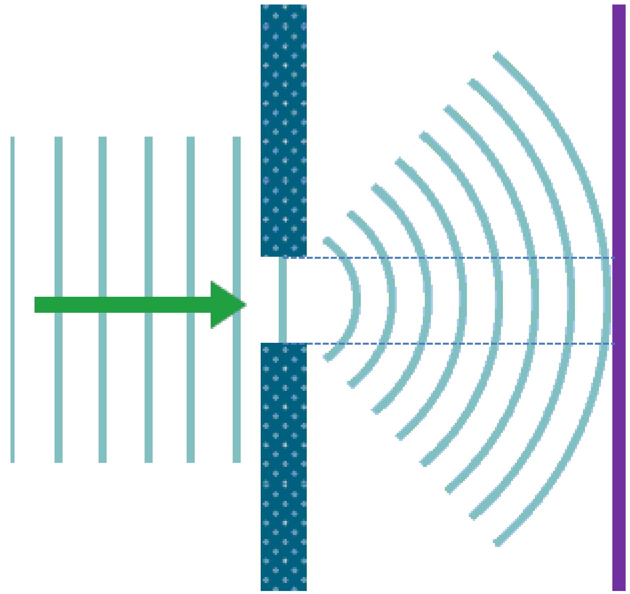
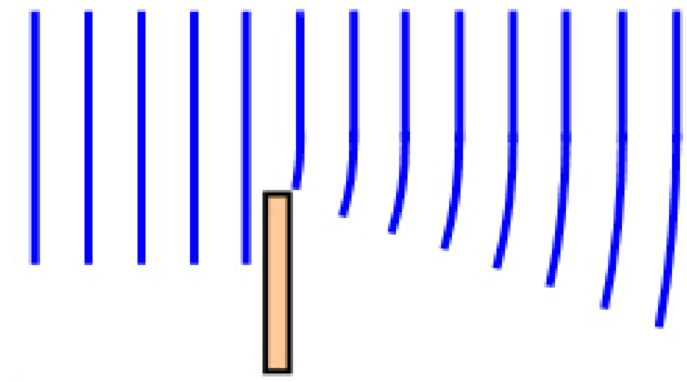
Diffraction of Light





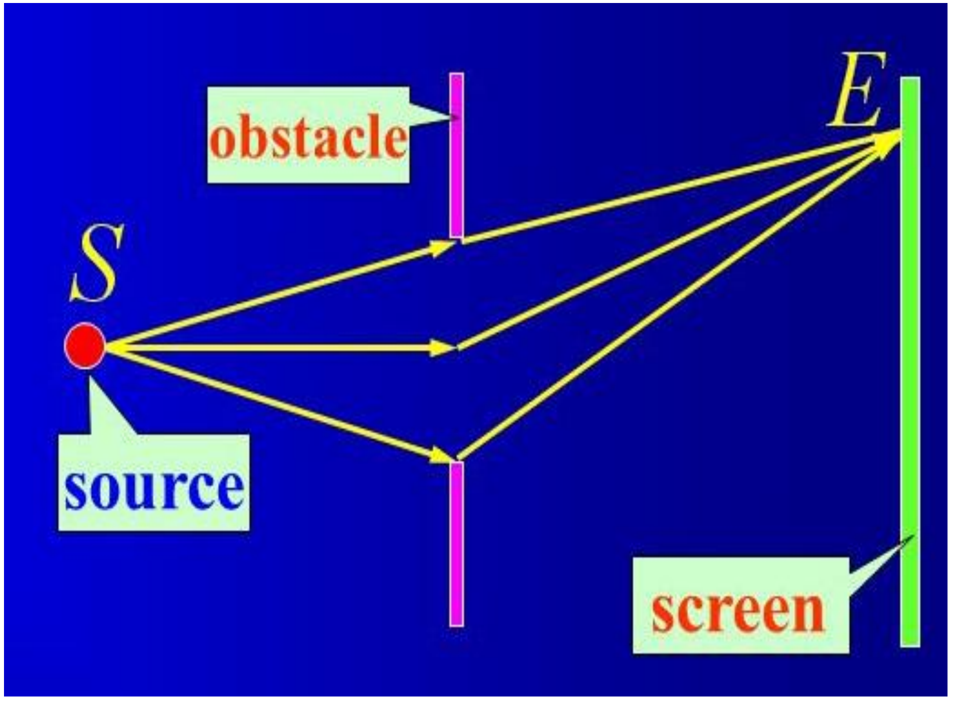
Diffraction is the phenomena of bending of light rays round the sharp corners and entering into the geometrical shadow region

