N96- 18156

PRINCIPLES AND CHARACTERISTICS OF OPTICAL FIBERS

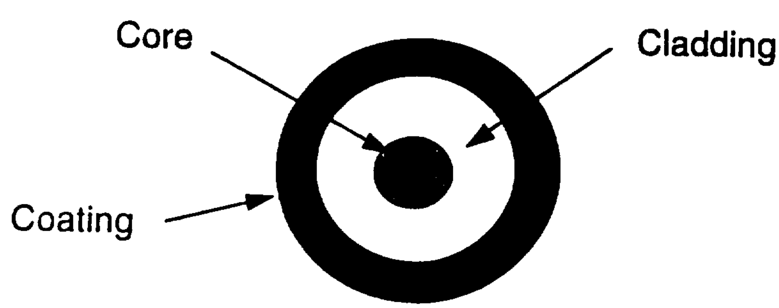
Atikem Haile-Mariam

Corning Inc., 27 W. Market St., ME-R3-O3-1, Corning, NY 14831

DEFINITIONS

Core, Cladding, Coating

- An optical fiber is made of three sections:
- The core carries the light signals
- The cladding keeps the light in the core
- The coating protects the cladding



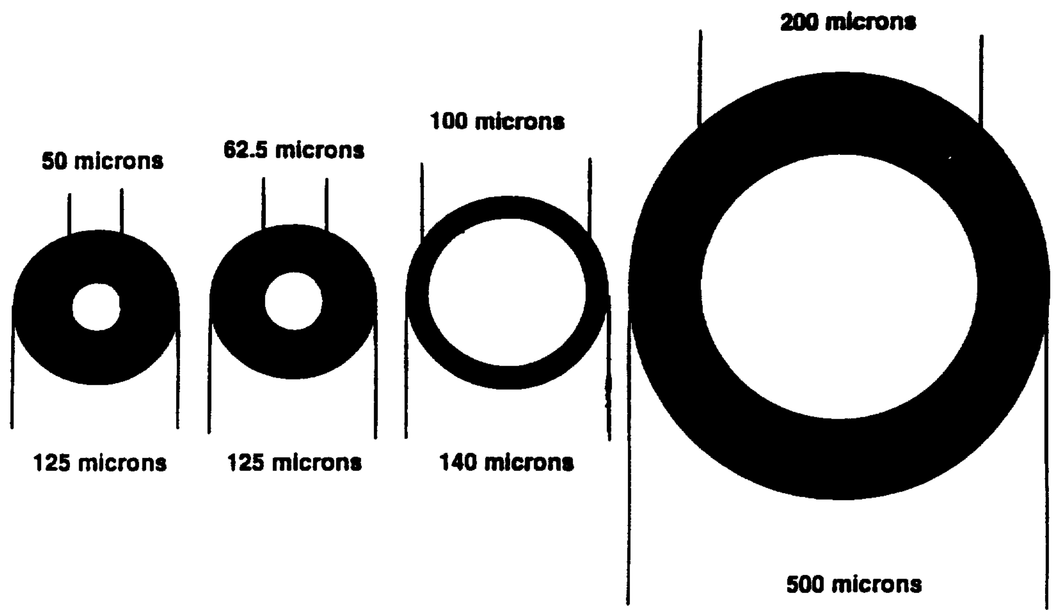
How an Optical Fiber Works

- An Optical Fiber works on the principle of Total Internal Reflection
- Light rays are reflected and guided down the length of an optical fiber.
- The acceptance angle of the fiber determines which light rays will be guided down the fiber.

