Fiber Optics Fundamentals

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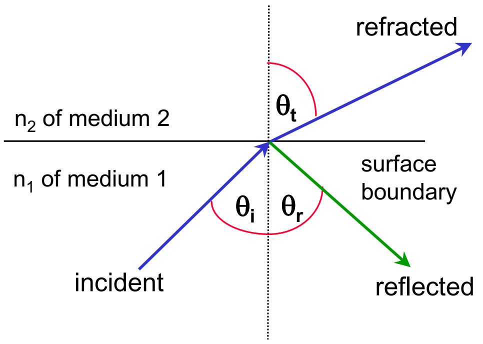
Bending of Light Ray



- θ_i = angle of incidence
- θ_r = angle of reflection
- θ_t = angle of refraction

refraction index : n = c/v

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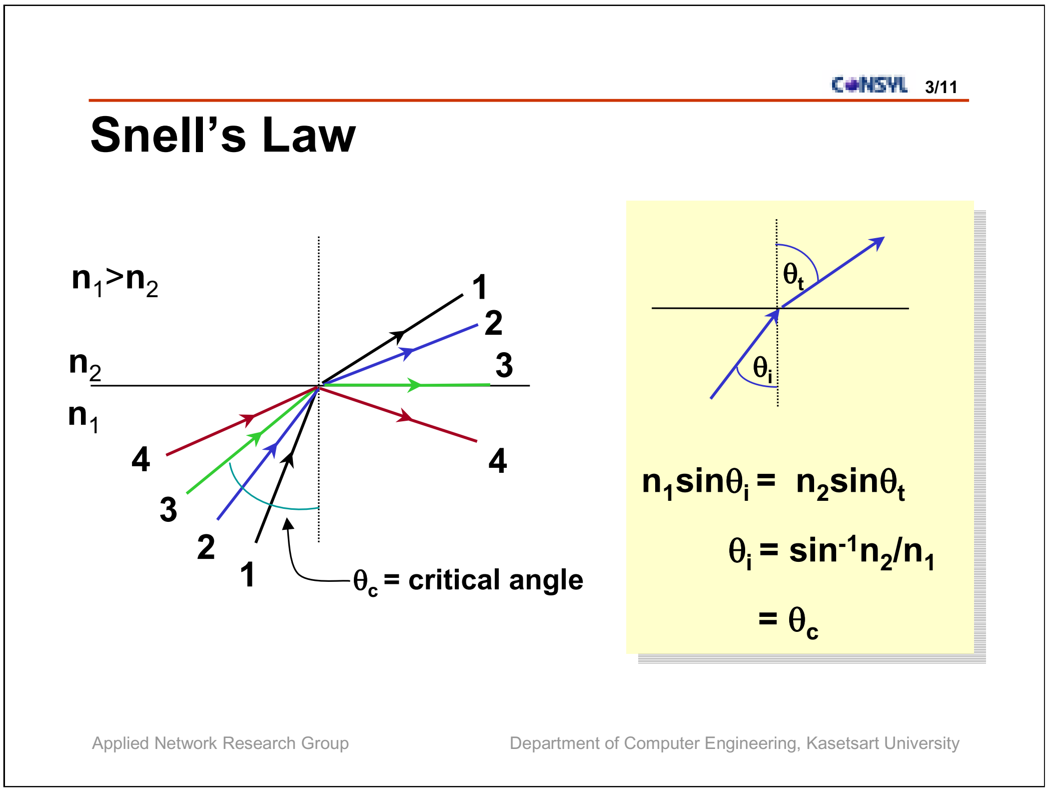
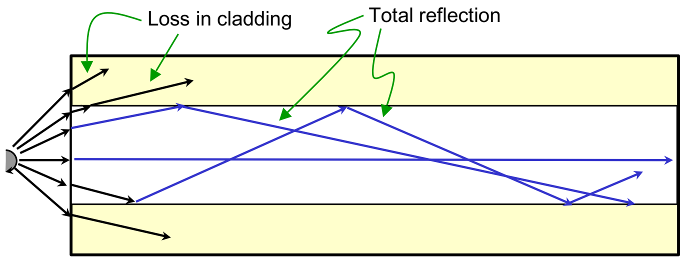
The surface represents a boundary between two media. Let θ_i be the angle at which the light wave intersects the boundary. Some of the light will reflect back at an $\theta_r=\theta_i$ and some will cross the boundary into the other medium.



From Snell's law, if θ_t reach 90° , θ_i will equal to $\sin^{-1} n_2/n_1$. This θ_c is called critical angle of incidence. Any light rays that are incident at angles greater than critical angle will reflect back into medium.