It can be explained only on the basis of wave nature of light or Huygen's theory

II. Classification

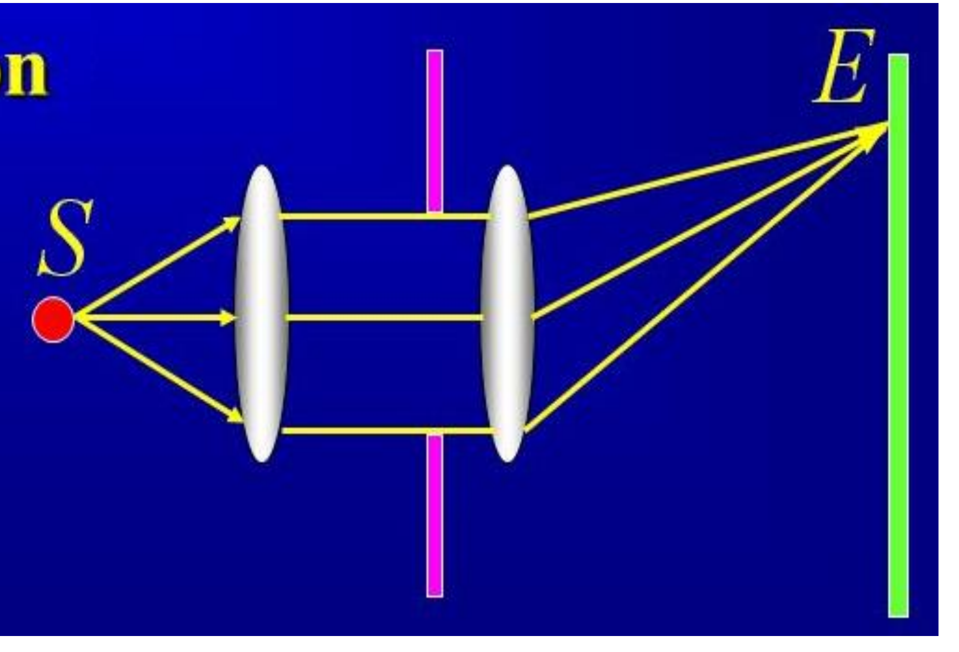
① Fresnel diffraction

--the source or the screen or both are at finite distance from the diffracting obstacle.

