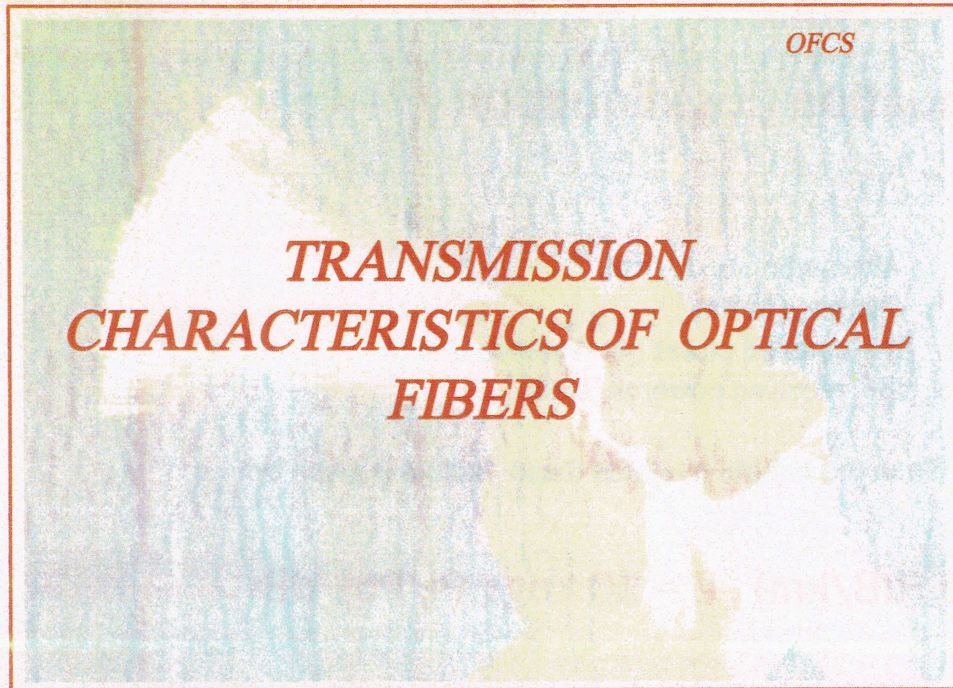




Attenuation

- Attenuation is a measure of decay of **signal strength** or loss of **light power**, that occurs as light pulses **propagate** through the length of fiber optic cable.
- The **attenuation** is mainly caused by two physical factors:
 - **Absorption** — because of fiber material
 - **Scattering losses** — due to structural imperfections within the fiber.
 - **Radiative loss**

Attenuation (loss Equation)

If

- α Attenuation in dB/Km
- L Distance in Km
- P_i The coupled power (at distance $L = 0$)
- P_o the received power at L km ,

Then the equation relates these factors is given by:

$$\alpha \text{ (dB/km)} \cdot L = 10 \text{ Log (} P_i/P_o \text{) dB}$$

Attenuation relation with(Input power, Output power) and length of FOC

- α Attenuation in dB / Km
- L Distance in Km
- $\alpha \text{ (dB/km)} \cdot L = 10 \text{ Log (} P_i/P_o \text{)}$
- $(\alpha \text{ (dB/km)} \cdot L) / 10 = \text{Log (} P_i/P_o \text{)}$

$$(\alpha \cdot L) / 10 = \text{Log (} P_i/P_o \text{)} \quad \text{and}$$

$$\alpha = (10/L) \text{ Log (} P_i/P_o \text{)} , \quad \text{Log}(P_i/P_o) = (\alpha \cdot L)/10$$

continue

- $P_i/P_o = 10^{\alpha L/10}$

- $P_i = P_o 10^{\alpha L/10}$

- $P_o = P_i / (10^{\alpha L/10})$

- $P_o = P_i \cdot 10^{-\alpha L/10}$ **Watt,**
and

$$10 \log(P_o) = 10 \log(P_i \cdot 10^{-\alpha L/10})$$

$$10 \log(P_o) = 10 \log P_i + 10 \log 10^{-\alpha L/10}$$

$$10 \log P_o = 10 \log P_i + 10(-\alpha L/10) \log 10$$

$$P_o \text{ dB} = P_i \text{ dB} - \alpha L$$

Another Attenuation equation

- As attenuation leads to loss of power along the fiber, the output power is less than the coupled power(input power)

