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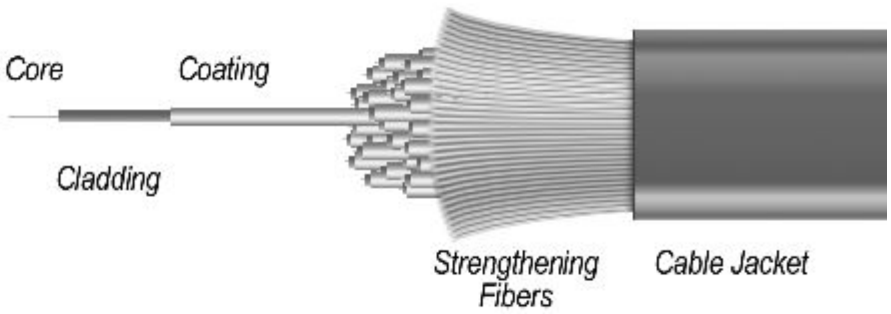
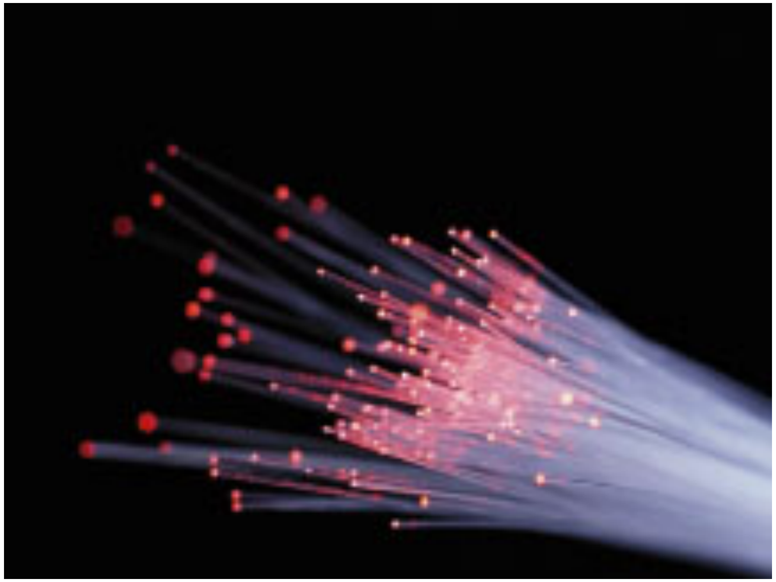
18PYB101J MODULE-5 LECTURE 9

- Fiber optics - Basic principles
- Physical structure of optical fiber
- Total Internal Reflection

