Prof. N. B. Kanirkar
Associate Professor,
ECED, SVNIT.

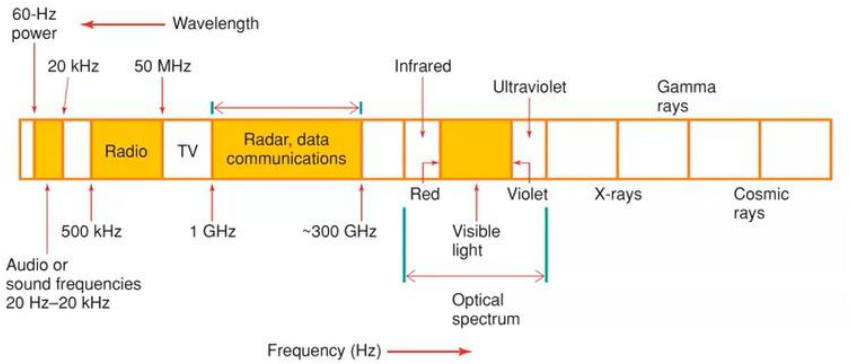
DIGITAL COMMUNICATION

- Prof. N. B. Kanirkar

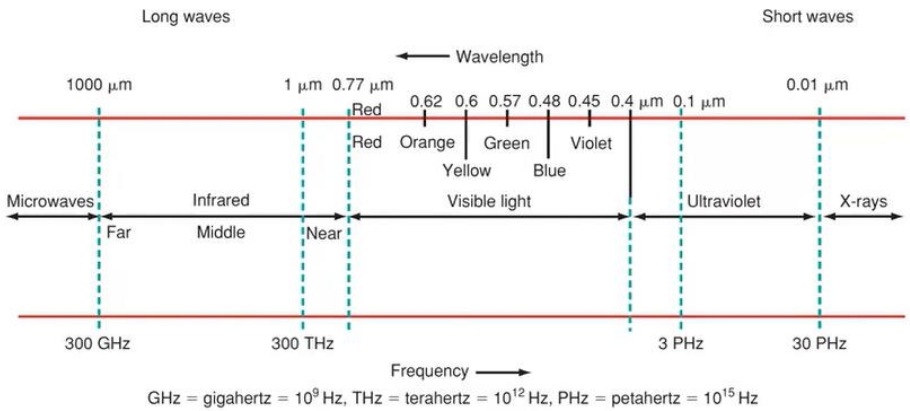
- FIBER OPTIC COMMUNICATION

Optical Spectrum

The optical spectrum. (*a*) Electromagnetic frequency spectrum showing the optical spectrum. (*b*) Optical spectrum details.



(*a*)



GHz = gigahertz = 10^9 Hz, THz = terahertz = 10^{12} Hz, PHz = petahertz = 10^{15} Hz

(*b*)

Light

Light, radio waves, and microwaves are all forms of electromagnetic radiation. Light frequencies fall between those of microwaves and X-rays, as shown in Fig.
Radio frequencies range from approximately 10 kHz to 300 GHz. Microwaves extend from 1 to 300 GHz. The range of about 30 to 300 GHz is generally defined as millimeter waves.

Further up the scale is the *optical spectrum,* made up of infrared, visible, and ultraviolet light. The frequency of the optical spectrum is in the range of 3×10^{11} to 3×10^{16} Hz. This includes both the infrared and the ultraviolet bands as well as the visible parts of the spectrum. The visible spectrum is from 4.3×10^{14} to 7.5×10^{14} Hz.

An **optical fiber** is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair. Optical fibers are used most often as a means to transmit light between the two ends of the fiber and find wide usage in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data transfer rates) than electrical cables.

Fibers are used instead of metal wires because signals travel along them with less loss; in addition, fibers are immune to electromagnetic interference, a problem from which metal wires suffer. Fibers are also used for illumination and imaging, and are often wrapped in bundles so they may be used to carry light into, or images out of confined spaces, as in the case of a fiberscope.

Specially designed fibers are also used for a variety of other applications, some of them being fiber optic sensors and fiber lasers.