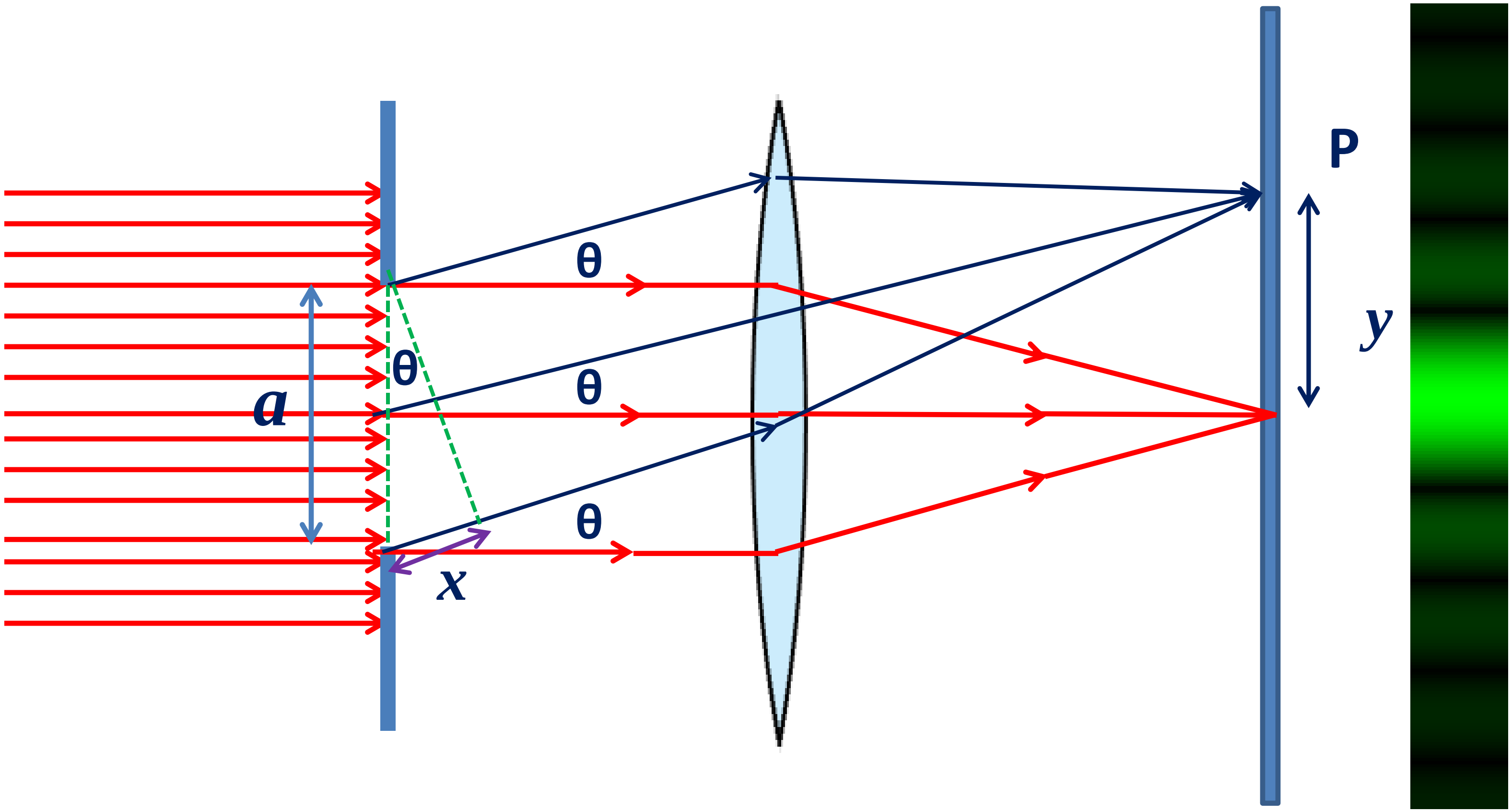


② Fraunhofer diffraction

--the source and the screen are at infinite distance from the diffracting obstacle.



Fraunhofer Diffraction at Single Slit



Path difference between two extreme rays diffracted at angle θ

$$x = a\sin\theta$$

If path difference is λ or its integral multiple, then we get dark fringe instead of bright. Hence **conditions** of dark and bright fringes get interchanged here