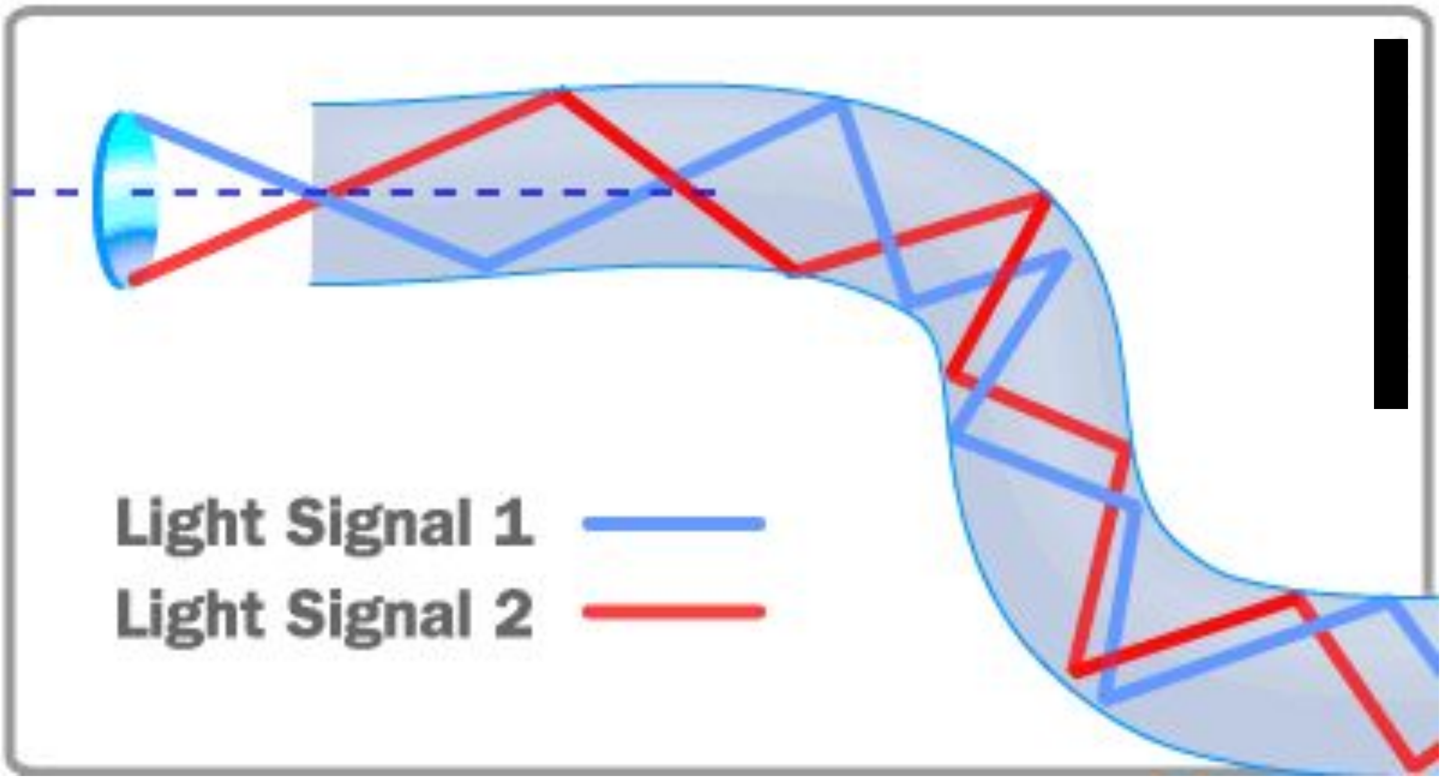
Fiber Optic Cables





SOURCE: SURFNET.NL

How Does an Optical Fiber Transmit Light?

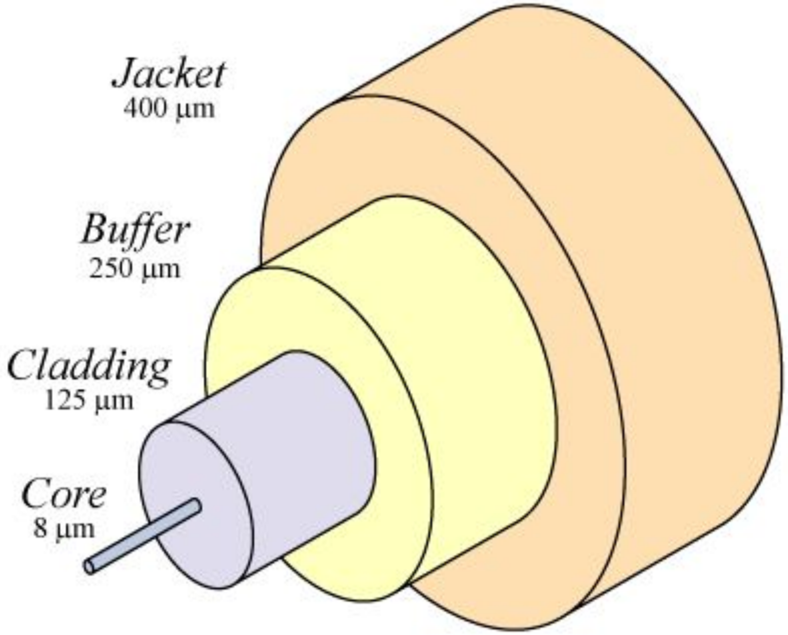


Fiber optics

- The most electronic communication was carried by copper cables, whether twisted pairs, coaxial cables or copper waveguides.
- Communication was accomplished by sending electrical signals through the copper cables or waveguides.
- In recent years, a new medium has been introduced: Optical fibers.
- In optical fiber communication, light signals replace electrical signals.
- This branch of science is called fiber optics.

