OPTICAL FIBER-2

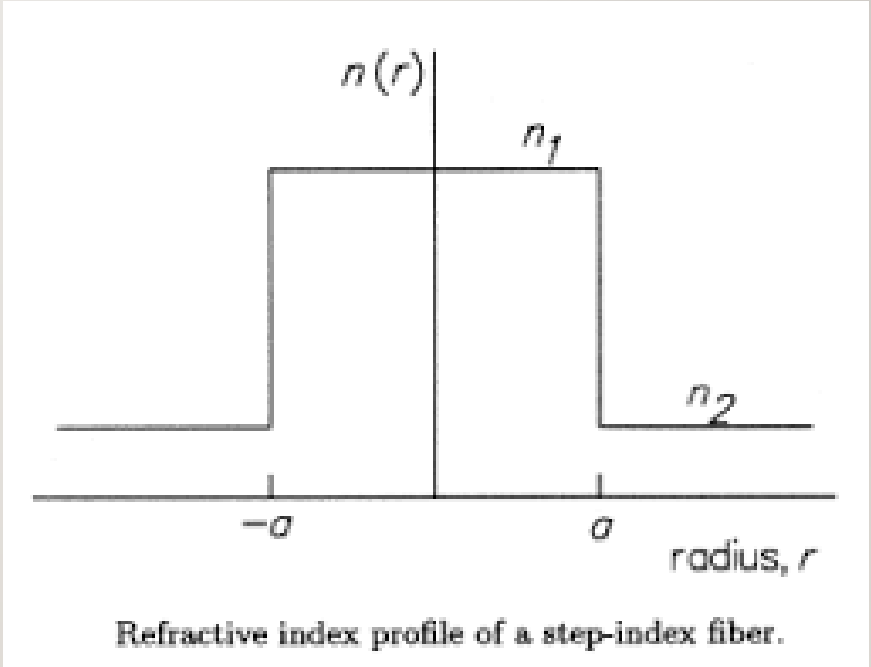
TYPES OF OPTICAL FIBERS

Optical fibers mainly have been classified according to their refractive index profile as

- **1. Step index single mode fiber.**
- **2. Step index multimode fiber.**
- **3.Graded index multimode fibers.**

REFRACTIVE INDEX PROFILE

Refractive index profile is a graph which shows variation of refractive index along the diameter of the optical fiber. i.e. graph plotted between the refractive index and radial distance



Refractive index profile of a step-index fiber.

