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FIBRE OPTICS

Syllabus

- Basic principle of optical fibre, step index and graded index fibers
- parameters of optical fibers, acceptance angle, acceptance cone, numerical aperture, normalized frequency, No. of modes,
- Attenuation in optical fibers, intermodal and intramodal dispersion (no derivation), optical fibers in communication.

Introduction

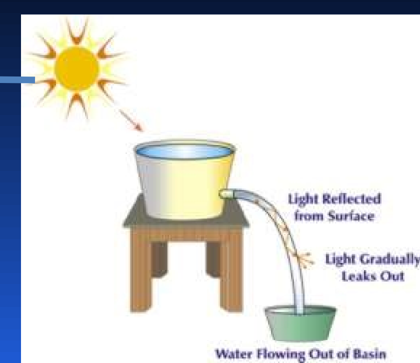
An optical fiber is essentially a waveguide for light

- An optical fiber (or fibre) is a glass or plastic fiber designed to guide light along its length by confining as much light as possible in a propagating form.
- They are arranged in bundles called optical cables and used to transmit light signals over long distances.
- Based on the principle of "Total Internal Reflection"
- Optical fibers are widely used in fiber-optic communication, which permits transmission over longer distances and at higher data rates than other forms of wired and wireless communications.

The light-guiding principle behind optical fibers was first demonstrated

in by Daniel Colladon and Jaques Babinet in the 1840s,

with Irish inventor John Tyndall offering public displays using water-fountains .

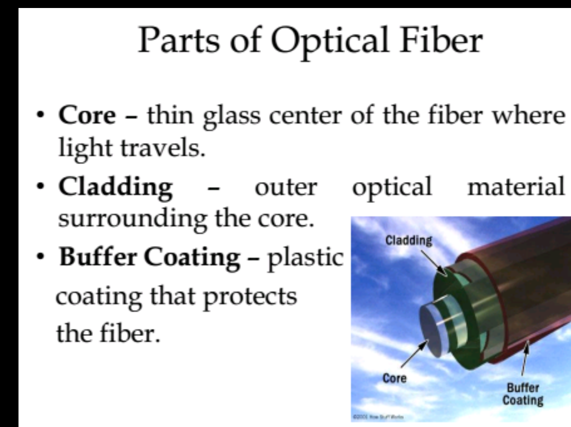


A fibre optic cable consists of glass or plastic threads, which are protected by the thin polyvinyl chloride (PVC) or metal sheath. The central part of optical fibe is known as core, which is surrounded by cladding. These layers are further protected by PVC sheath

1. **Core** is made up of thin glass or plastic layer through which light travels.

2. **Cladding** is outer optical material surrounding the core and reflects back the light into the core.

3. **Sheath** is plastic coating that protects fibre from any damage or other environmental conditions.

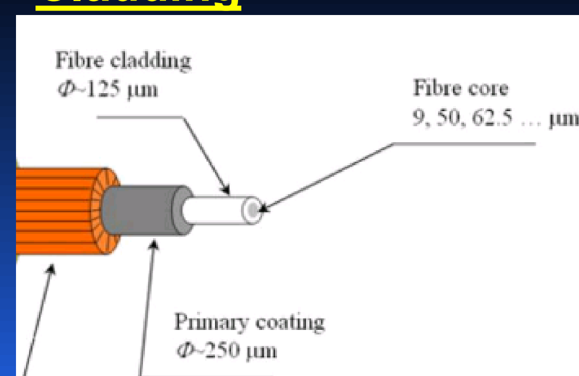


Parts of Optical Fiber

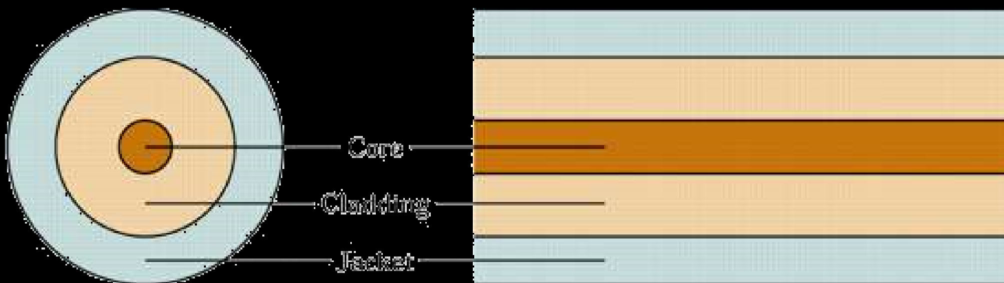
- **Core** – thin glass center of the fiber where light travels.
- **Cladding** – outer optical material surrounding the core.
- **Buffer Coating** – plastic coating that protects the fiber.

Core Refractive Index Is slightly greater than that of Cladding

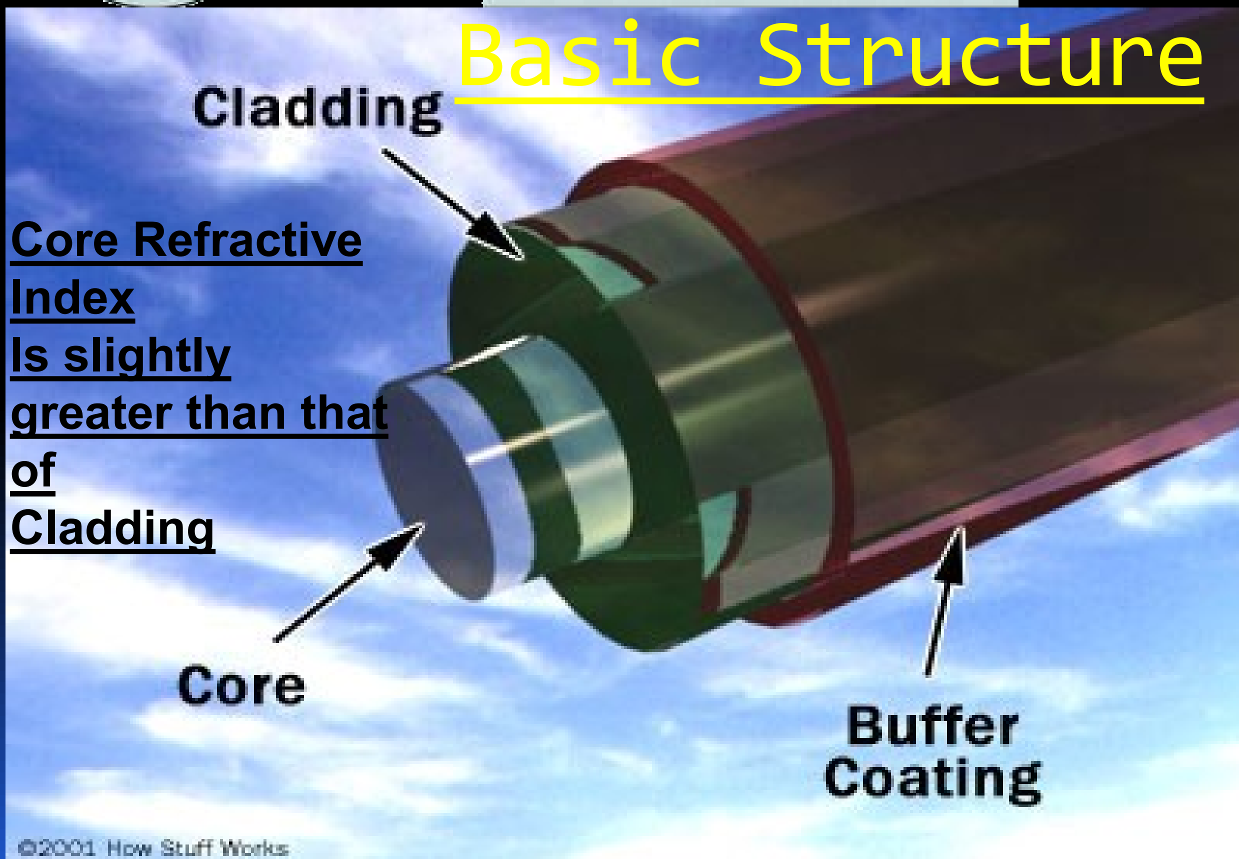
The range of the core diameter is 5-100 micrometer.
The cladding diameter is usually 125 um and sheath diameter is about 250 um.



Optical fibers are very fine fibers of glass. They consist of a glass core, roughly fifty micrometres in diameter, surrounded by a glass "optical cladding" giving an outside diameter of about 125 Micrometres.



Basic Structure



Core Refractive Index Is slightly greater than that of Cladding

Core
- Glass or plastic with a higher index of refraction than the cladding
- Carries the signal

Cladding
- Glass or plastic with a lower index of refraction than the core

Protective Sheath/Buffer Coating
- Protects the fiber from damage and moisture

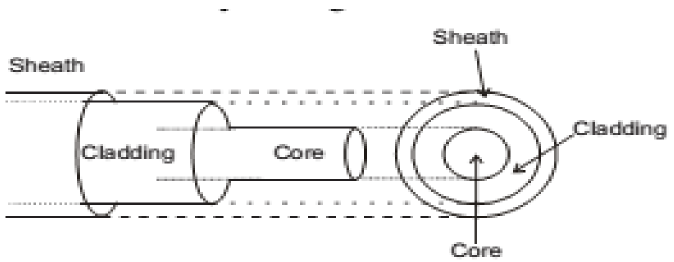
Jacket
- Holds one or more fibers in a cable

Optical fibres are fabricated from glass or plastic material which are transparent to optical frequencies. Therefore, based on the nature of core and cladding the optical fibres are of three types :

(i) plastic core with plastic cladding

(ii) glass core with plastic cladding and

(iii) glass core with glass cladding.



- In case of plastics, the core is made up of polystyrene or polymethyl metha acrylate (PMMA) and cladding is made from silicon or teflon.
- On the other hand in case of glass, it is made of silica (SiO_2) with refractive index 1.458.
  1. The refractive index of pure silica can be increased by doping with germania (GeO_2) or phosphorous pentaoxide (P_2O_5).
  2. Likewise, the refractive index of pure silica can be decreased by doping with Boria (B_2O_3) or fluorene.

Hence the doped silica can be used as both core or cladding materials.

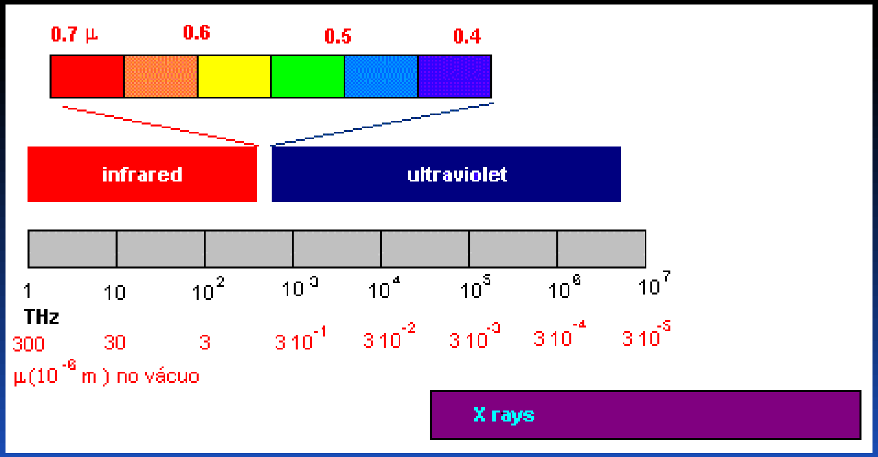
Advantages of optical fiber :

- Greater bandwidth
- Lower loss
- Immunity to **crosstalk**
- No electrical hazard
- Free from electromagnetic interferences

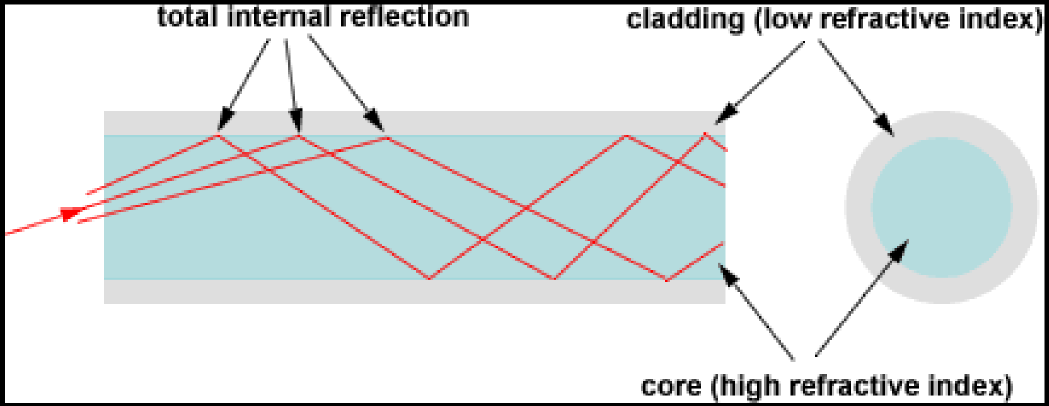
Light Propagation

- Visible light extends from 380 nm (violet) to 780 nm (red).
  - For smaller wavelengths ultra-violet radiation (UV) occurs. Longer wavelengths correspond to the infrared region (IR).