Optical Fiber

- Core
  - Glass or plastic with a higher index of refraction than the cladding
  - Carries the signal
- Cladding
  - Glass or plastic with a lower index of refraction than the core
- Buffer
  - Protects the fiber from damage and moisture
- Jacket
  - Holds one or more fibers in a cable



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Physics of Light

- The propagation of light can be analyzed in detail using electromagnetic wave theory.
- Light falls in the general category of electromagnetic waves, much like radio waves.
- The behaviour of light is sometimes easier to explain by using ray tracings
- The propagation of light in a fiber can be described in terms of rays.

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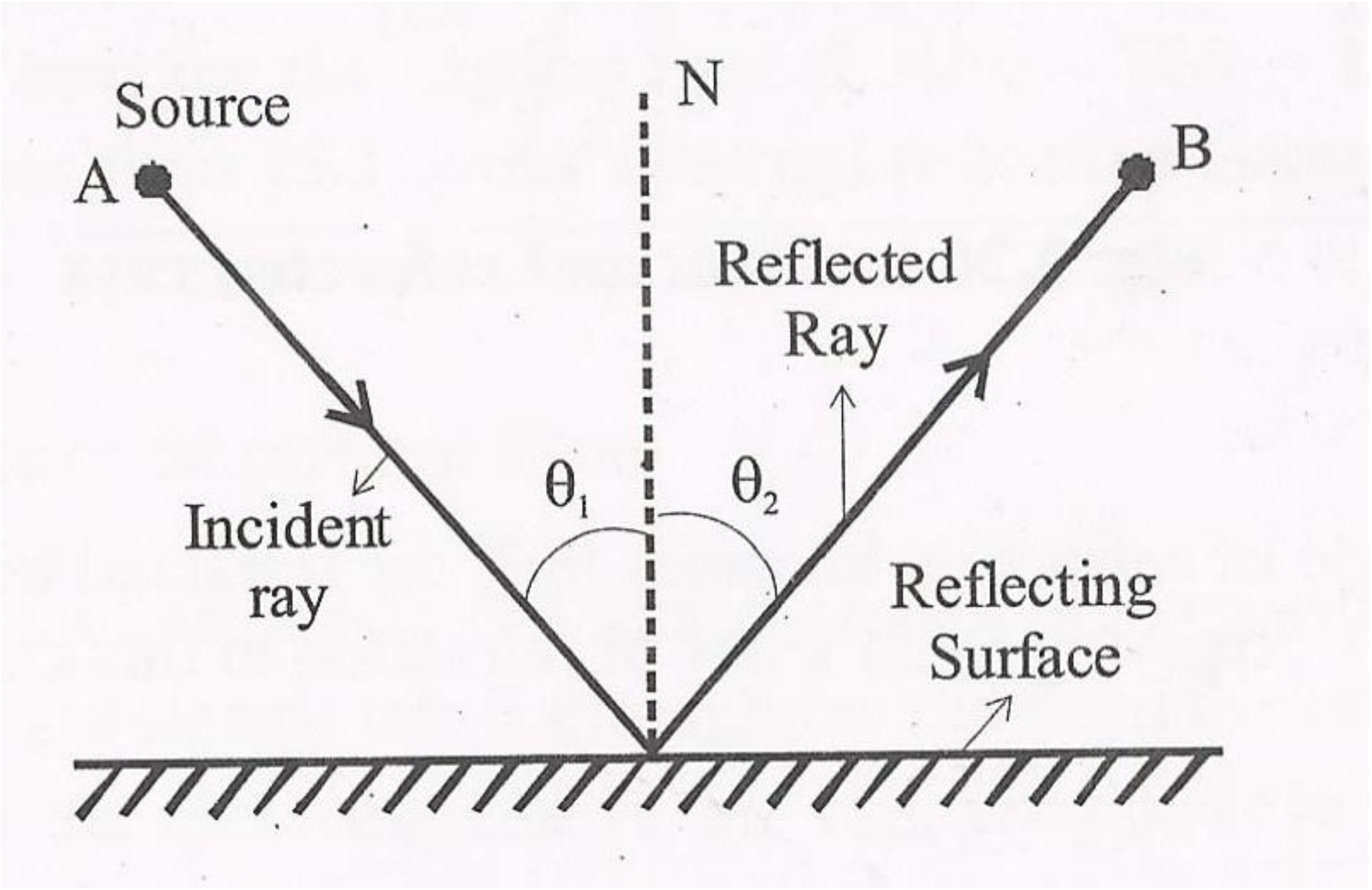
Reflection