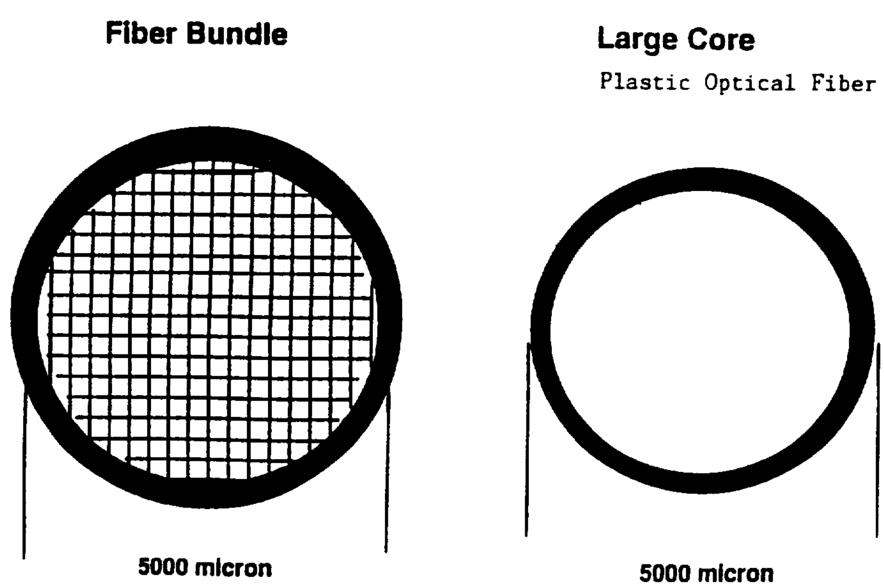
CORE CHARACTERISTICS

1. The diameter of the light carrying region of the fiber is the "core diameter."
2. The larger the core, the more rays of light that travel in the core.
3. The larger the core, the more optical power that can be transmitted.
4. The core has a higher index of refraction than the cladding.
5. The difference in the refractive index of the core and the cladding is known as delta.

STANDARD OPTICAL FIBER SIZES

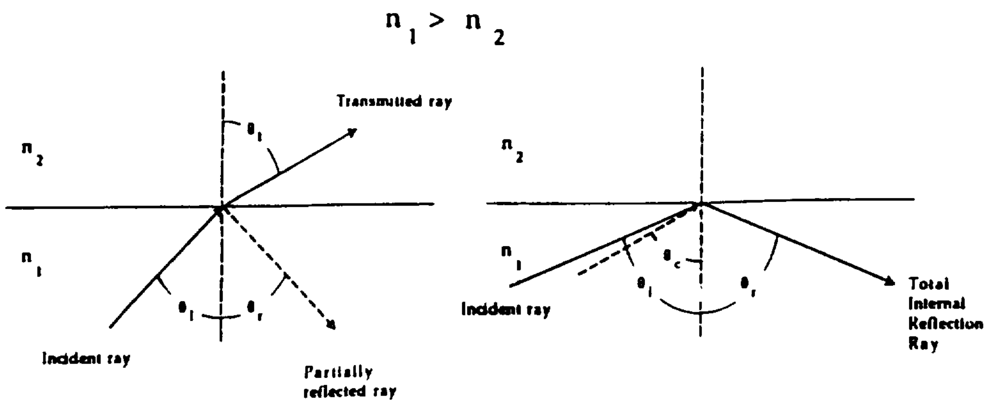


SPECIALTY ILLUMINATION FIBER



Total Internal Reflection

Total Internal Reflection occurs when any ray traveling from a medium with a high refractive index is incident on a boundary of a lower refractive index at an angle greater than or equal to the critical angle.



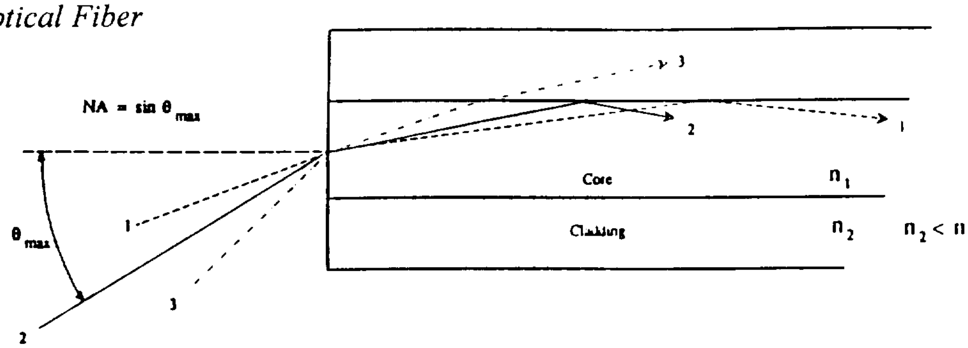
The transmitted ray is bent away from the normal Total internal reflection: $\theta_i > \theta_c$

(From: Michael Brininstool, 1993, Fiber Optic Design Principles Tutorial, ROV93 Conference San Diego, CA.)

