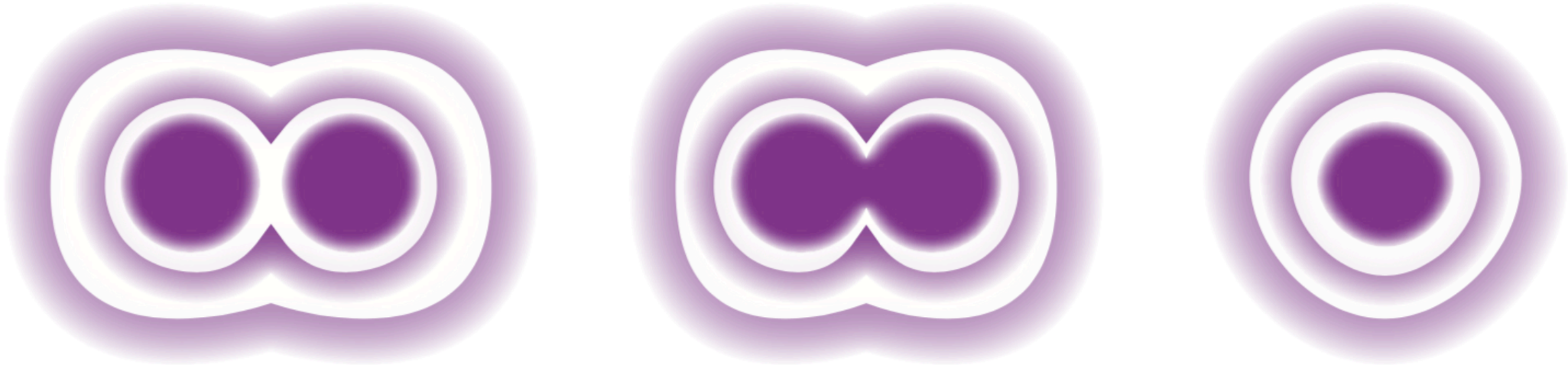
$$R.P = \frac{\lambda}{d\lambda} = nN$$

- It is the ability of the instrument to discriminate wavelength λ and λ+dλ
- If dλ tends to Zero, spectral lines overlap with each other.
- By increasing number of lines sharpness and resolution will be increased

can be resolved, if the principal maximum corresponding to wavelength λ+dλ falls on the first mi

Rayleigh's Criteria for Resolution

- Monochromatic light passing through a small circular aperture produces diffraction pattern. The effect of passing light through a small circular aperture is shown in the picture below.



Just resolved | Well resolved | Un-resolved

- Instead of a bright spot with sharp edges, we obtain a spot with a fuzzy edge surrounded by circles of light. This pattern is caused by diffraction.