- When a light ray is incident on a reflecting surface, the ray bounces back like a handball when it hits a wall.
- A reflecting surface is one that is highly polished, opaque and coated with special reflective materials.
- The law of reflection states that the angle of incidence is equal to the angle of reflection.
- The incident ray is the line AO, the reflected ray is OB and ON is the normal to the reflecting surface.
- The incident and reflected angles, θ_1 and θ_2, respectively, are those between the rays and the line perpendicular to the surface.

Incident and reflected rays



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- The incident and reflected angles, θ_1 and θ_2, respectively, are those between the rays and the line perpendicular to the surface
- $$\theta_1 = \theta_2$$
- A direct result of this law is the fact that if θ_1 is 90°, θ_2 is 90° and the reflected ray is in line with the incident ray.

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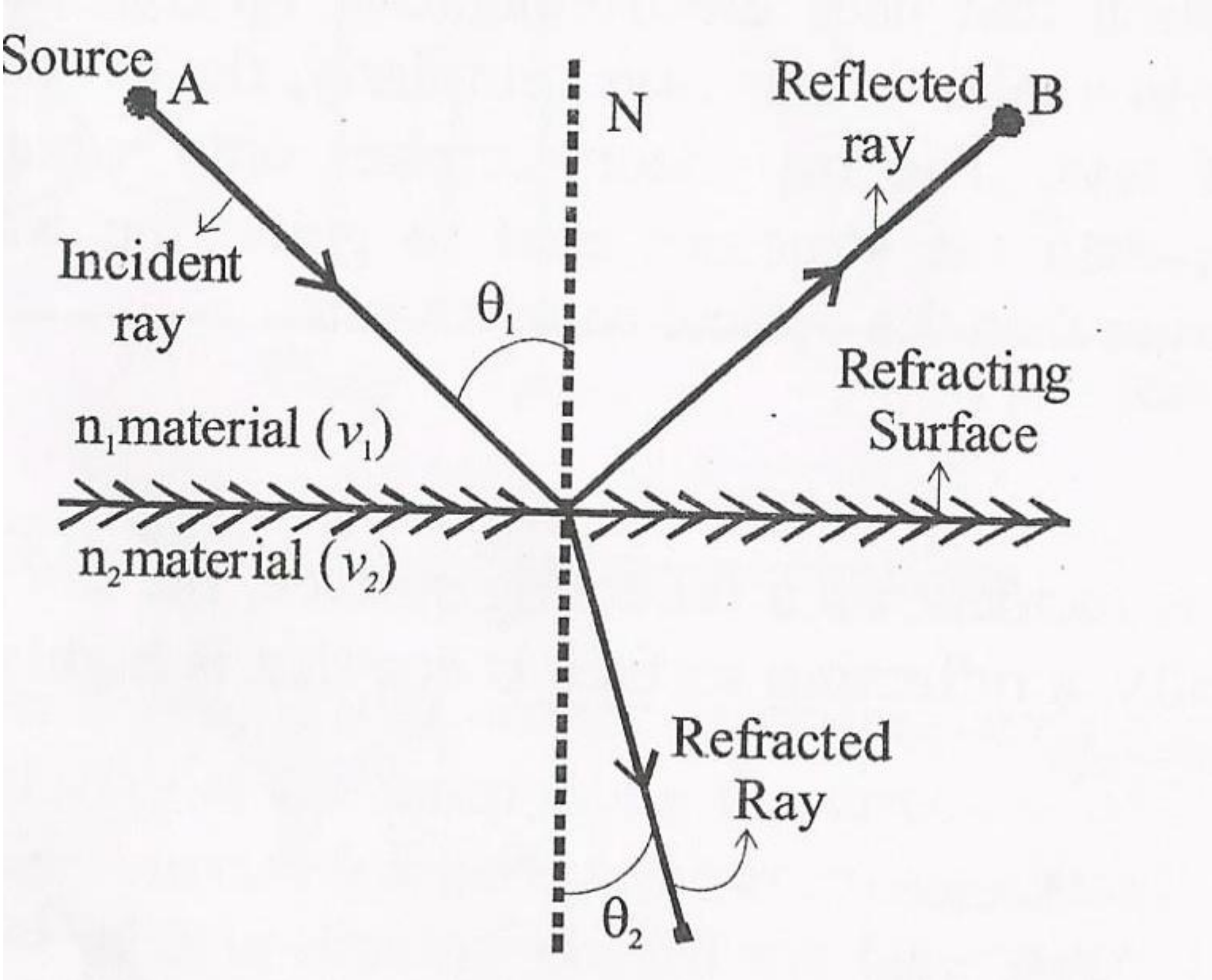
Refraction and Snell's Law