- If coupled optical power denoted by $P(O)$, then the power at distance Z is given by: $P(Z)$ such that,

$$P(Z) = P(O) e^{-\alpha P Z}$$

where αp is fiber attenuation constant (per Km), and

$$\alpha p = \frac{1}{Z} \ln(P_o/P_z)$$

$$\alpha(\text{dB/Km}) = 10 \frac{1}{Z} \log(P_o/P_z) \quad \text{and}$$

$$\alpha(\text{dB/Km}) = 4.343 \alpha p$$

Example

A fiber has a coupled power -8dBm and attenuation of 6 dBm/km, and a length 2 km. Calculate the output power

$$P_c = -8 \text{ dBm} \quad \alpha = 6 \text{ dBm/km}$$

$$P_o = P_c - \alpha L \text{ [dB]}$$

$$= -8 - 6(2) = -20 \text{ dBm}$$

$$P_o = 10^{-20/10} \text{ mW} = 10^{-2} \text{ mW} = 10 \text{ nW}$$

$$\alpha L = 6 \times 2 = 12 \text{ dB}$$

$$P_c = -8 \text{ dBm}$$

$$= 10^{-0.8} \text{ mW}$$

$$= 0.158 \text{ mW}$$

$$P_o = P_c - 12 \text{ dB}$$

$$= 0.158 \times 10^{-2}$$

$$= 10 \text{ nW}$$

Example

A fiber coupled power -8dBm and attenuation of 6 dBm/km. Find the fiber length if the output power is -30dBm.

$$P_o = P_c - \alpha L \Rightarrow \alpha L = P_c - P_o = -8 + 30 = 22 \text{ dBm}$$

$$L = \frac{22 \text{ dBm}}{6 \text{ dBm/km}} = 3.67 \text{ km}$$

► **Example 3.1.1 :** A low loss fiber has average loss of 3 dB/km at 900 nm. Compute the length over which -

a) Power decreases by 50%

b) Power decreases by 75%

Solution : $\alpha = 3 \text{ dB/km}$

a) Power decreases by 50%

$$\Rightarrow \frac{P(0)}{P(z)} = 50\% = 0.5$$

α is given by

$$\alpha = 10 \cdot \frac{1}{z} \cdot \log \left[\frac{P(0)}{P(z)} \right]$$

$$3 = 10 \cdot \frac{1}{z} \log [0.5]$$

$$z = 1 \text{ km}$$

... Ans.

b) $\frac{P(0)}{P(z)} = 25\% = 0.25$

Since power decreases by 75%

$$3 = 10 \times \frac{1}{z} \log [0.25]$$

$\therefore$

$$z = 2 \text{ km.}$$

... Ans.

► **Example 3.1.2 :** For a 30 km long fiber attenuation 0.8 dB/km at 1300 nm. If a 200 μ watt power is launched into the fiber, find the output power.

Solution :

$$Z = 30 \text{ km}$$

$$\alpha = 0.8 \text{ dB/km}$$

$$P(0) = 200 \mu\text{W.}$$

attenuation in optical fiber is given by

$$\alpha = 10 \times \frac{1}{z} \log \left[\frac{P(0)}{P(z)} \right]$$

$$0.8 = 10 \times \frac{1}{30} \log \left[\frac{200 \mu\text{W}}{P(z)} \right]$$

$$2.4 = \log \left[\frac{200 \mu\text{W}}{P(z)} \right]$$

$$\frac{200 \mu\text{W}}{P(z)} = 10^{2.4}$$

$$P(z) = \frac{200 \mu\text{W}}{251.1886} = 0.7962 \mu\text{W}$$

... Ans.

The attenuation is mainly caused by two physical factors:

1. Absorption

- Absorption loss is related to material composition and fabrication process of fiber cable.
- Absorption loss results in dissipation of some optical power as heat in optical cable.
- Absorption is caused by **three different mechanism:**
 - Absorption by atomic defects in glass composition.
 - Intrinsic absorption by basic constituent atom of fiber
 - Extrinsic absorption by impurity atom of fiber.