- Optical Fibres communication elements operate in the micrometer wavelength zone of the frequency spectrum (frequencies between 10^{14} Hz to 10^{15} Hz).



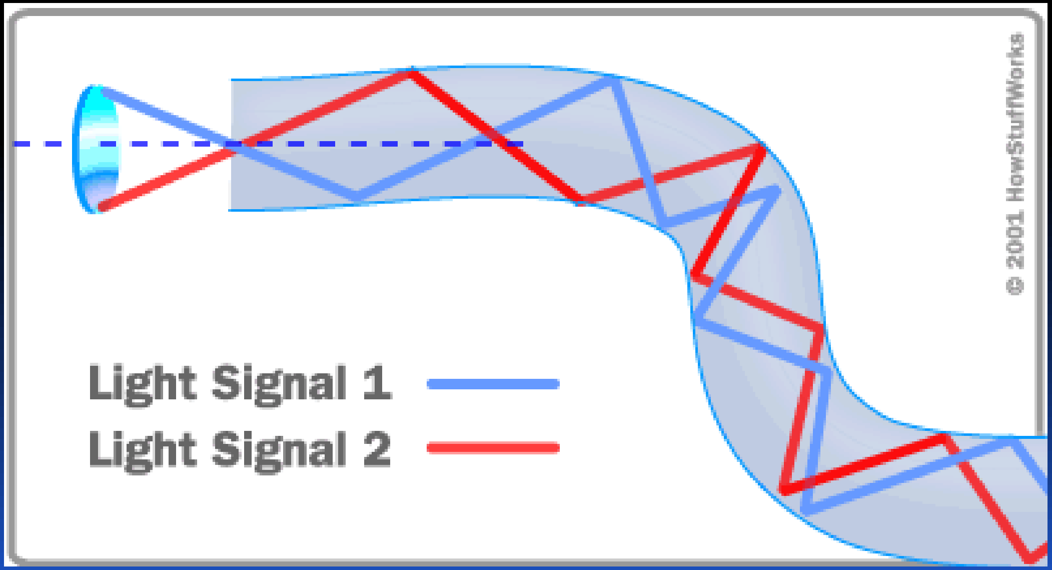
Transmission of Light in Optical Fibre



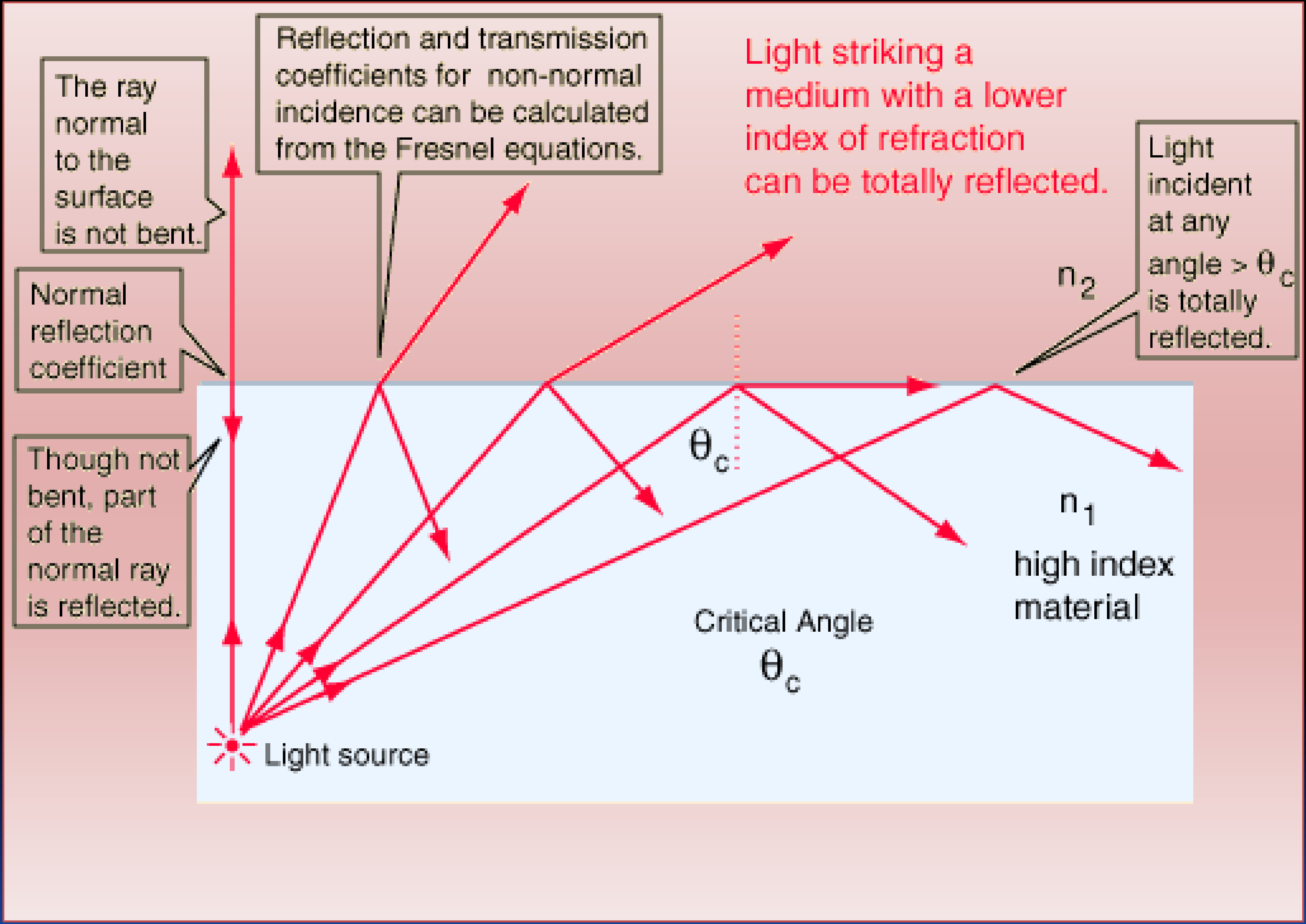
An optical fiber guides light waves in distinct patterns called *modes*.

Mode describes the distribution of light energy across the fiber.

Total Internal Reflection



The precise patterns depend on the wavelength of light transmitted and on the variation in refractive index that shapes the core.



The ray normal to the surface is not bent.
Reflection and transmission coefficients for non-normal incidence can be calculated from the Fresnel equations.
Light striking a medium with a lower index of refraction can be totally reflected.
Light incident at any angle > θ c is totally reflected.
Normal reflection coefficient
Though not bent, part of the normal ray is reflected.
n 2
θ c
n 1
high index material
Critical Angle
θ c
Light source

Total Internal Reflection & Critical Angle

Expression for Critical Angle :

According to Snell's Law,

$$n_1 \sin\phi_1 = n_2 \sin\phi_1$$

If angle of incidence = Critical Angle ($\phi_1 = \phi_c$),

Then, $\phi_2 = 90^o$

$$n_1 \sin\phi_c = n_2 \sin 90$$

$$\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

In case of optical fibre, the refractive index of core (n_1) is slightly greater than the refractive index of cladding (n_2). Then light signal is totally internally reflected. As a result, light ray undergoes multiple total internal reflections at core cladding interface until it emerges out of the other end of the fibre even if the fibre is bent.

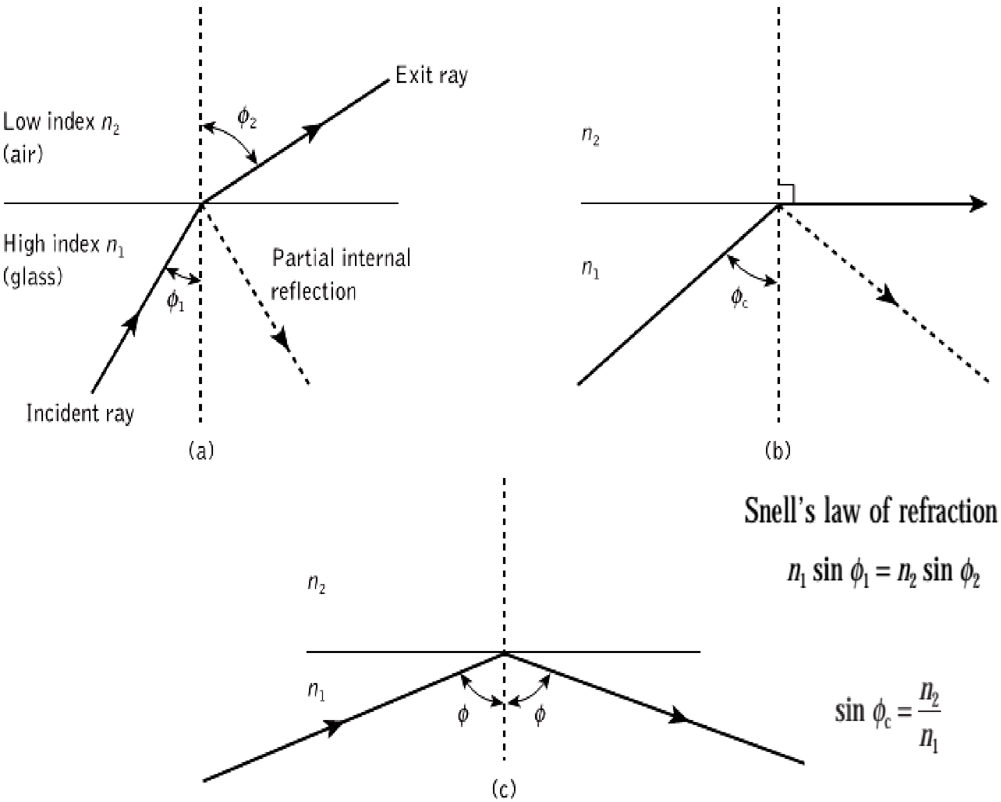
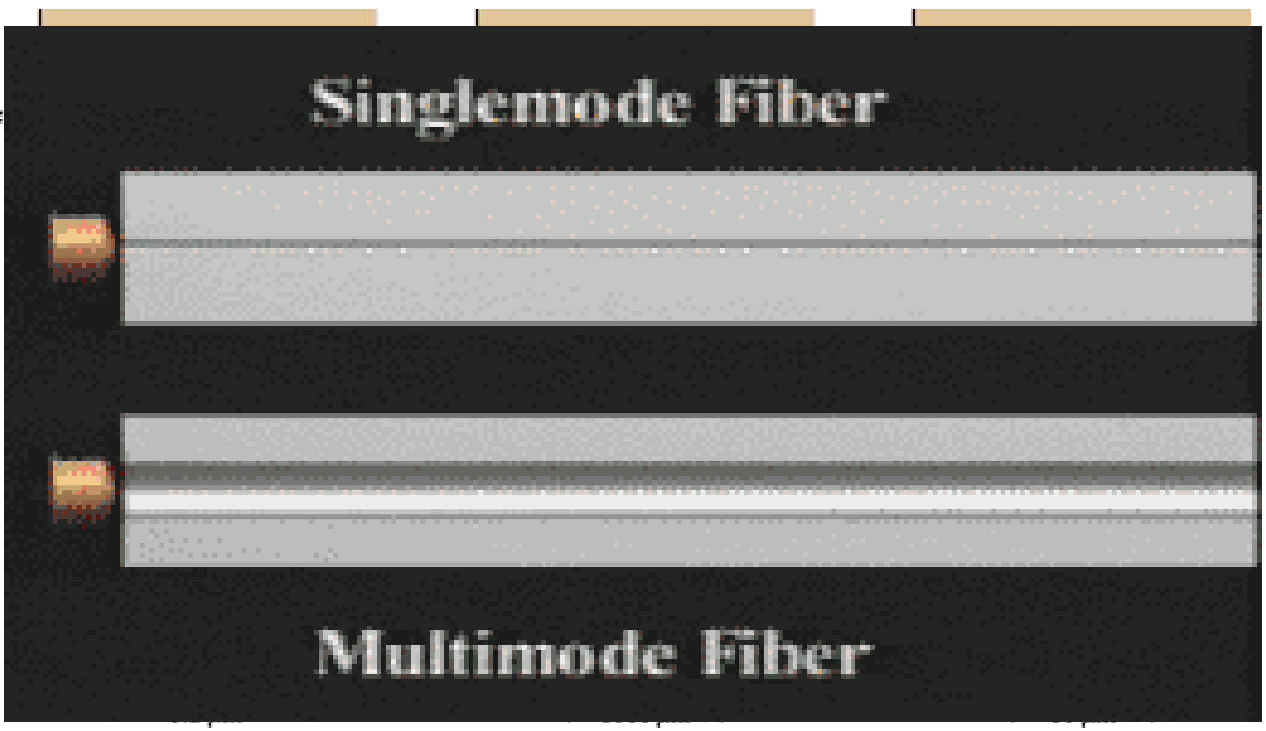