When a ray travels across a boundary between two materials with different refractive indices n_1 and n_2, both refraction and reflection takes place. The case where $n_1 > n_2$; that is where the light travels from high to low refractive index materials.

The refracted ray is "broken" that is, the angle θ_2 is not equal to θ_1. The relation between θ_1 and θ_2 is given by **Snell's law of refraction**.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \text{(or)} \qquad \frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

Incident and refracted rays



- A ray travelling from a high to a low index material will move away from the perpendicular.
- The angle of incidence is smaller than the angle of the refracted ray.
- The reverse holds for rays travelling from low to high index material. The relation between the incident and refracted angles can be stated in terms of the propagation velocities in the media

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} \quad \text{where} \quad v_1 = \frac{c}{n_1} \quad \text{and} \quad v_2 = \frac{c}{n_2}$$

- Here, the two materials involved are transparent and allow light propagation.

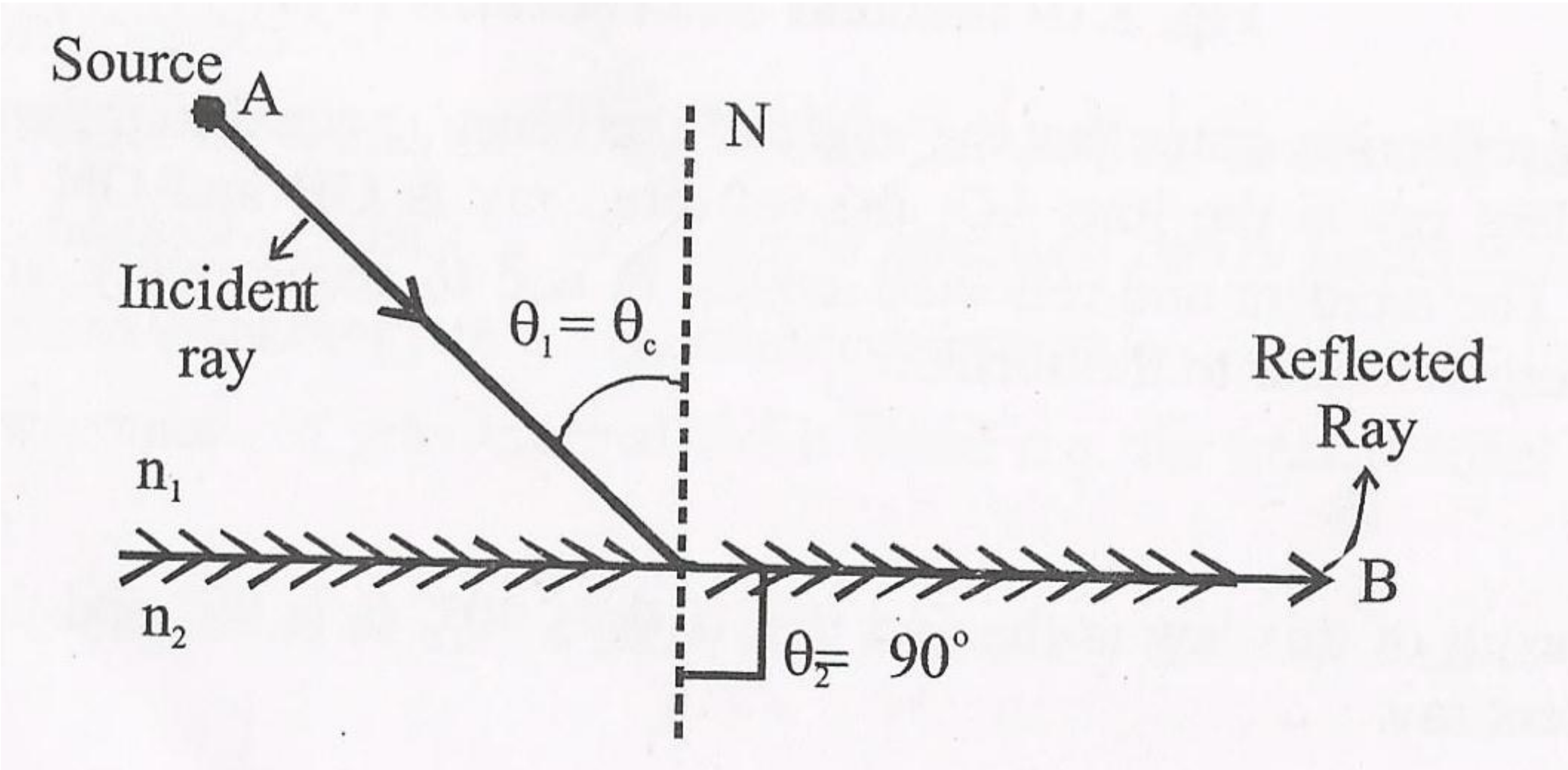
Total Internal reflection

When $\theta_{2,}$ the angle of refraction becomes 90°, the refracted beam is not traveling through the n_2 material. Applying Snell's law of refraction,

$$\sin\theta_1 = \frac{n_2}{n_1}$$

The angle of incidence θ_1 for which $\theta_2 = 90°$ is called the critical angle θ_c:

Refraction at the critical angle



- If the ray is incident on the boundary between n_1 and n_2 materials at the critical angle, the refracted ray will travel along the boundary, never entering the n_2 material.
- There are no refracted rays for the case where $\theta_1 \geq \theta_c$.
- This condition is known as **total internal reflection**, which can occur only when light travels from higher refractive index material to lower refractive index material.

- The light can be restricted to the material with the higher index of refraction if the incident angle is kept above the critical angle.
- A sandwich of high index material placed between two slabs of low index material will allow a beam of light to propagate in the high index material with relatively little loss.
- This concept is used in constructing fibers for fiber optic communication.