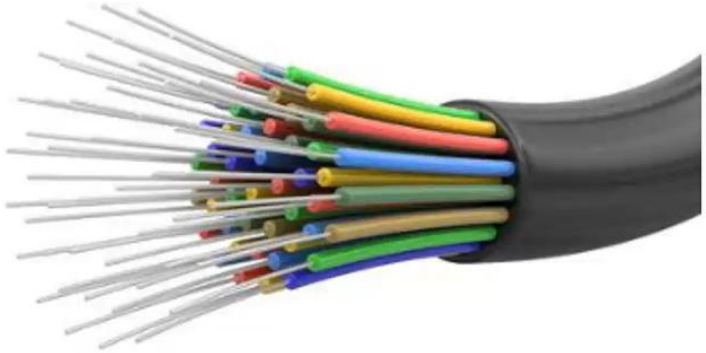
Optical fibers typically include a core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by the phenomenon of total internal reflection which causes the fiber to act as a waveguide.

Fibers that support many propagation paths or transverse modes are called multi-mode fibers, while those that support a single mode are called single-mode fibers (SMF).

Multi-mode fibers generally have a wider core diameter and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,000 meters (3,300 ft).

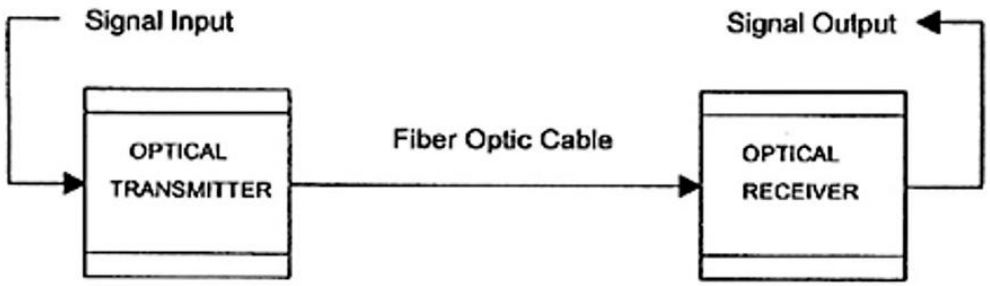
What are optical fibers

- Thin strands of pure glass
- Carry data over long distances
- At very high speeds
- Fiber can be bent or twisted



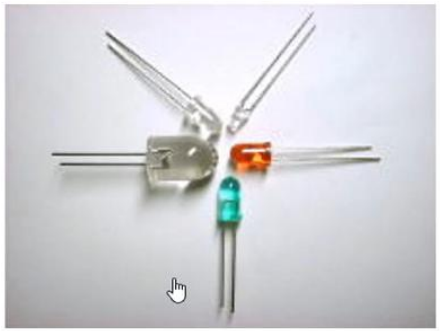
Fiber optic technology

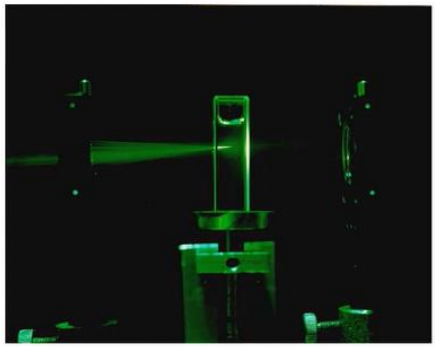
- Sources
- Transmission medium
- Detectors



Sources of light

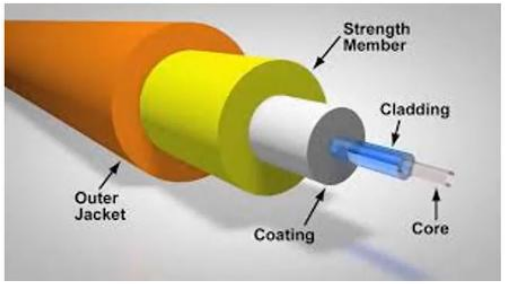
- ✓ Light emitting diodes
- ✓ Lasers





Sources

- Modulate electrical signals into optical signals
- Mostly modulate at 850nm, 1300nm and 1550 nm
- Lasers give high intensity, high frequency light
- LEDs are economical



