Guided media: Optical Fiber

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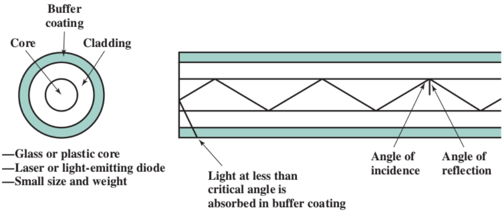
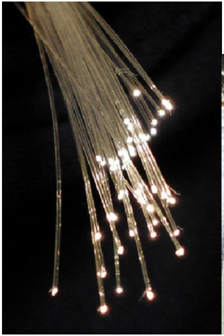
Guided media - optical fiber



- a thin, flexible medium capable of guiding an optical ray
- Three concentric sections:
  - the core (8 to 62.5 μm) — thin strands of glass/plastic
  - the cladding — glass/plastic coating (diameter 125μm)
    interface between core and cladding: acts as a reflector to confine light that would otherwise escape the core
  - hard plastic coating that protects the glass from moisture and physical damage

Optical fiber cable



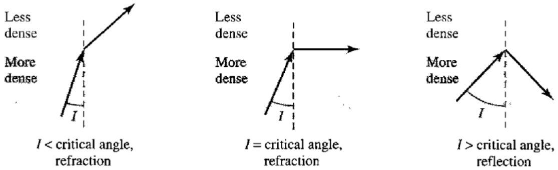

- provides protection to the fiber from stress during installation and from the environment once it is installed
- one to hundreds of fibers inside
- outer most layer : jacket

Figure source: wikipedia

Comparison with twisted pair/coaxial cables

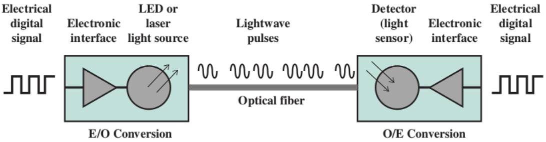
- Greater capacity: 100s of Gps over 10s of km (CC: 100s of Mps over 1 km, TP: 100Mbps - 10Gbps over 10s of m)
- Smaller size and lighter weight
- Lower attenuation, constant over a wide range
- Electromagnetic isolation: Invulnerable to interference, impulse noise, or crosstalk. Does not radiate energy. Security from evesdropping. Difficult to tap
- Greater repeater spacing: 10s of km (CC and TT: every few km)

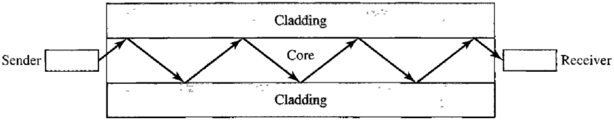
Bending of a light ray



- Critical angle is a property of the substance and varies from one substance to another
- Optical fibers use reflection guide light through a channel
- refractive index = sin (angle of incidence) / sin (angle of refraction)

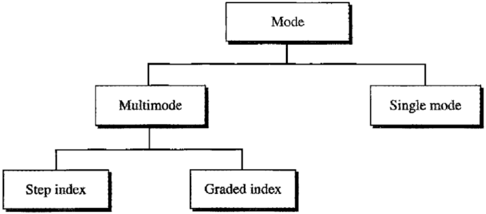
Optical fiber





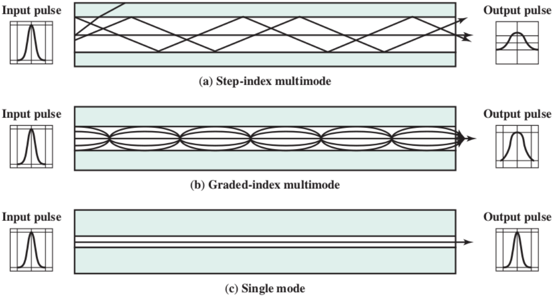
- The difference in density of the core and the cladding must be such that a beam of light moving through the core is reflected off the cladding

Modes of propagation



- Multimode: multiple beams from a light source move through the core in different paths

Modes of propagation



Step-index multimode: Rays at shallow angles are reflected and propagated along the fiber; other rays are absorbed by the surrounding material.

- multiple propagation paths exist, each with a different path length
- each path takes a different time to traverse the fiber
- signal elements (light pulses) spread out in time
- limits the rate at which data can be accurately received
- suitable for very short distances

Modes of propagation

Single-mode propagation: highly focused source of light and step-index fiber of low refractive index

- Since the critical angle is close enough to 90 degrees to make the propagation of beams almost horizontal
- Thus the propagation of beams is almost identical
- Delays are negligible
- Suitable for long-distance applications

Modes of propagation

Graded-index multimode

- Variable index of refraction of the core
- intermediate between the other two in characteristics
- higher refractive index at the center makes the light rays moving down the axis advance more slowly than those near the cladding.
- light in the core curves helically (rather than zig-zagging off the cladding) because of the graded index, reducing its travel distance.
- The shortened path and higher speed allows light at the periphery to arrive at a receiver at about the same time as the straight rays in the core axis
- Often used in LANs

Both single mode and multimode can support several different wavelengths of light and can employ laser or LED light sources

Applications

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- Local area networks

Light sources used

- Light Emitting Diode (LED)
- – less costly
- – operates over a greater temperature range
- – has a longer operational life
- Injection Laser Diode (ILD)
- – more efficient
- – can sustain greater data rates
- Both are devices that emit a beam of light when a voltage is applied

Frequency Utilization for Fiber Applications

Wavelength (in vacuum) range (nm)	Frequency Range (THz)	Band Label	Fiber Type	Application
820 to 900	366 to 333		Multimode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	C	Single mode	WDM
1561 to 1620	192 to 185	L	Single mode	WDM

WDM: Wavelength Division Multiplexing, 1THz $= 10^{12}$Hz

- The four transmission windows are in the infrared portion of the frequency spectrum (below the visible-light portion — 400 to 700 nm)
- The loss is lower at higher wavelengths, allowing greater data rates over longer distances
- Increasing order of expenditure, data rates and distances supported:
  - 850-nm LED light sources (100 Mbps, a few kilometers)
  - 1300-nm LED or laser source
  - 1500-nm laser sources

  Example for LAN (Ethernet): 100BASE-FX: 4B5B NRZI coded signaling, multi-mode optical fiber, 400 meters for half-duplex connections, 2 km for full-duplex connections

Attenuation of typical guided media