Numerical Aperture (NA)

1. Measure of the acceptance angle of light that a fiber can support through total internal reflection.
2. Designed into the fiber by the difference in indices of refraction between the core and the cladding material.

Ray Tracing in Optical Fiber



Ray 1: Light is coupled into fiber since ray is within acceptance cone of fiber.

Ray 2: Light is at the maximum acceptance angle of fiber and is coupled.

Ray 3: Light is radiated out of fiber since ray is outside acceptance cone of fiber.

(From: Michael Brininstool, 1993, Fiber Optic Design PrinciplesTutorial, ROV93 Conference San Diego, CA.)

FIBER PERFORMANCE

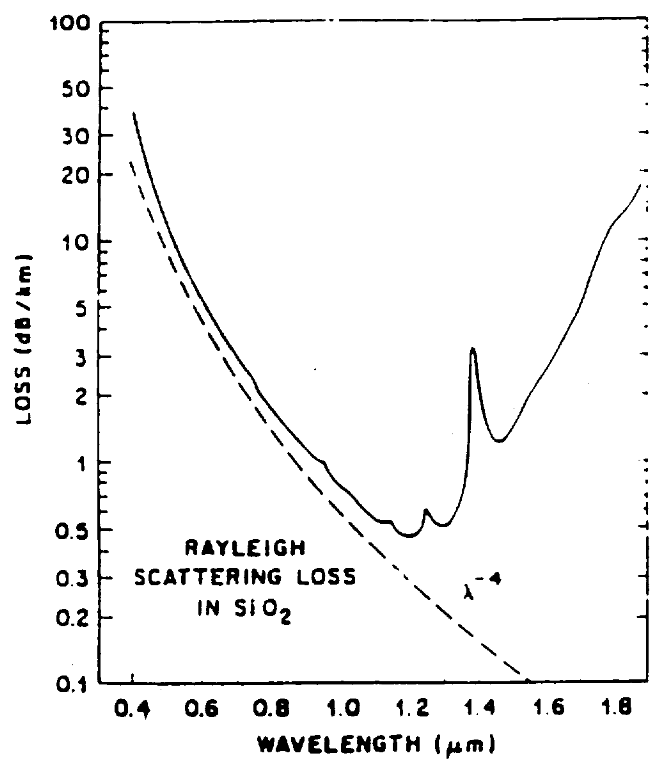
The efficiency of light transmission of optical fibers depends on fiber design and physical environment.

FIBER MATERIAL COMPOSITION

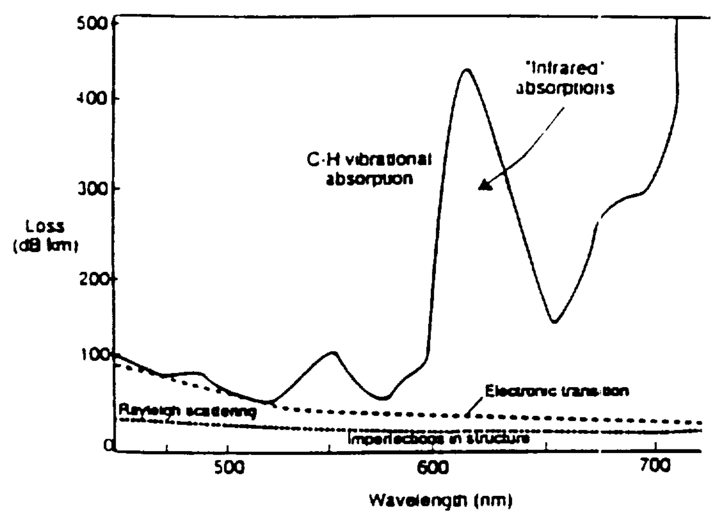
1. Corning optical fiber is an amorphous noncrystaline material made of pure fused silica and germania dopant.
2. Plastic optical fiber is generally made of a polymethyl methacrylate (PMMA).
3. Experimental fibers are made of other materials such as sapphire.
4. Coatings are usually proprietary to the manufacturer but are usually acrylate or polyimide based.
5. The primary function of coating is to protect the glass fiber from flaws.