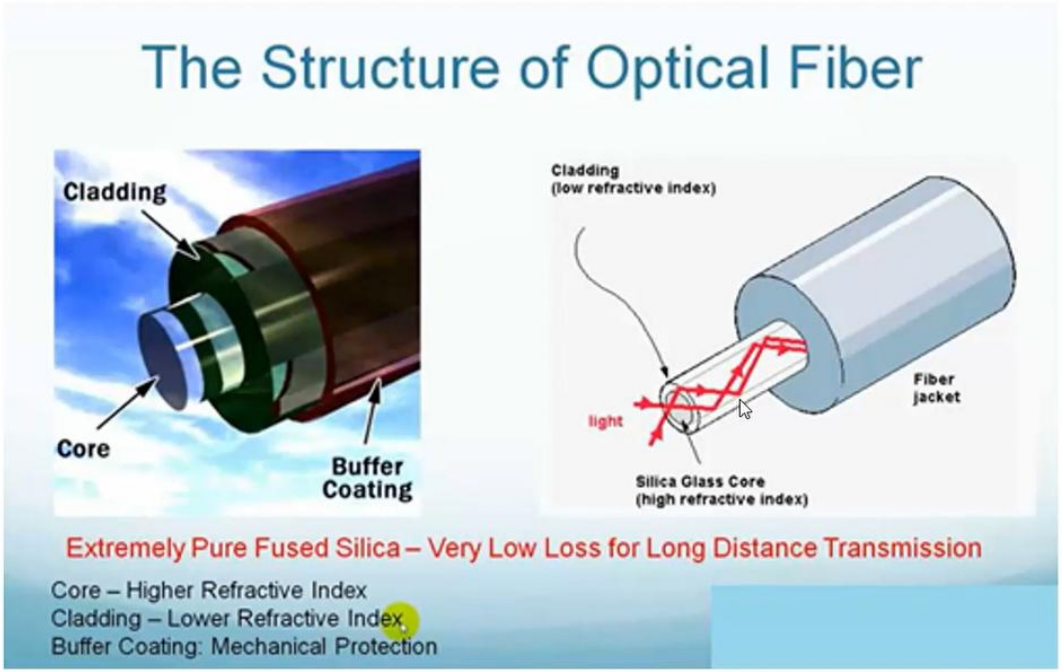
Transmission medium

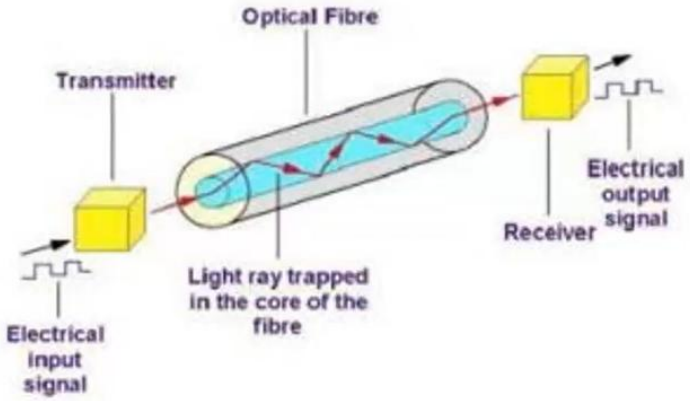
- ❑ Optical fiber is replacing copper
- ❑ Light is used as the carrier of information
- ❑ Much higher data rate