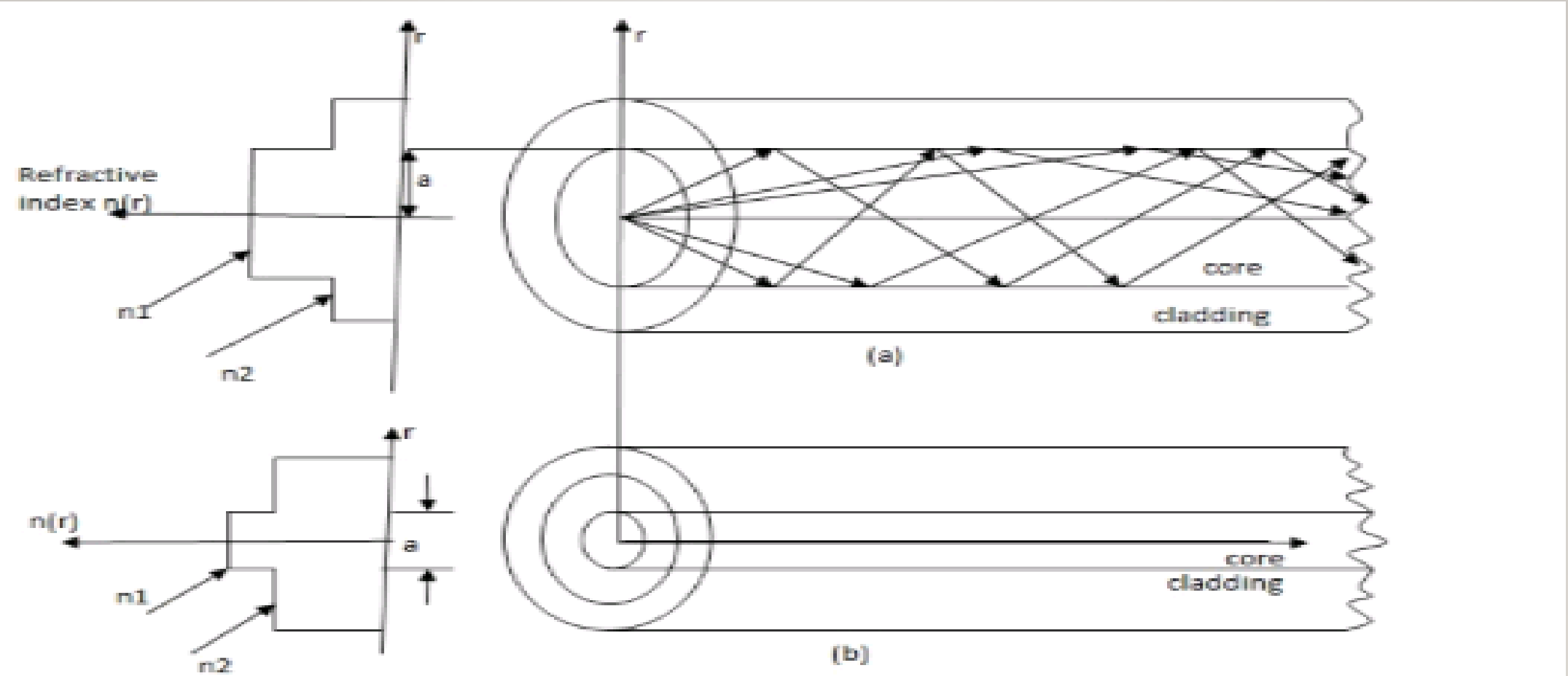
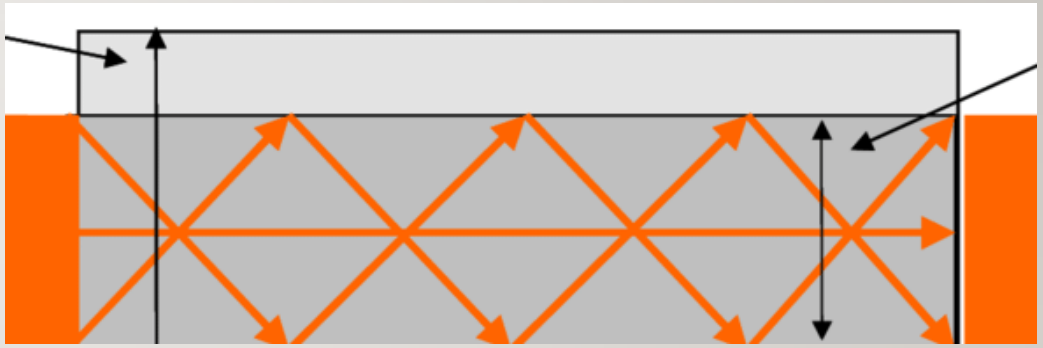


Figure 1.6: The Refractive Index profile and ray transmission in step Index fibers: (a) Multimode step index fiber; (b) Single-mode step index fiber

STEP INDEX FIBERS

- Fig shows R.I. profile of step index fiber where R.I.P. appears like a step.
- The refractive indices of the core and cladding vary like a step and so it called as step index fiber.
- It has constant higher value of refractive index of core and constant lower value of refractive index of cladding.
- The light rays propagating through it are in the form of meridional rays which will cross the fiber axis during every reflection at the core-cladding boundary and are propagating in a zig-zag manner.