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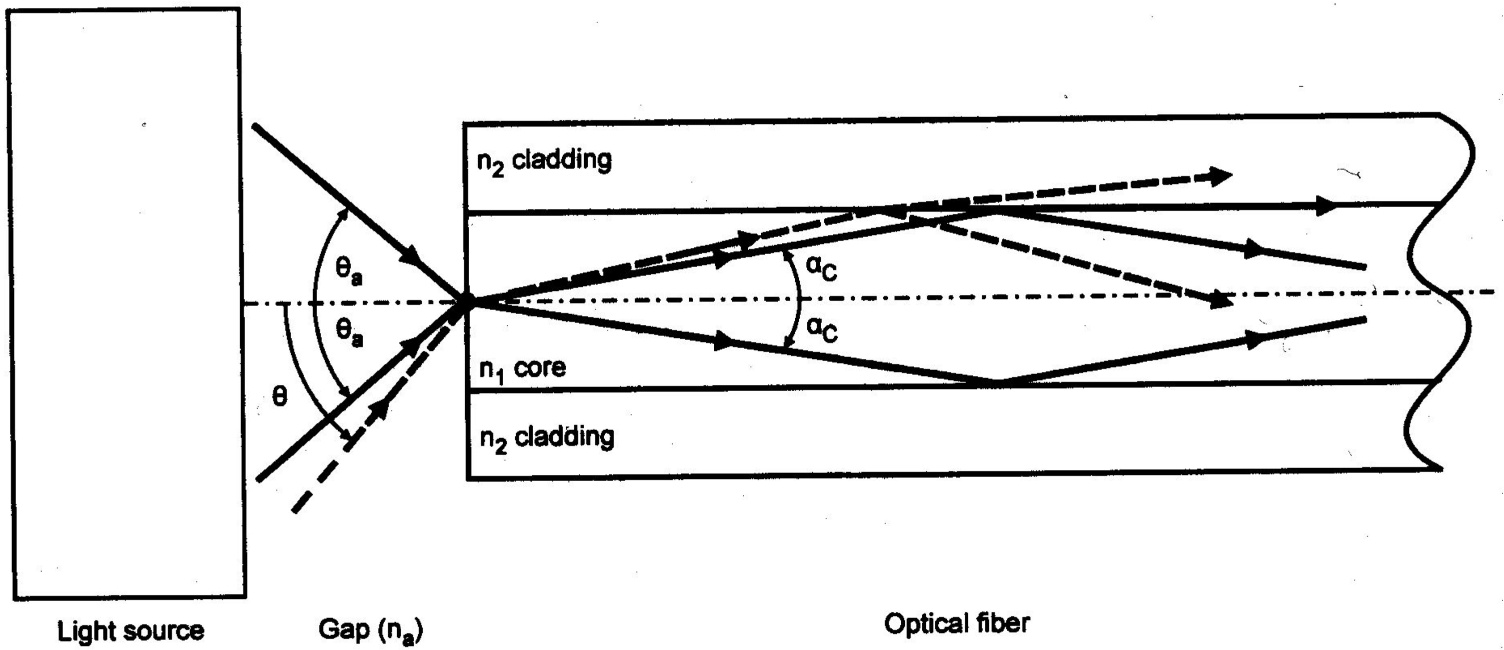
Physical structure of optical fiber

An optical fiber is a transparent rod, usually made of glass or clear plastic through which light can propagate.

- The light signals travel through the rod from the transmitter to the receiver and can be easily detected at the receiving end of the rod, provided the losses in the fiber are not excessive.
- The structure of the modern fiber consists of an optical rod **core** coated with a **cladding**.
- The core and the cladding have different refractive indices and hence different optical properties