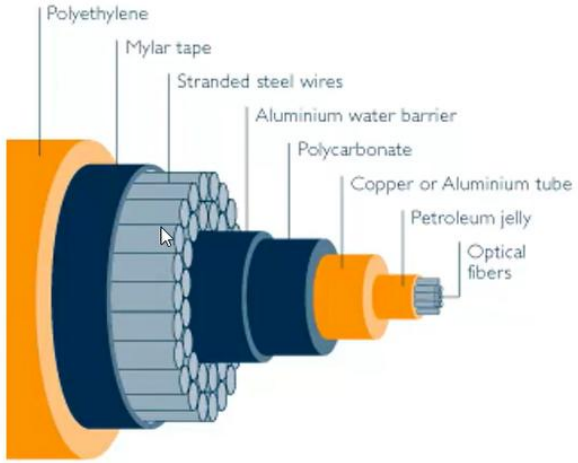
Physics of optical fibers

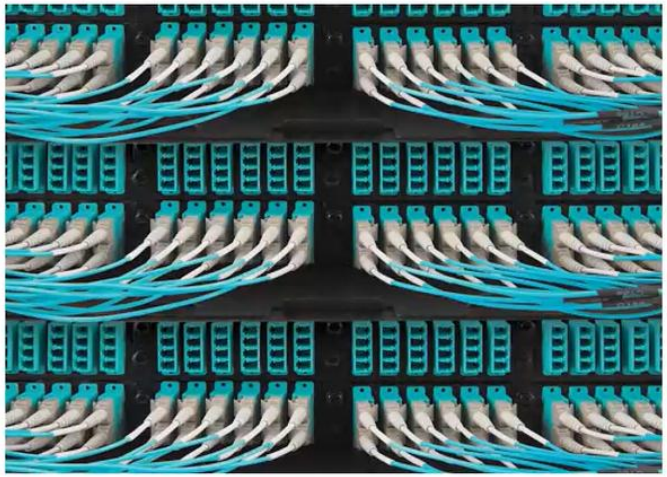
Index of refraction of material : ratio of speed of light in vacuum to speed of light in medium

Refraction of light : bending of light as it travels from one media to another





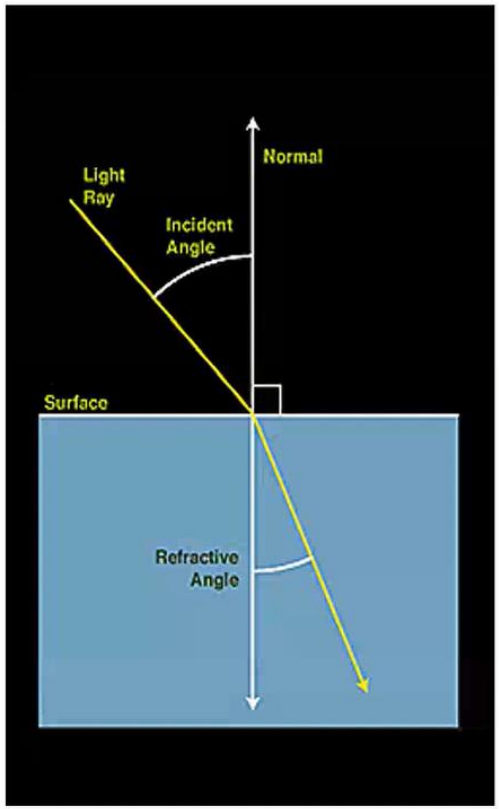




Light Refraction

Refraction of light

Speed of light changes as it across the boundary of two media Angles w.r.t normal



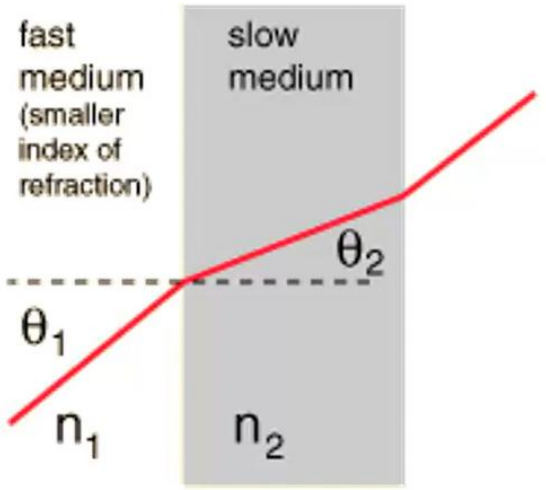
Refraction Indices

- Vacuum…….1.00000 (exactly)
- Air ……1.00029
- Alcohol 1.329
- Diamond 2.417
- Glass 1.5
- Ice 1.309
- Sodium Chloride (Salt) 1.544
- Sugar Solution (80%) 1.49
- Water (20 C) 1.333

