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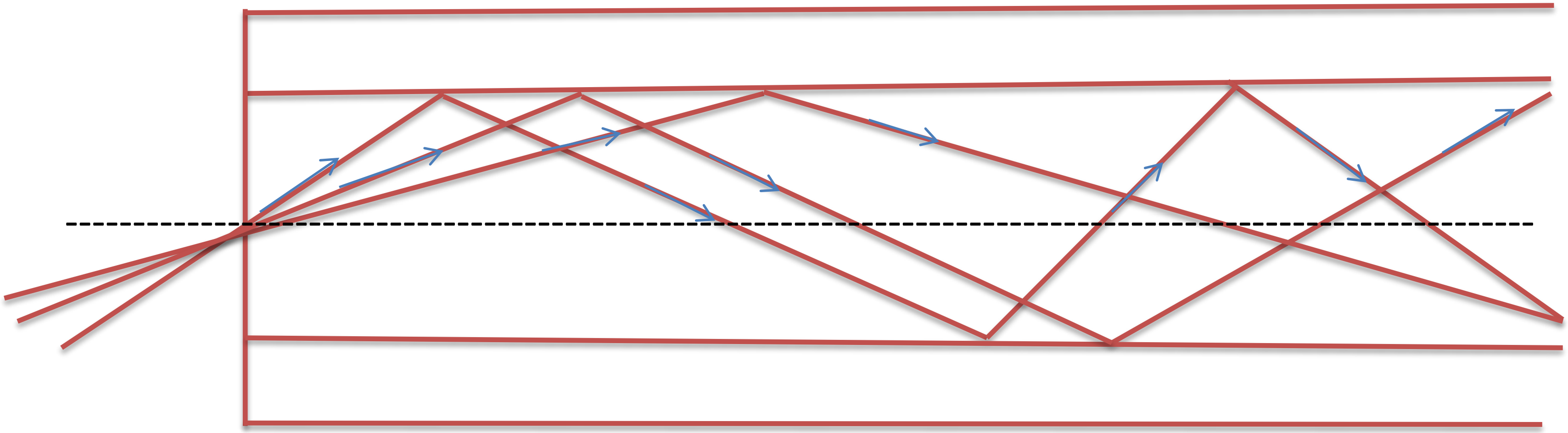
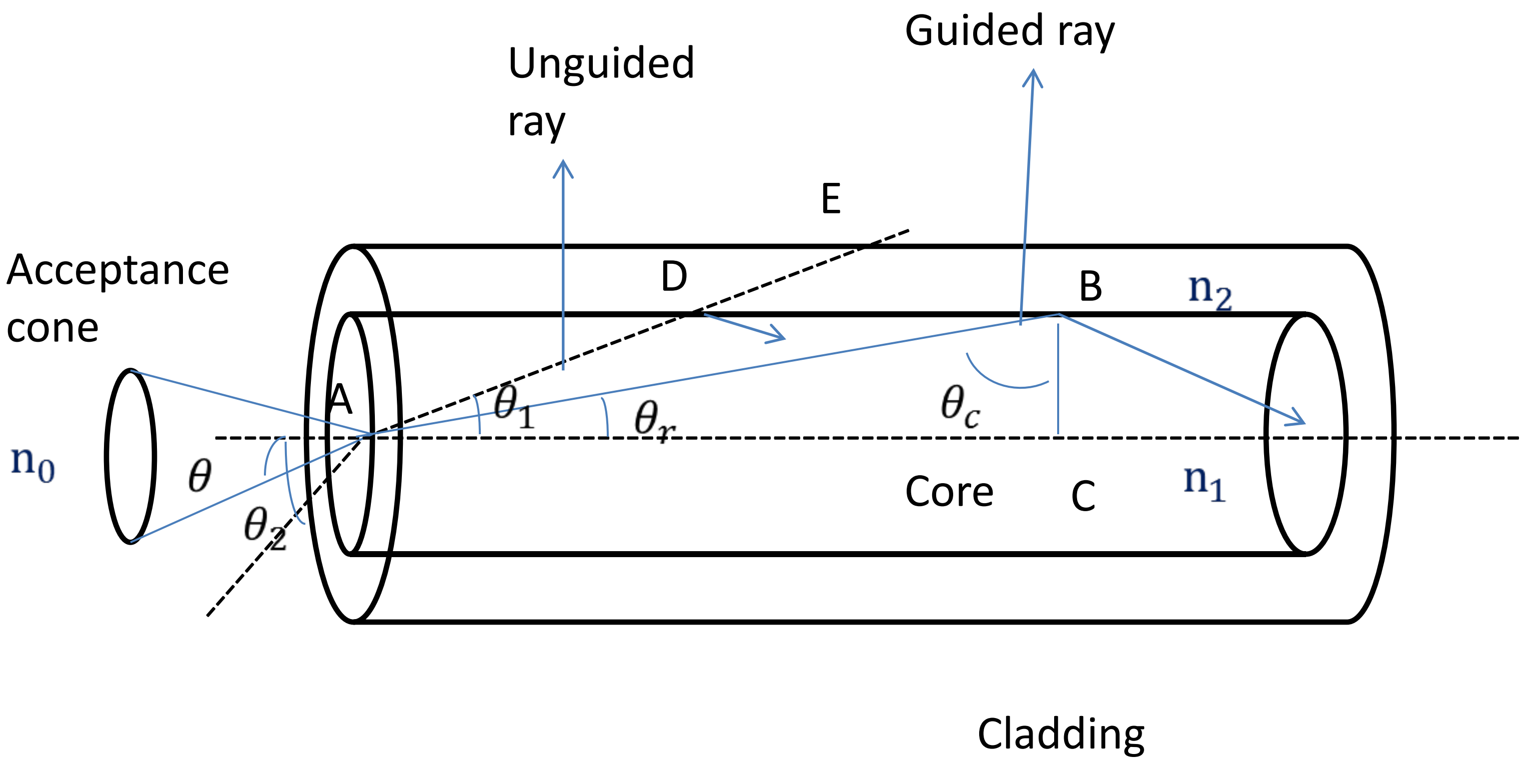
PROPAGATION OF LIGHT THROUGH AN OPTICAL FIBRE