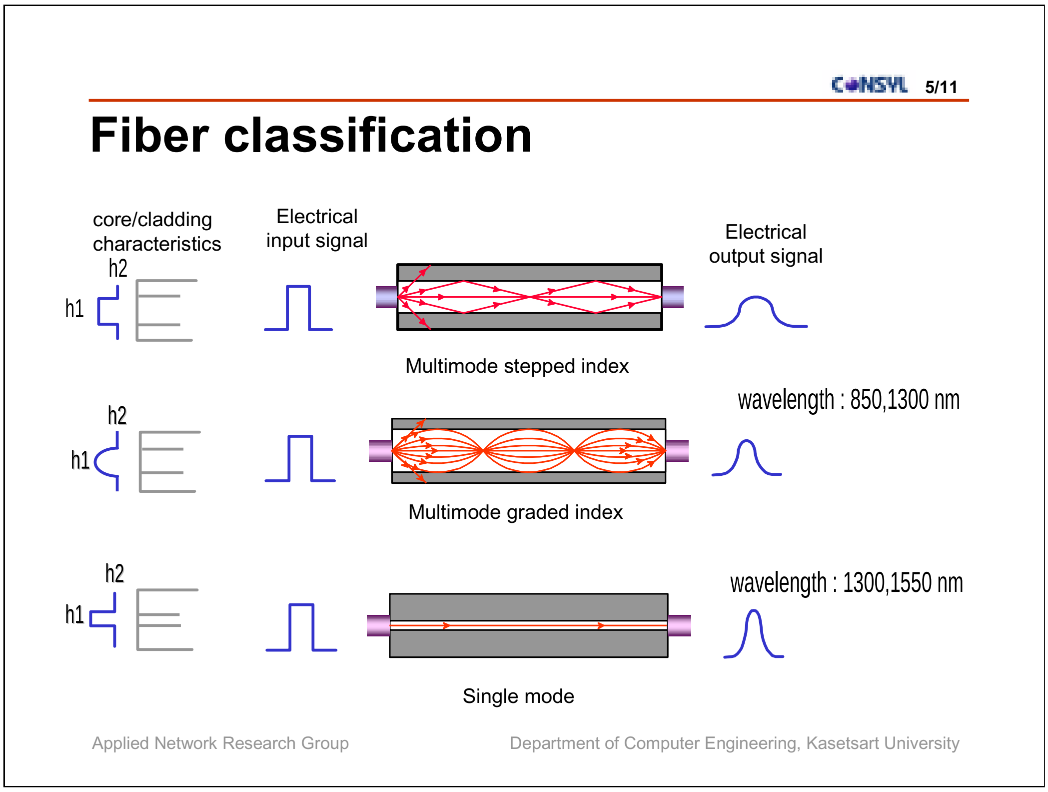
Propagation Modes



$$M = \frac{\left(\frac{\pi d}{\lambda}\sqrt{(n_1)^2-(n_2)^2}\right)^2}{2}$$

M = the number of modes
d = core diameter (m)
λ = wavelength (m)
n_1 = refraction index of core
n_2 = refraction index of cladding

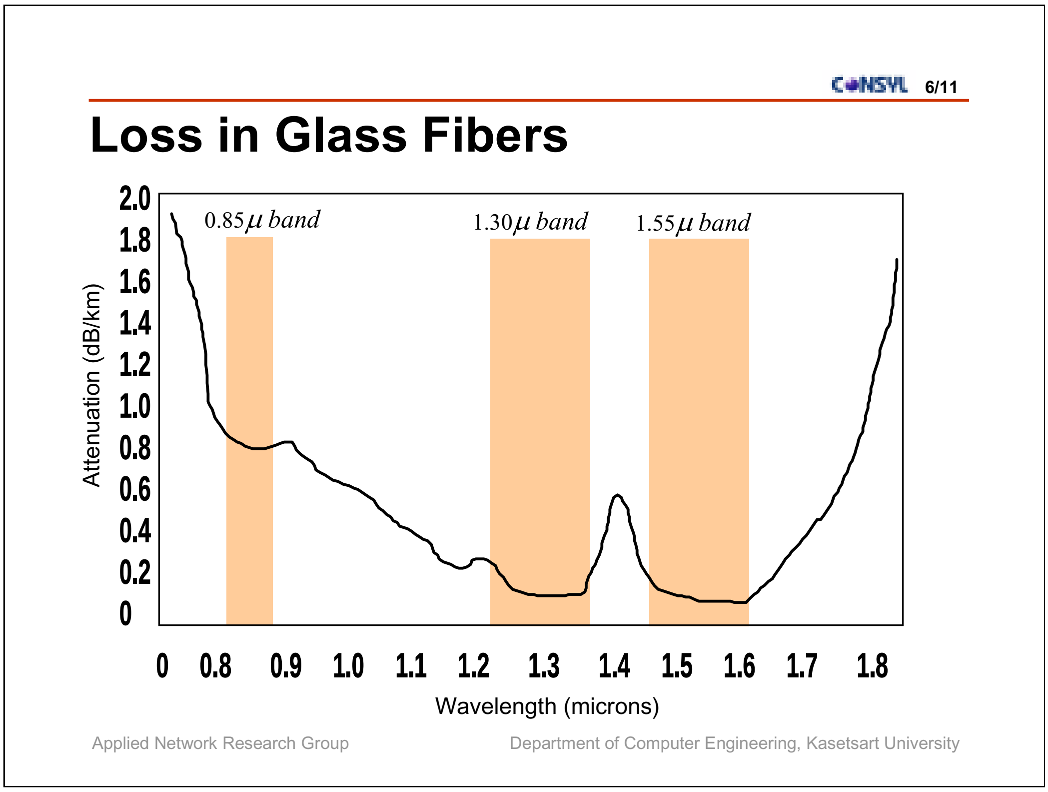
A fiber core is fairly thick relative to a wavelength of light and allow the light to enter it at many difference angles. There is a finite number of angles at which the rays reflect and propagate the length of the fiber. Each angle defines a path or a mode.