Snell's Law

Snell's Law

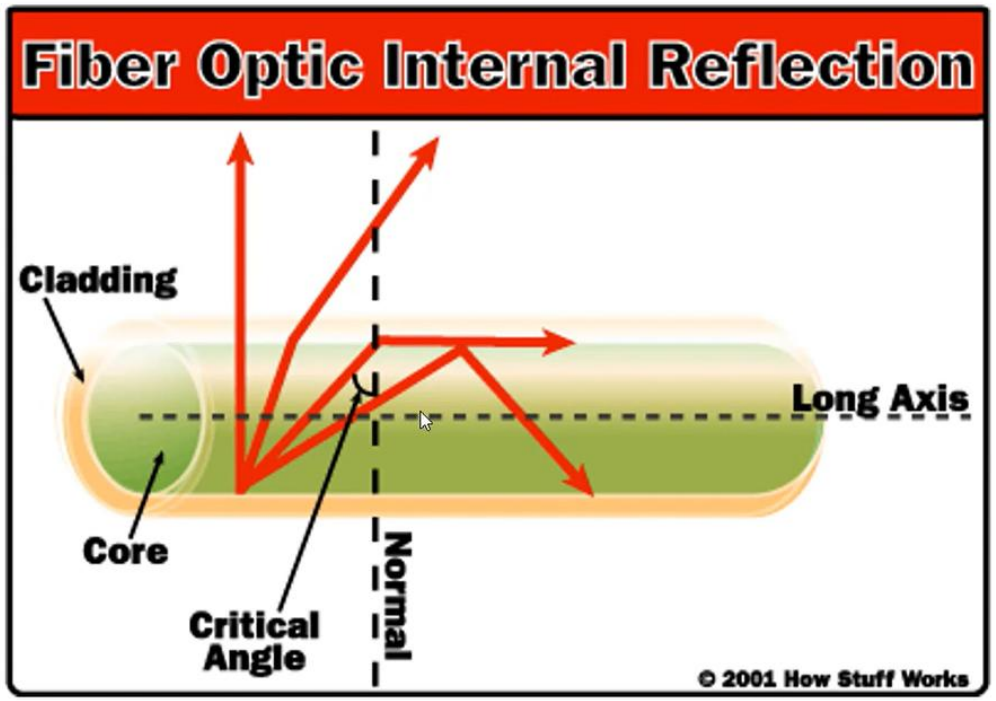
$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$



Critical angle: Angle of incidence at which angle of refraction = 90^0

Total internal reflection

Trapping light in the fiber



Fibers can be bent!!

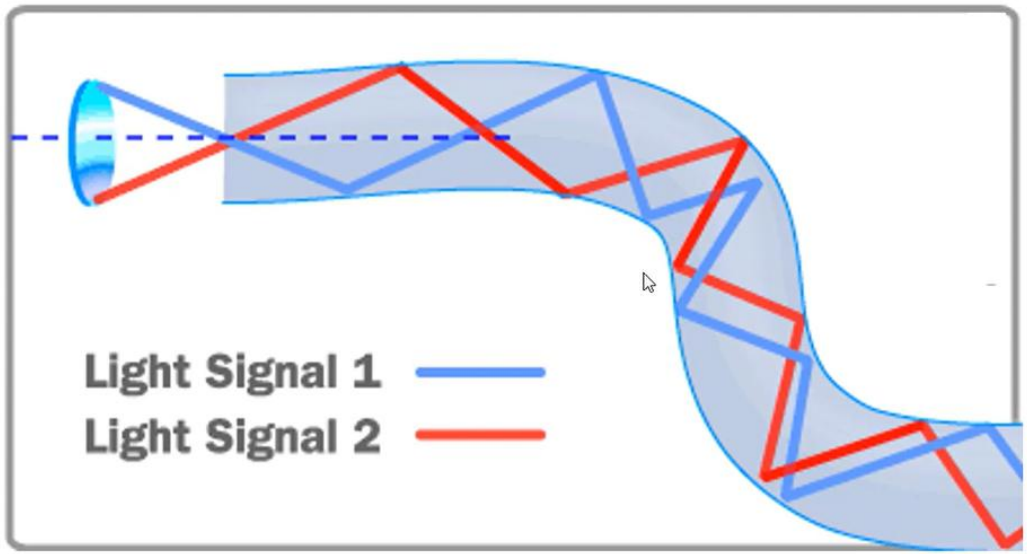


Fig: illustration of total internal reflection

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
- Rayleigh Scattering Losses
- Absorption Losses
- Leaky Modes
- Mode Coupling Losses
- Bending Losses
- Combined Fiber Losses

Splices and Connectors

- ✓ To connect to fibers mechanically or by fusion
- ✓ Lot of signal loss possible
- ✓ Very accurate alignment necessary
- ✓ Most important cost factor
- ✓ Now being replaced by optical amplifiers

Optical Receivers

- Must be very sensitive
- Capable of picking up and amplifying signals of nanowatts
- Photodiodes and phototransistors
- These devices get 'turned ON' by light
- Produce photocurrent

Advantages of optical fibers

- ✓ Can carry much more information
- ✓ Much higher data rates
- ✓ Much longer distances than co-axial cables
- ✓ Immune to electromagnetic noise
- ✓ Light in weight
- ✓ Unaffected by atmospheric agents