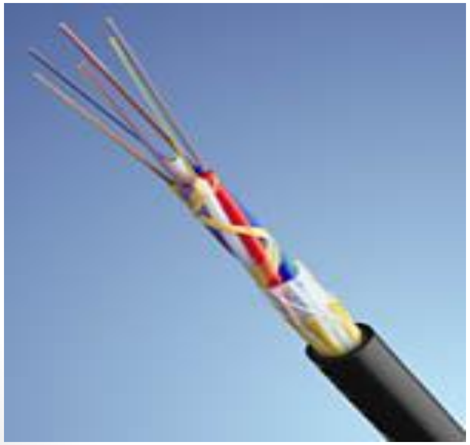
- **Optical fiber**

Content:

- **Fundamental ideas about optical fiber propagation mechanism.**
- **Acceptance angle and cone**
- **Numerical aperture**
- **Single and multimode fibers.**

Fiber Optics

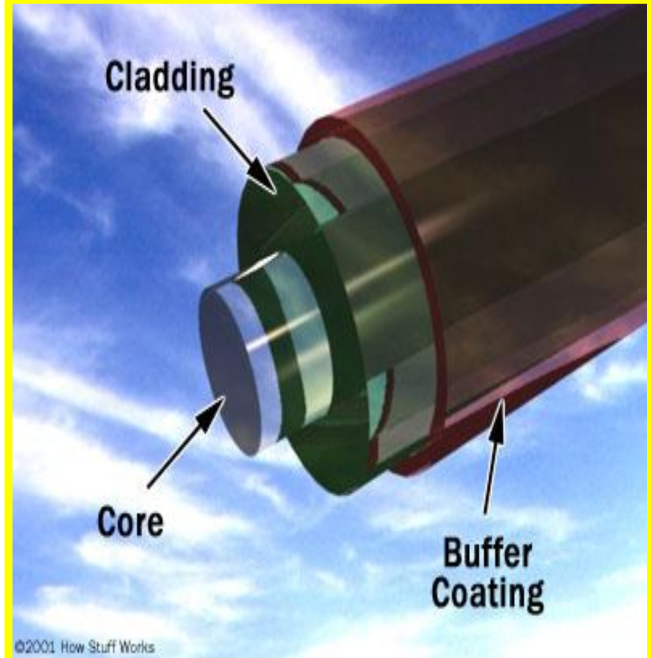
- **Fiber optics** (optical fibers) are long, thin strands of very pure glass about the diameter of a human hair.
- They are arranged in bundles called **optical cables** and used to transmit light signals over long distances.

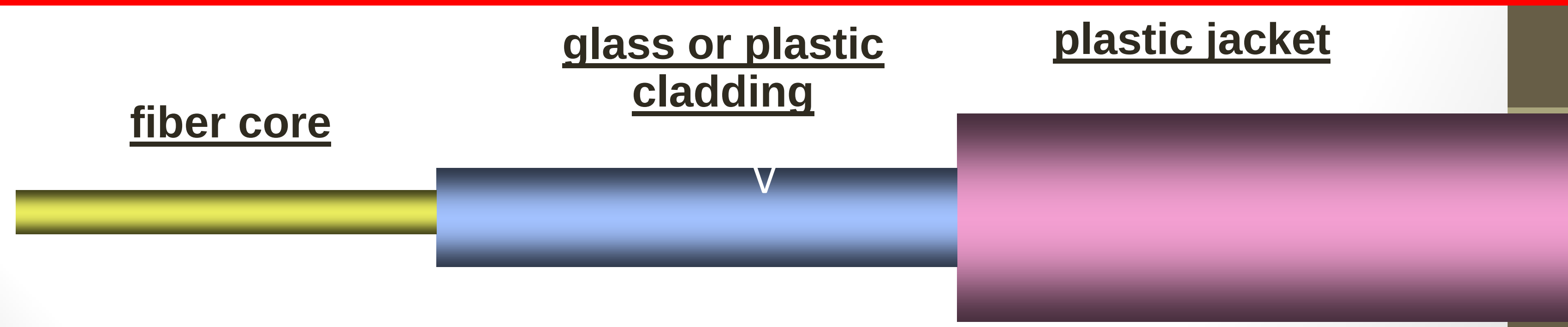


Various parts of Optical fiber

❑ **Optical fiber has the following parts:**

- ❑ **Core -** Thin glass center of the fiber where the light travels .
- ❑ **Cladding** - Outer optical material surrounding the core that reflects the light back into the core .
- ❑ **Buffer coating** - Plastic coating that protects the fiber from damage and moisture .
- ❑ **The index of refraction-** of the cladding is less than that of the core, causing rays of light leaving the core to be refracted back into the core.



