Engineering Physics

(PHY1701)

Dr. B. Ajitha

Assistant Professor
Division of Physics
VIT University
Chennai, India
ajitha.b@vit.ac.in

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- Light propagation through fibers,
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- Dispersion-intermodal and intramodal (AG 29-40, 65, 78)

❖ Introduction to Fiber Optics, Ajoy Ghatak and K. Thyagarajan, Cambridge University Press, 2010 (AG)

Attenuation

- Attenuation limits the optical power which can reach the receiver, limiting the operating span of a system.
- Once the power of an optical pulse is reduced to a point where the receiver is unable to detect the pulse, an error occurs.
- **Attenuation** is mainly a result of:
- **Light Absorption**
- **Scattering of light**
- **Bending losses**
- **Attenuation** is defined as the ratio of optical input power (P_i) to the optical output power (P_o).

- The loss in optical fiber is defined differently depending on the types of loss described and the design of the fiber.
- **ATTENUATION LOSS** is generally measured in terms of the decibel (dB) which is a logarithmic unit.
- The decibel loss of optical power in a fiber is calculated through the following formula

Attenuation

$$Loss\ of\ optical\ fiber = -10\log\left(\frac{P_{out}}{P_{in}}\right)\text{dB}$$

$$Loss\ /\ km = -\left(\frac{10}{L}\right)\log\left(\frac{P_{out}}{P_{in}}\right)\text{dB/ km}$$

Where

P_{out} is the power coming out of the fiber

P_{in} is the power launched into the fiber

L is the length of the fiber tested

- The loss per kilometer (or dB/km) is a standard unit for describing attenuation loss in all fiber designs

Types of Attenuation

Absorption Loss:

- Caused by the fiber itself or by impurities in the fiber, such as water and metals.

Scattering Loss:

- Intrinsic loss mechanism caused by the interaction of photons with the glass itself.

Bending loss:

- Loss induced by physical stress on the fiber.

Material Absorption Losses

- Material absorption is caused by absorption of photons within the fiber.
- – When a material is illuminated, photons can make the valence electrons of an atom transition to higher energy levels
- – Photon is destroyed, and the radiant energy is transformed into electric potential energy. This energy can then
- • Be re-emitted (scattering)
- • Frees the electron (photoelectric effects) (not in fibers)
- • Dissipated to the rest of the material (transformed into heat)
- In an optical fiber Material Absorption is the optical power that is effectively converted to heat dissipation within the fiber.
- • Two types of absorption exist:
- – **Intrinsic Absorption**, caused by interaction with one or more of the components of the glass.
- – **Extrinsic Absorption**, caused by impurities within the glass.

Material Absorption Losses

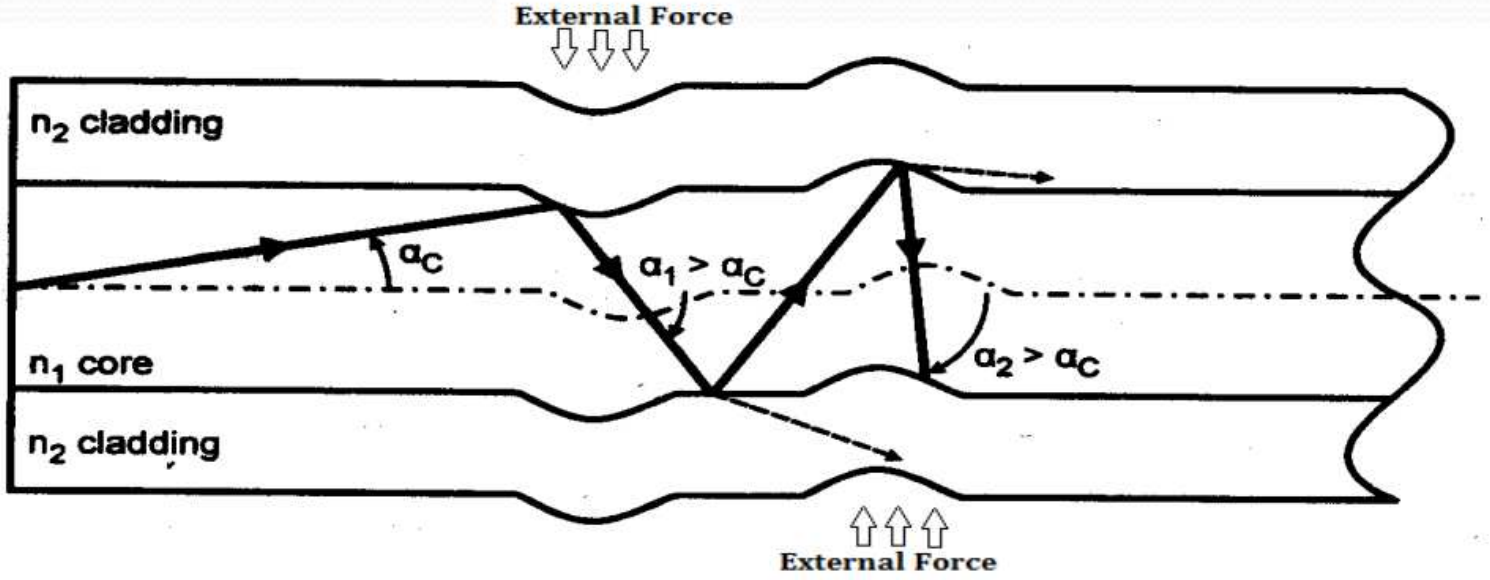
- **Intrinsic Absorption** is caused by basic fiber material properties. If an optical fiber is absolutely pure, with no imperfections or impurities, ten all absorption will be intrinsic. Intrinsic absorption in the ultraviolet region is caused by electronic absorption bands. **Intrinsic Absorption** occurs when a light particle (photon) interacts with an electron and excites it to a higher energy level.
- **Extrinsic Absorption** is caused by impurities caused by impurities introduced into the fiber material. The metal impurities such as iron, nickel and chromium are introduced into the fiber during fabrication. **Extrinsic Absorption** is caused by the **electronic transition** of these metal ions from one energy level to another energy level.