STEP INDEX FIBERS -TYPES

- step index single mode fiber
- step index multi-mode fiber

STEP INDEX SINGLE MODE FIBER

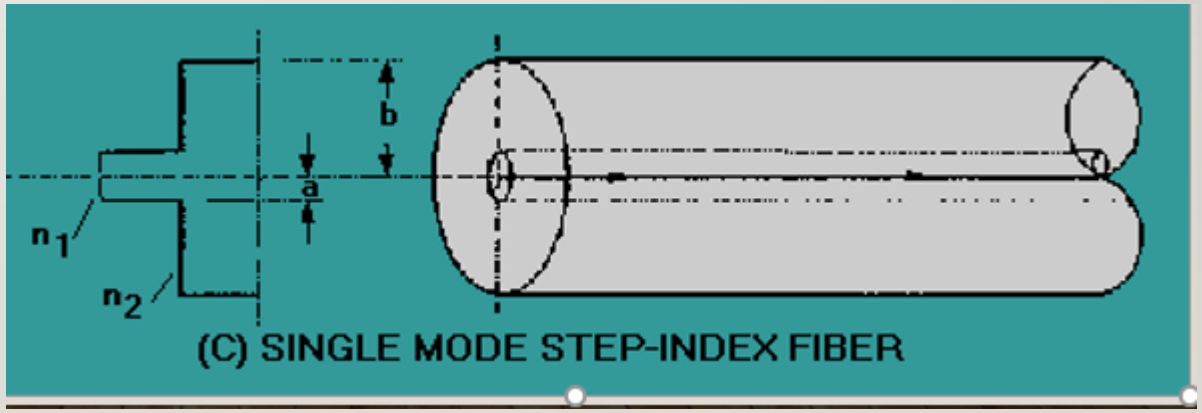
- **A single mode fiber is one in which light follows a single path for the propagation through the core.**
- **These fibers will have the core diameter of the order of 8 to 10 µm and cladding diameter of the order of 60 to 70 µm.**
- **Because of narrow core only zeroth order mode is allowed in a single mode** as shown

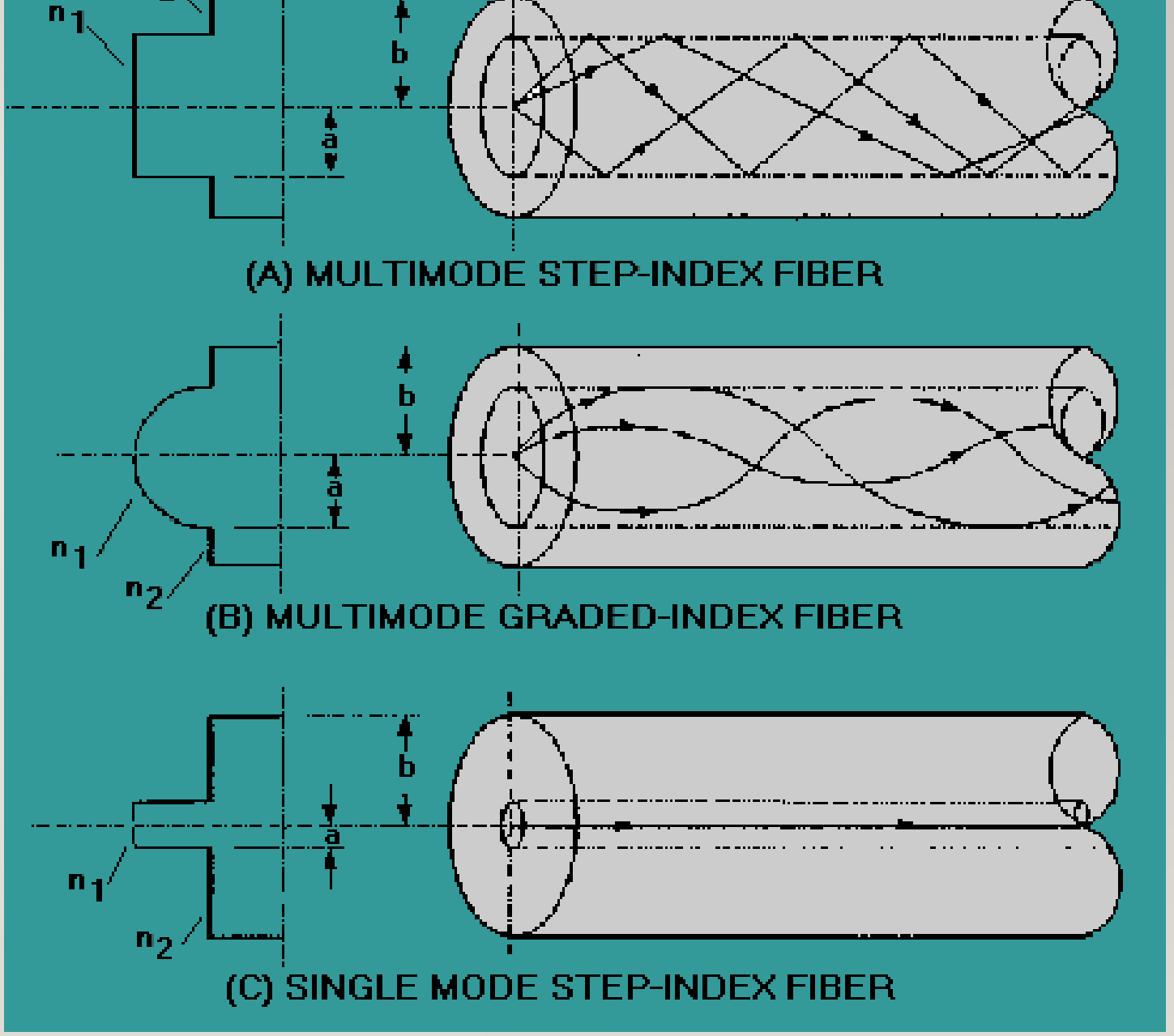
Characteristics of single mode step index fiber