Rayleigh's Criteria for Resolution

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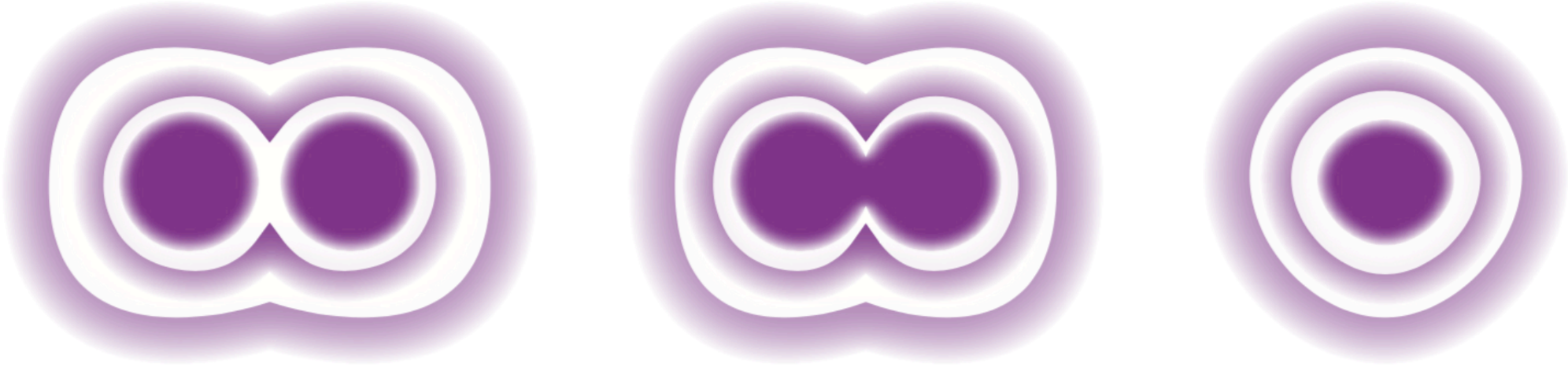
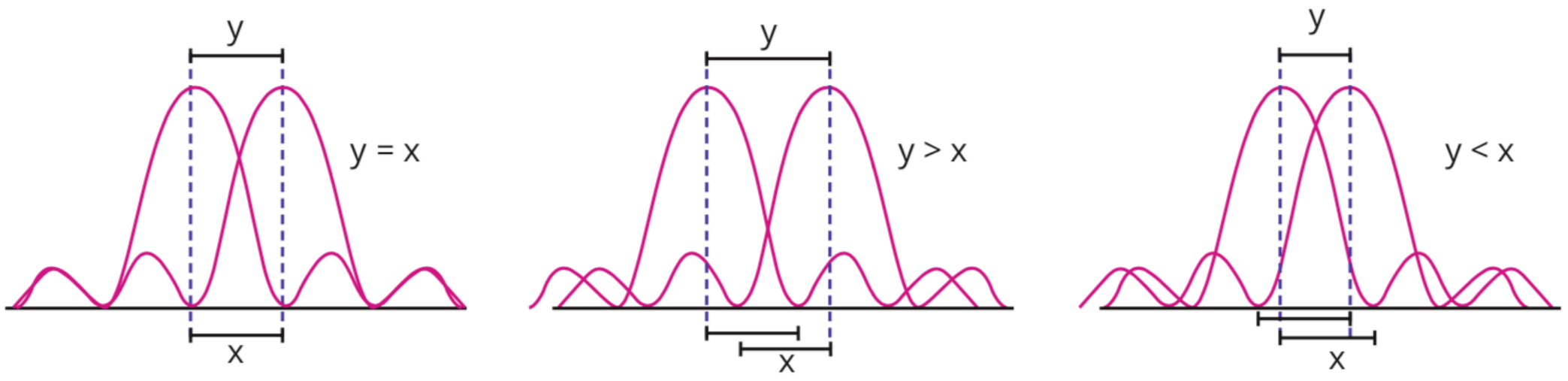


Just resolved | Well resolved | Un-resolved

- The Rayleigh criterion states that two closely spaced point sources are just resolved by an optical instrument only if central maximum in the diffraction pattern of one coincide the first minimum in the diffraction pattern of the other and vice-versa.