EXAMPLES OF SPECTRAL ATTENUATION IN OPTICAL FIBER

Silica Core



PMMA Core



(From Product Information Sheet: Mitsubishi-Rayon Co. Inc.)

COMPARISON OF GLASS AND PLASTIC OPTICAL FIBER

Characteristics	Glass	Plastic
Fiber core diameter, microns clad diameter	50-200 125-500	250-5000 450-6000
Attenuation at 650 nm, dB/km	4.0	150*
Maximum transmission distance for 75% power loss, meters	1,500	.53
Usable spectral range	UV,VIS,IR	VIS
Numerical aperature	.1-.4	.3-.65
Acceptance angle (cone)	35 degrees	60-75 degrees

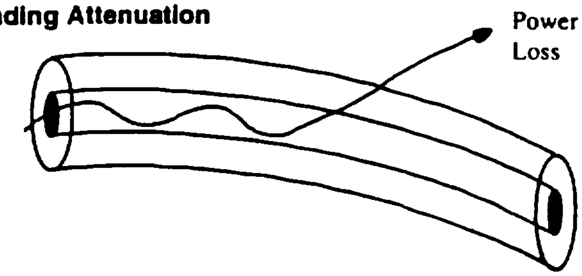
*Current commercial limits, not theoretical limits

PHYSICAL ENVIRONMENT

Bend Induced Attenuation

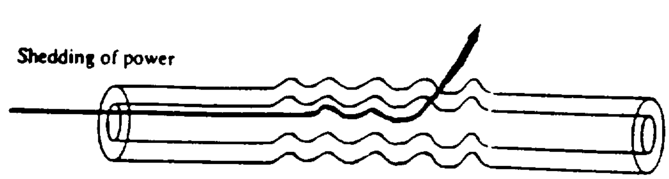
1. Macrobending
2. Large bends in an Optical Fiber will shed rays of light. Power is lost at the bend.

Macrobending Attenuation



1. Microbending
   - Small axial bends/bumps along the fiber axis that cause mixing or loss of power. This can be induced by fiber jacketing, cabling or environment.

Microbending Attenuation



Cable Design

1. Performance of fibers in cables depends on the following components:
   strength members (kevlar, steel)
   fill compounds
   tight buffer vs loose tube
2. Temperature/Humidity
   The performance of fiber/cable depends on the extent to which temperature and humidity produce microbending.

Specifications

3. Temperature (Celsius)
   Standard Glass Optical Fiber - -60 to +85 degrees
   Specialty Glass Optical Fiber - -60 to +200 degrees
   Plastic Optical Fiber -40 to 85 degrees
4. Temperature/Humidity
   Standard Glass Optical Fiber - -10 to +85 degrees and 4% to 98% RH
   Specialty Glass Optical Fiber - -10 to +85 degrees and 4% to 98% RH
   Plastic Optical Fiber - max 85% humidity for 2000 hours

TECHNICAL ISSUES THAT MERIT FURTHER INVESTIGATION

1. Cost effective diffusers and concentrators
2. Cost effective coupling techniques between light sources and fibers
3. "Multi-use' fibers

SUMMARY

1. Optical fibers works on the principle of total internal reflection.
2. Optical fibers can be used at various wavelengths including illumination applications.
3. Factors affecting the performance of fiber include material composition, geometry, and the physical environment.
4. Fiber/cabling can be optimized for the specific application and environment.
5. Manufacturing processes are available for producing glass fibers of differing refractive indices and diameters.