Figure: Light rays incident on a high to low refractive index interface (e.g. glass–air): (a) refraction; (b) the limiting case of refraction showing the critical ray at an angle ϕ_c; (c) total internal reflection where $\phi > \phi_c$

Types of Fiber

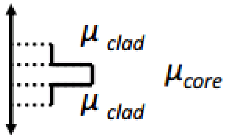
1. Step Index Single Mode
2. Multi-Mode
    1. Step Index
    2. Graded Index



- Step-index fibers → because the index of refraction changes radically (in step) between the core and the cladding
- Graded-index fiber is a compromise multimode fiber, here the index of refraction gradually decreases away from the center of the core
- Graded-index fiber has less dispersion than a multimode step-index fiber

Single (Mono) Mode :

This is called so because the refractive index of the fibre ‘**step**’ up as we move from the cladding to the core and this type of fibre allows single mode to propagate at a time due to very small diameter of its core.

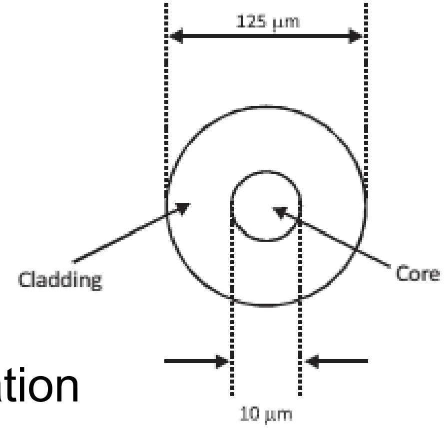


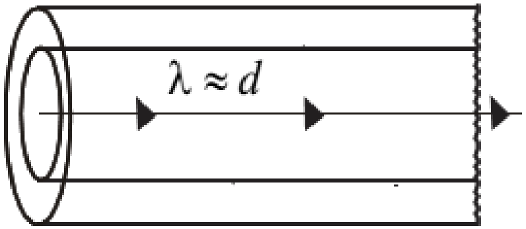
- In this fibre, the refractive indices of the cladding and the core remain constant

- In this fibre, the size of its core (diameter) is typically around 9-10 µm.

ADVANTAGE:

1. Best for high speeds
2. Long distances
3. High bandwidth





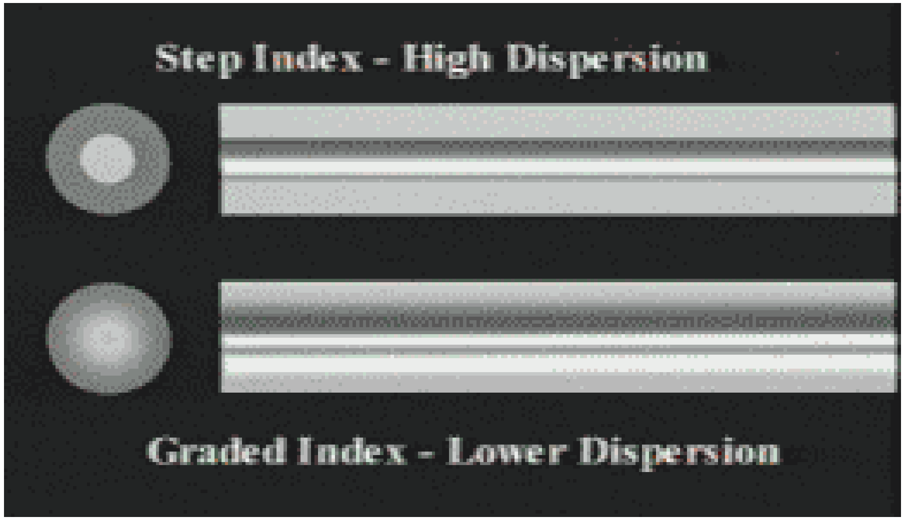
Allows only one mode of propagation

Multimode fibre :

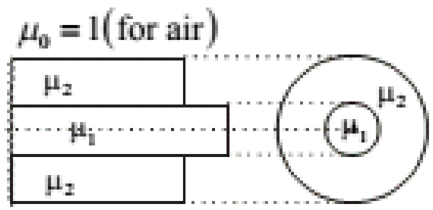
This is called so because it allow more than one mode to propagate. Over more than 100 modes can propagate through multimode fibres at a time. The size of its core is typically around 50 µm or 62.5 µm.

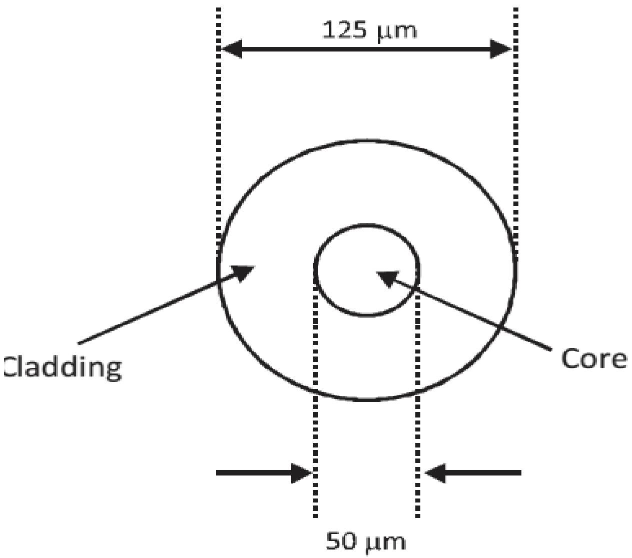
Two Types

- Step Index Fibres
- Graded Index Fibres



- *Multi Mode Optical Fibre(Step-Index)* : Allows many modes of propagation





- Numerical Aperture (NA) varies from 0.20 to 0.29 respectively.
- Typically the core diameter is 50 μm to 100 μm
- Due to higher value of NA , and larger core size in this case, fibre connections and launching of light is very easy
- Due to several modes, the effect of dispersion gets increased, i.e. the modes arrive at the fibre end slightly different times and so spreading of pulses takes place.

Features:

Large core size, so source power can be efficiently coupled to the fiber

High attenuation (4-6 dB / km), Low bandwidth (50 MHz-km)

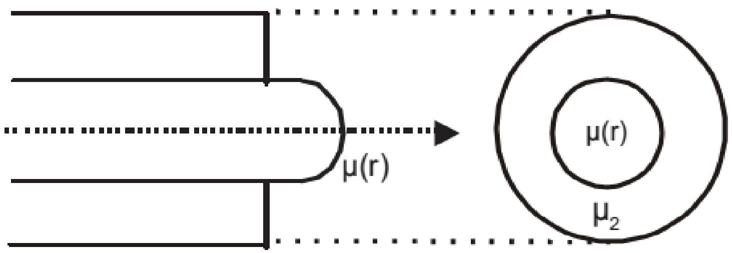
Used in short, low-speed data links

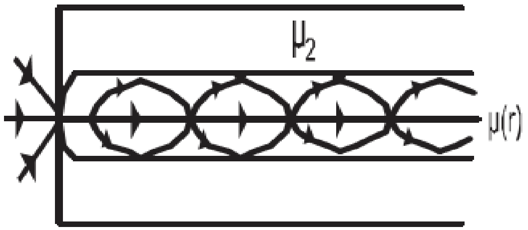
Also useful in high-radiation environments, because it can be made with pure silica core

Graded index Multimode Fibre

The profile of the refractive index is nearly parabolic that results in continual refocusing of the ray in the core, and minimizing the modal dispersion.

Standard graded index fibres typically have a core diameter of 50 µm or 62.5 µm and the cladding diameter of 125 µm.





The refractive index of graded index fibre is given by

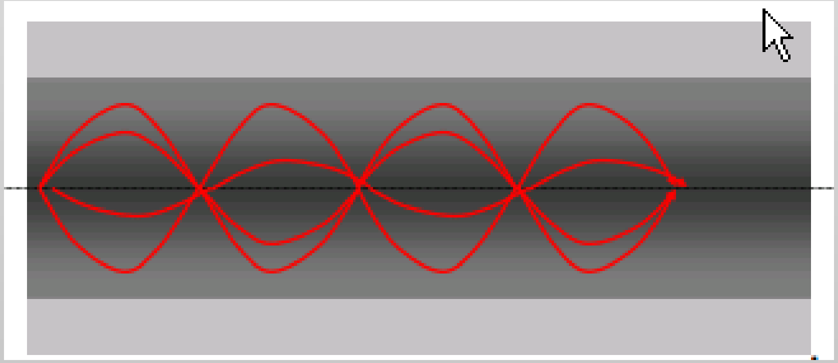
$$\mu(r) = \mu_1 \sqrt{1 - 2\Delta\left(\frac{2r}{d}\right)^{\alpha}}$$

$\mu(r)$ is the core index at radial distance 'r' from the core axis, μ_1 is refractive index at core axis, Δ is fractional refractive index difference, d is core diameter and α is grading profile index number.