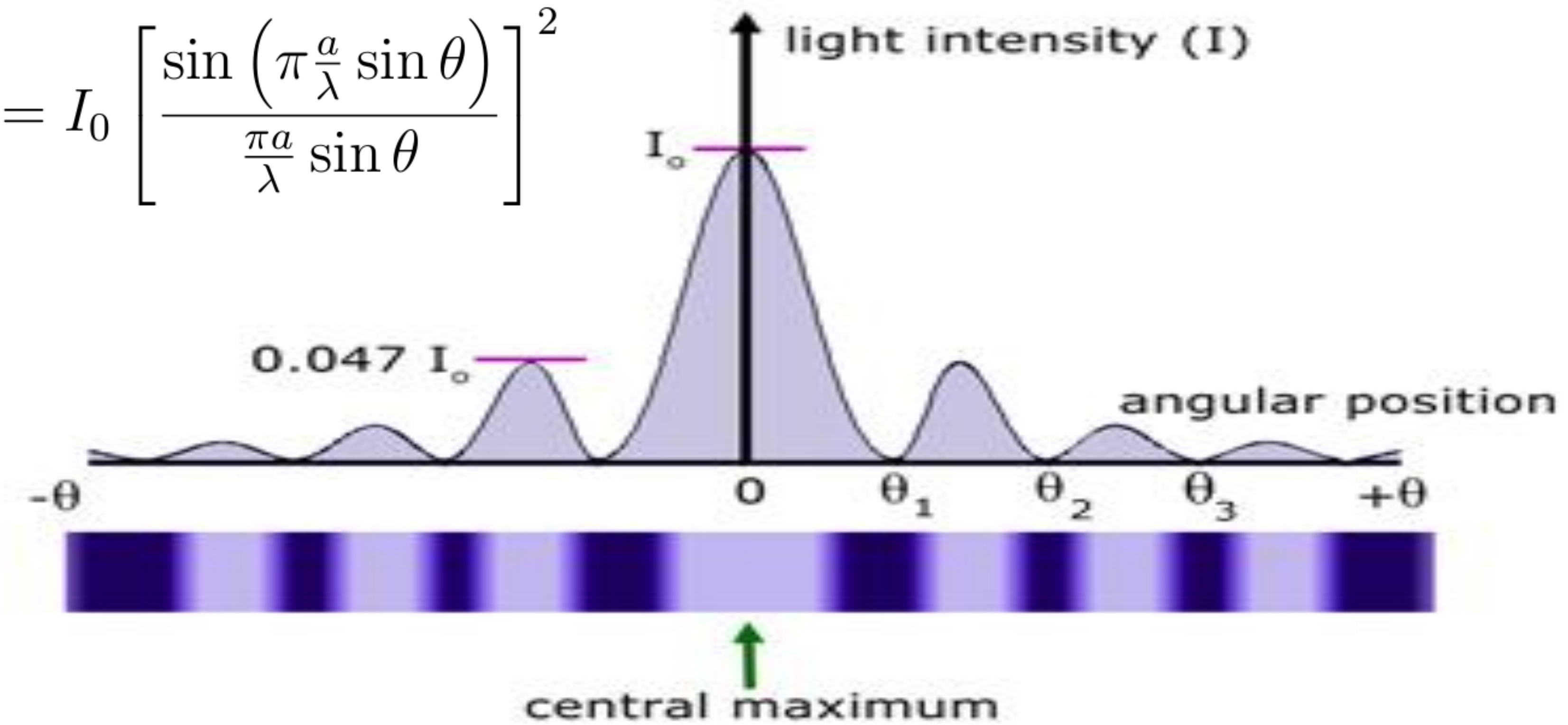
For bright fringes

$$a \sin \theta_n = \frac{(2n+1)}{2} \lambda$$

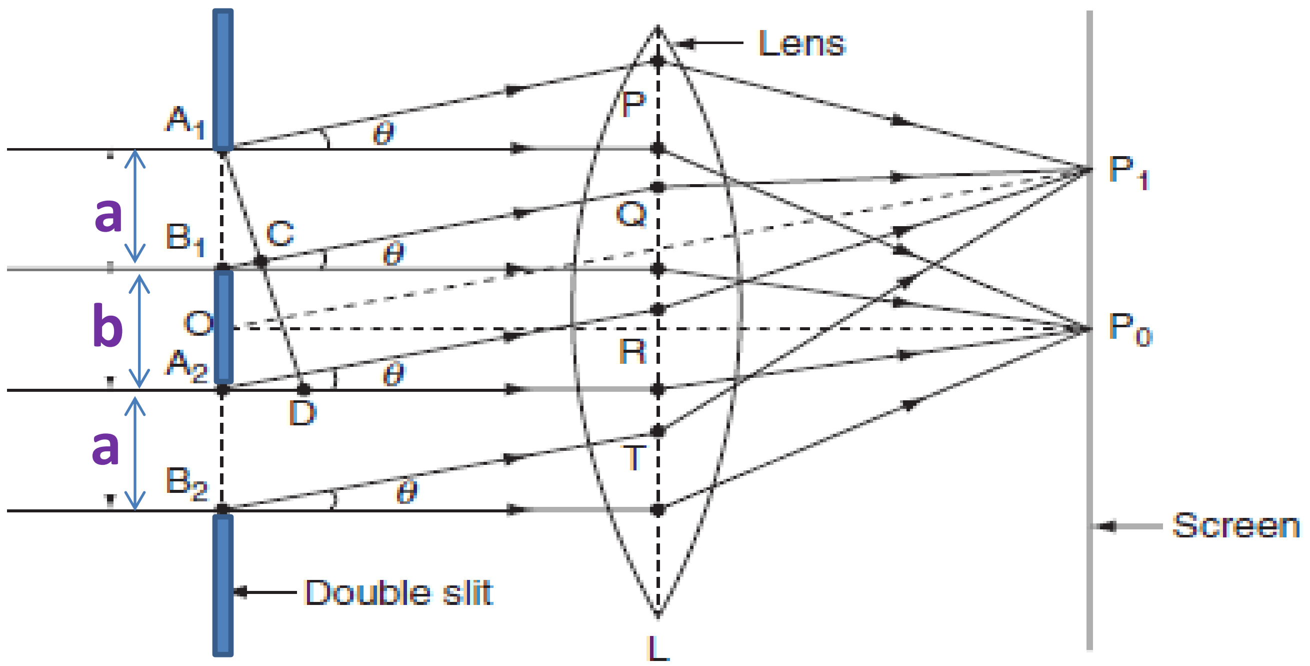
For dark fringes

$$a \sin \theta_m = m \lambda$$

$$I = I_0 \left[\frac{\sin\left(\pi \frac{a}{\lambda} \sin\theta\right)}{\frac{\pi a}{\lambda} \sin\theta} \right]^2$$



Fraunhofer Diffraction at Double Slit



Intensity distribution on screen is due to two types of phenomena

1. ***Diffraction pattern*** **due to individual slits which coincide exactly with each other**

2. ***Interference pattern*** **due to superposition of corresponding rays from two slits**

1. Diffraction Pattern

For bright fringes

$$a \sin \theta_n = \frac{(2n+1)}{2} \lambda$$

For dark fringes

$$a \sin \theta_m = m \lambda$$

2. Interference Pattern

Path difference between any two corresponding rays diffracted at angle θ is:

$$x = (a + b) \sin \theta$$

For n^{th} order interference maximum

$$(a + b) \sin \theta_n = n \lambda$$

For n^{th} order interference minimum

$$(a + b) \sin \theta_n = \frac{(2n+1)}{2} \lambda$$

Missing order of interference

If n^{th} order Interference maximum is located exactly at the location of m^{th} order Diffraction minimum, then these orders of interference fringes will be absent from the resultant pattern on screen

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

$$a\sin\theta = m\lambda$$

Interference maximum and Diffraction minimum are located exactly at the same angular position θ