Fiber Bend Losses

Bending loss is classified according to the bend radius of curvature :

1. Microbend Loss 2. Macrobend Loss

- **Microbend Loss** are caused by small discontinuities or imperfections in the fiber. Uneven coating applications and improper cabling procedure increases micro bend loss. External forces are also a source of micro bends.

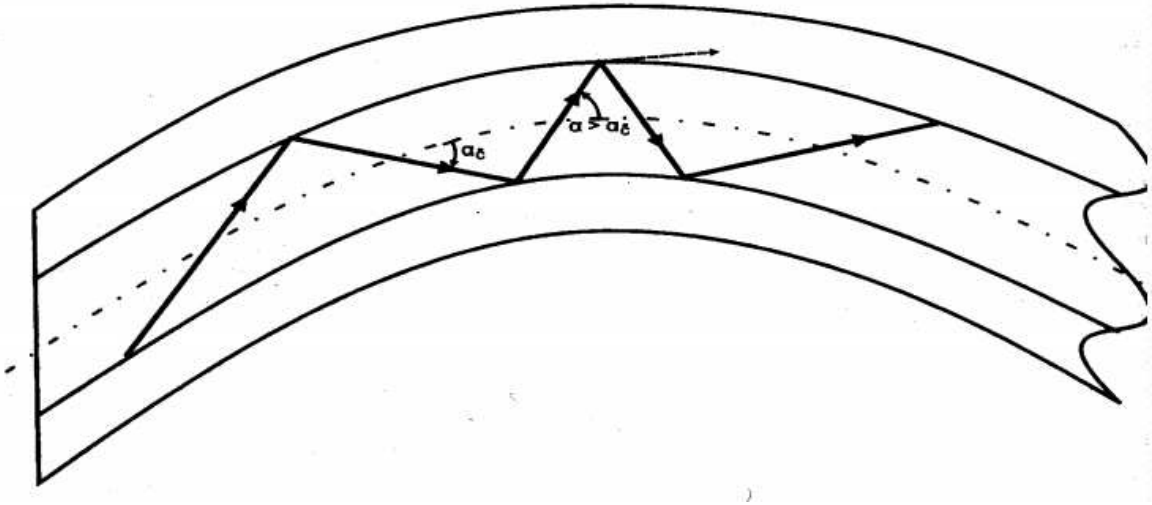


Fiber Bend Losses

Bending loss is classified according to the bend radius of curvature :

1. Microbend Loss **2. Macrobend Loss**

- **Macrobend Losses** are observed when a fiber bend's radius of curvature is large compared to the fiber diameter. These bends are a great source of loss when the radius of curvature is less than several centimeters.

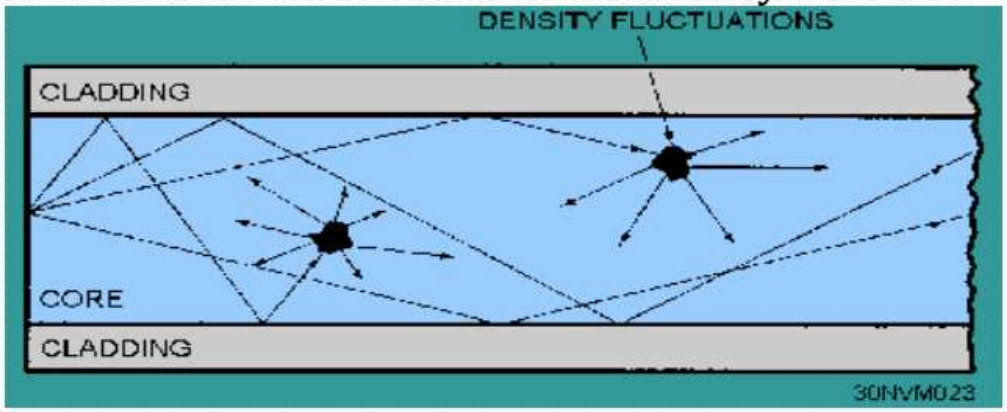


Linear Scattering Losses

- **Light scattering** is a form of scattering in which light in the form of propagating energy is scattered.
- Light scattering can be thought of as the deflection of a ray from a straight path, for example by irregularities in the propagation medium, particles, or in the interface between two media.
- Deviations from the law of reflection due to irregularities on a surface are also usually considered to be a form of scattering.
- When these irregularities are considered to be random and dense enough that their individual effects average out, this kind of scattered reflection is commonly referred to as diffuse reflection.

Linear Scattering may be of two types

- **Rayleigh Scattering**
- **Mie Scattering**



Rayleigh Scattering

- The scattering losses are caused by the interaction of light with density fluctuations within a fiber.
- Density changes are produced when optical fibers are manufactured.
- During manufacturing, regions of higher and lower molecular density areas, relative to the average density of the fiber, are created.
- Light travelling through the fiber interacts with the density areas then partially scattered in all directions.
- In commercial Fibers operating 700nm and 1600nm wavelength, the main source of loss is called **Rayleigh Scattering (named after the British physicist Lord Rayleigh).**
- **Rayleigh Scattering** is the main loss mechanism between the **ultraviolet** and **infrared** regions.
- **Rayleigh scattering** occurs when the **size of density fluctuations (Fiber defect) is less than one-tenth of the operating wavelength of light.**
- As the **wavelength increases**, the loss caused by **Rayleigh Scattering decreases.**