1. It has small core diameter.
2. It has high bandwidth.
3. It has small numerical aperture around 0.02.
4. It has less attenuation.

Advantages

It has very high capacity. Nearly 80% of the fibers are of step index single mode. Fabrication of fibers, Launching of light into single mode fibers and joining of two fibers are very difficult. They need lasers as a source and are used in long distance communications. They find application in submarine cable systems.



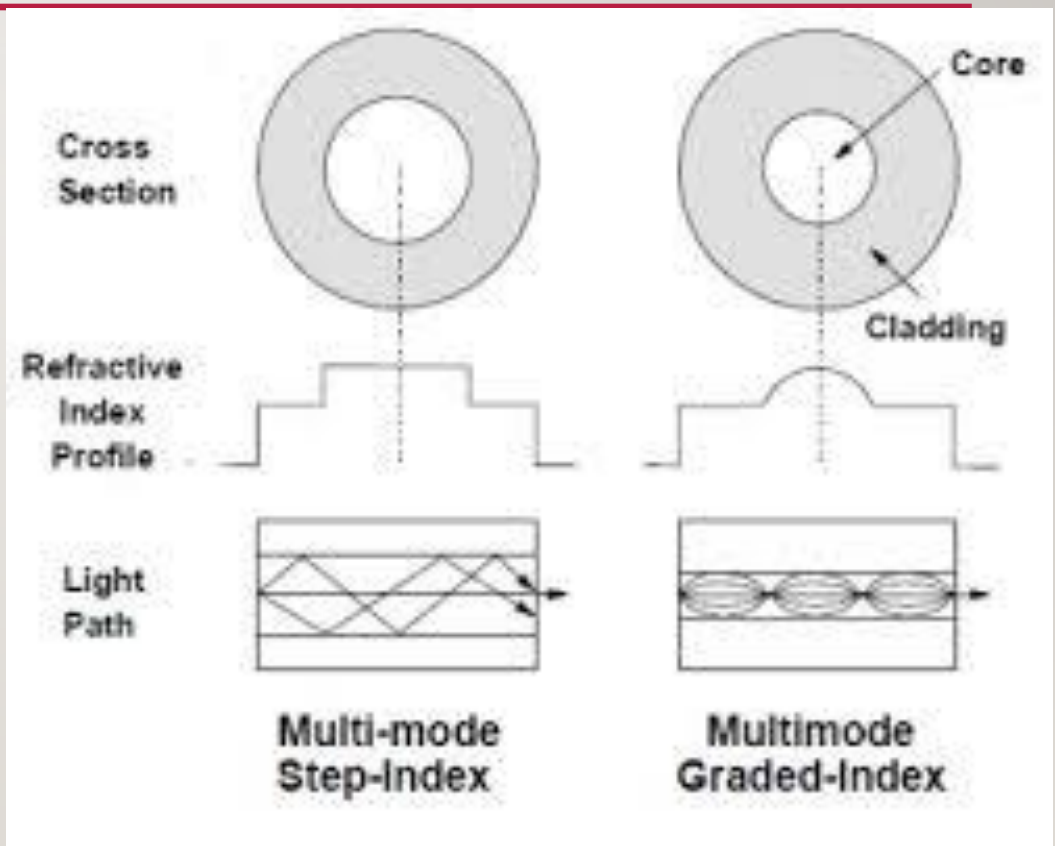

n1
b
a
(A) MULTIMODE STEP-INDEX FIBER
n1
n2
b
a
(B) MULTIMODE GRADED-INDEX FIBER
n1
n2
b
a
(C) SINGLE MODE STEP-INDEX FIBER

STEP INDEX MULTI-MODE FIBER

- **Multimode fiber is one in which light follows many path (more than one) through the core for the propagation.**
- **These fibers will have core diameter of the order 50 to 200 μm and cladding diameter of 100 to 250 μm.**
- **Due to large core diameter it can support large number of modes**

CHARACTERISTICS OF MULTIMODE STEP INDEX FIBER

- It has high core diameter.
- It has low band width.
- It has high numerical aperture around 0.3.
- They suffer from intermodal dispersion so attenuation is more.

