UNIT-3(FIBER OPTICAL)

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## PROPAGATION OF LIGHT THROUGH AN OPTICAL FIBER

### 35. PROPAGATION OF LIGHT THROUGH AN OPTICAL FIBER

### What is Optical Fiber?

An **optical fiber** is a **thin, flexible, transparent wire** made of glass or plastic that transmits **light signals** from one point to another with **very low loss**.

It works based on the principle of **Total Internal Reflection (TIR)**.

### Structure of Optical Fiber:

An optical fiber has **three main parts**:

1. **Core**:
    - The **inner part** through which the light travels.
    - Made of high refractive index material.
2. **Cladding**:
    - Surrounds the core.
    - Has a **lower refractive index** than the core to allow total internal reflection.
3. **Outer Jacket**:
    - Protective layer to shield the fiber from damage.

### Principle: Total Internal Reflection (TIR)

- When light enters the fiber at a specific angle, it gets **totally reflected** at the core-cladding boundary.
- This reflection keeps happening as the light travels, **bouncing back and forth** inside the core without escaping.
- This process is called **Total Internal Reflection**.

### Propagation Process:

1. **Light enters the fiber** at one end at a suitable angle.

2. It strikes the **core-cladding boundary** at an angle **greater than the critical angle**.
3. **Total internal reflection** occurs, and the light continues to bounce within the core.
4. The light reaches the **other end of the fiber** with **minimal loss**.

### Conditions for TIR:

- The core must have **higher refractive index ($n_1$)** than the cladding ($n_2$).

  ($n_1 > n_2$)

- The **angle of incidence** inside the core must be **greater than the critical angle**.

Here is a simple and clear explanation of the requested **optical fiber concepts**, in your preferred format:

## 36. ACCEPTANCE ANGLE, NUMERICAL APERTURE, TYPES OF OPTICAL FIBER, AND REFRACTIVE INDEX PROFILE

### What is Acceptance Angle?

- The **acceptance angle** is the **maximum angle** at which light can enter the fiber and still be guided through it by **total internal reflection**.
- Light rays entering the fiber **within this angle** will propagate through the core.

### Formula:

$$\sin \theta_0 = \text{NA}$$

Where:

- $\theta_0$ = acceptance angle (maximum entrance angle)
- NA = numerical aperture

### What is Numerical Aperture (NA)?

- **Numerical Aperture** is a measure of the **light-gathering ability** of an optical fiber.
- It defines how much light can be accepted into the fiber.

### Formula:

$$\text{NA} = \sqrt{n_1^2 - n_2^2}$$

Where:

- $n_1$ = refractive index of the **core**
- $n_2$ = refractive index of the **cladding**

**Types of Optical Fiber**

Optical fibers are classified based on:

**A. Mode of Transmission**

1. **Single-mode Fiber**
   - Carries **only one light mode**.
   - Used for **long-distance** communication.
   - Core diameter is **very small** (~8–10 μm).
2. **Multi-mode Fiber**
   - Carries **multiple light modes**.
   - Used for **short distances**.
   - Core diameter is **larger** (~50–100 μm).

**B. Refractive Index Profile**

1. **Step-Index Fiber**
   - The refractive index **changes abruptly** at the core-cladding boundary.
   - Used in both single and multi-mode types.
2. **Graded-Index Fiber**
   - The refractive index of the core **gradually decreases** from the center to the edge.
   - Reduces dispersion and improves performance in **multi-mode** fibers.

**37. DOUBLE CIRCLE METHOD**

**What is the Double Circle Method?**

The **Double Circle Method** is a **graphical method** used in optics to **determine the numerical aperture (NA)** and **acceptance angle** of an **optical fiber** using geometrical construction.

It is a **visual technique** used to understand how light enters and travels through the optical fiber.

**Purpose of the Method:**

- To **illustrate how light rays** enter the optical fiber and how **total internal reflection** happens.
- To **graphically find** the **acceptance angle** and **NA** using two concentric circles representing the core and cladding.

**Construction of the Double Circle Method:**

1. **Draw two concentric circles**:
   - Inner circle represents the **core**.
   - Outer circle represents the **cladding**.
2. Mark the **refractive indices**:
   - Core refractive index = $n_1$
   - Cladding refractive index = $n_2$ (with $n_2 < n_1$)

   **From a point on the fiber axis (center of the circles):**
   - Draw a **light ray** entering the fiber at an angle $\theta_0$ **with respect to the fiber axis** (the central line).
3. Use geometry and **Snell's law**:
   - $n_0 \sin \theta_0 = n_1 \sin \theta_c$
   - Here,
     - $n_0$ = refractive index of air (usually ≈ 1)
     - $\theta_0$ = acceptance angle (in air)
     - $\theta_c$ = critical angle inside the core at the core-cladding interface.

   Adjust the incoming ray so that the **angle at the core-cladding interface** is **equal to or greater than the critical angle**, ensuring total internal reflection.

Here is a clear and simple explanation of **Losses in Optical Fiber** and **Applications of Optical Fiber**, in your preferred format:

**38. LOSSES IN OPTICAL FIBER**

**What are Losses in Optical Fiber?**

Losses refer to the **reduction in light intensity** as it travels through the optical fiber.

These losses affect the efficiency of signal transmission.

**Types of Losses:**

1. **Absorption Loss**
    - Caused by impurities and defects in the fiber material.
    - Light energy is absorbed and converted to heat.
2. **Scattering Loss**
    - Mainly **Rayleigh scattering** due to microscopic fluctuations in the material density.
    - Scatters light in all directions, reducing transmitted intensity.
3. **Bending Loss**
    - Occurs when the fiber is bent beyond a certain radius.
    - Light escapes the core because total internal reflection fails at sharp bends.
4. **Connector and Splice Loss**
    - Losses occur at fiber joints or connectors due to misalignment or gaps.
5. **Dispersion Loss**
    - Pulse spreading causes signal overlap and reduces clarity (not energy loss but affects quality).

## 39. APPLICATIONS OF OPTICAL FIBER

### 1. Communication

- Used extensively in **telephone networks**, **internet cables**, and **television** broadcasting due to high bandwidth and low loss.

### 2. Medical Field

- Used in **endoscopy** to view inside the human body.
- Used in **laser surgeries** and imaging.

3. Military and Aerospace

- Used in **secure communication** systems.
- Used in **sensors** and **guidance systems**.

4. Industrial Applications

- Used for **data transmission** in harsh environments.
- Used in **inspection and monitoring** with fiber optic sensors.

5. Networking

- Backbone for **local area networks (LANs)** and **data centers**.

6. Lighting and Decorations

- Used in **fiber optic lights** and **display signs**.