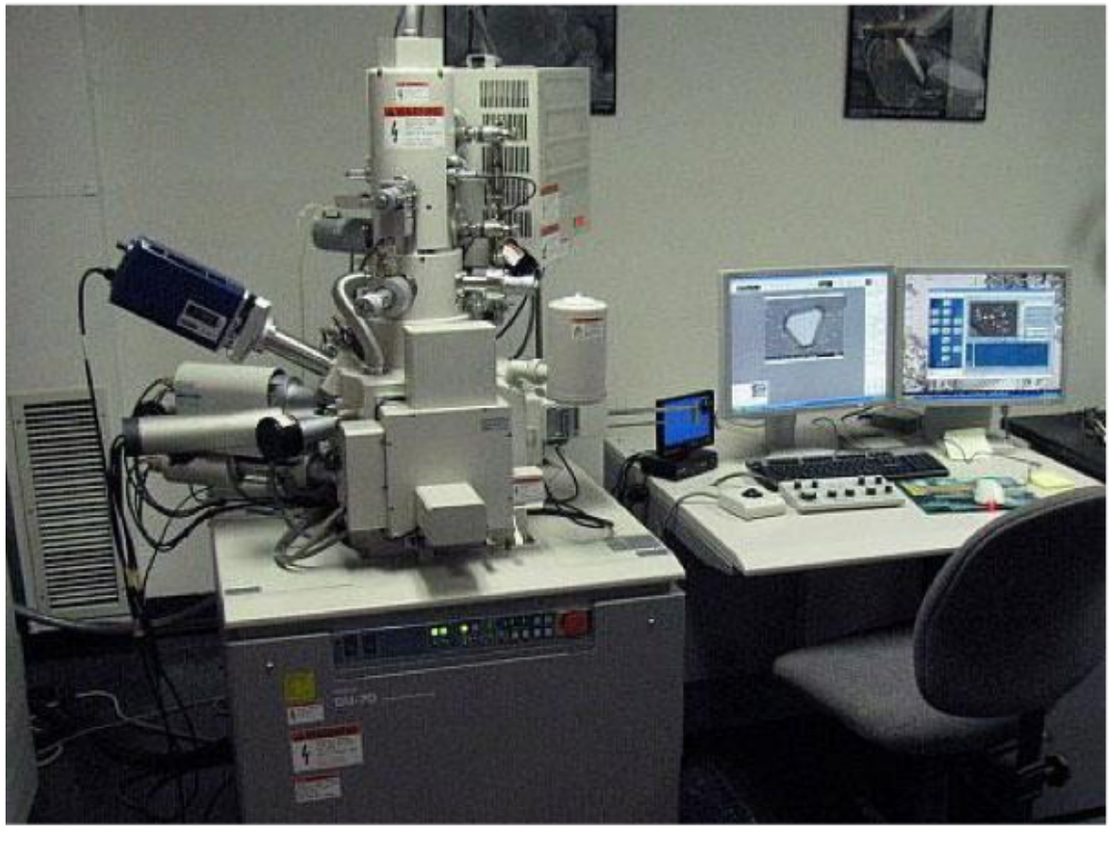


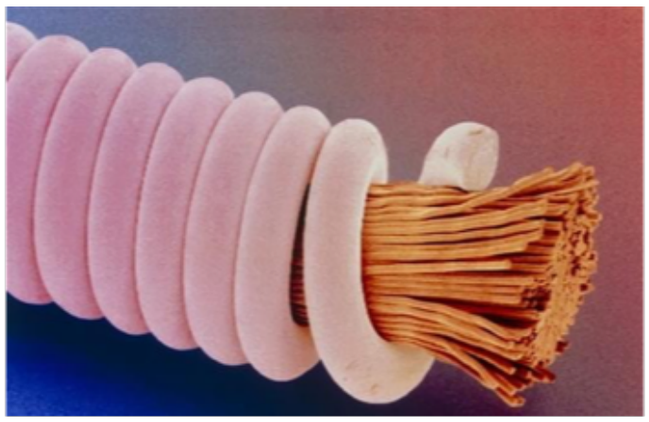
Just resolved | Well resolved | Un-resolved

Applications of Diffraction

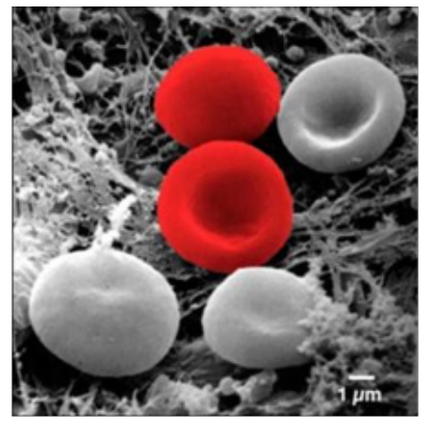
Why electron microscope is incredibly superior to Optical microscope?

In electron microscope, electrons are used for imaging instead of light. the wavelength of electrons is extremely small (100000 times) as compared to light. Therefore they are incredible superior to optical microscope

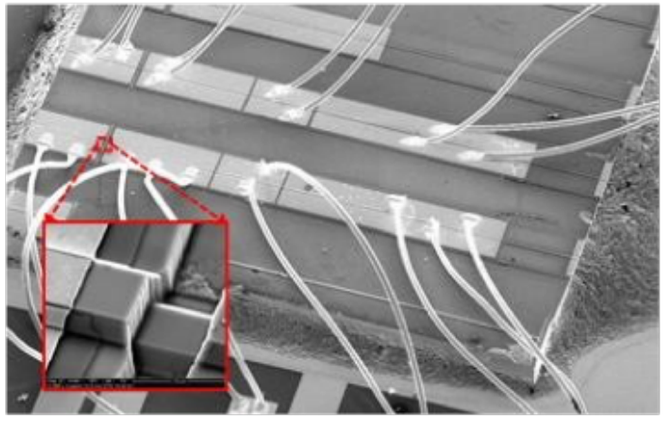




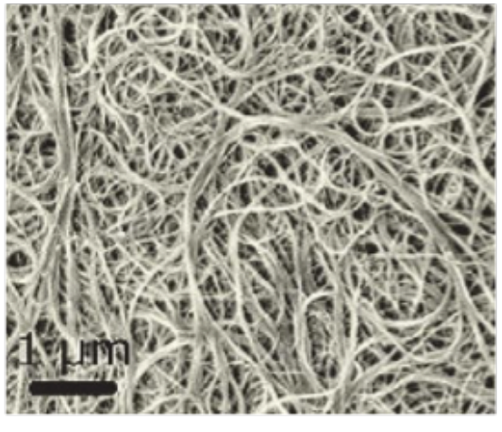
String of a guitar



Blood cells



Integrated circuit



Carbon Nanotubes

Applications of Diffraction

Why multi-array telescopes and radars have enhanced resolving power?