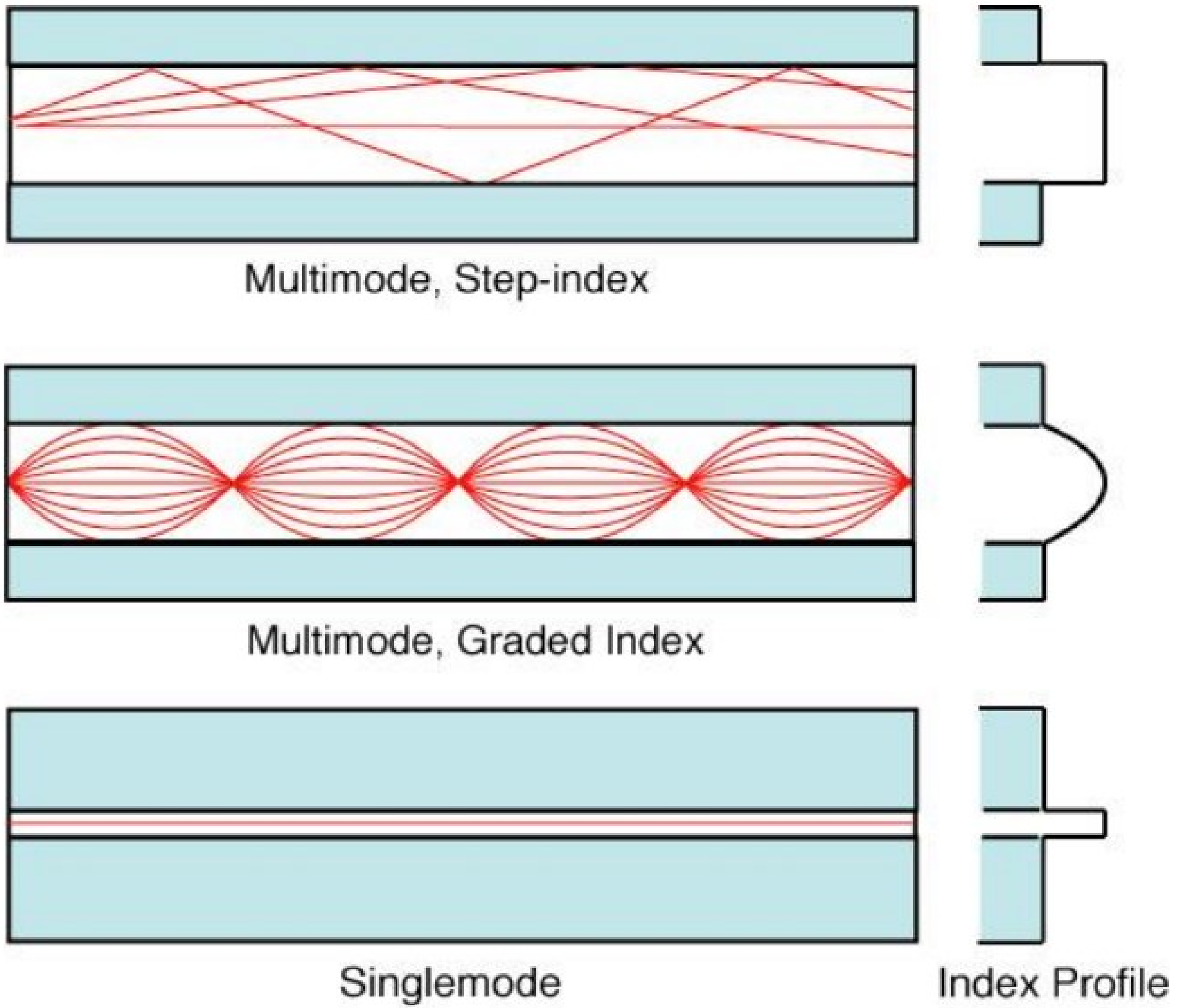
Features of Graded Index Fibre

1. The light wave follow sinusoidal paths along the fibre.
2. In this fibre, the refractive index of the core decreases with increasing radial distance from the fibre axis.
3. The value of the refractive index is highest at the centre of the core and decreases to a value at the edge of the core that equal the refractive index of the cladding.
4. Useful for "premises networks" like LANs, security systems, etc.
   1. 62.5/125 micron has been most widely used
   2. Works well with LEDs, but cannot be used for Gigabit Ethernet

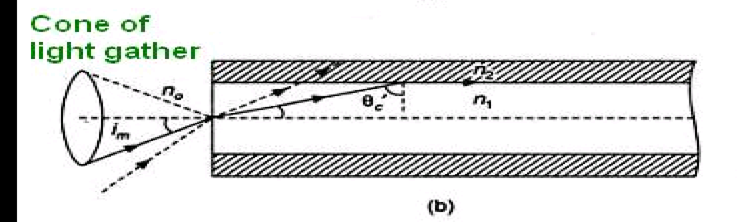
- Low modal Dispersion
  - Longer path is now located in lower index region; the larger time taken is compensated by faster travel leading to less pulse broadening



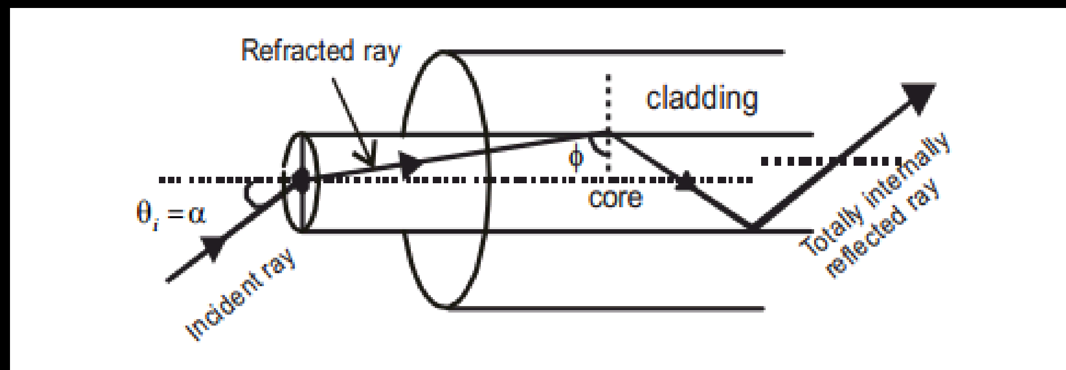
Types/index profile



Acceptance Angle



- **Acceptance angle:-** The acceptance angle is the maximum angle made by incident ray of light with the axis of core at core-outside medium, so that it gets totally internally reflected at core cladding interface.



Let α be the acceptance angle.

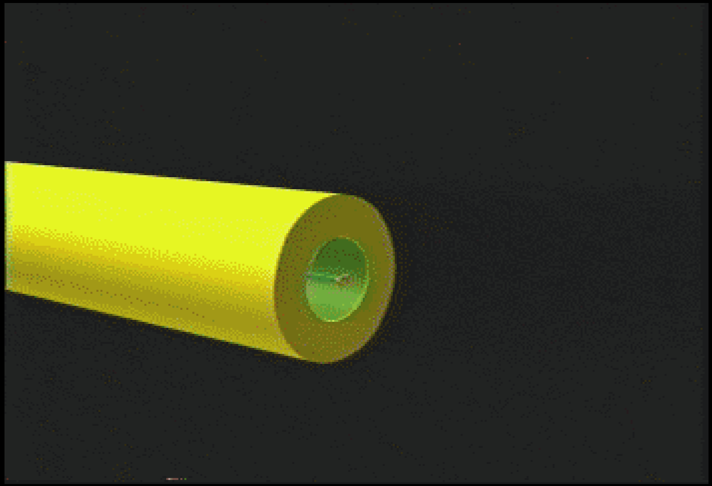
Then for $\theta_i = \alpha_{max}$, $\phi = \theta_c$ (Criticle angle)

For $\theta_i < \alpha_{max}$, $\phi > \theta_c$, total internal reflection takes place

For $\theta_i > \alpha_{max}$, $\phi < \theta_c$, signal transmisson does not takes place.

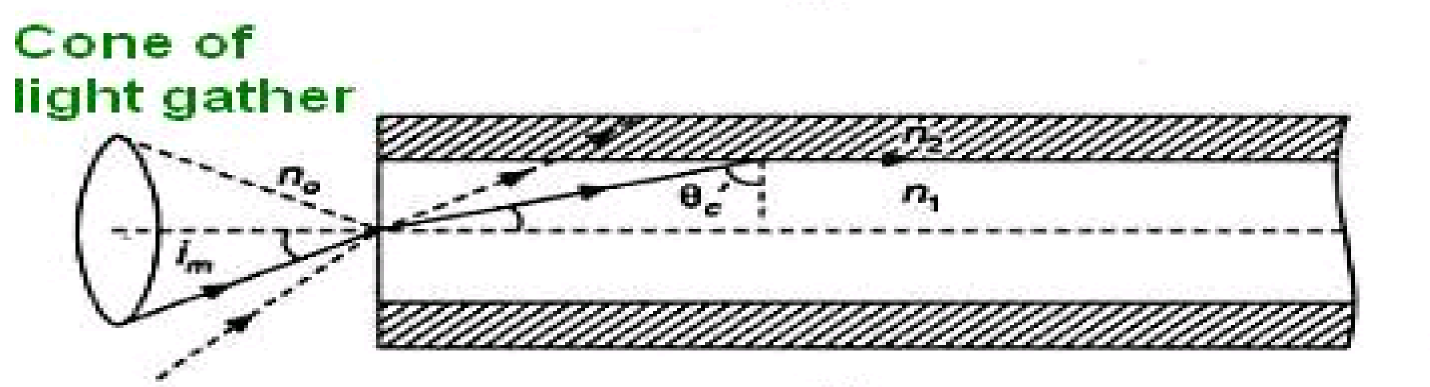
The **acceptance angle** of an optical fiber is **defined** based on a purely geometrical consideration (ray optics): it is the maximum **angle** of a ray (against the fiber axis) hitting the fiber core which allows the incident light to be guided by the core.

Acceptance Cone



(ii) Acceptance cone

Acceptance cone is a cone around core axis having angle 2 α_{max} = maximum acceptance angle. Therefore only those rays get totally internal reflected and able to travel through optical fibre, which enter the optical fibre through acceptance cone.



(b)

(iii) **Numerical aperture**

Numerical aperture is most important parameter of an optical fibre. It measure the amount of light collected by an optical fibre at core-cladding outside medium interface .

The numerical aperture (N.A) is defiend as the sine of acceptance angle.

$$\therefore \quad \text{Numerical aperture (N.A)} = \mu_0 \sin \alpha_{max} = \sqrt{\mu_1^2 - \mu_2^2}$$

Where μ_1 = refractive index of core, μ_2 = refractive index of cladding medium and μ_0 is the refractive index of outer medium.

In presence of air $\mu_o = 1$

$$\therefore \quad N.A = \sin \alpha_{max} = \sqrt{\mu_1^2 - \mu_2^2} \qquad \text{..... (3.3)}$$

also known as figure of merit of the optical fibre

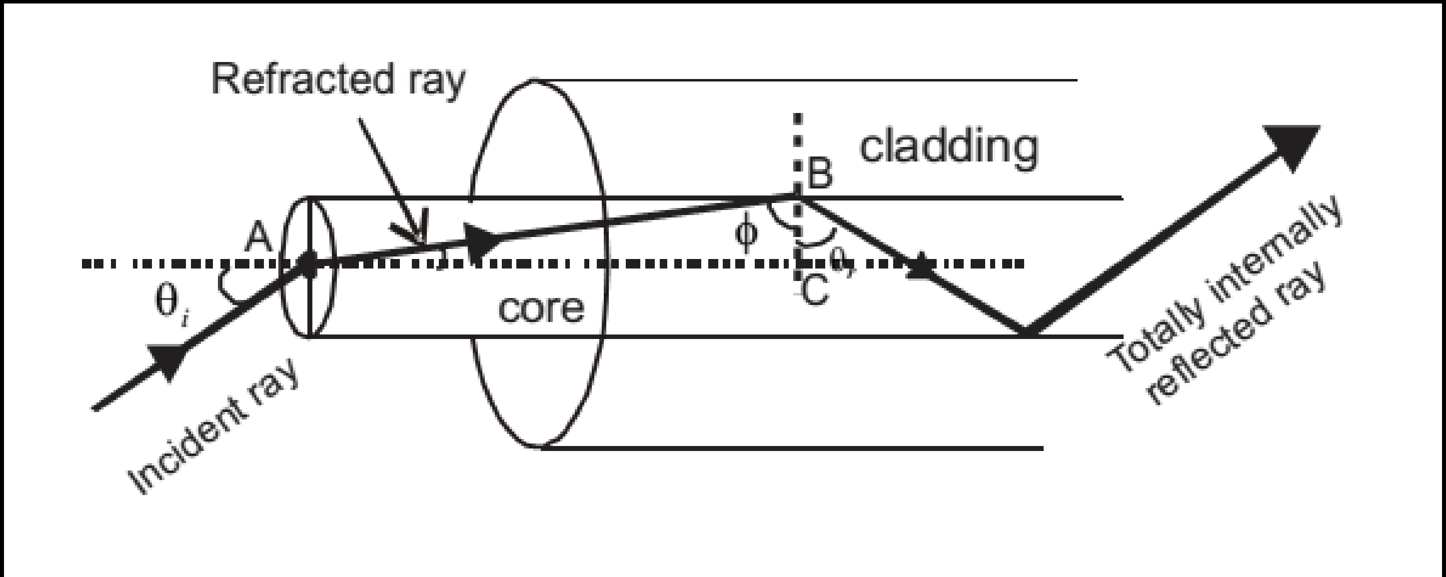
(iv) **Fractional Refraction index/Relative refractive index**

Fractional refrective index difference is defiend as the ratio of the difference between the refrective indices of core and the cladding to the refractive index of core .It is denoted by Δ ,

$$\therefore \quad \Delta = \frac{\mu_1 - \mu_2}{\mu_1}$$

The value Δ is always positive. For effective transmission of optical signal $\Delta \approx 0.01$.