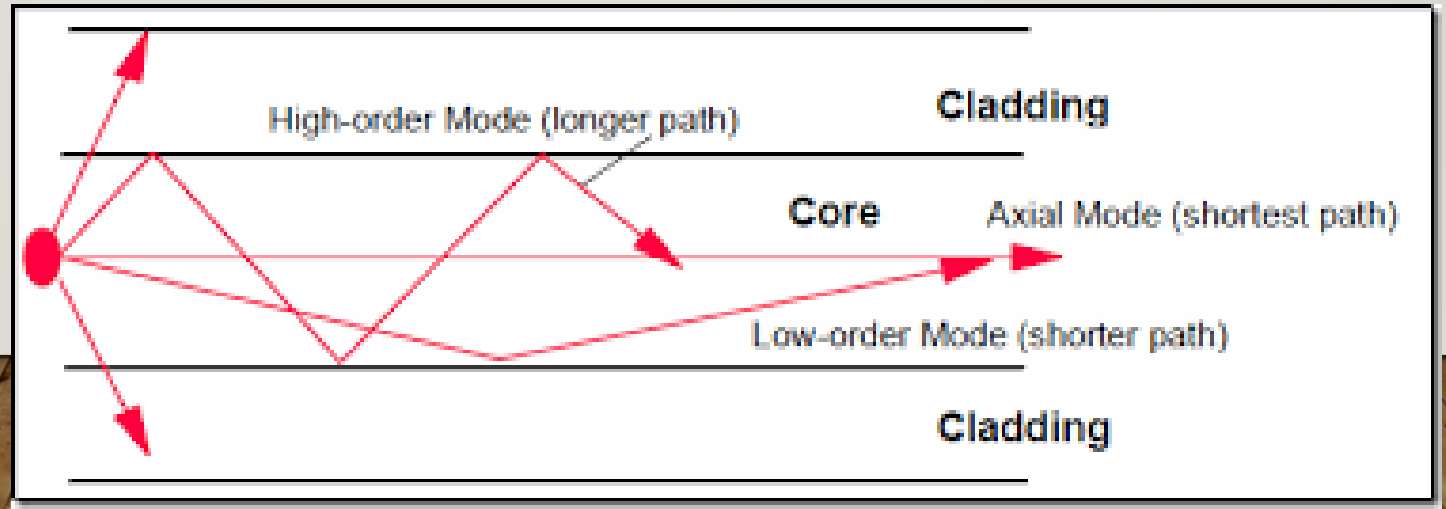


ADVANTAGES

- They are easier to manufacture.
- They have simple circuitry.
- LED or Laser can be used as a source. Fabrication, Launching of light into fiber and joining of two fibers are easy in these fibers so they are cheap. They are used as data links for communication purposes which has lower bandwidth requirements.

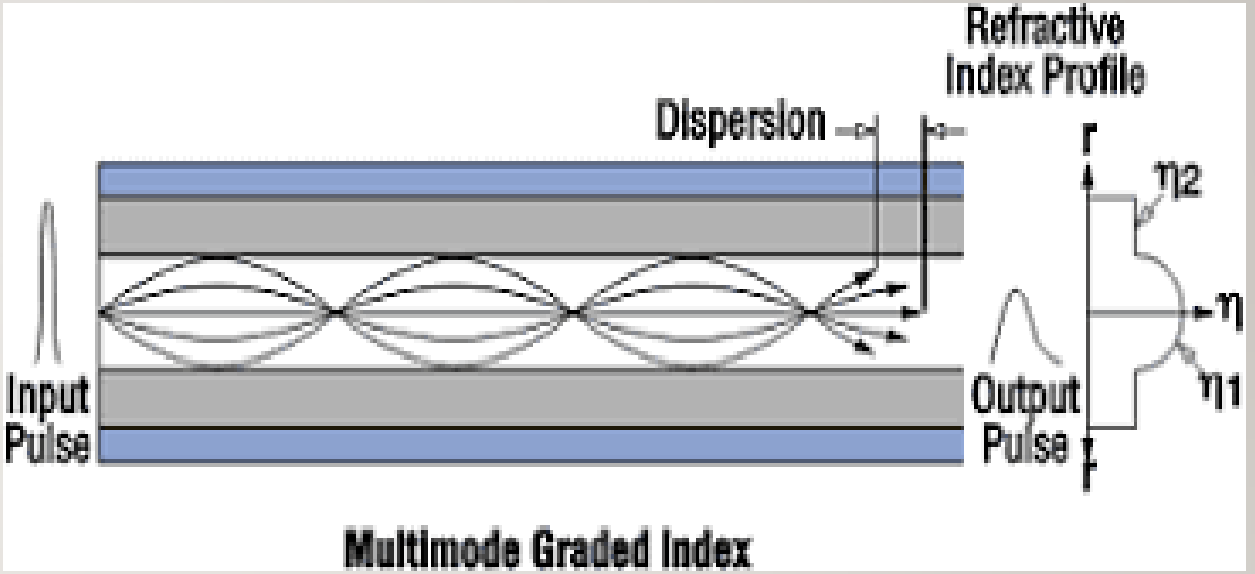
LIMITATION OF STEP INDEX MULTIMODE FIBERS