There are basically two modes of a transmission in a fiber. A *multimode* fiber has a number of paths in which light ray may travel. A *single mode* has a light ray in one direction only.

Fibers are further classified by the refractive index profile of their core. They can be either *step index* or *graded index*. Three main types of fibers are *multimode step-index fiber* , *multimode grades index fiber* and *single mode fiber.*

The refraction index of multimode step-index fiber is uniformly throughout the core. The refraction index of multimode graded-index fiber is gradually less dense), light travels radically outward it begins to bend back toward the center, eventually reflecting back. Because the material also less dense, the light travels faster. Reducing the core diameter to that of a single wavelength (3-10 µm) will let the light propagates along a one mode only.



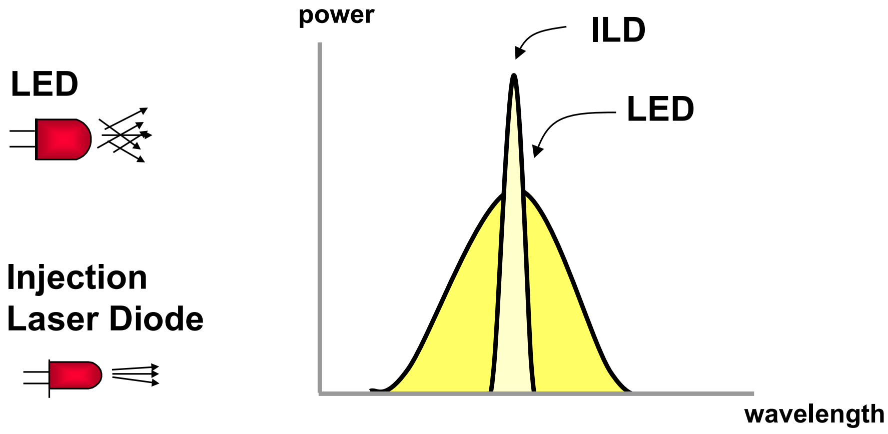
Because of the attenuation versus wavelength characteristics of glass optical fiber, there are three wavelength ranges, or windows, preferred for transmission.

With the first window at 850 nm, light sources and electronics can be made from alloy semiconductors with $Ga_{1-x}Al_xAs$.

The second window is around 1300 nm. Above this window there is a peak attenuation due to absorbation of light by the hydroxyl (OH) ions trapped in the fiber during processing. This window coincides with the point of minimum chromatic dispersion of the fiber.

The fiber attains its greatest transparency at wavelengths around 1550 nm, where attenuation decreases to only 0.2 dB per kilometer. Above 1600 nm, it increases again due to absorbtion. [Powers,P. John, *An Introduction to Fiber Optic Systems*, Aksen Assoc. Inc. Publishers, 1993]. Above 1600 nm, glass is no longer transparent to infrared light. Instead, the light is absorbed and converted to heat,

Light Source

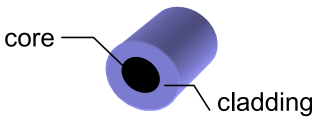


A light source such as a LED or a laser is placed at one end of the fiber. The light source emit short but rapid pulses of light that enter the core at different angles. The laser produce a very pure and narrow beam. It also has a high-power output, allowing the light to propagated further that produced by the LED. The LED produces less concentrated light consisting of many wavelengths.