Dividing these equations, we get

$$\boxed{\frac{a+b}{a} = \frac{n}{m}}$$

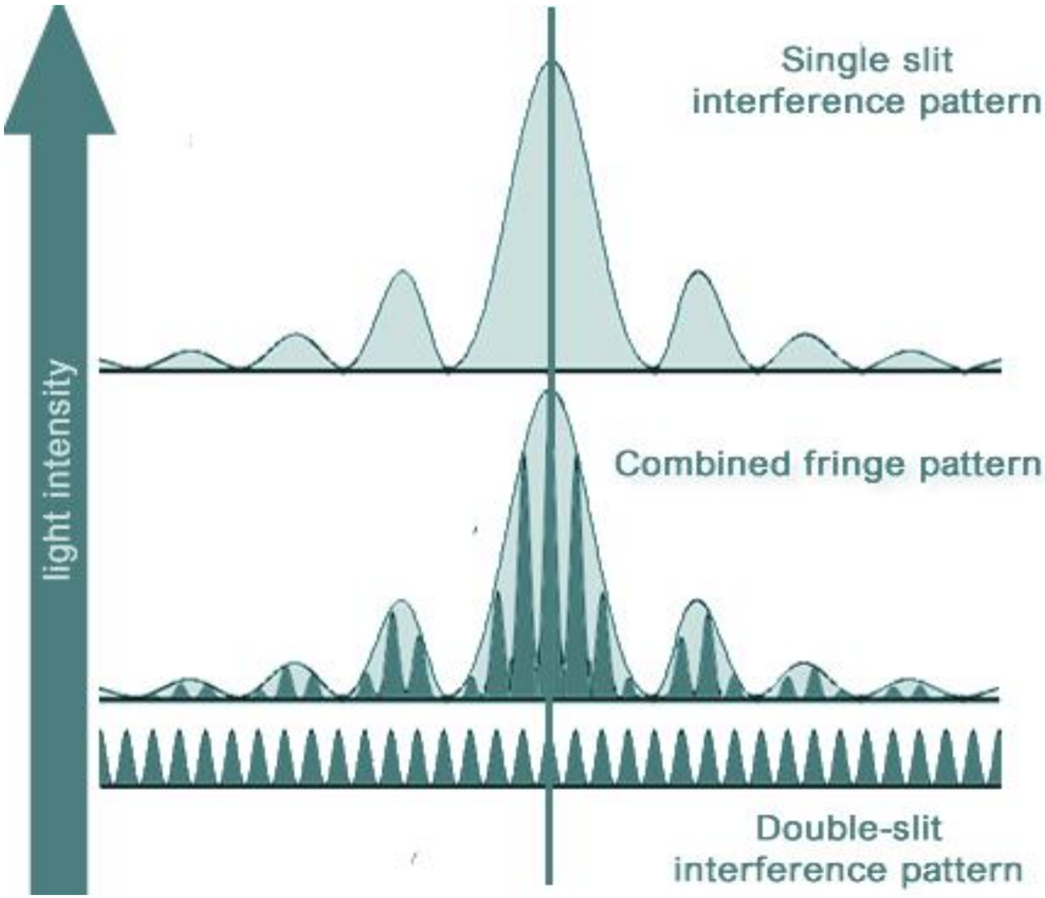
If $a = b$ then $n = 2m$ *and at* $m = 1,2,3,\ldots$ $n = 2,4,6,\ldots$ *will be missing*

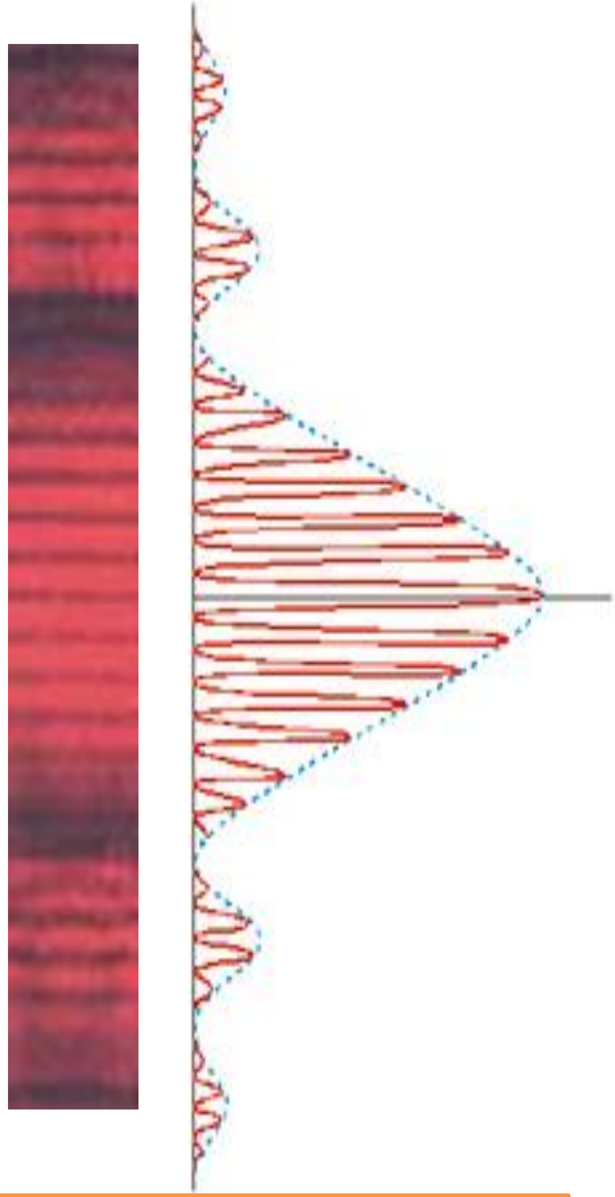
If $2a = b$ then $n = 3m$ *and at* $m = 1,2,3,\ldots$ $n = 3,6,9\ldots$ *will be missing*