Relationships



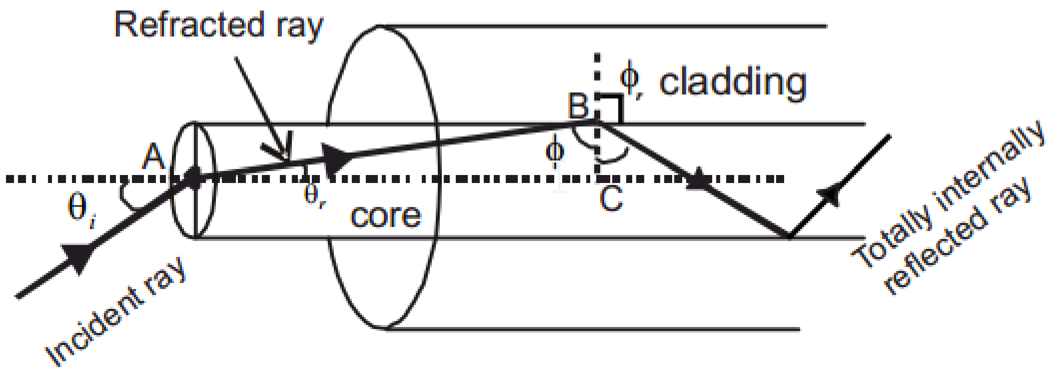
$$\alpha_{max} = \text{Acceptane angle} = \sin^{-1}(N.A)$$

For air, $n_o \sim 1$

$$\sin \alpha_{max} = \mu_1 \sqrt{2\Delta}$$

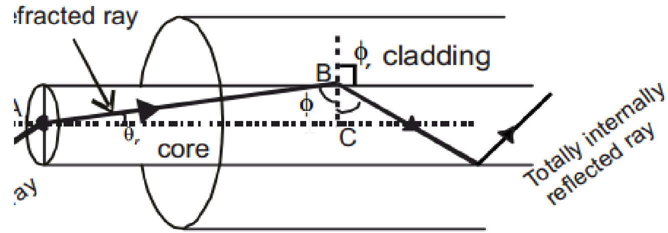
Relationship between acceptance angle and numerical aperture

Let us consider the light propagation in an optical fibre. Here, μ_1 is the refractive index of core, μ_2 is refractive index of cladding and μ_o is the refractive index of outer medium. Let a light ray enter the fibre at an angle θ_i and θ_r is the angle of refraction. The refracted ray strikes the core-cladding interface at an angle ϕ.



If $\phi > \theta_c$ (critical angle), the ray undergoes total internal reflection at core-cladding interface. As long as $\phi > \theta_c$, the light remains within the fibre by multiple total internal reflections.

Apply Snell's law for incident ray at point 'A'



$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{\mu_1}{\mu_0}$$

From Δ ABC

$$\sin\theta_r = \sin(90-\phi) = \cos\phi$$

$$\sin\theta_i = \sin\theta_r \frac{\mu_1}{\mu_0}$$

When $\phi = \phi_c$, $\theta_i = \alpha_{max}$

$$\therefore \quad \sin\alpha_{max} = \frac{\mu_1}{\mu_0}\cos\phi_c$$

$$\cos\phi_c = \frac{\mu_0}{\mu_1}\sin\alpha_{max}$$

Apply Snell's law at point B

$$\mu_1 \sin\phi = \mu_2 \sin\phi_r$$

$$\sin\phi = \frac{\mu_2}{\mu_1}\sin\phi_r$$

When $\phi = \phi_c$, $\phi_r = 90^\circ$

$$\therefore \quad \sin\phi_c = \frac{\mu_2}{\mu_1}$$

$$\sin^2\phi_c + \cos^2\phi_c = \frac{\mu_2^{\,2}}{\mu_1^{\,2}} + \frac{\mu_0^{\,2}}{\mu_1^{\,2}}\sin^2\alpha_{max}$$

$$\therefore \quad \frac{\mu_1^{\,2} - \mu_2^{\,2}}{\mu_1^{\,2}} = \frac{\mu_0^{\,2}}{\mu_1^{\,2}} \sin^2 \alpha_{max} \quad \therefore \quad \sin^2 \alpha_{max} = \frac{\mu_1^{\,2} - \mu_2^{\,2}}{\mu_0^{\,2}}$$

$$\sin \alpha_{max} = \frac{\sqrt{\mu_1^{\,2} - \mu_2^{\,2}}}{\mu_0} \text{ or } \alpha_{max} = \sin^{-1}\left[\frac{\sqrt{\mu_1^{\,2} - \mu_2^{\,2}}}{\mu_0}\right]$$

$$\alpha_{max} = \text{Acceptane angle} = \sin^{-1} (\text{N.A})$$

$$\text{N.A} = \sqrt{\mu_1^{\,2} - \mu_2^{\,2}}$$

V-number (normalized frequency) : measure of the number of supported modes

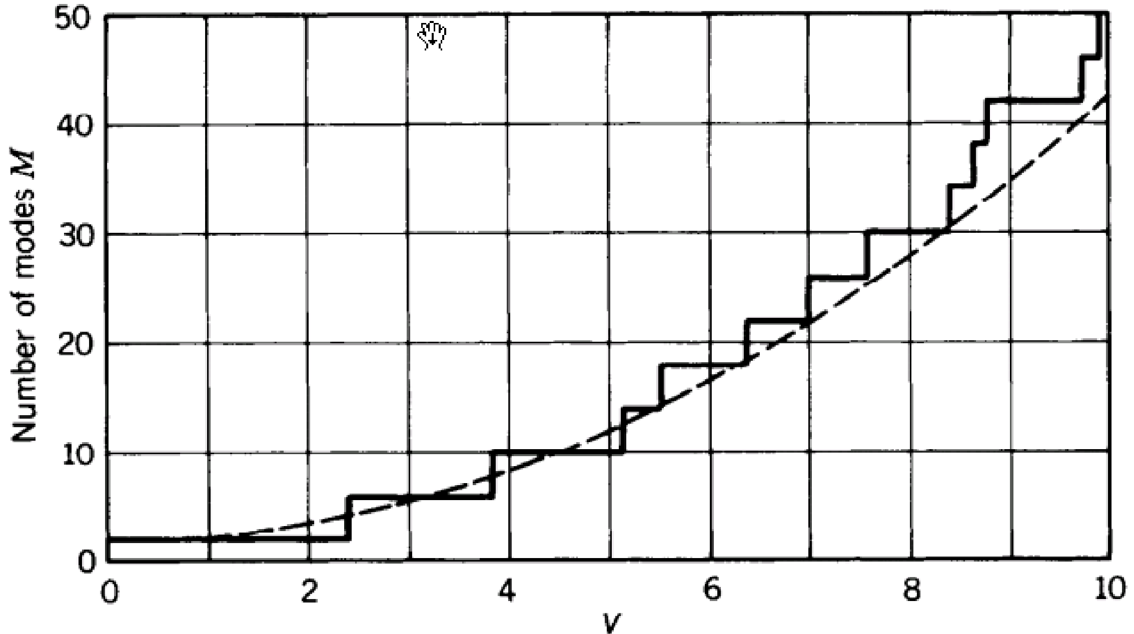
$$V = \frac{2\pi a}{\lambda}\sqrt{\mu_1^2 - \mu_2^2}$$

$$V = \frac{2\pi a}{\lambda}\ (\mathrm{N.A})$$

'a' is the radius of core

λ is the wavelength of optical signal

V-number & Number of Modes



When (i) V< 2.405, the optical fibre can support only one mode.

(ii) V > 2.405, the optical fibre can support more than one mode and known as multi mode optical fibre.

(iii) V = 2.405, the wavelength corresponding to V = 2.405 is known as cut off wavelength (λ_c).

$$\therefore \quad \lambda_c = \frac{2\pi a}{2.405} \sqrt{\mu_1^2 - \mu_2^2}$$

Cutoff Wavelength - this is the minimum wavelength at which the fiber will support only one mode. Wavelengths that are shorter than the cutoff wavelength, can actually allow higher-order modes to propagate.

Cut-off Wavelength

Definition: the wavelength below which multiple modes of light can be propagated along a particular fiber, i.e., $\lambda >= \lambda_c$, single mode, $\lambda < \lambda_c$, multi-mode

$$\boxed{\lambda_c = \frac{\pi d}{2.405} \times NA}$$

d: diameter of the core

Number of Modes (for large V-number)

For optical fibres with large V-number, the possible number of supported modes is approximately given by

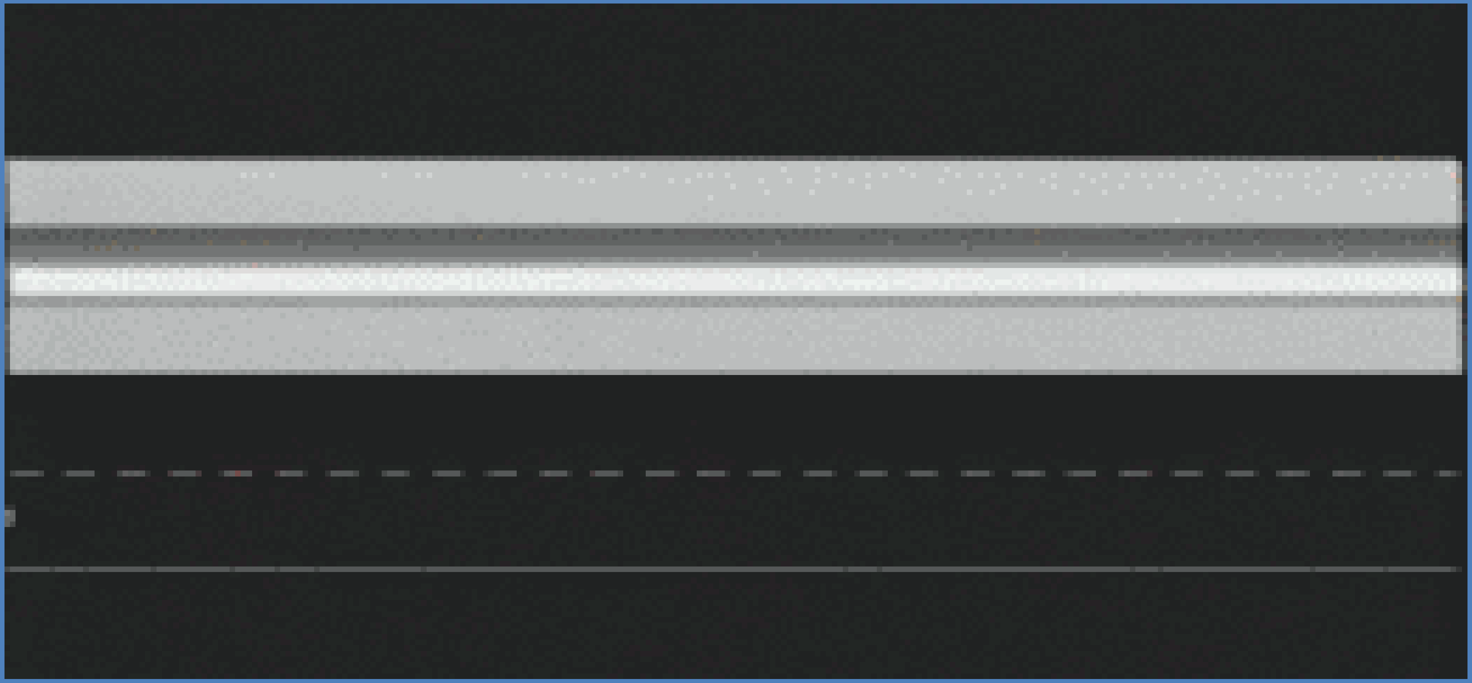
$$N \approx \frac{1}{2} V^2 \quad \Rightarrow$$

Only an Approximate formula
Valid for Large V-Numbers Only

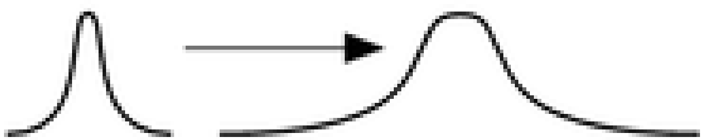
Note : This is a approximate formula and should not be used for fibre carrying only a few modes i.e. small V-number.

