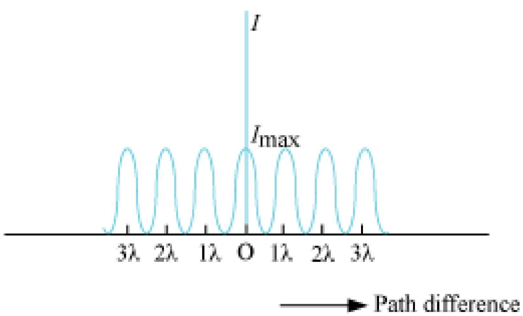
10. Interference and Diffraction

Young's Double-Slit Experiment

- In Young's Double-Slit Experiment, two slits are illuminated by a monochromatic source of light.
- For the distance d between the slits, alternate bright and dark bands are observed on a screen placed at distance D from the slits.
- Conditions for the bright fringes x distance apart from each other:
    - path difference between the light waves for the nth bright fringe = $xdD= n\lambda$
    - path difference between the light waves for the nth dark fringe = $xdD=(2n-1)\lambda 2$
- All the bright and dark fringes are of equal width, as $\beta_1 = \beta_2$.
- Graph of intensity distribution in Young's Double-Slit Experiment:



- **C onditions for producing steady interference pattern:**
    - The sources of light must be coherent.
    - The sources of light must be monochromatic.
    - The two waves that are interfering must have the same state of polarisation.
    - The separation between the sources of light should be very small.
    - The distance of the screen from the two sources of light should be large.
- In a bi-prism experiment, wavelength is calculated using

$\lambda = XdD$ and $d=d1d2$.

Diffraction of light:

- A single slit of width '*a*' gives a diffraction pattern with a central maximum. The intensity reduces to zero at $\sin\theta =\pm\lambda a,\pm 2\lambda a$ etc. with successively weaker secondary maxima in between.
- **Central Maximum** − The waves from points equidistant from the centre C lying on the upper and lower half reach point O with zero path difference and hence, reinforce each other producing maximum intensity at point O.
- Position of secondary maxima,

y'n=(2n+1)Dλ2a

- Position of secondary minima,

$$y_n = \frac{nD\lambda}{a}$$

- Width of secondary maxima,

  β=Dλa

- Width of secondary minima,

  β'=Dλa

- Diffraction limits the angular resolution of a telescope to λD, where *D* is the diameter. Two stars closer than this give strongly overlapping images. Similarly, a microscope objective subtending angle 2*b* at the focus, in a medium of refractive index *n*, will just separate two objects spaced at a distanceλ2nsinβ, which is the resolution limit of a microscope.

- A beam of width *a* travels a distance a2λ (called the Fresnel distance), before it starts to spread out due to diffraction.
- Diffraction may be classified into two types: Fraunhofer diffraction and Fresnel diffraction.
- According to Rayleigh's Criterion , the image of two point objects are regarded as resolved if the central maximum of one falls on the first minimum of the other.
- Interference patterns are due to the interaction of light from two different wavefronts of two coherent sources, but diffraction pattern is due to the interaction of light coming from different parts of the same wavefront .
- Differences between interference and diffraction :
  - In an interference pattern, all the bright fringes have same intensity. In a diffraction pattern, all the bright fringes are not of the same intensity.
  - In an interference pattern, the dark fringe has zero or very small intensity, and the bright and dark fringes can easily be distinguished. In diffraction, all the dark fringes are not of zero intensity.
  - In intereference, the widths of all the fringes are almost same. In diffraction, fringes are of different widths.