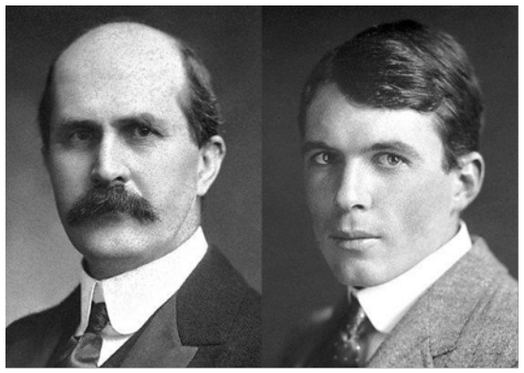
26 huge antennas at in GMRT

VLA at New Mexico. The images from the telescopes interfere constructively when the condition $dsin\theta = m\lambda$ is satisfied

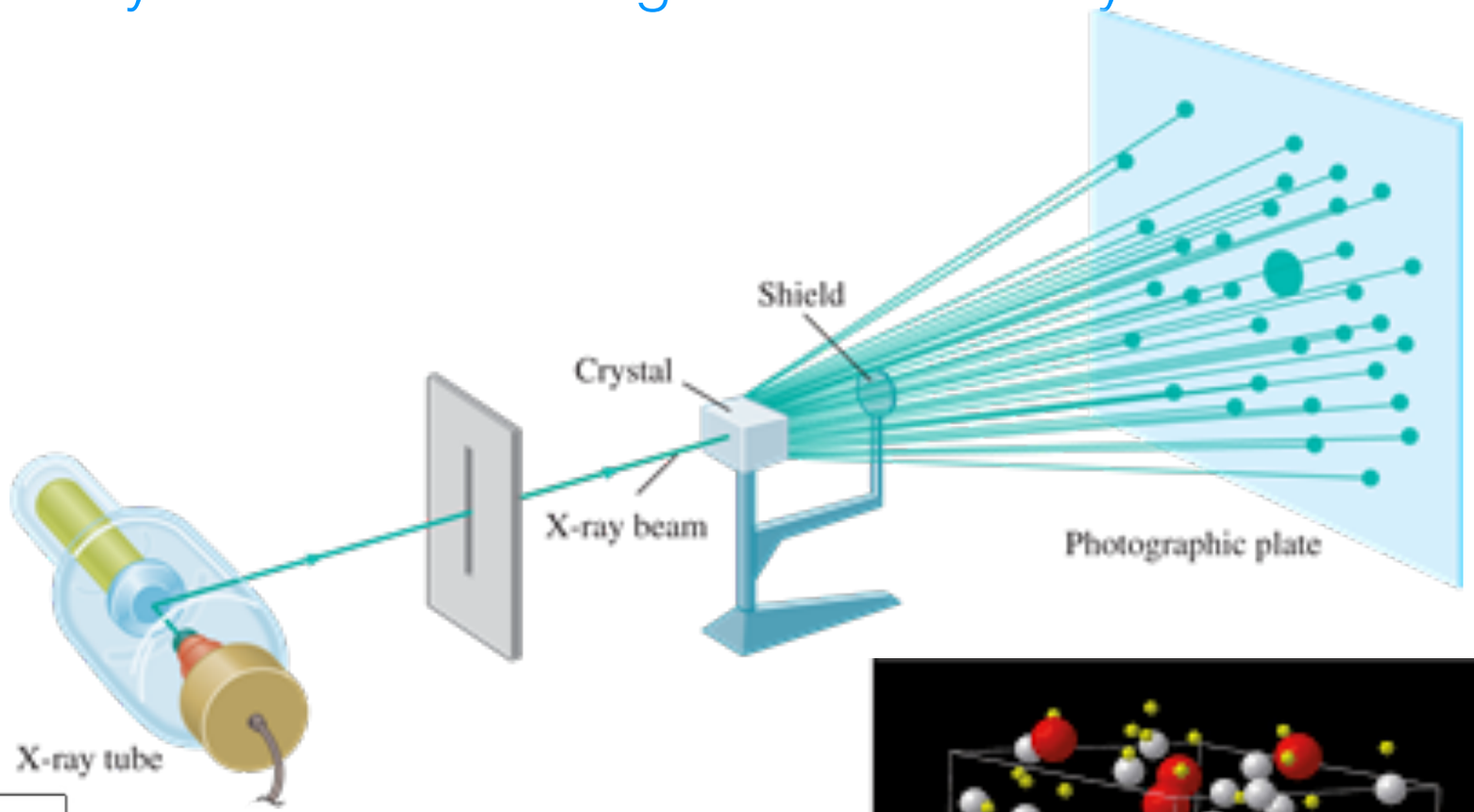
Why a multi-slit diffraction grating has better resolving power than a single slit? Images become sharp. Same is the reason here