DISPERSION

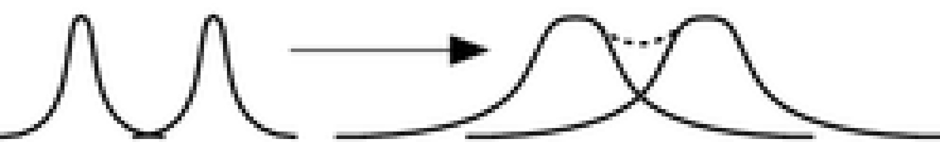
The light signals propagate through any optical fibre suffer with various dispersion effects. As a result the shape of the output signal change relative to the input signal. **This spreading of output pulse in the time domain known as dispersion or distortion in optical fibre.**

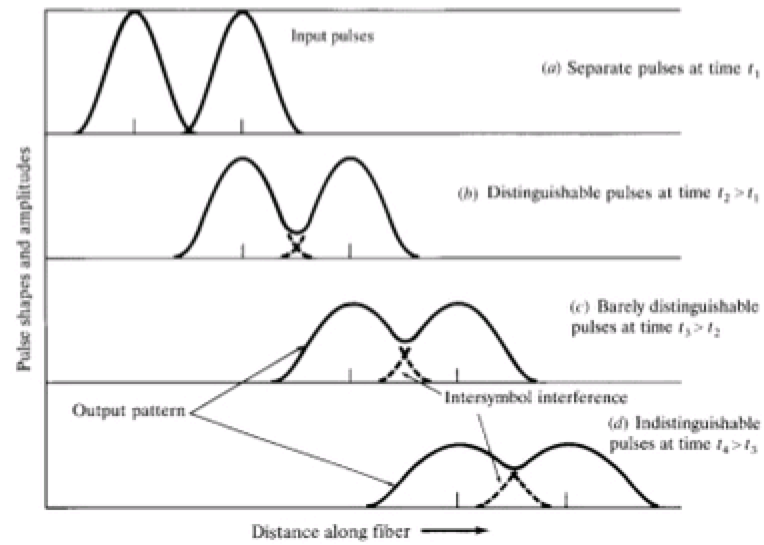


Dispersion



As a pulse travels down a fiber, dispersion causes pulse spreading. This limits the distance and the bit rate of data on an optical fiber.





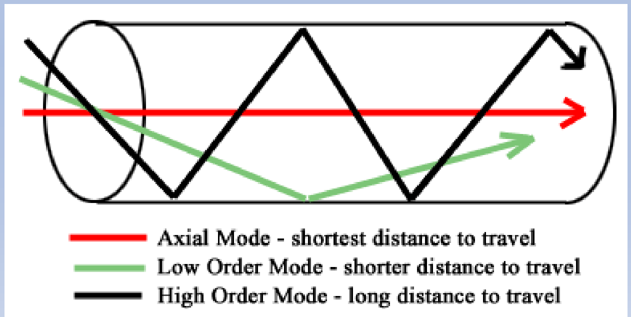
TYPES OF DISPERSION

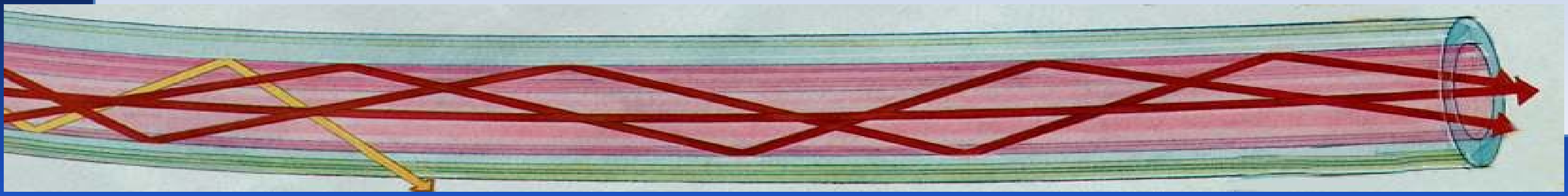
Intermodal Dispersion: Different rays take different times to propagate through a given length of the fibre.
Or Different modes travel with different speeds

Intramodal Dispersion Any given source emits over a range of wavelength and because of the intrinsic property of the material of the fibre, different wavelength takes different amount of time to propagate along the same path.

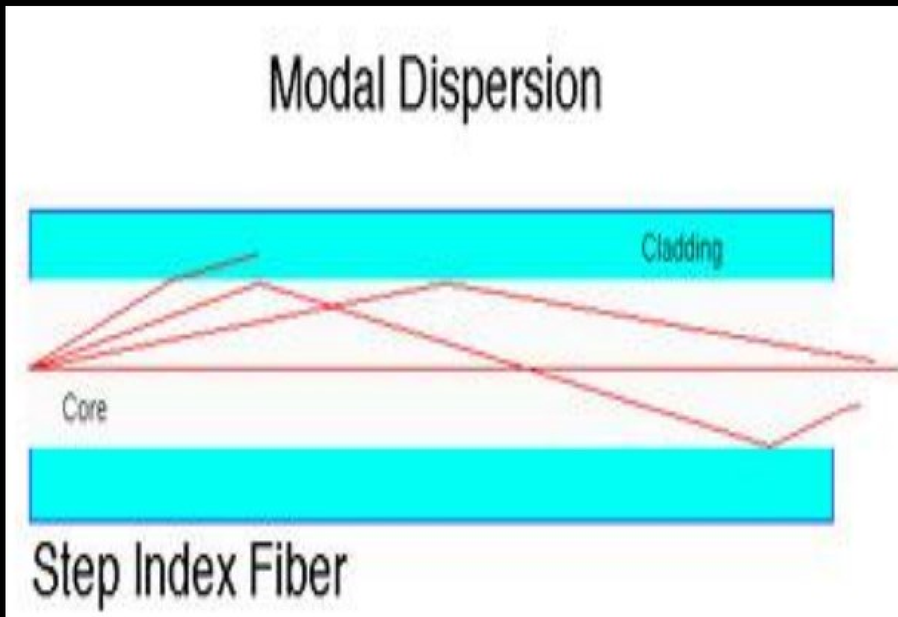
Intermodal Dispersion: Affects only Multimode

- Also known as Modal Dispersion
  - Spreading of a pulse because different modes (paths) through the fiber take different times
  - Only happens in multimode fiber
  - Reduced, but not eliminated, with graded-index fiber





Intermodal Dispersion

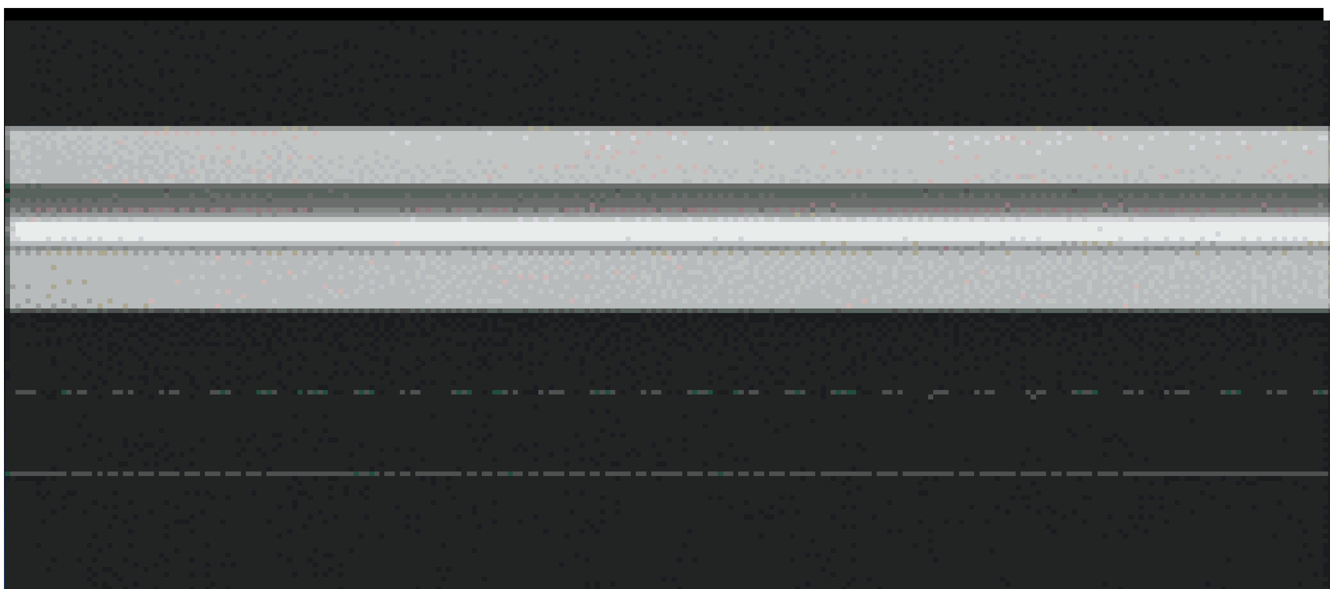


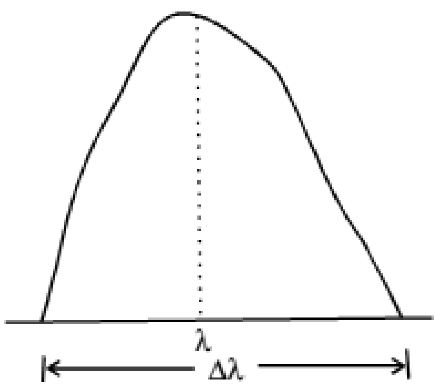
Different rays take different times to propagate through a given length of the fibre.
In the language of wave optics, this is known as intermodal dispersion because it arises due to the different modes travelling with different speeds.

The distortion in which the pulse spreading of the optical signal is due to result of multiple modes having different value of the group velocity at a single frequency is called intermodal distortion.

Intramodal dispersion/chromatic disp.

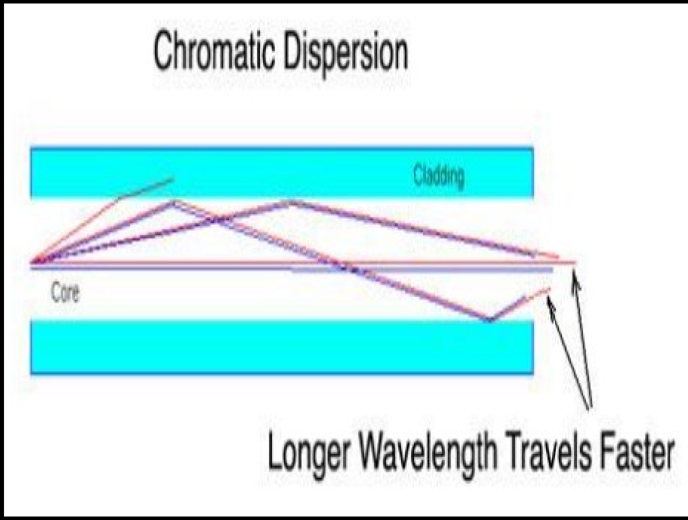
The dispersion or distortion in which pulse spreading occurs within a single mode is known as intramodal dispersion. It is also known as chromatic dispersion. The magnitude of intramodal distortion depends upon wavelength of the optical signal and it increases with increase in the spectral width of optical signal, where $\Delta\lambda$ - spectral width.