Critical angle of propagation



θ_c = Critical propagation angle

From the triangle ABC,

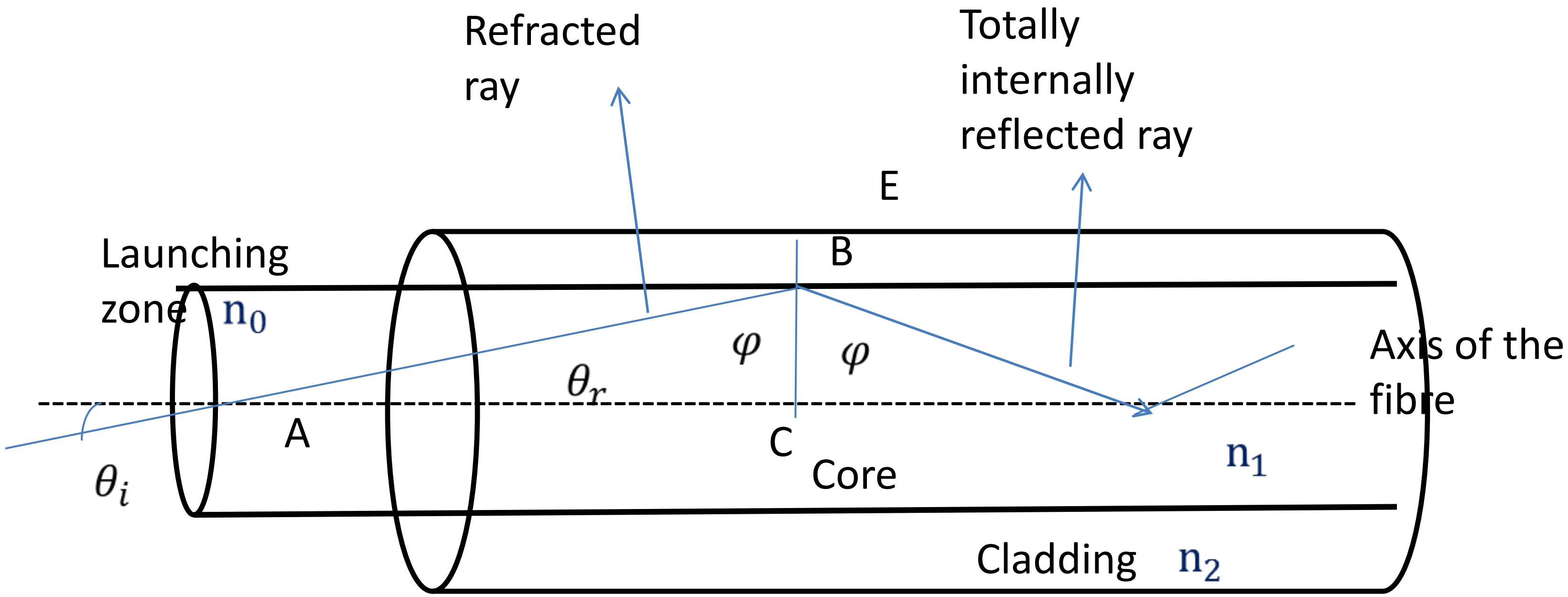
$$\frac{AC}{AB} = \sin\varphi c \qquad \text{also, } \frac{AC}{AB} = \cos\theta c$$

