

Optical Communications System:

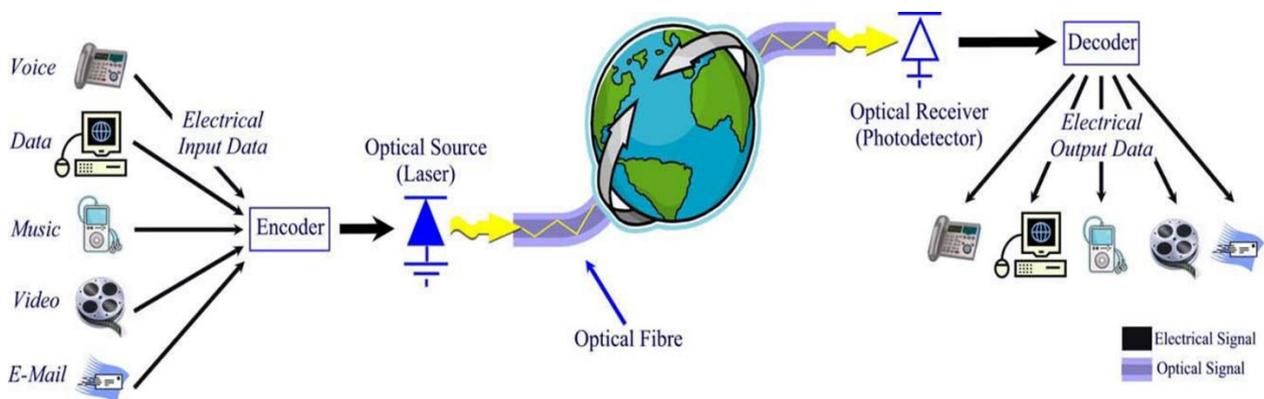
An optical communication system is any form of telecommunication that uses light as the transmission medium.

Equipment consists of a transmitter, which encodes a message into an optical signal, a communication channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal.

Fiber-optic communication systems transmit information from one place to another by sending light through an optical fiber. The light forms a carrier signal that is modulated to carry information.

- Main components are:
 - Optical source (Laser)
 - Optical fibre
 - Optical receiver (Photodetector)

The architecture of a communication system is shown below:

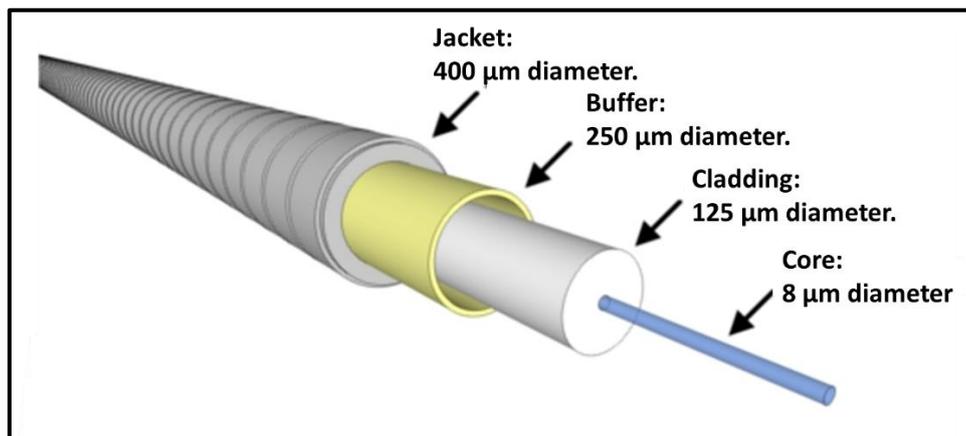


- The key elements in this diagram are: transducers (*Encoder/Decoder*) and the channel (*Optical Fibre*).
- A transducer is a device that matches the properties of the signal out of signal processing to those of the channel. In optical communications the transducer at the transmit end is an electro-optic device. Such a device accepts signals in electronic form and delivers photons that “move” in “sympathy” with the information.

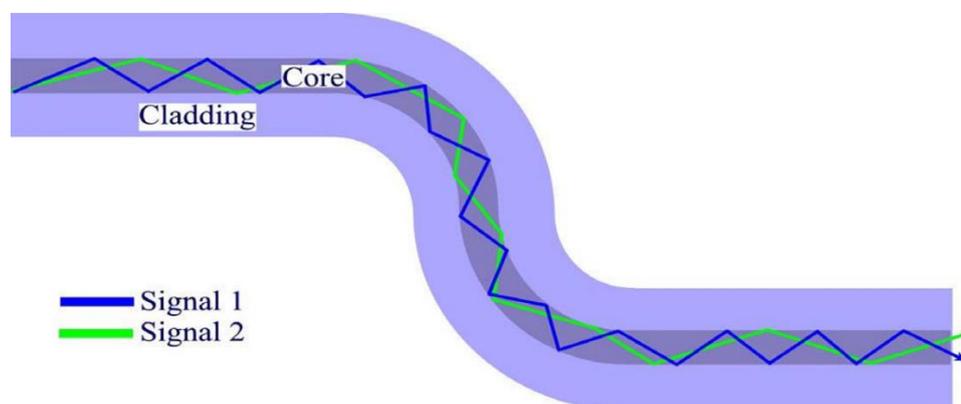
Optical Fibre:

An optical fiber is made by drawing glass or plastic to a desired length and diameter (slightly larger than a human hair). This flexible and highly pure fiber is most commonly used to transmit light for a wide range of applications including visible light displays, sensors, and high-speed communications. A typical glass optical fibre has a diameter of 125 (μm). This is actually the diameter of the cladding, or outer reflecting layer.

