CSE 350
DATA COMMUNICATIONS

Lecture 3: Transmission Media

Maheen Islam

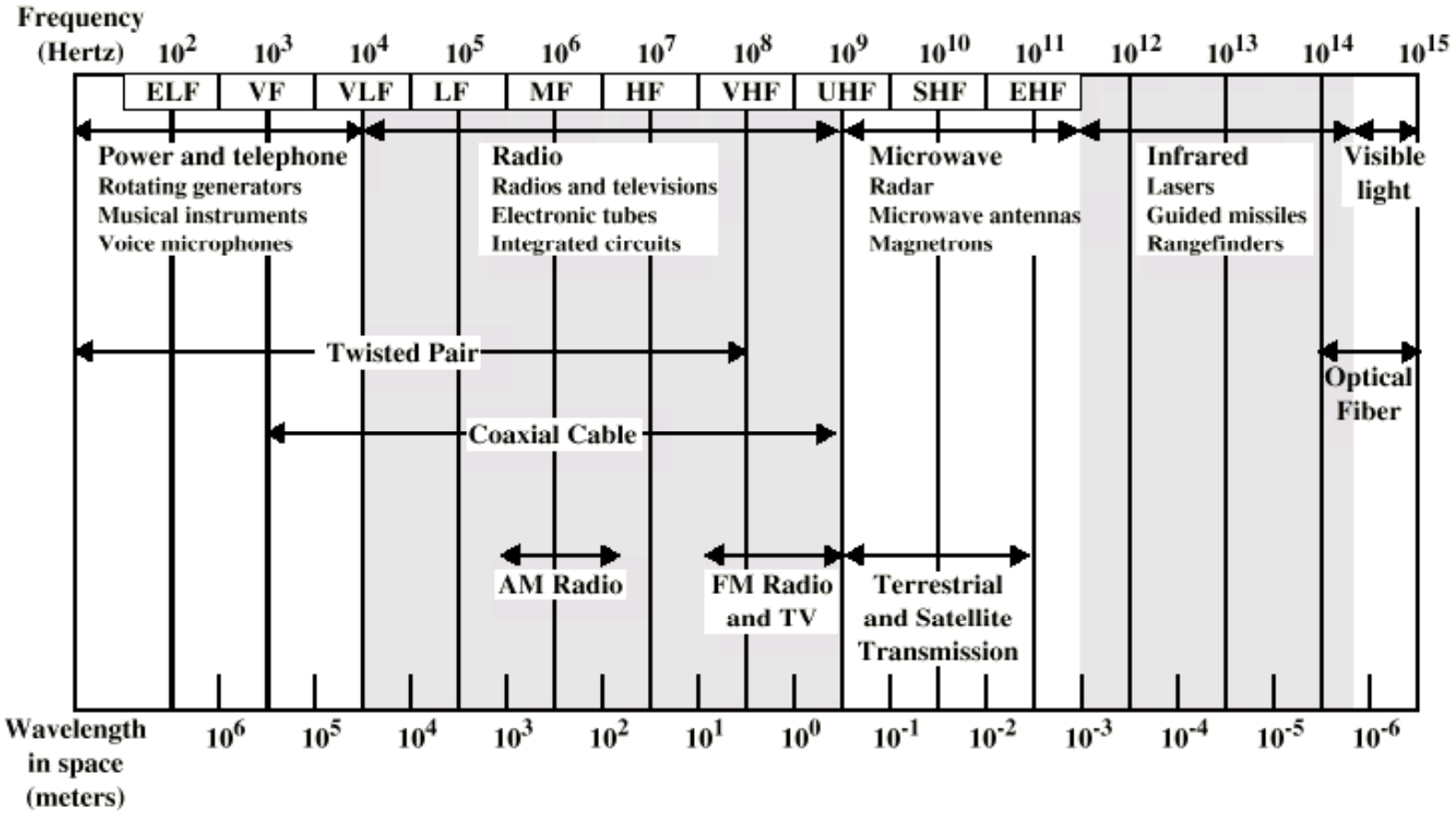
Overview

- Guided - wire
- Unguided - wireless
- Characteristics and quality determined by medium and signal
- For guided, the medium is more important
- For unguided, the bandwidth produced by the antenna is more important
- Key concerns are data rate and distance

Design Factors

- Bandwidth
  - Higher bandwidth gives higher data rate
- Transmission impairments
  - Attenuation
- Interference
- Number of receivers
  - In guided media
  - More receivers (multi-point) introduce more attenuation