We know that, $\sin\varphi c = n_2/n_1$

$$\cos\theta c = n_2/n_1$$

$$\theta c = \cos^{-1}(n2/n1)$$

Acceptance angle



$$\theta_0 = \textbf{Acceptance angle}$$

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_1}{n_0}$$

From triangle ABC,

$$\sin\theta_r = \sin(90° - \varphi) = \cos\varphi$$

$$\sin\theta_i = \frac{n_1}{n_0}\cos\varphi$$

When, $\varphi_c = \varphi$,

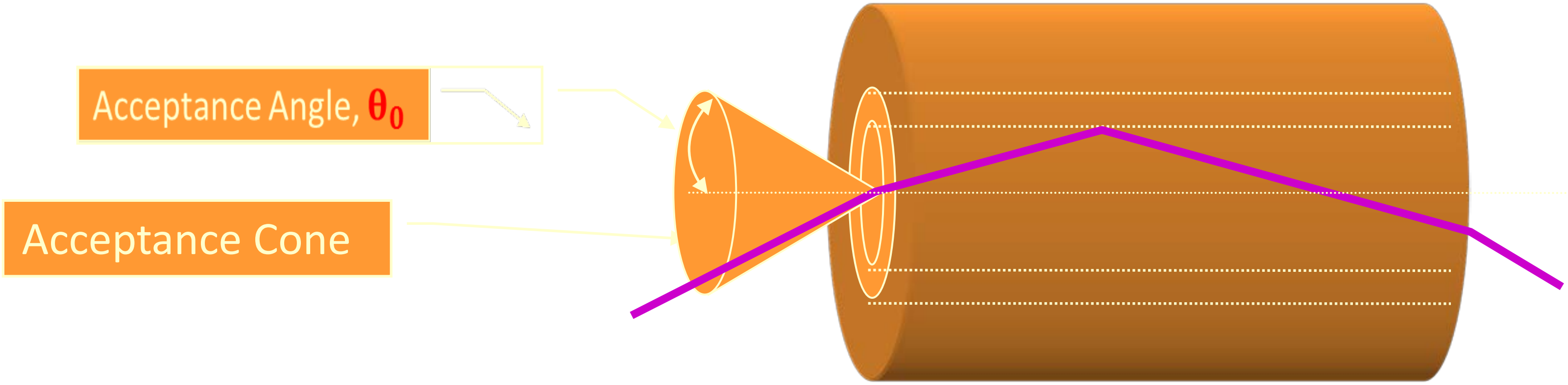
$$\sin\theta_{i\,max} = \frac{n_1}{n_0}\cos\varphi c$$

$$\sin\varphi_c = \frac{n_2}{n_1}$$

$$\cos\varphi c = \sqrt{(n_1{}^2 - n_2{}^2)/n_1}$$

$$\sin\theta_{i\,max} = \sqrt{}(n_1{}^2 - n_2{}^2)/n_0$$

$$\theta_0 = \sin^{-1}\sqrt{}(n_1{}^2 - n_2{}^2)$$



Acceptance Angle, θ_0
Acceptance Cone

FRACTIONAL REFRACTIVE INDEX CHANGE

- The fractional difference between the refractive index of the core and the cladding is known as fractional refractive index change.