If $b = 0$ then $n = m$ *and at* $m = 1,2,3,\ldots$ $n = 1,2,3,\ldots$ *will be missing*

i.e. all interference fringes are absent

Intensity Distribution on Screen





So, distribution on screen consists of Interference pattern within the Diffraction fringes

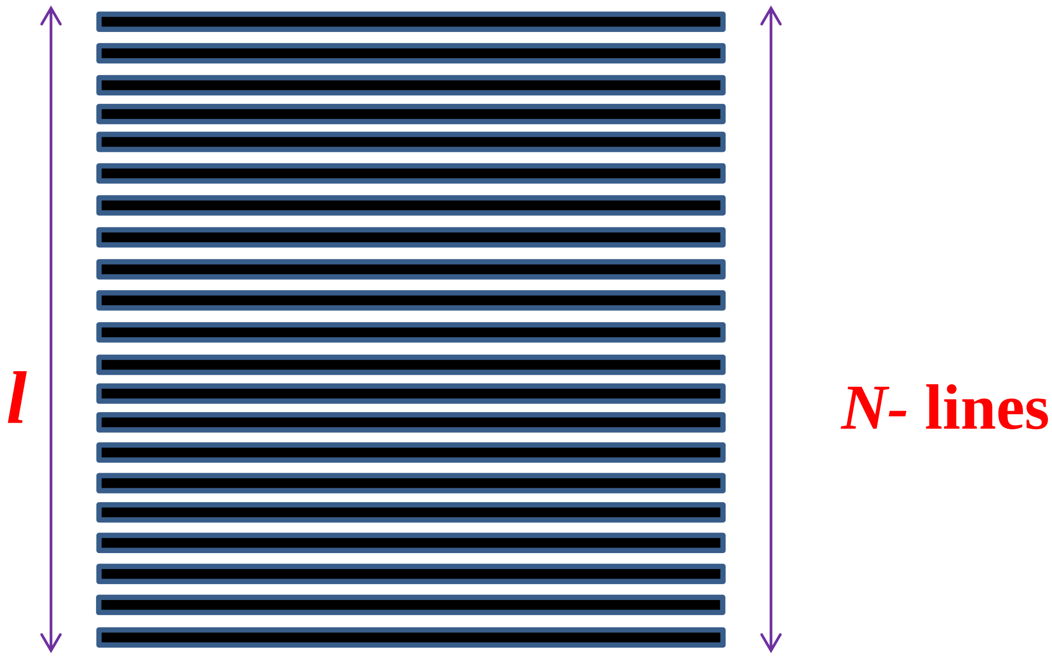
Diffraction Grating/Plane Transmission Grating

An arrangement consisting of a large number of equidistant parallel rectangular slits of equal width separated by equal opaque portions is known as a diffraction grating.

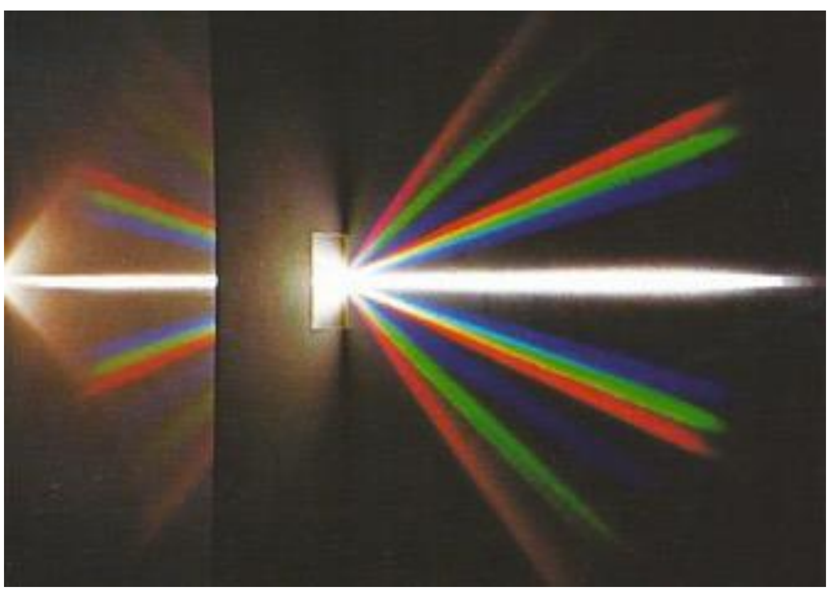
Constructed by ruling equidistant parallel lines with a fine diamond point on an optically plane glass plate. There can be about 12,000 to 30,000 lines drawn per inch.