- Light travels through inner core ($\sim 8\mu\text{m}$) by constantly being guided (reflected) by the cladding.
- Core has higher refractive index than the cladding.
- Very little light lost ($\sim 3.5\%$ per km).
- Can transmit for $>100\text{km}$ without amplification.



The principle behind a fibre optic cable is that light is reflected along the cable until it reaches the other side, like in this diagram:



Optical Receiver

- Incoming light (photons) from optical fibre are absorbed, raising an electron to a higher energy band.
- Results in a current flow that is proportional to light falling on it.
- Optical pulse falls on photodetector generates electrical “1” in external circuit.



Fundamentals of optics:

To understand the working of an optical fibre:

- 1) Basic principles of optics:
 - Refractive index
 - Snell's law
 - Total Internal Reflection (TIR)
 - Interference
- 2) Interaction of light with matter:
 - Light guiding in optical fibres
 - Properties of optical fibre

Refractive Index:

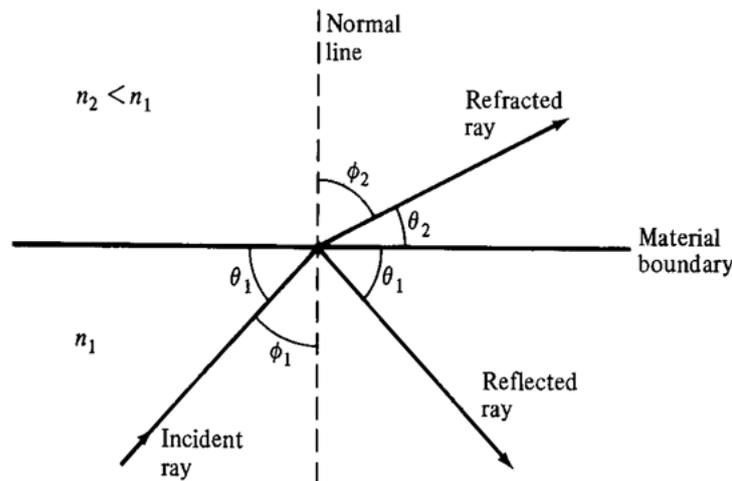
Refractive index, defined as the ratio of light in a vacuum to the speed of light in a material.

$$n = \frac{c_{\text{vacuum}}}{c_{\text{material}}} \approx \frac{c_{\text{air}}}{c_{\text{material}}}$$

- n of air = 1.000293
- n of water = 1.33
- n of glass = 1.5
- For normal optical materials, $n > 1.0$

When a light ray encounters a boundary separating two different media, part of the ray is reflected back while the remainder is bent (refracted) as it enters the second material.

Refraction at the interface takes place as a result of the difference in speed in the two materials with different n .

**Snell's Law:**

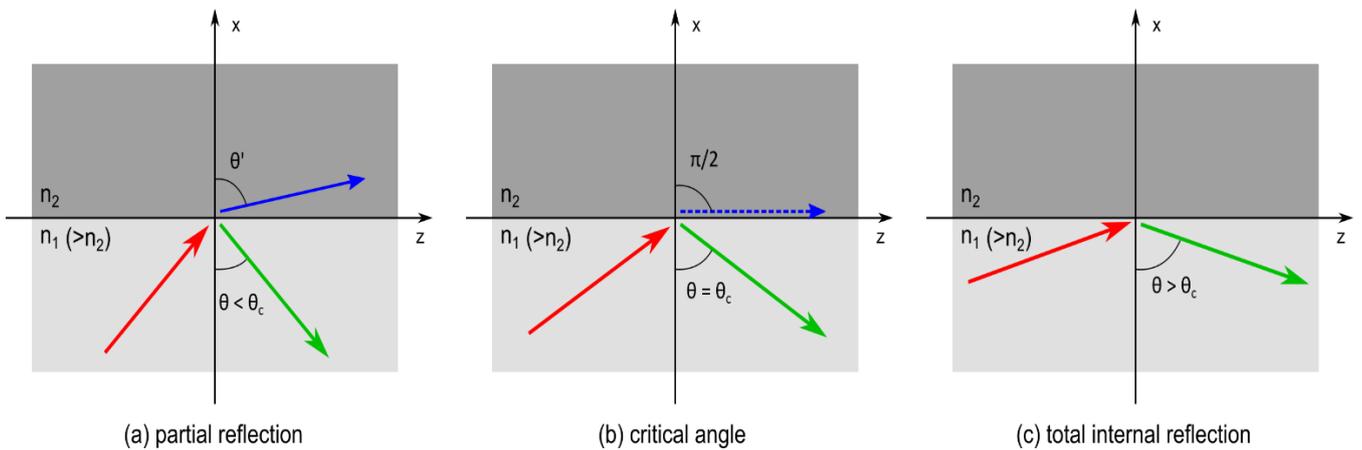
The relationship at the interface could be expressed mathematically by Snell's law.

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

- n_1 = refractive index of initial medium
- n_2 = refractive index of secondary medium
- θ_1 = angle of incidence light
- θ_2 = angle of refraction light

Total Internal Reflection (TIR):

As the angle of incidence in an optically denser material becomes larger, the refracted angle in a “lighter” material approaches $\pi/2$. A steeper angle of incidence, a certain point reached where refraction is no longer possible. This particular angle is called the critical angle where TIR takes place, can't use Snell's law. At the critical angle the ray lies along the boundary. Beyond the critical angle, TIR takes place.



For total internal reflection (TIR), $n_1 \sin \theta_c = n_2 \sin 90^\circ$, the critical angle could be expressed by:

$$\theta_c = \sin^{-1} \frac{n_2}{n_1}$$