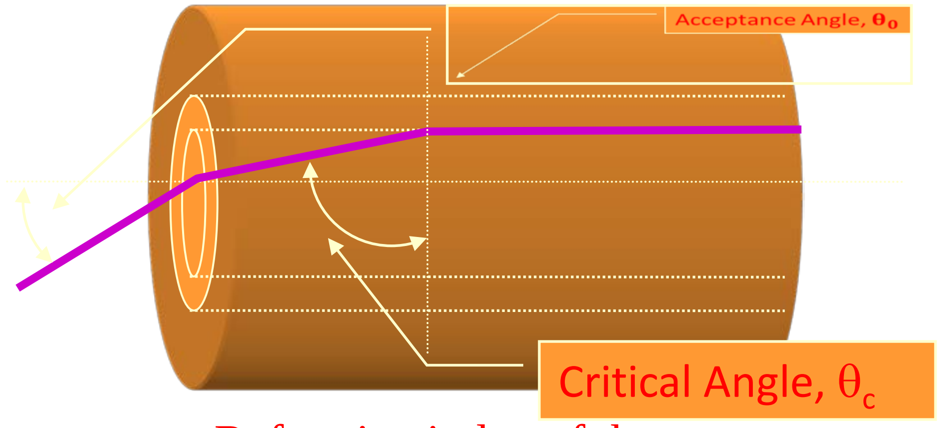
$$\Delta = \frac{(n_1 - n_2)}{n_1}$$

Acceptance Angle and NA

- The angle of light entering a fiber which follows the critical angle is called the *acceptance angle*, α

$$\theta_0 = \sin^{-1}[(n_1^2 - n_2^2)^{1/2}]$$

- Numerical Aperature (NA) describes the light-gathering ability of a fiber



n_1 = Refractive index of the core
n_2 = Refractive index of the cladding

NA Derivation

We know that $\sin\theta_2 = \frac{n_2}{n_1}$ because θ_2 is the critical angle

And $n_0 \sin\theta_0 = n_1 \sin\theta_1$ from Snell's Law

Now, $\cos\theta_1 = \sin\theta_2 = \frac{n_2}{n_1}$

We know that $\sin x = \sqrt{1-\cos^2 x}$ (Rule)