Continue- losses

2. Scattering losses

Scattering losses exists in optical fibers because of **macroscopic variations in the material density and composition.**

Attenuation

Attenuation

- Definition: a loss of signal strength in a lightwave, electrical or radio signal usually related to the distance the signal must travel.

Attenuation is caused by:

- Absorption
- Scattering
- Radiative loss

Losses in Fiber optic cable

Losses

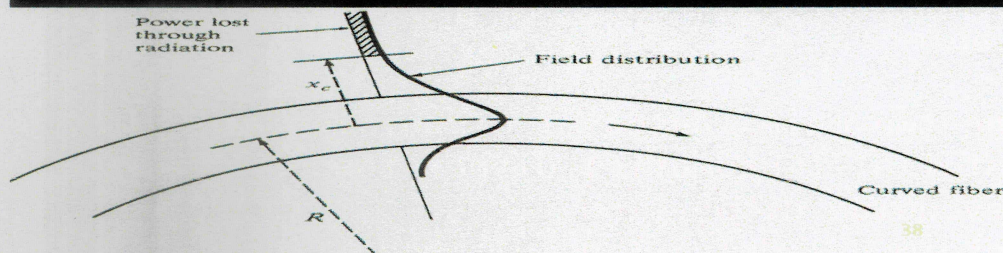
- ▣ Losses in optical fiber result from attenuation in the material itself and from scattering, which causes some light to strike the cladding at less than the critical angle
- ▣ Bending the optical fiber too sharply can also cause losses by causing some of the light to meet the cladding at less than the critical angle
- ▣ Losses vary greatly depending upon the type of fiber
 - ▣ Plastic fiber may have losses of several hundred dB per kilometer
 - ▣ Graded-index multimode glass fiber has a loss of about 2-4 dB per kilometer
 - ▣ Single-mode fiber has a loss of 0.4 dB/km or less

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Bending losses - Macro bending losses

Macrobending Loss:

- ▣ The curvature of the bend is much larger than fiber diameter. Lightwave suffers severe loss due to radiation of the evanescent field in the cladding region. As the radius of the curvature decreases, the loss increases exponentially until it reaches at a certain critical radius. For any radius a bit smaller than this point, the losses suddenly becomes extremely large. Higher order modes radiate away faster than lower order modes.

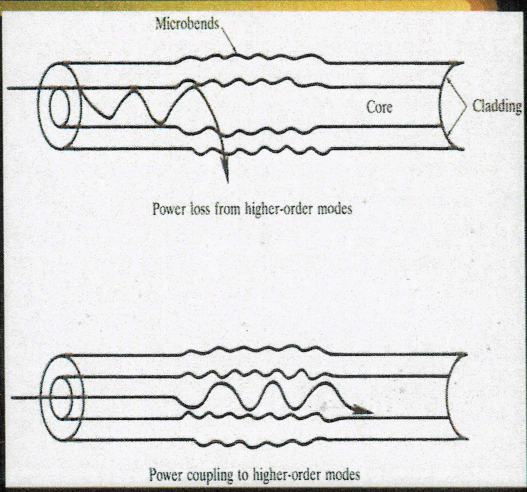


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Micro bending losses

Microbending Loss

■ **Microbending Loss:** microscopic bends of the fiber axis that can arise when the fibers are incorporated into cables. The power is dissipated through the microbended fiber, because of the repetitive coupling of energy between guided modes & the leaky or radiation modes in the fiber.



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Dispersion

Dispersion

- The phenomenon in an optical fibre whereby light photons arrive at a distant point in different phase than they entered the fibre.
- Dispersion causes receive signal distortion that ultimately limits the bandwidth and usable length of the fiber cable

The two main causes of dispersion are:

- Material (Chromatic) dispersion
- Waveguide dispersion
- Intermodal delay (in multimode fibres)

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Continue

- ▮ Dispersion in fiber optics results from the fact that in multimode propagation, the signal travels faster in some modes than it would in others
- ▮ Single-mode fibers are relatively free from dispersion except for *intramodal dispersion*
- ▮ Graded-index fibers reduce dispersion by taking advantage of higher-order modes