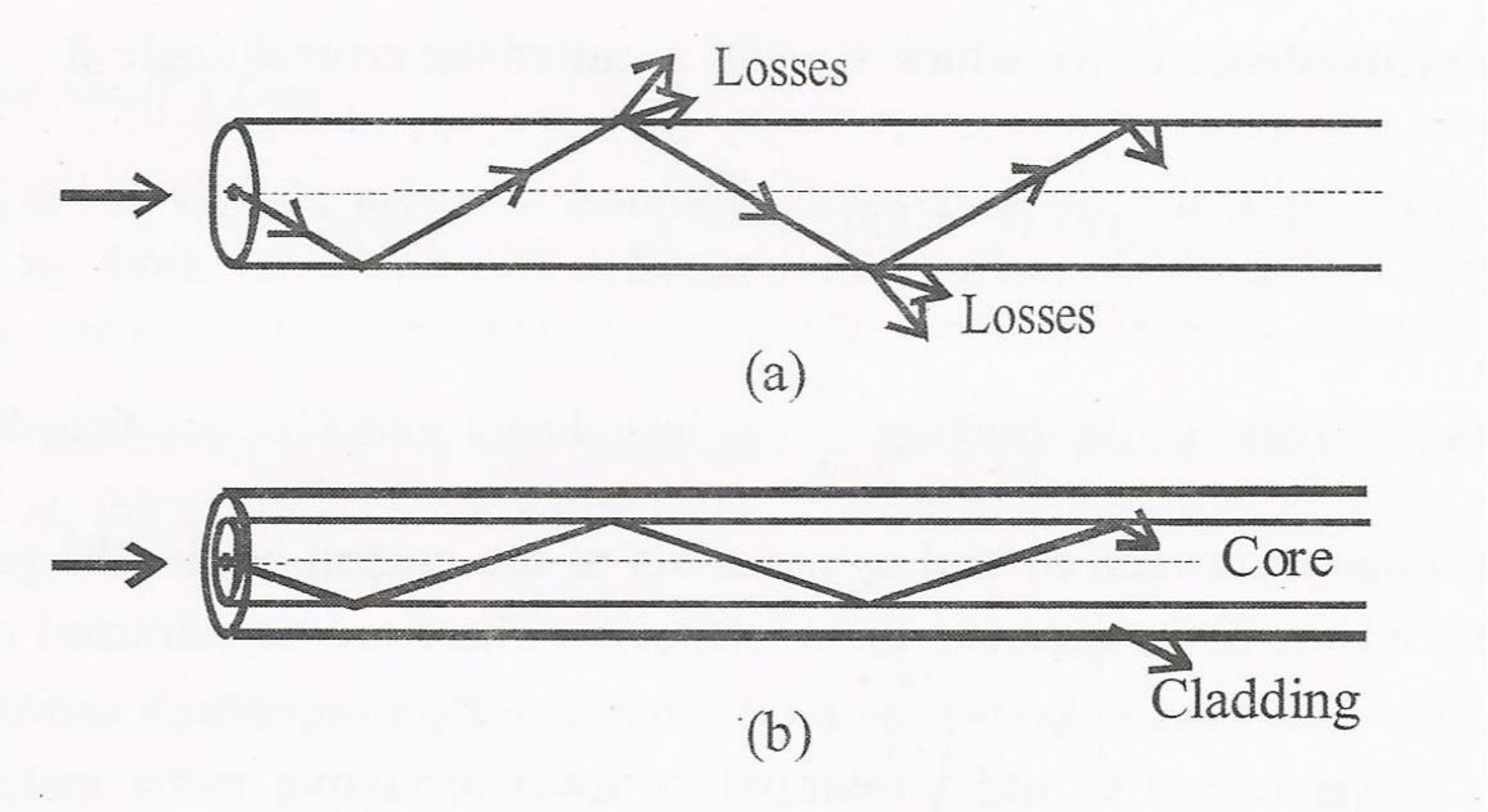
- The refractive index of the core is always greater than that of the cladding (i.e.) $n_1 > n_2$.
- The light travels within the core by the principle of total internal reflection
- An unclad fiber and a clad rod through which the light travels.
- With the unclad rod, only a small potion of the light energy is kept inside; most of the light leaks to the surroundings.
- The clad fiber is a much more efficient light carrier.

Coupling Light into an Optical Fiber



Fiber Optics Communication Technology-Mynbaev & Scheiner

- The losses of the light as it travels through the fiber are much smaller for the clad fiber than for the unclad one.
- The thickness of the core of a typical glass fiber is nearly 50 μm and that of cladding is 100 – 200 μm.
- The overall thickness of an optical fiber is nearly 125 – 200 μm.
- Thus an optical fiber is small in size and light weight unlike a metallic cable.



Light guides (a) Simple glass rod (b) Glass rod and cladding with different refraction qualities