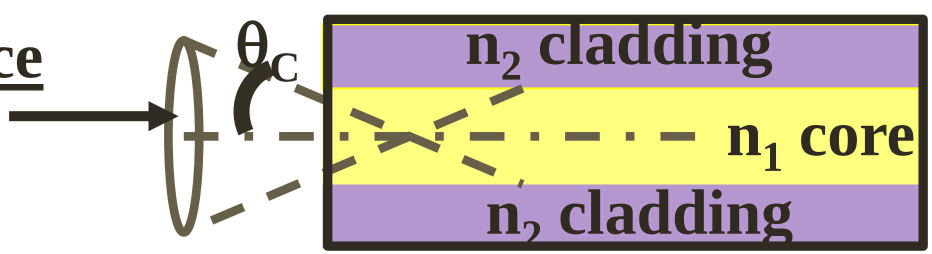


Acceptance Cone & Numerical Aperture

Optical fiber will only propagate light that enters the fiber within a certain cone, known as the acceptance cone of the fiber.The half angle of the cone is called the acceptance angle $\theta_{max.}$ (n_1 belongs to core and n_2 refers to cladding).

- ❑ **If the angle too large → light will be lost in cladding.**
- ❑ **If the angle is small enough → the light reflects into core and propagates.**

Acceptance Cone



$$\theta_C = \sin^{-1}\sqrt{n_1^{\,2} - n_2^{\,2}}$$

How Does an Optical Fiber Transmit Light?

.

- The light in a fiber-optic cable travels through the core (hallway) by constantly bouncing from the cladding (mirror-lined walls), a principle called **total internal reflection**.

- Because the cladding does not absorb any light from the core, the light wave can travel great distances.

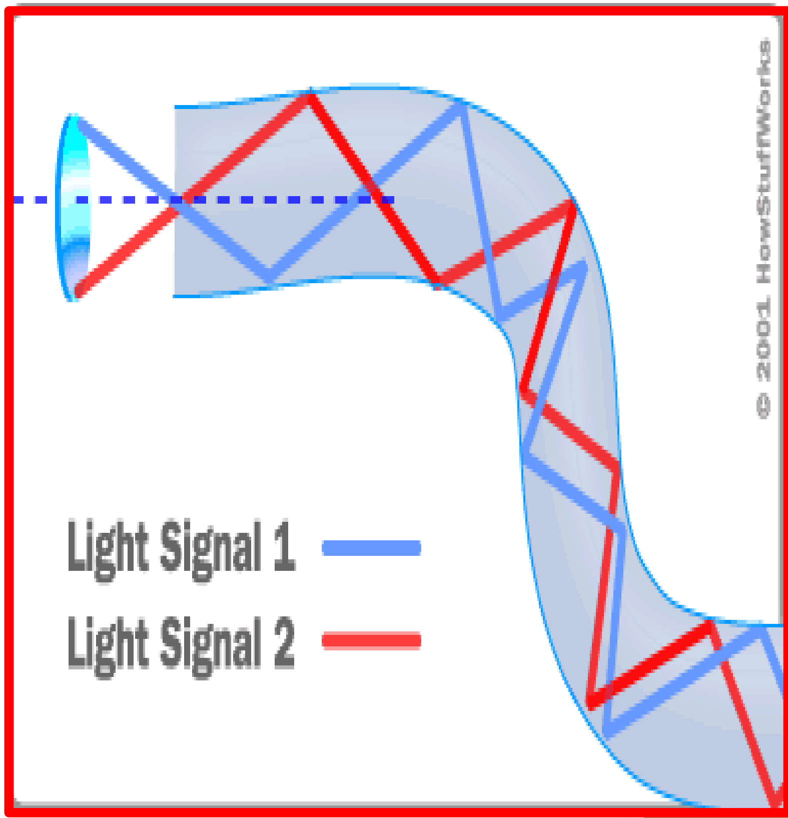
- However, some of the light signal **degrades** within the fiber, mostly due to impurities in the glass. The extent that the signal degrades depends on the purity of the glass and the wavelength of the transmitted light.

Total Internal Reflection

- Optical fibers work on the principle of total internal reflection

- The angle of refraction at the interface between two media is governed by Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



Types of fiber

.