Therefore $\sin\theta_1 = \sqrt{1-\frac{n_2^2}{n_1^2}}$

Since $n_0 = 1$ *then* $\sin\theta_0 = n_1\sqrt{1-\frac{n_2^2}{n_1^2}}$

Therefore the NA $= \sqrt{n_1^2 - n_2^2}$

Where n_1 = refractive index of the core

n_2 = refractive index of the cladding

$$(n_1^2 - n_2^2) = 2\, n_1^2 \Delta$$

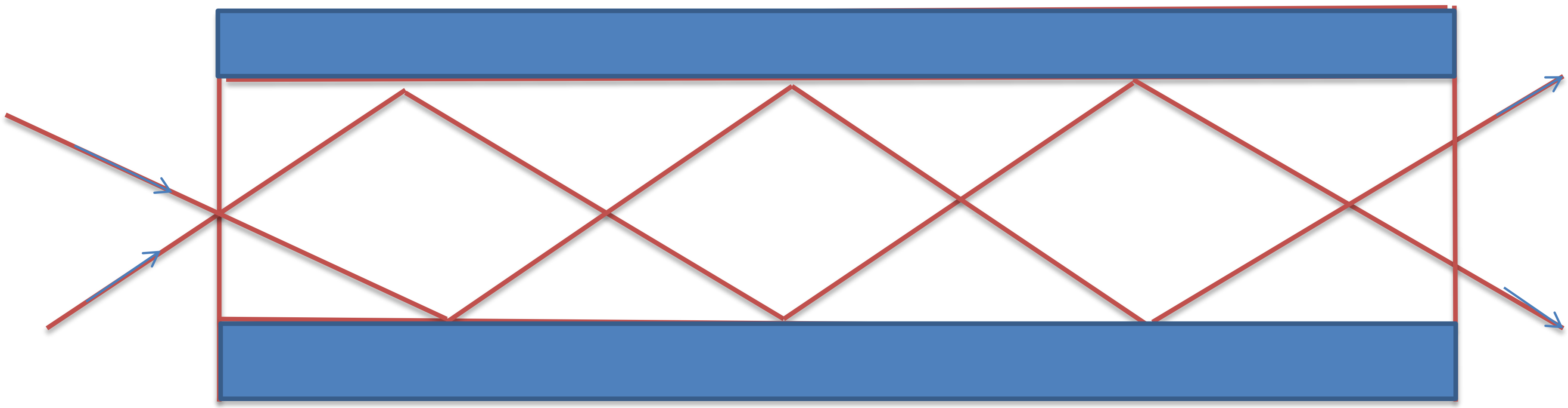
$$\text{NA} = \sqrt{2 n_1^2 \Delta}$$

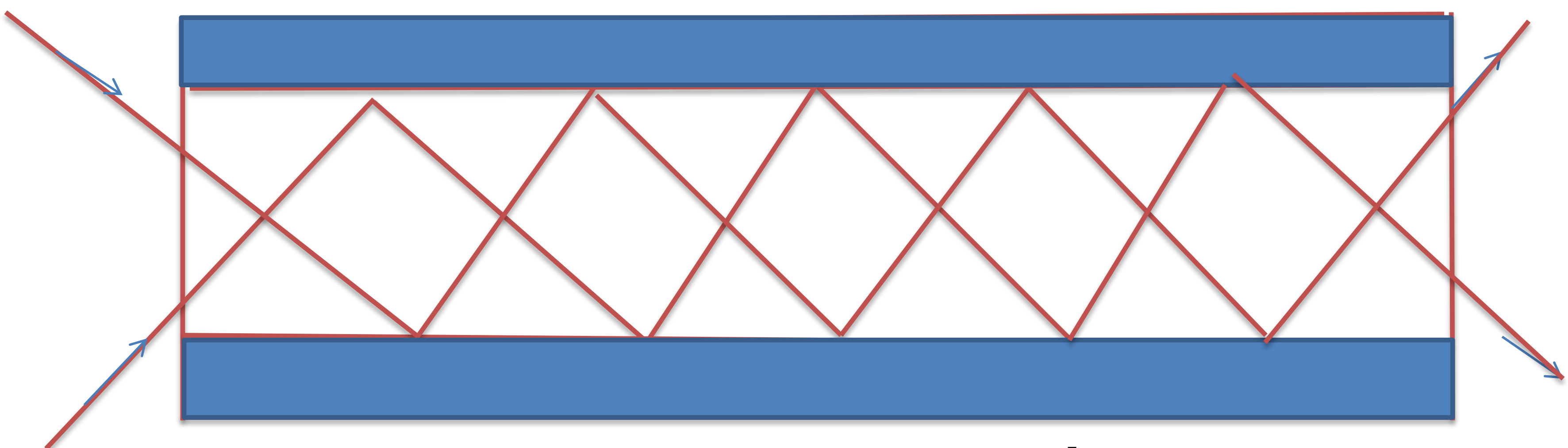
$$\text{NA} = n_1 \sqrt{2\Delta}$$

Numerical Aperture

- The Numerical Aperture is the sine of the largest angle contained within the cone of acceptance.
- NA is related to a number of important fiber characteristics.
  - It is a measure of the ability of the fiber to gather light at the input end.
  - The higher the NA the tighter (smaller radius) we can have bends in the fiber before loss of light becomes a problem.
  - The higher the NA the more modes we have, Rays can bounce at greater angles and therefore there are more of them. This means that the higher the NA the *greater* will be the dispersion of this fiber (in the case of MM fiber).