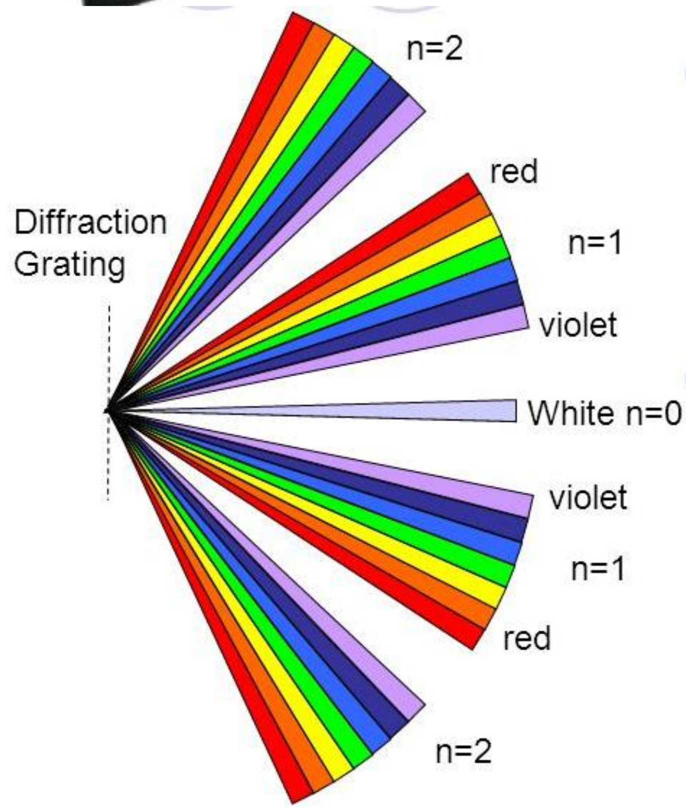
Ruled lines act as opaque regions called OPACITIES of width b each. While equal sized spaces among lines act as transparent regions called TRANSPARANCIES each of width a.

The factor $a + b$ is called grating constant and its reciprocal $\frac{1}{a+b}$ is number of lines per unit length on grating. If a total N lines are drawn over a grating of length l then $\frac{N}{l} = \frac{1}{a+b}$