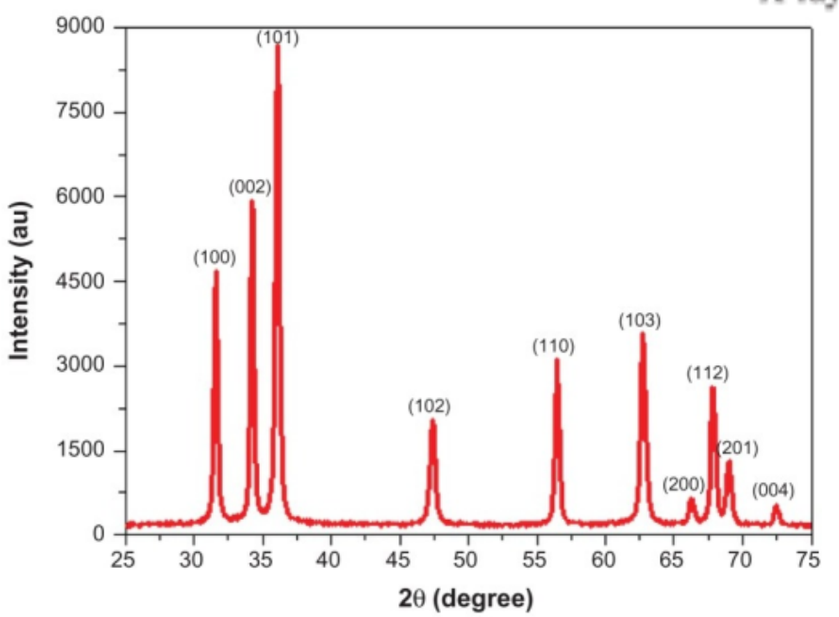
X-ray Diffraction

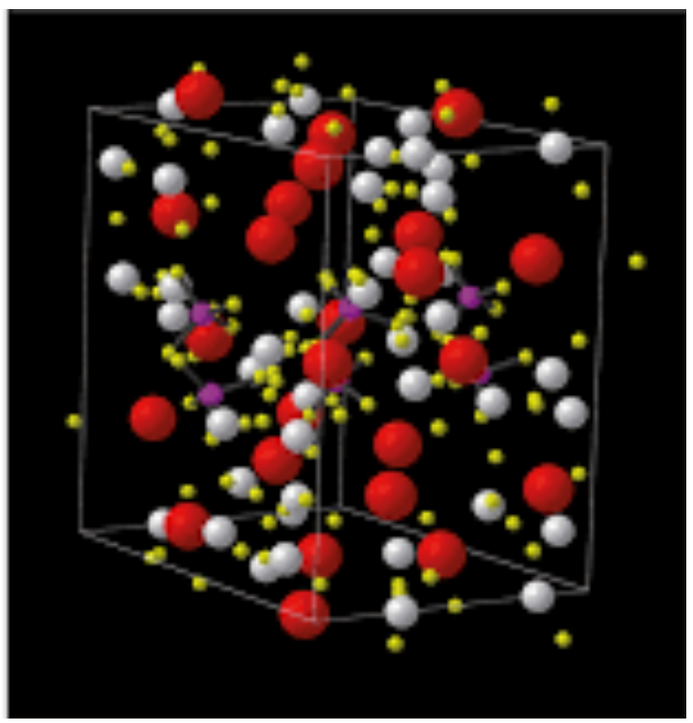
X-ray diffraction can able to study the atomic arrangement in the crystalline structure



William Bragg and
Lawrence Bragg,
NobelPrize 1915







Thank You