Light propagation in step index fibers is by multiple total internal reflections. In multimode step index fibers, there is a time delay between different pulses of lower order modes and high order modes travelling along different paths as shown in fig. Hence the pulse received at the other end is broadened. This is known as intermodal dispersion. This imposes limitation on the separation between pulses and reduces the transmission rate and capacity. To overcome this problem, graded index fibers are used.



GRADED INDEX FIBERS

- Fig shows R.I. profile of graded index fiber where refractive index of core is not constant but decreases as we move away from the axis of the core.
- But refractive index of cladding remains constant and its value is less than the core's refractive index.
- As there is continuous variation in the refractive index of the core, light propagates through refraction of light following a curved path as shown in figure.



- The light rays travel along the region of lower refractive index faster as compared to light travelling in the region of high refractive index, hence all the pulses of signals will reach at the other end of fiber simultaneously.

- Thus the problem of intermodal dispersion can be reduced to a large extent and attenuation is less in graded index fiber.

- Light rays propagating through it are in the form of skew rays (or) helical rays which will not cross the fiber axis at any time and are propagating around the fiber axis in a helical (or) spiral manner as shown.

CHARACTERISTICS OF GRADED INDEX MULTIMODE FIBERS

- **It is a high quality fiber.**
- **It has moderate bandwidth and capacity.**
- **It has small numerical aperture.**
- **It has low attenuation.**

Advantages:

LED or Laser can be used as a source for GRIN multimode fibers. It is most expensive of all. It is

easier to splice and interconnect. But these fibers are free from intermodal dispersion. It's typical

application is in telephone trunk between central offices.

Dispersion

The spreading of an optical pulse as it travels inside the core of an optical fiber is called dispersion. It is expressed in units of ns/km