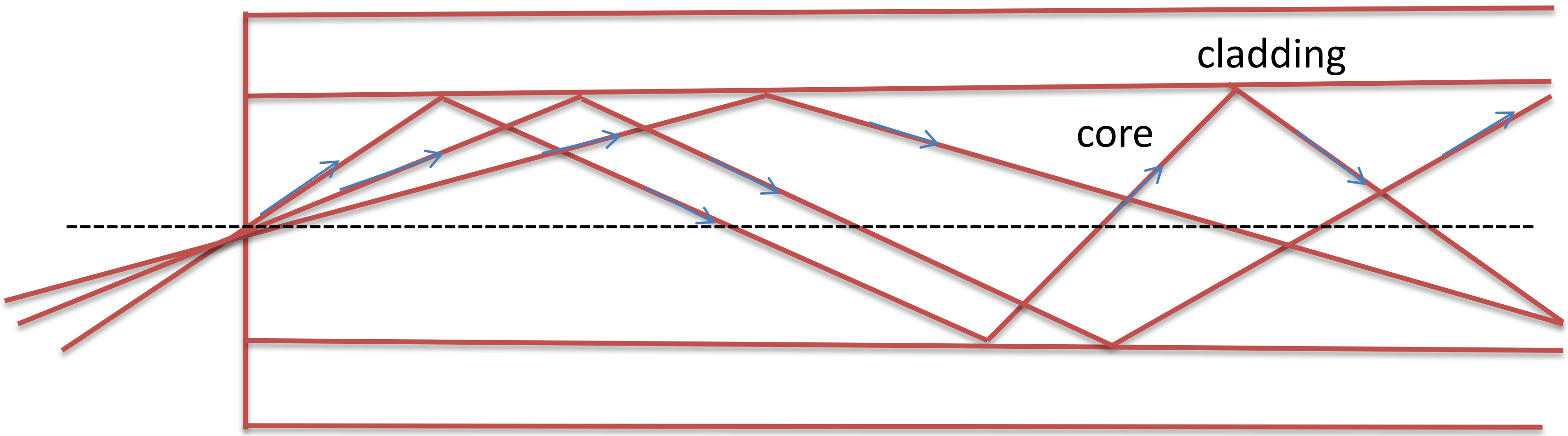
Low NA





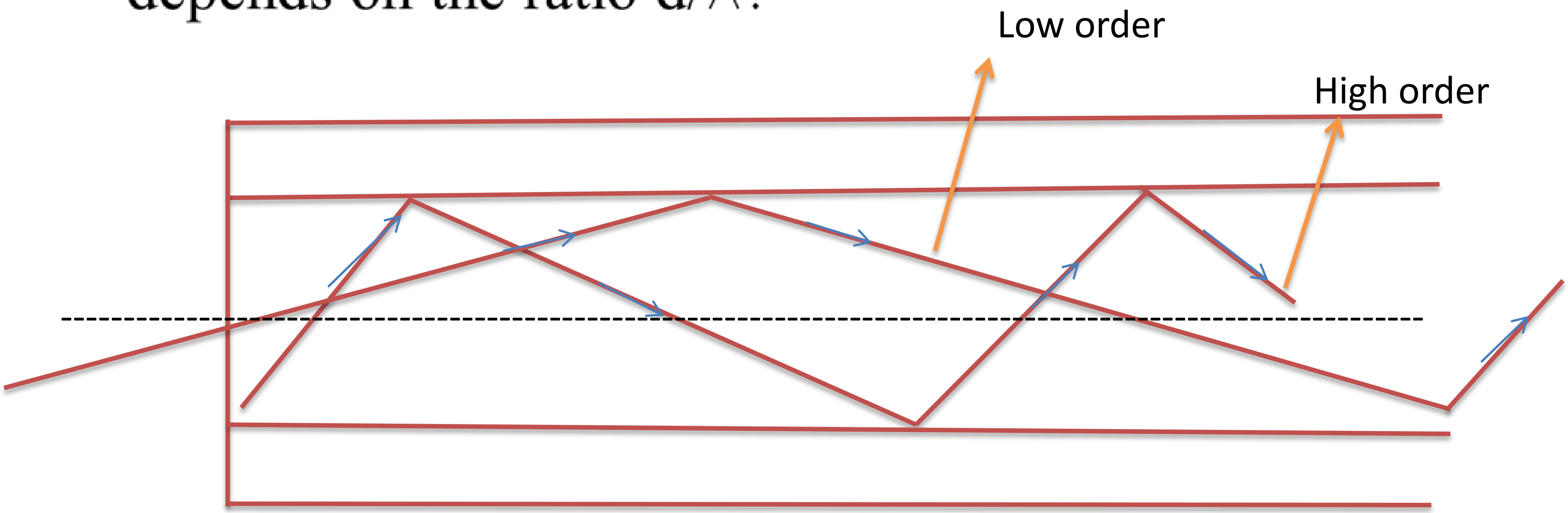
High NA

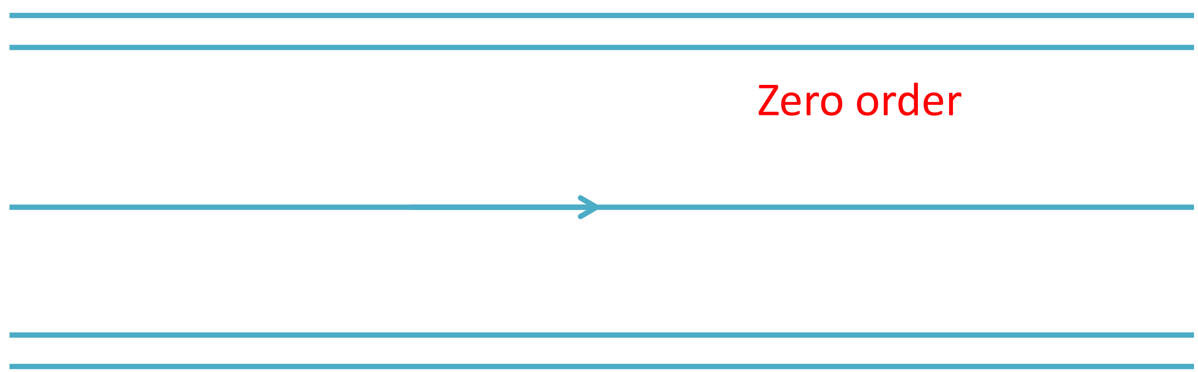
Modes of propagation



- Light propagates in opticalfibre as electromagnetic wave .
- Plane electromagnetic wave propagates in free space as a transverse electromagnetic wave .
- Light propagates through optical fibre in different types of modes such as TE,TM and Hybrid modes.
- The waves travelling along optical fibre in zigzag paths if it is inphase there exists formation of constructive interference and if it is out of phase there exists formation of destructive interference.

