# Unit-1

# Lecture -6

## Mode Theory, Structure of Fibers

# Single Mode Vs Multi Mode Fibers

Since the multimode fibers have larger core radii, it is easy to launch optical fiber into multimode mode fiber.

Optical power can be launched into multimode fiber using LED, whereas single-mode fibers are generally excited using lasers.

The multimode fibers suffer from intermodal dispersion.

# Rays and modes

We know that the light is an electromagnetic wave.

It is to be guided along the axis of the optical fiber.

It is represented by the superposition of bounded or trapped modes.

Also note that the guided modes consists of a set of simple electromagnetic field configurations.

For monochromatic light fields there is an exponential factor & is given by: $e^{j((J)t - Pz)}$

Where, m is frequency in radian

z is the direction (+ve) of propagation of light

p is the z component of the wave propagation constant k

$k = \frac{2n}{1}$

1 is known as wavelength

The mode field can be determined using Maxwell's equation and boundary conditions at core-cladding interface.

# Step-index fiber structure

In practical step-index fiber the core of radius a has a refractive index $n_1$ (1.48).

Let this is surrounded by a cladding of radius $n_2$, where $n_2$ =11t(1- )

The parameter 11 is called core-cladding index difference or simple index difference.

Since $n_2 < n_1$, electromagnetic energy at optical frequencies propagat es along the fiber waveguide through TIR at core cladding interface.

# Ray Optics Representation

Simple ray optic representation is useful to understand the mechanism of wave propagation in an ideal step index optical waveguide.

Basically **two kind of rays** propagate in a fiber,

**meridional and skew rays**.

**Meridional Rays** are confined to the meridional plane of the fibre.

Meridional Rays lie in a single plane.

Meridional Rays are further classified into **2 categories**.

**a. Bounded Rays**, are trapped in the core and propagate along the fiber axis.

**b. Unbounded Rays** are refracted out of the fiber core.

**Skew Rays** follow helical path along the fiber, they are not confined to a single plane.

Skew rays are actually leaky rays. So greater power loss arises.

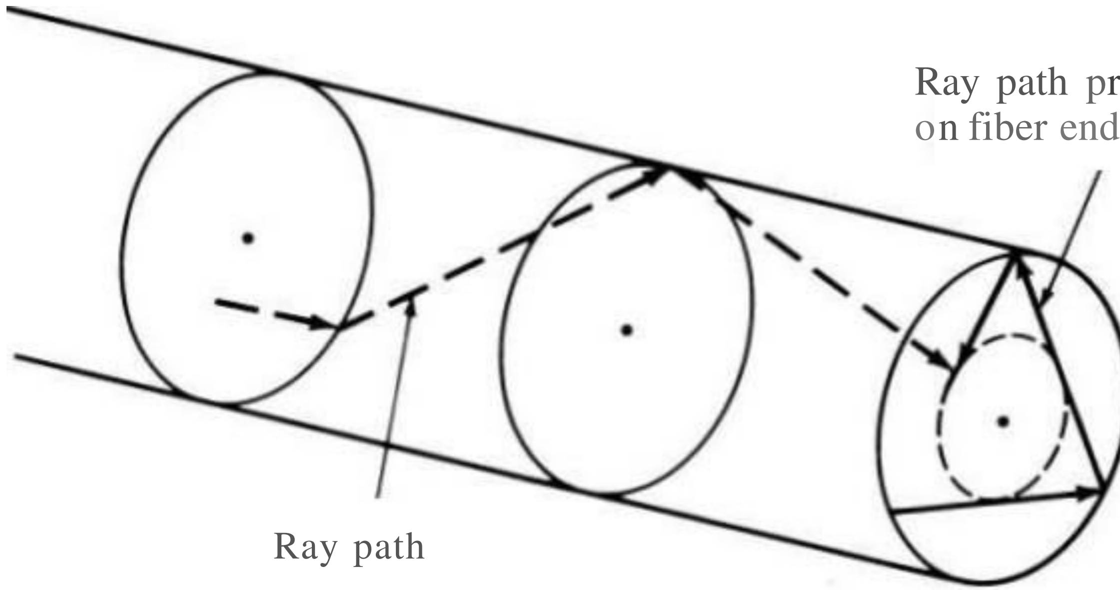


Fig.: Skew rays

The leaky rays are partially confined to the fiber core.