Chromatic Dispersion

- Different wavelengths travel at different speeds through the fiber
- This spreads a pulse in an effect named *chromatic dispersion*



✓Chromatic dispersion
- ✓occurs in both singlemode and multimode fiber
- ✓A far smaller effect than modal dispersion

Chromatic Dispersion

Material Dispersion

Arises from the variation of refractive index with wavelength

+

Waveguide Dispersion

Arises from the dependence of the fibre's waveguide properties on wavelength

=

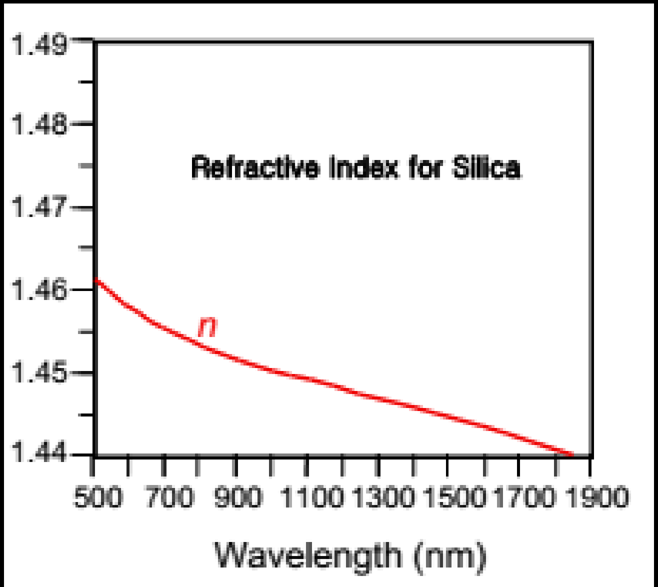
Chromatic Dispersion

Material Dispersion

This is caused by the fact that the refractive index varies (slightly) with the wavelength.

- Some wavelengths therefore have higher group velocities and so travel faster than others. Since every pulse consists of a range of wavelengths it will spread out to some degree during its travel.

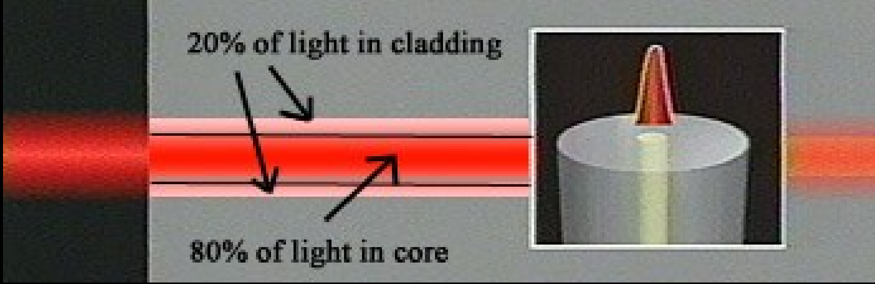
- *All optical signals consist of a range of wavelengths*.



a) Material dispersion: Any guided mode of optical signal consists of well modulated pattern of the groups of waves. In case of material dispersion the core material of the optical fibre offers different refractive index at different angles to the different wavelengths of the optical signal. As a result different spectral components of an optical pulse have different transit time and therefore the spectral components of the pulse combine to produce broadened pulse with a lower peak amplitude at the fibre end. This type of dispersion or distortion is analogous to the dispersion phenomena exhibit by which light travels in prism.

Waveguide dispersion

(Affects mainly single mode)



In a single mode,

- 20% signal is travelling through the cladding and remaining 80% signal travels through the core by multiple total internal reflections.
- As the refractive index of the cladding is less as compare to the refractive index of core, therefore light signal propagation through the cladding is faster as compare to light signal propagation through core.
- Hence, the shape of output signal distorted due to overlapping of core and cladding signals. Such type of dispersion is known as waveguide dispersion.

✓The shape (profile) of the fibre has a very significant effect on the group velocity.

- This is because the electric and magnetic fields that constitute the pulse of light extend outside of the core into the cladding.

✓The amount that the fields overlap between core and cladding depends strongly on the wavelength. The longer the wavelength the further the the electromagnetic wave extends into the cladding.

Waveguide dispersion???

Caused by the wavelength dependence of distribution of energy for the fundamental mode in the fibre

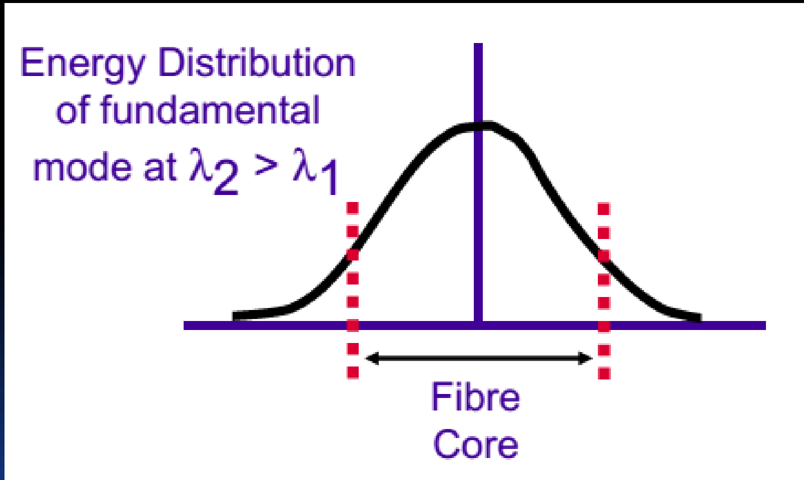
Mainly a problem for singlemode, in multimode mode penetration into the cladding is very small relatively.

As wavelength increases an increasing proportion of the mode energy propagates in the cladding.

But the cladding refractive index is lower thus faster propagation

Waveguide dispersion

Even if refractive index does not change, v_g depends on frequency (wavelength)



Attenuation

- When light travels along the fibre, there is a loss of optical power, which is called attenuation.

Absorption losses over a length L of fiber can be described by the usual exponential law for light intensity (or irradiance) I

$$I = I_0 e^{-\alpha L}$$

I_0 is the initial intensity or the irradiance of the light

α:Attenuation coefficient

$$\alpha = \frac{10}{L} \log_{10} \frac{I_o}{I} \quad \text{(in dB/km)}$$

OR

$$\alpha = \frac{10}{L} \log_{10} \frac{P_i}{P_0}$$

P_i → Input power

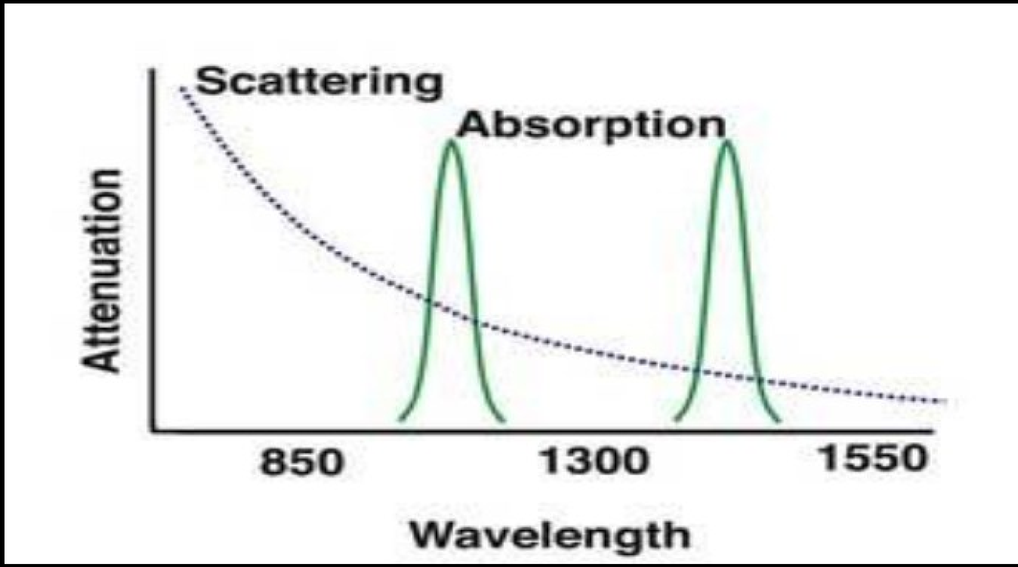
P_o → Output power

Length **L** of the fibre is expressed in **kilometers**

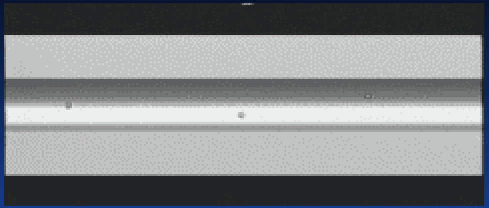
unit of Attenuation is decibels/kilometer i.e. **dB/km**

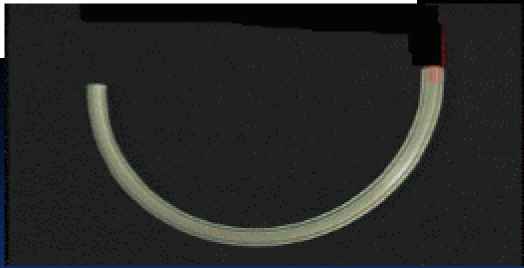
Cause/Reasons:

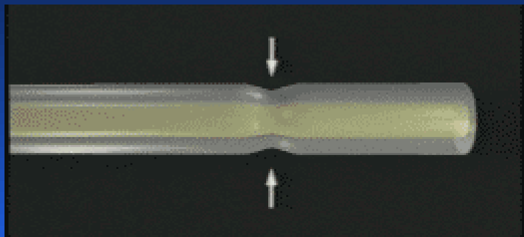
- Absorption
- Scattering
- Bending losses