- The light ray paths along which the waves are in phase inside the fibre are known as modes.
- The number of modes increases as θ_c *or* Δ increases and decreases as core refractive index decreases & depends on the ratio d/λ.




Zero order

TYPES OF RAYS

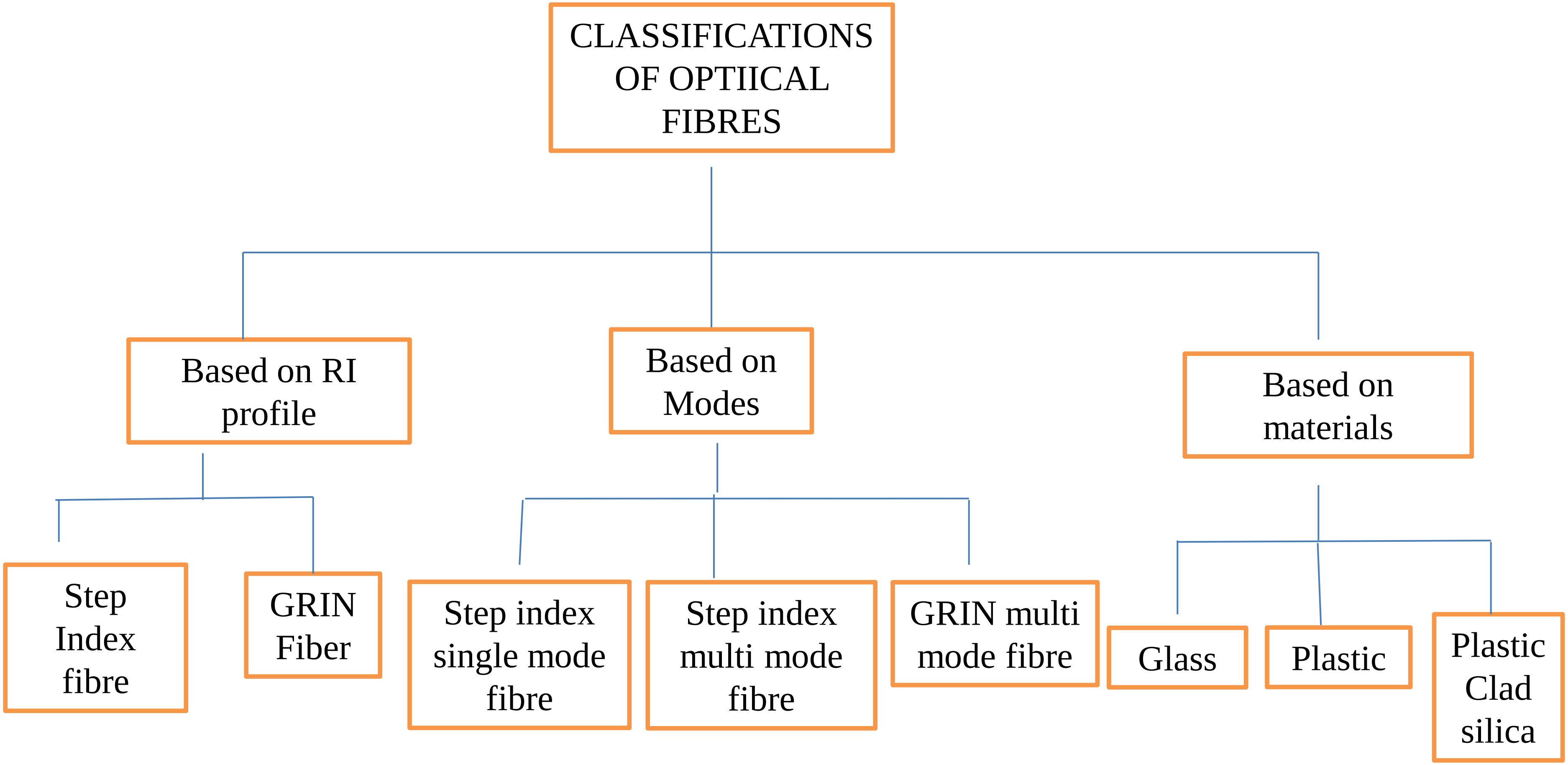
Meridional ray:

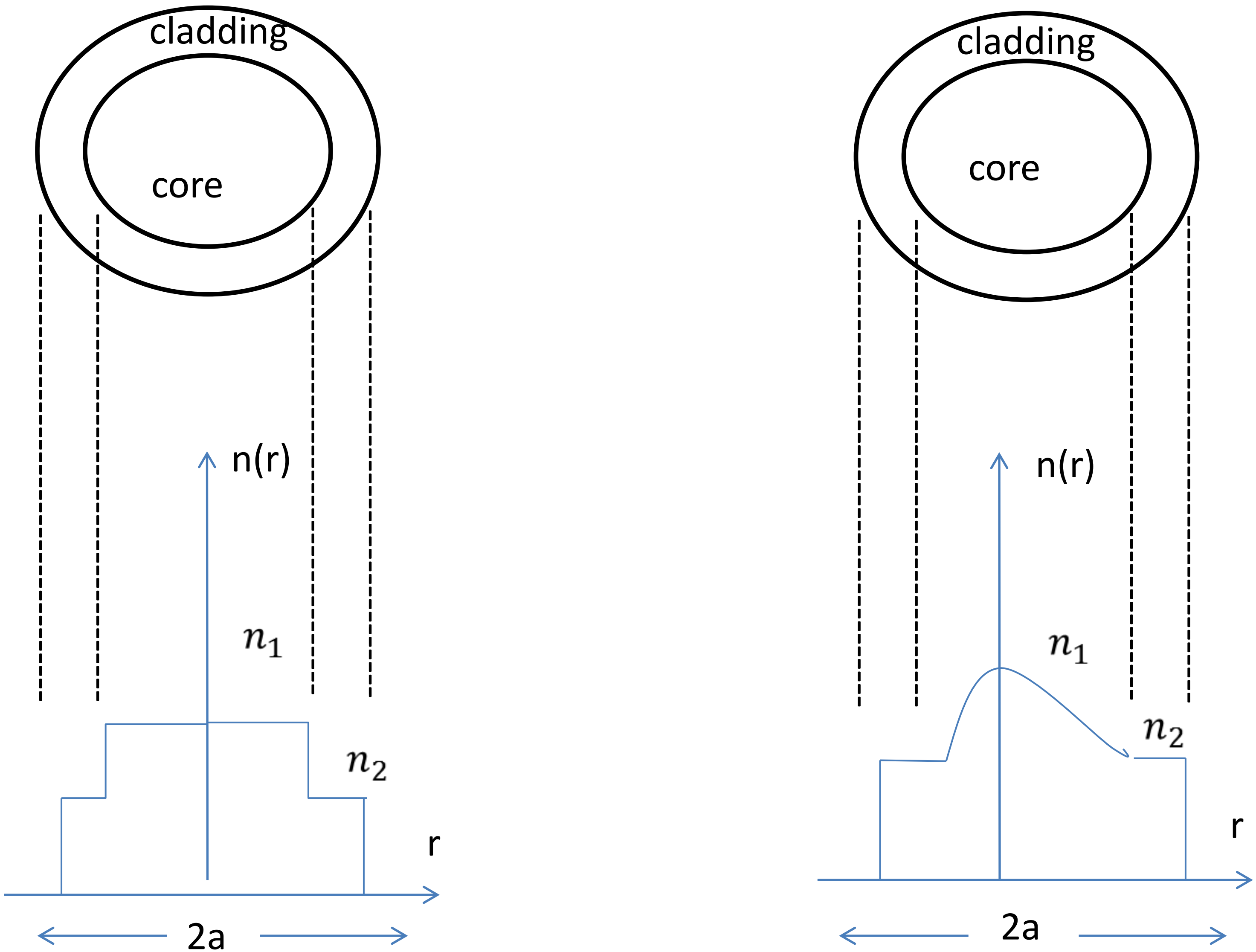
A ray that passes through the optical fiber undergoing total internal reflection is called as Meridional ray only in TM or TE modes.

Skew rays:

A ray that passes through the optical fiber in angular helical path is called as Skew ray only in either hybrid EH or HE modes.

CLASSIFICATION OF OPTICAL FIBRES




cladding
core
n(r)
n_1
n_2
r
2a
cladding
core
n(r)
n_1
n_2
r
2a

Types of optical fibers

- Single mode
  - only one signal can be transmitted
  - use of single frequency

- Multi mode
  - Several signals can be transmitted
  - Several frequencies used to modulate the signal

Losses in optical fibers

- Attenuation loss
- Dispersion loss
- Waveguide loss