Types of dispersion

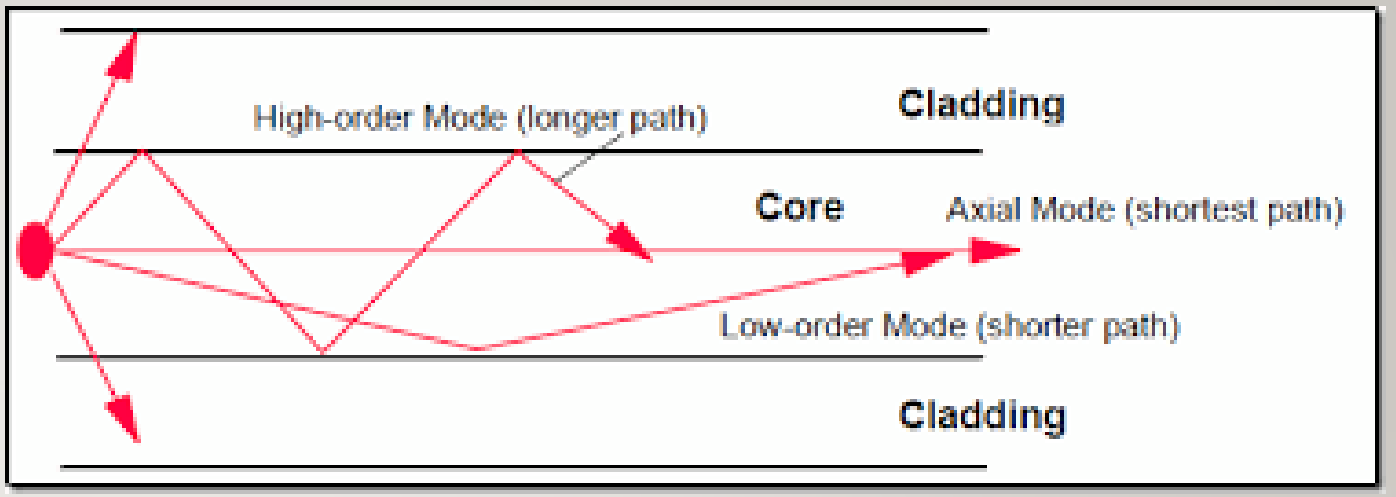
1) Intermodal dispersion

2) Intramodal dispersion

INTERMODAL DISPERSION

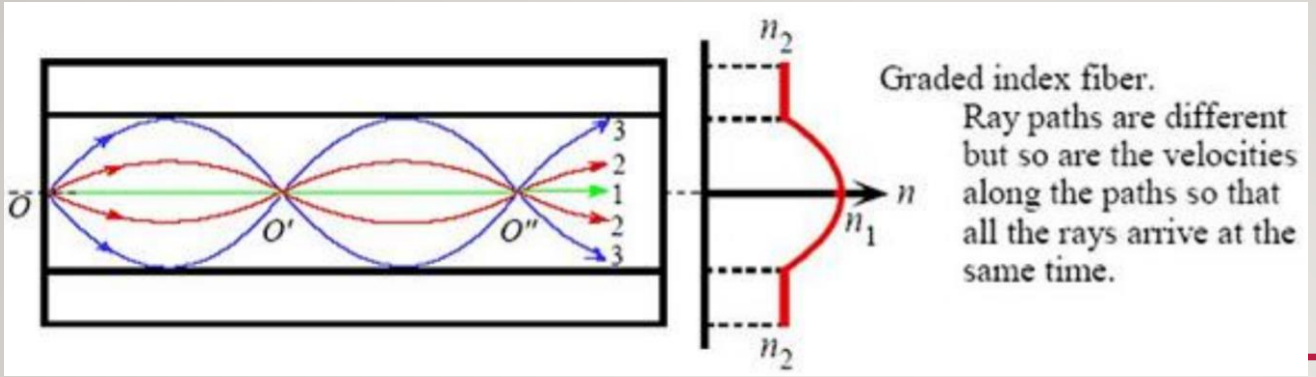
- **When light travels in the step-index multimode fiber, each ray is reflected many times.**
- **The higher order modes travel longer distance than the lower order modes to reach the end of fiber.**
- **Hence higher order modes arrive later than the lower order and pulses broaden causing signal distortion.**
- **The path length of the zeroth order (along the axis of fiber) is the shortest among the allowed modes.**

Therefore the part of the input energy that takes this mode arrives at the receiving end earliest compared to those which take higher order modes.



Hence the pulse received at the other end is broadened. This type of distortion is known as intermodal dispersion

- **This imposes limitation on the separation between pulses and reduces the transmission rate and capacity. To overcome this problem, graded index fibers are used.**



Graded index fiber.
Ray paths are different but so are the velocities along the paths so that all the rays arrive at the same time.

- In graded index fiber light ray travel at different speeds in different parts of the fiber because refractive index varies across the core.
- The rays near the outer edge of core travel faster than the rays in the center of the core and arrive at the end of the fiber at approximately at the same time.