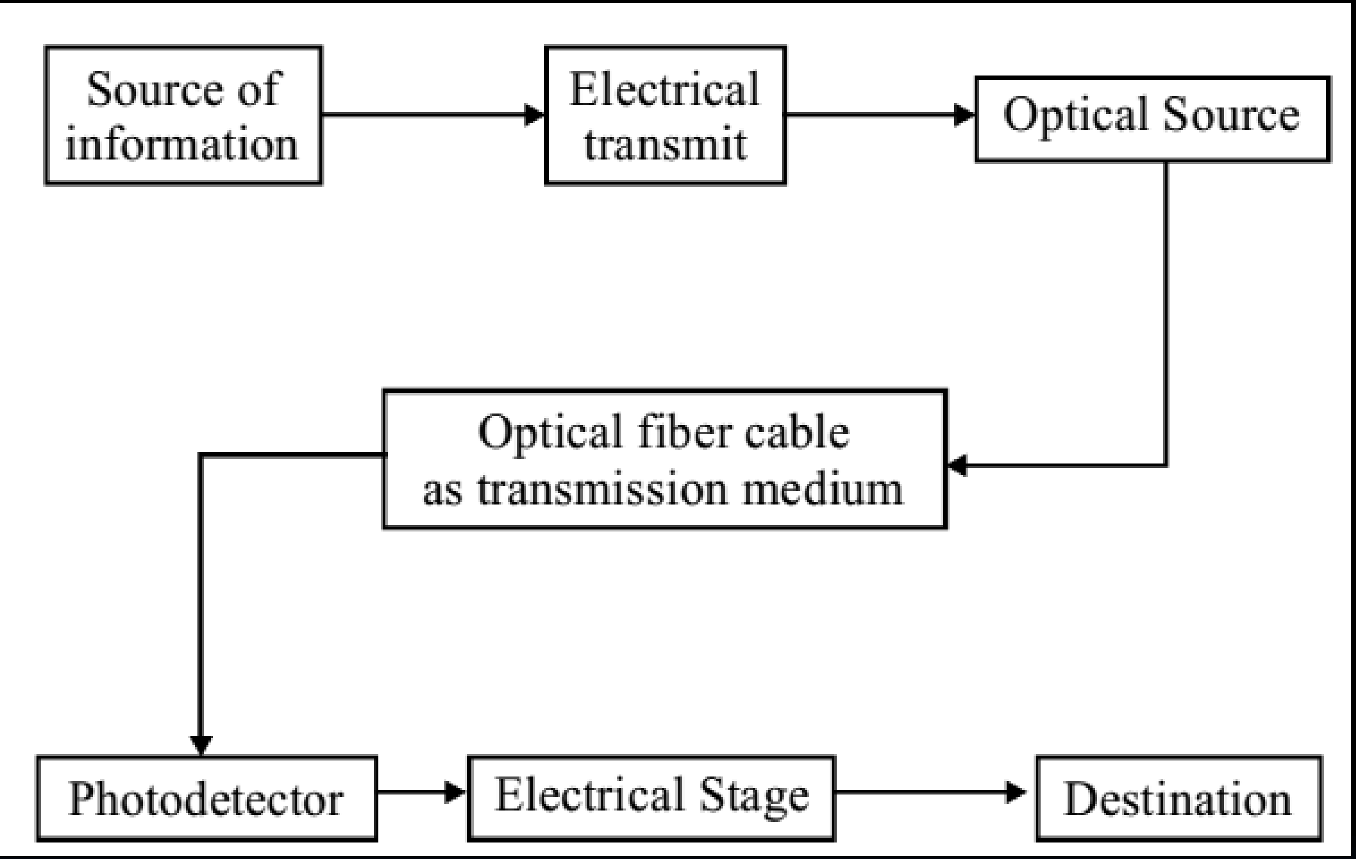
Each mechanism of loss is influenced by the properties of fibre Material and fibre structure.



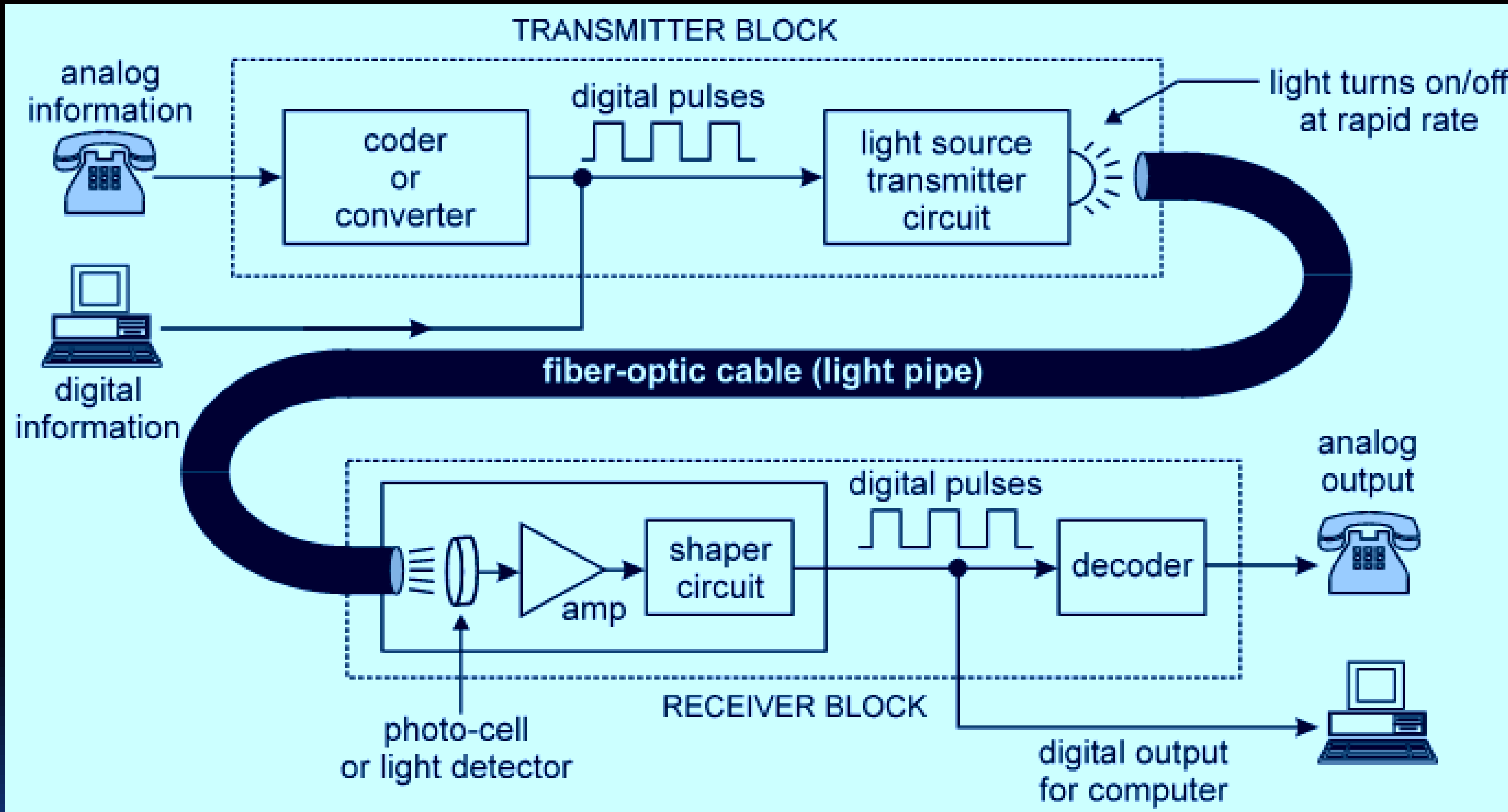




Optical fibre communication system



Optical fibre communication system



An optical fibre communication system consists of transmitter unit, optical fibre and receiver unit as shown in figure (3.14). In transmitter unit, the information that is to be transmitted is first converted into an optical signal from an electric signal. Transmitter unit consists of modulator and optical source, which may be either light emitting diode (LED) or laser diode (LD). The optical fibre essentially serves the purpose of transmitting the light signal by multiple total internal reflections. The receiver unit consists of optical detector and demodulator. The optical detector may be a semiconductor device or most commonly a PIN diode, which convert the optical signal back into an electric signal. The response of a detector should be well matched with the optical frequency of signal received. The signal output is finally communicated by load speaker (if it is audio signal) or by CRO (if it is video signal).

Light Emitting Diodes used in Optical Fiber Communication

- In optical fiber communication systems, LEDs serve as optical sources to convert electrical signals into light pulses.
- **LEDs are well-suited for shorter-distance multi-mode fiber links** due to their wider spectral output compared to lasers. They act as transmitters by injecting light into the fiber core.
- Optical fibers are like super highways for data, letting us transmit huge amounts of information quickly. LEDs play a key role in this fiber optic technology.

Advantages of LEDs in Fiber Optic Communication

LEDs have some great benefits that make them well-suited for use in fiber optic communication systems. Let's look at why LEDs are the preferred light source for transmitting data over optical fibers.

1. **Compact Size**
   LEDs are super small, allowing them to be easily coupled to the tiny cores of optical fibers. Their small emitting area matches well with the small diameter fiber cores. This maximizes light injection into the fiber.
2. **Cost Effective**
   Producing LEDs is relatively affordable compared to other light sources like lasers. This makes LEDs a cost-effective option for cheaper, shorter-distance fiber links.
3. **Energy Efficient**
   LEDs convert electrical currents to light very efficiently. This results in lower power consumption compared to lasers or other sources. Being energy efficient is a big plus!
4. **Reliable**
   LEDs are solid-state devices with no fragile filaments or glass. This makes them resistant to vibrations and shocks. LEDs can withstand fluctuating temperatures and harsh conditions. This high reliability is a key advantage.
5. **Easy Modulation**
   The output light from LEDs can be easily modulated and encoded with data by varying the input electrical signal. This allows rapid flickering for high-speed data transmission.
6. **Directional Emission**
   Unlike ordinary light bulbs that spread light everywhere, LEDs emit light in a narrow, directed beam. This makes it easy to capture the light into optical fibers.

Photodiodes in Fiber communication

Photodiodes are essential components in optical fiber communication systems, primarily functioning as light detectors that convert optical signals into electrical signals. Their role is crucial for the operation of receivers in fiber-optic communication systems. Here's how photodiodes are used in optical fibers:

1. Signal Detection:

•A photodiode is used at the receiving end of the system to convert the optical signals (light) back into electrical signals, which can then be processed further.

2. High-Speed Operation:

•Photodiodes are designed to operate at high speeds to handle the rapid transmission of data over optical fibers.

3. Noise and Signal Integrity:

•The efficiency of a photodiode directly impacts the signal-to-noise ratio (SNR) in optical systems. An ideal photodiode will minimize noise, maintaining the integrity of the transmitted data.

Injection Laser Diode (ILD)

An **Injection Laser Diode (ILD)**, commonly referred to as a **semiconductor laser** or **laser diode**, is a vital component in optical fiber communication systems. ***Its primary function is to convert electrical signals into coherent light that can be transmitted through optical fibers over long distances***.

Laser diodes are preferred in high-speed communication systems due to their efficiency, high output power, and ability to operate at the precise wavelengths required for fiber optic communication.

Role of Injection Laser Diodes in Optical Fibers:

1. Light Source for Data Transmission:

•Injection laser diodes are used as light sources at the **transmitting end** of the optical fiber communication system. They emit a narrow, coherent beam of light, which is modulated with data (digital signals). This light is then coupled into the optical fiber for transmission over long distances.

2. Precise Wavelength Emission:

•Injection laser diodes emit light at specific wavelengths that correspond to the low-loss transmission windows of optical fibers. The most common wavelengths used are:

- **850 nm** for multimode fiber systems.
- **1310 nm** and **1550 nm** for single-mode fiber systems, which are the most widely used in long-distance communication.
- These wavelengths minimize attenuation (loss of signal strength) and dispersion, allowing data to travel long distances with minimal signal degradation.

Difference of Injection laser diode and photodiode in fiber communication

Injection laser diode (ILD)

- ***Transmitter Component:*** ILDs are used as the **light source** at the **transmitting end** of the optical fiber system. They convert electrical signals into light signals that carry data through the optical fiber.
- Capable of high-speed modulation, meaning the intensity or phase of the light can be varied rapidly, allowing for the transmission of high-bandwidth data.
- Converts electrical signals into optical signals (light).
- Acts as the **source** of light, usually emitting at specific wavelengths like 850 nm, 1310 nm, or 1550 nm.

Photodiode

- ***Receiver Component*:** Photodiodes are used at the **receiving end** of the optical system to detect the incoming light signals from the fiber and convert them back into electrical signals. They perform the reverse operation of the ILD.
- Converts optical signals back into electrical signals.
- Acts as a **detector** of light at the receiver.
- Its primary role is to absorb photons from the light signal and generate electron-hole pairs, producing a current proportional to the light intensity.

Assignment:

1. What are Optical Fibres? Summarize the principle behind the transmission of light signal through an optical Fibre.
2. Write the advantages of using optical fibre communication system.
3. Explain the structure/construction of an optical fibre with the help of an appropriate diagram.
4. The refractive index of core should be slightly greater than that of cladding. Justify the statement by citing appropriate reasons.
5. Compare single mode and multimode optical fibres.
6. Justify the name “step index optical fibre” .
7. Difference between step index and graded index multimode OF
8. Derive the expression for (i) Critical Angle (ii) Acceptance Angle (iii)Numerical Aperture.
9. Define and/or write expressions for : (i) Critical Angle (ii) Acceptance Angle (iii)Numerical Aperture (iv) Fractional Refractive Index Difference (v) V-number (vi) Number of Modes
10. Express acceptance angle and numerical aperture in terms of fractional refractive index difference.