Optical fiber is a waveguide, light can propagate in a number of modes:

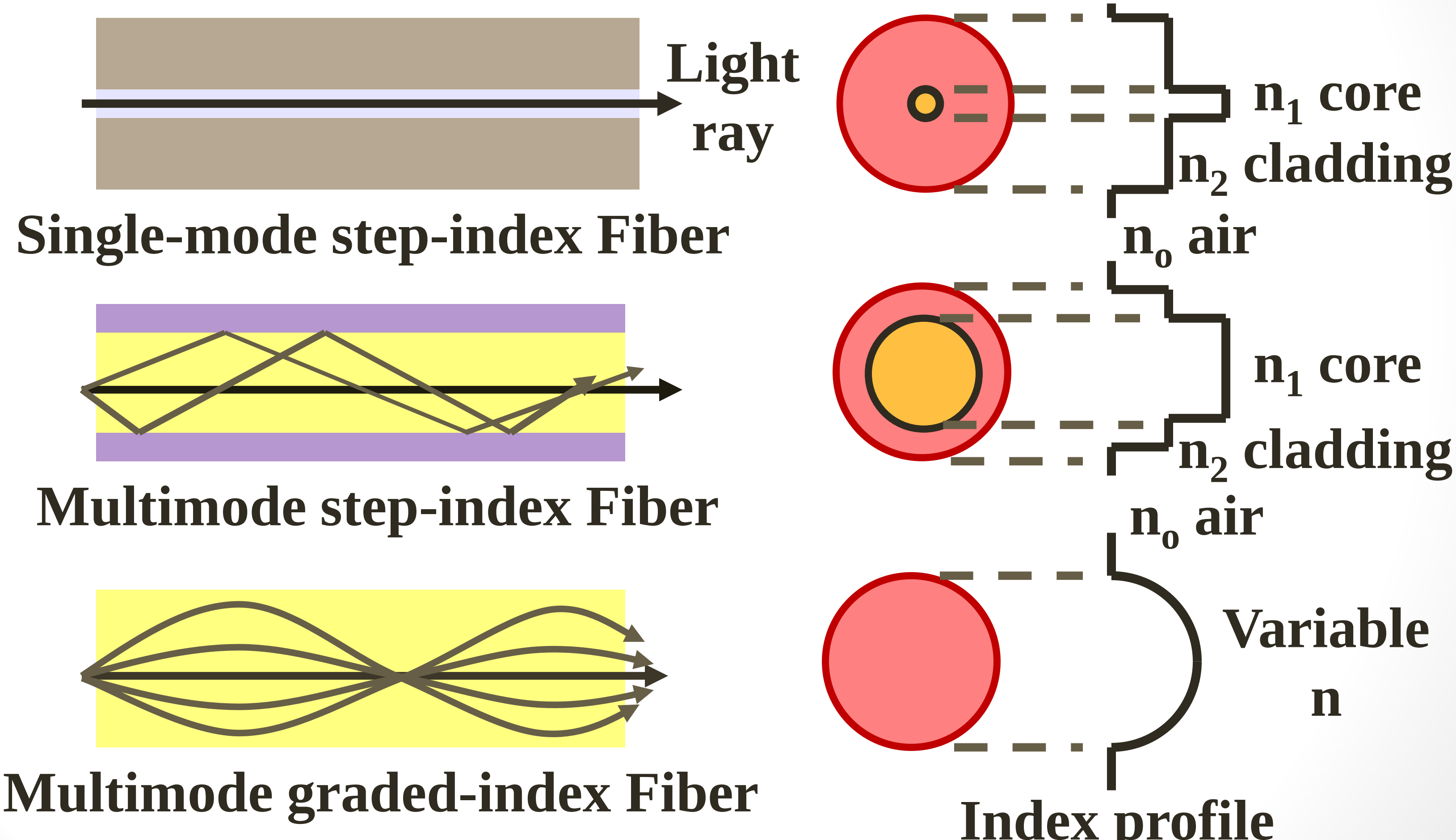
- **Multimode fibers:** Fibers that can carry more than one mode at a specific light wavelength.

Multimode propagation will cause **dispersion**, which results in the spreading of pulses and limits the usable bandwidth.

- **Single mode fiber:** These fibers have very small diameter that can carry only one mode which travels as a straight line at the centre of the core.

Single-mode fiber has much less dispersion but is more expensive to produce. Its small size, together with the fact that its numerical aperture is smaller than that of **multimode** fiber, makes it more difficult to couple to light sources.