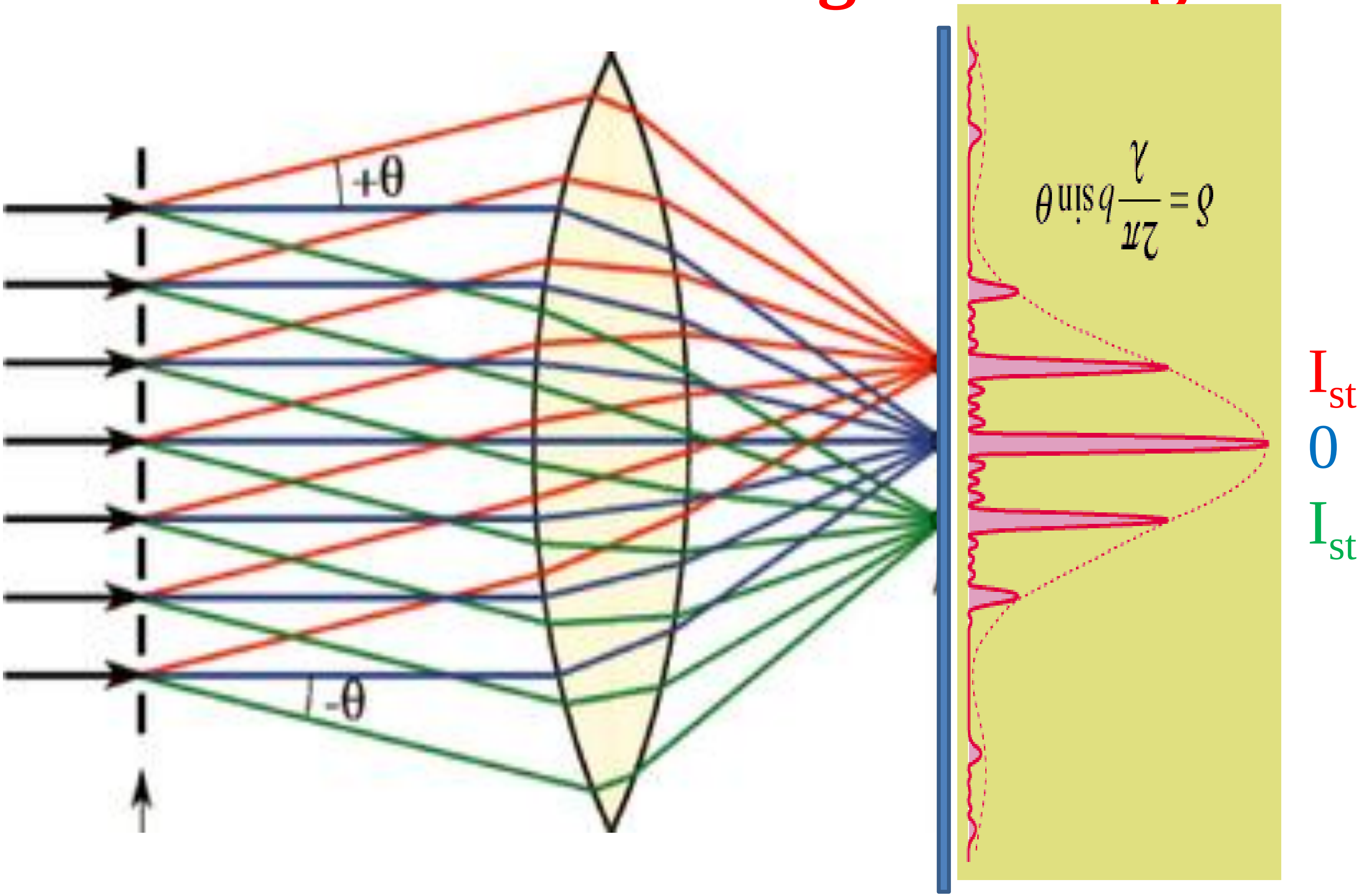

l
N- lines

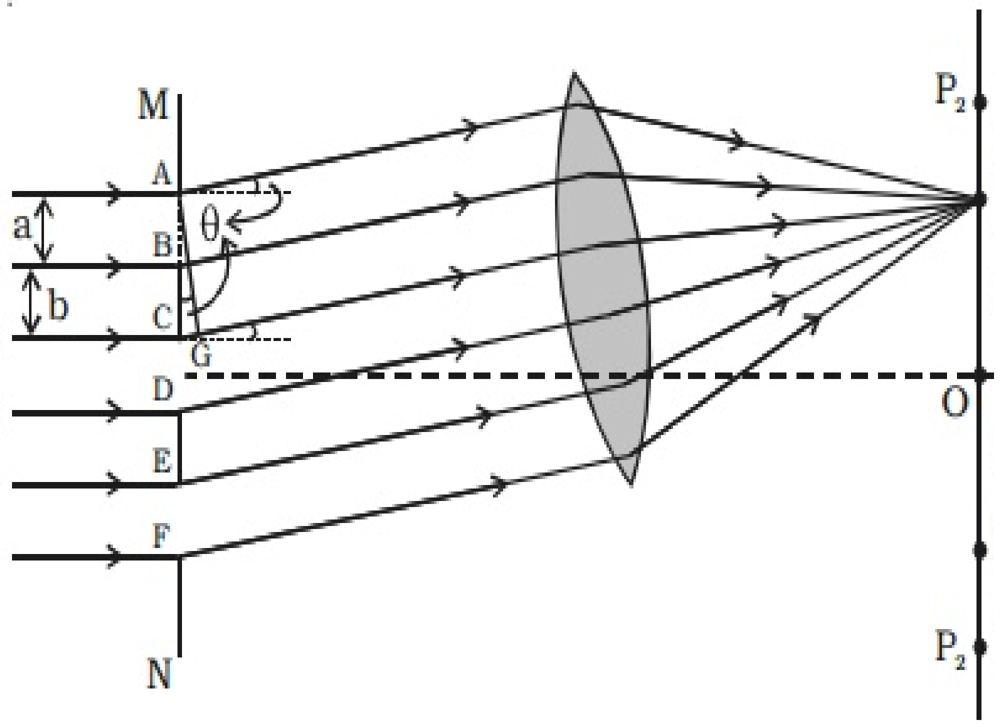

DIFFRACTION GRATING
600 LINES PER MM




n=2
red
Diffraction
Grating
n=1
violet
White n=0
violet
n=1
red
n=2

Diffraction through Grating





The intensity pattern on screen consists of *Principal Maxima and Minima* due to interference among corresponding rays and *Secondary maxima and minima* due to diffraction from whole grating

Condition for various order Principal maxima

$$(a+b)\sin\theta_n = n\,\lambda$$

Condition for first order Secondary Minimum just after n^{th} order Principal maxima

$$(a+b)\sin(\theta+d\theta) = n\,\lambda + (\lambda/\mathrm{N})$$

Determination of λ using Grating Method

To find λ we use the following relation

$$(a+b)\sin\theta_n = n\,\lambda$$