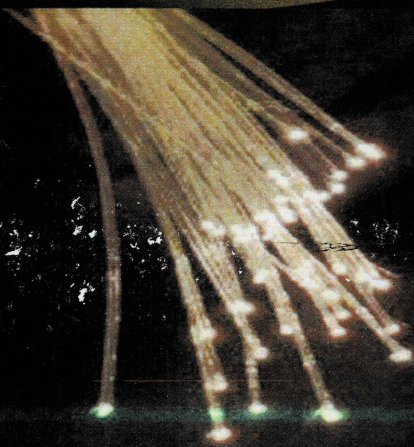
Continue

- ▮ One form of intramodal dispersion is called *material dispersion* because it depends upon the material of the core
- ▮ Another form of dispersion is called *waveguide dispersion*
- ▮ Dispersion increases with the bandwidth of the light source

Advantages of Optical cable

Advantages of Optical Fibre

- Thinner
- Less Expensive
- Higher Carrying Capacity
- Less Signal Degradation & Digital Signals
- Light Signals
- Non-Flammable
- Light Weight



continue

Advantages of fiber optics

- Much Higher Bandwidth (Gbps) - Thousands of channels can be multiplexed together over one strand of fiber
- Immunity to Noise - Immune to electromagnetic interference (EMI).
- Safety - Doesn't transmit electrical signals, making it safe in environments like a gas pipeline.
- High Security - Impossible to "tap into."

Continue

Advantages of fiber optics

- Less Loss - Repeaters can be spaced 75 miles apart (fibers can be made to have only 0.2 dB/km of attenuation)
- Reliability - More resilient than copper in extreme environmental conditions.
- Size - Lighter and more compact than copper.
- Flexibility - Unlike impure, brittle glass, fiber is physically very flexible.

continue

Fiber Optic Advantages

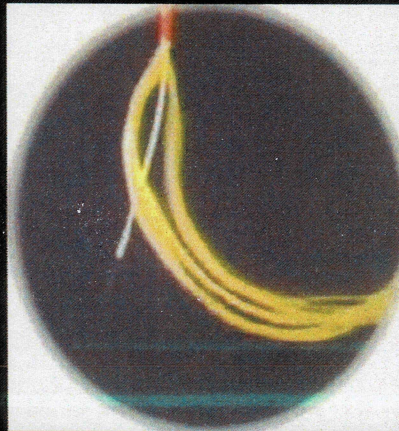
- ▣ greater capacity (bandwidth up to 2 Gbps, or more)
- ▣ smaller size and lighter weight
- ▣ lower attenuation
- ▣ immunity to environmental interference
- ▣ highly secure due to tap difficulty and lack of signal radiation



Disadvantages

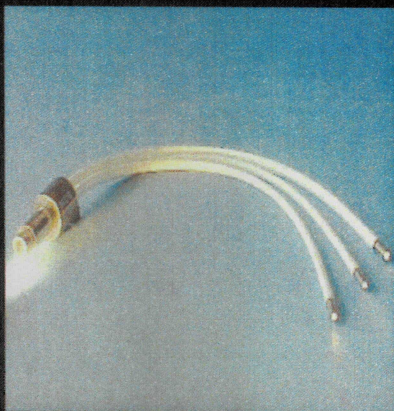
Disadvantages of fiber optics

- ▣ Disadvantages include the cost of interfacing equipment necessary to convert electrical signals to optical signals. (optical transmitters, receivers)
- ▣ **Splicing** fiber optic cable is also more difficult



Area of application

Areas of Application



- ▣ Telecommunications
- ▣ Local Area Networks
- ▣ Cable TV
- ▣ CCTV
- ▣ Optical Fiber Sensors

Formula summary

Formula Summary

Index of Refraction	$n = \frac{c}{v}$
Snell's Law	
Critical Angle	$n_1 \sin \theta_1 = n_2 \sin \theta_2$
Acceptance Angle	$\theta_c = \sin^{-1} \left(\frac{n_2}{n_1} \right)$
Numerical Aperture	$\alpha = \sin^{-1} \left(\sqrt{n_1^2 - n_2^2} \right)$
	$NA = \sin \alpha = \sqrt{n_1^2 - n_2^2}$