They suffer attenuation as the light travels along the optical waveguide.

The meridional ray is shown on next slide.

The light ray enters the fiber core from medium of refractive index n at an angle with respect to the fiber axis.

The light ray then strikes the core-cladding at a normal angle phi

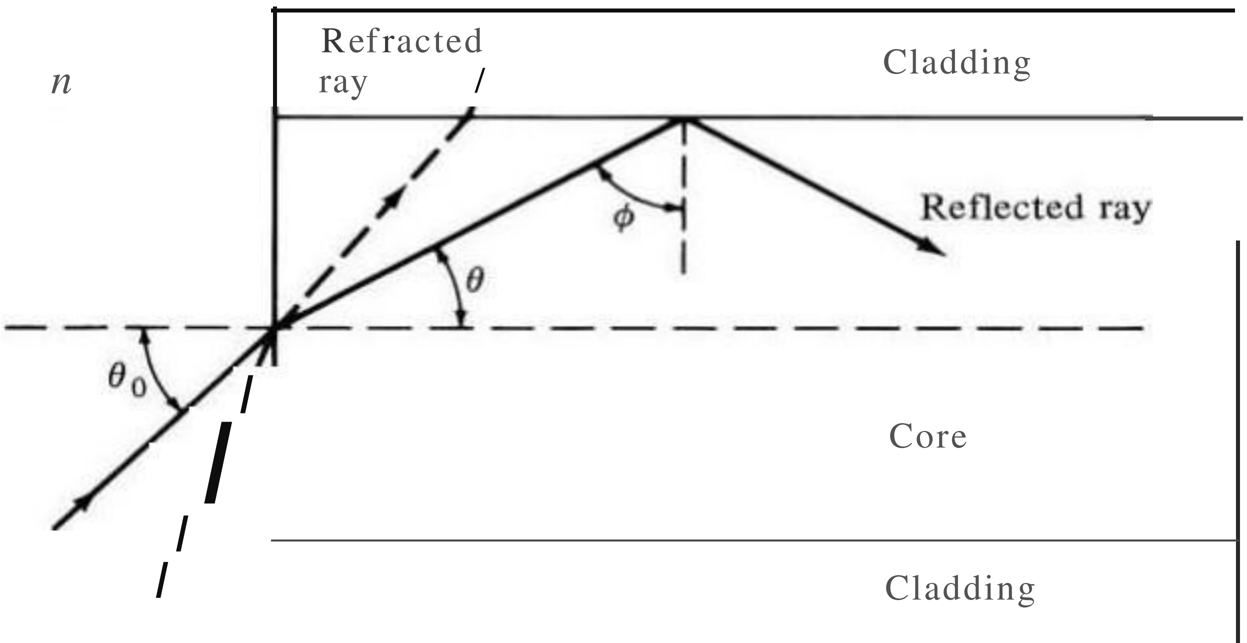


Fig: Meridional ray representation

It the ray follows TIR, then meridional ray follows a zigzag path along the fiber core.

in this case meridional rays passes through the axis of the waveguide.

From Snell's law, the minimum angle that supports TIR for the meridional ray is given by

$$\sin \phi_{min} = \frac{n_2}{n_1}$$

If the ray strikes less than this angle, then it will refract out of the core and will be lost in cladding.

At air-fiber core boundary, the Snell's law is related to maximum entrance angle as,

$$n \sin \theta_{0,\max} = n_1 \sin \theta_c = \sqrt{n_1^2 - n_2^2}$$

Where, ¢;=e.

The above equation defines ·A of a step-index fiber

$$NA = n \sin \theta_{0,\max} = (n_1^2 - n_2^2)^{1/2} \approx n_1 \sqrt{2\Delta}$$

A is used to describe light acceptance of a fiber.

It is dimensionless quantity.