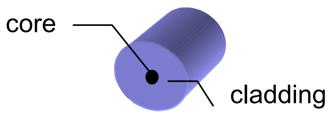
Optical Fiber Comparison

	Multimode	Single mode
Light source	LED/ILD	ILD
Bandwidth	>1 GHz/km	up to 1000 GHz/km
Wavelength	850, 1300	1300,1550
core/cladding	62.5/125*	8/125
Applications	LAN, backbone	Long distance, Telcom lines

* options with 50/125, 100/140



62.5/125 micron

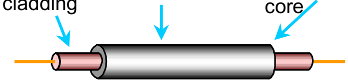


8/125 micron

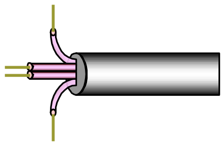
Standard fibers are categorized as *single mode* or *multimode*. Single mode fibers are appropriate for long distance with high data rate. Multimode fiber are for shorter distance or local area networks. The most popular one is 62.5/125 type.

Typical Fiber Cable

Single core



Multicore

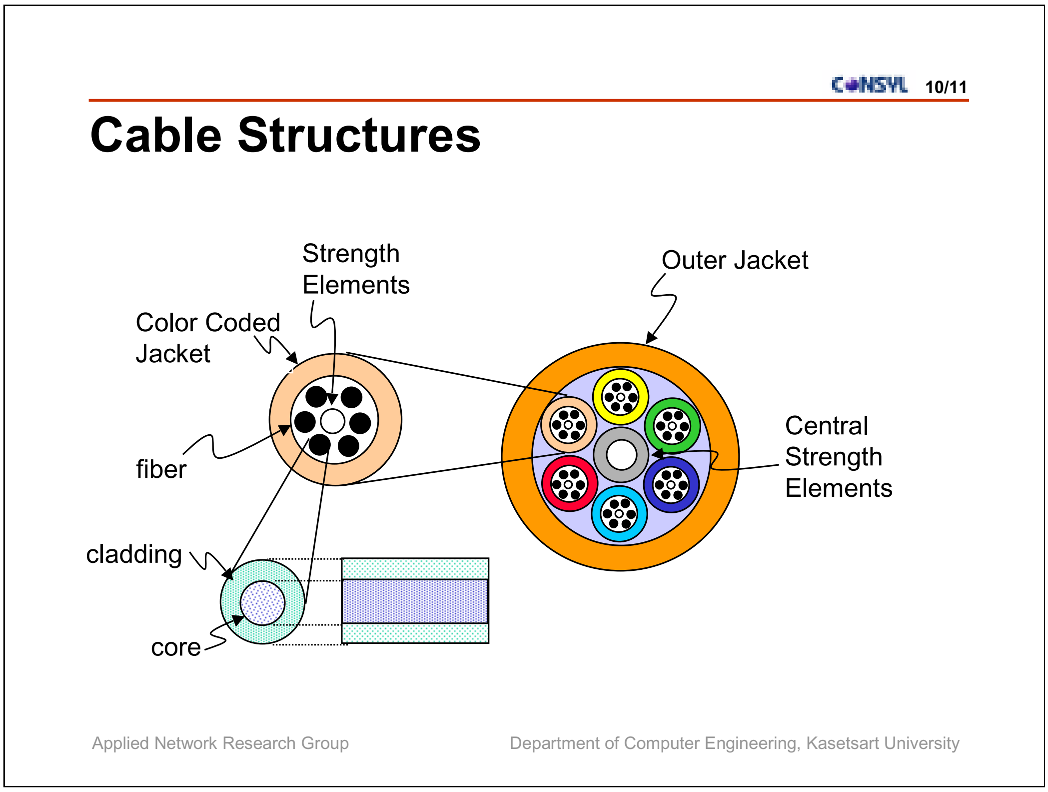


- **Materials for cladding and core:**
  - glass cladding/glass core
  - plastic cladding/glass core
  - plastic cladding/plastic core

The major components of a fiber-optics cable are the core, cladding, buffer, strength, strength member and the jacket.

The core is made of glass or plastic. Plastic is easier to manufacture and use but works shorter distance than glass. The core can be anywhere from about 2 to several hundred microns (1 micron = 10^{-6} m).

The core and cladding are actually manufacture as a single unit. The cladding is usually of plastic with a lower index of reflection than core.



Fiber cables are normally bundled with several cores e.g. 2, 4,6 ,8 ,12,24, 36 or 72 (depends on manufacturing).

Fiber in use

- **Plenums or non-plenums**
  - plenum cable has a fire-resistant jacket, which will not burn, smoke or
  - give off toxic fumes when expose to heat
- **Riser cables**
  - cable that runs vertically; e.g. between floors in a building
- **Indoor or Outdoor**
  - Indoor cable used in building. Outdoor cable used in underground,
  - directed buries, and aerial applications between building.

Outdoor cable is fill with a compound formulated to protected the fibers from environmental damage such as moisture.