INTRAMODAL DISPERSION

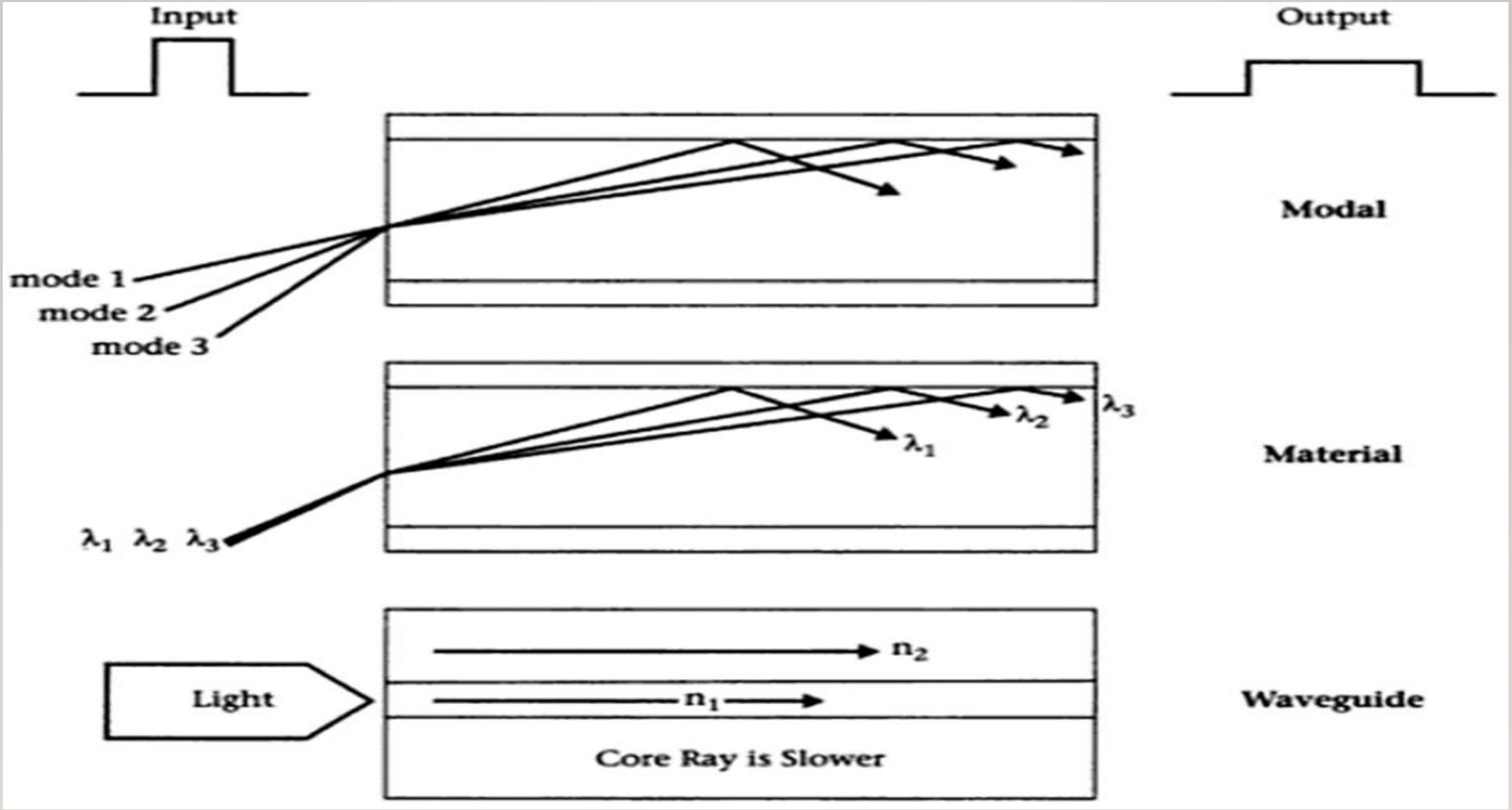
Intramodal dispersion is again divided into two parts

(i) Material dispersion

(ii) Waveguide dispersion

MATERIAL DISPERSION

- A light pulse is a wave packet, composed of a group of components of different wavelengths.
- The different wavelength components will travel at different speeds along the fiber.
- The short wavelengths travel slower than long wavelengths. Consequently, pulses of light tend to broaden as they travel down the fiber.
- It is often called the chromatic dispersion. Material dispersion occurs in all type of fibers.


Input
Output
Modal
mode 1
mode 2
mode 3
Material
λ_1 λ_2 λ_3
λ_1
λ_2
λ_3
Waveguide
Light
n_2
n_1
Core Ray is Slower

WAVEGUIDE DISPERSION

- **Waveguide dispersion arises from guiding properties of the fiber.**
- **It occurs in single mode fibers.**
- **It is caused by the different refractive indices of the core and cladding of an optical fiber.**
- **Regardless of the nature of the light source and optical fiber, some light travels in the cladding as well.**
- **The light propagating in the cladding travels faster than the light confined to the core and hence, broadening of pulses occur.**

- **In a multimode step index fiber, all three pulse spreading mechanism exist simultaneously.**
- In case of step index single mode fiber only material and waveguide dispersion exist.