Types Of Optical Fiber



Single-mode step-index Fiber

Advantages:

- Minimum dispersion: all rays take same path, same time to travel down the cable. A pulse can be reproduced at the receiver very accurately.
- Less attenuation, can run over longer distance without repeaters.
- Larger bandwidth and higher information rate.

Disadvantages:

- Difficult to couple light in and out of the tiny core.
- Highly directive light source (laser) is required.
- Interfacing modules are more expensive.

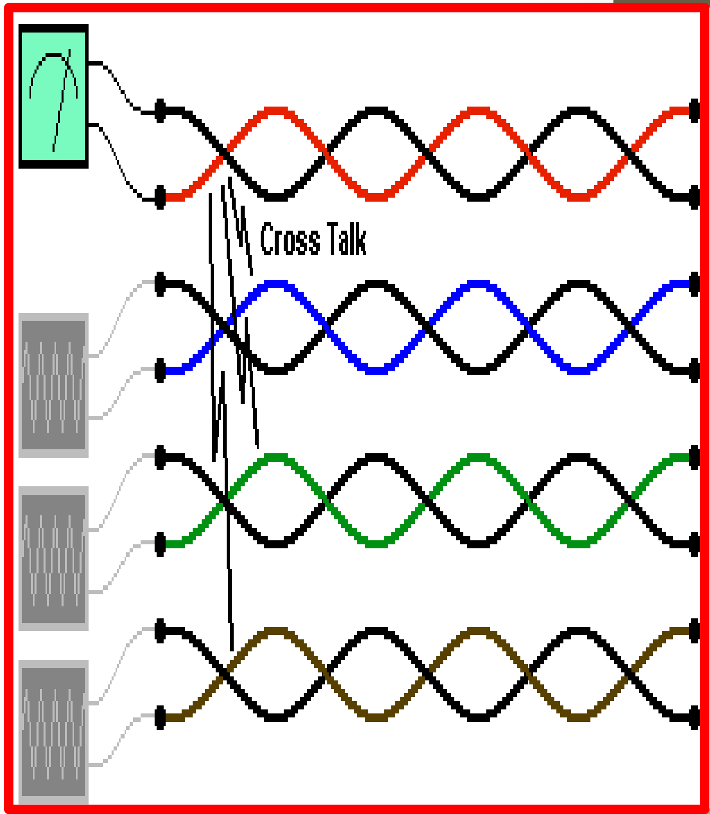
Losses In Optical Fiber Cables

The predominant losses in optic Fibers are:

- **Absorption** :losses due to impurities in the Fiber material.
- **Material or Rayleigh scattering** :losses due to microscopic irregularities in the Fiber.
- **Chromatic or wavelength dispersion:** because of the use of a non-monochromatic source.
- **Radiation:** losses caused by bends and kinks in the Fiber.
- **Pulse spreading or modal dispersion**: due to rays taking different paths down the Fiber (ms/km).
- **Coupling:** losses caused by misalignment & imperfect surface finishes.

Advantages

- Capacity: much wider bandwidth (10 GHz)
- Crosstalk immunity
- Immunity to static interference
  - Lightening
  - Electric motor
  - Florescent light
- Higher environment immunity
  - Weather, temperature, etc.
- Safety: Fiber is non-metalic
  - No explosion, no chock
- Longer lasting
- Security: tapping is difficult.
- Economics: Fewer repeaters
  - Low transmission loss



Disadvantages

- Higher initial cost in installation
- Interfacing cost
- More expensive to repair/maintain
  Tools: Specialized and sophisticated
- Difficulty in jointing(splicing).
- Highly skilled staff would be required for maintainence
- Precision and costly instruments are required
- Special interface equipments required for block working

Losses In Optical Fiber

The predominant losses in optic Fibers are:

- **Absorption losses :** due to impurities in the Fiber material.
- **Material or Rayleigh scattering losses** : due to microscopic irregularities in the Fiber.
- **Chromatic or wavelength dispersion:** because of the use of a non-monochromatic source.
- **Radiation losses:** caused by bends and kinks in the Fiber.
- **Pulse spreading or modal dispersion:** due to rays taking different paths down the Fiber.
- **Coupling losses :** caused by misalignment & imperfect surface finishes.

Areas of Application

- Telecommunications
- Local Area Networks
- Cable TV
- CCTV
- Optical Fiber Sensors