Electromagnetic Spectrum



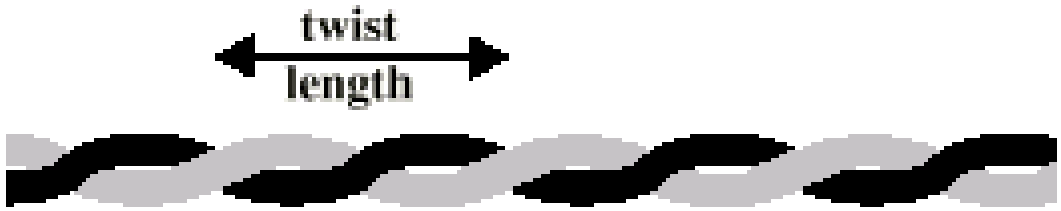
ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

Guided Transmission Media

- Twisted Pair
- Coaxial cable
- Optical fiber

Twisted Pair

—Separately insulated
—Twisted together
—Often "bundled" into cables
—Usually installed in building during construction



(a) Twisted pair

Twisted Pair - Applications

- Most common medium
- Telephone network
  - Between house and local exchange (subscriber loop)
- Within buildings
  - To private branch exchange (PBX)
- For local area networks (LAN)
  - 10Mbps or 100Mbps

Twisted Pair - Pros and Cons

- Cheap
- Easy to work with
- Low data rate
- Short range

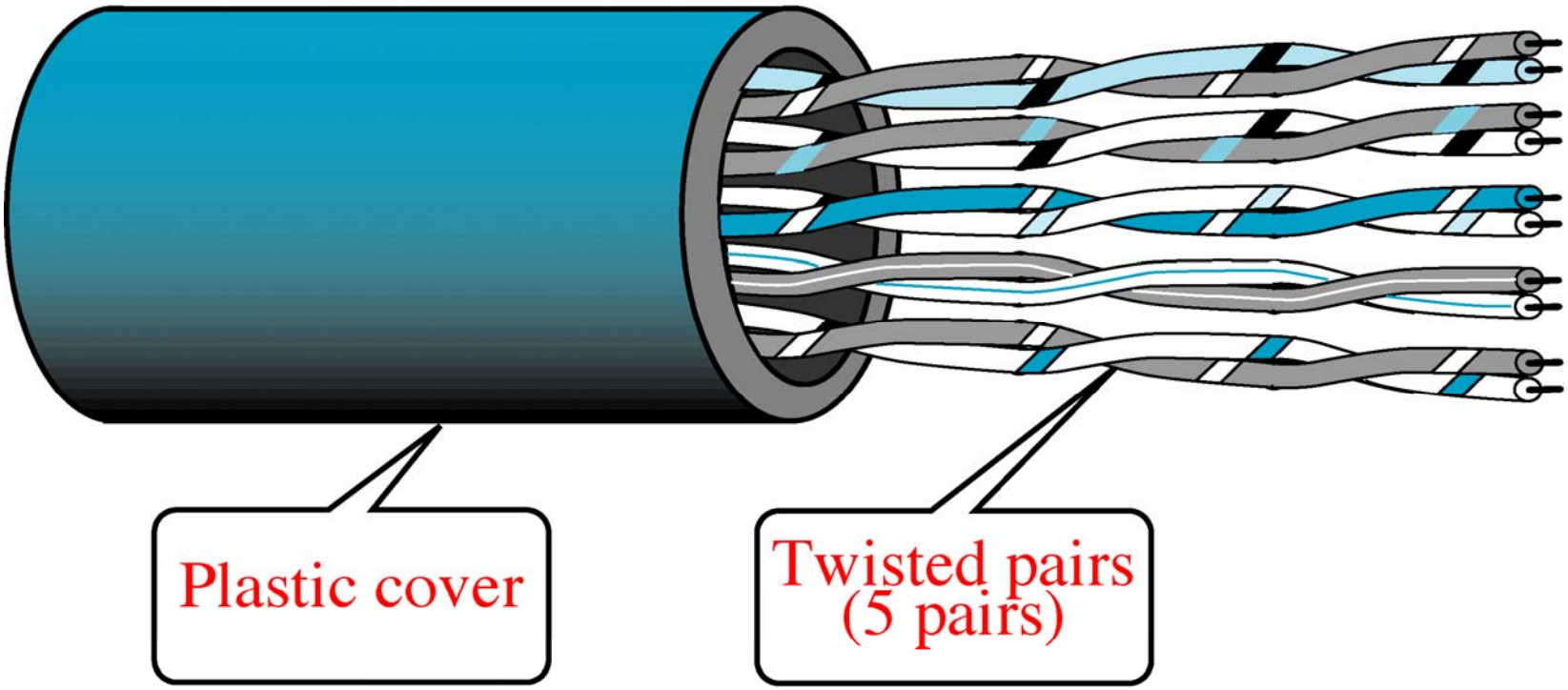
Twisted Pair - Transmission Characteristics

- Analog
  - Amplifiers every 5km to 6km
- Digital
  - Use either analog or digital signals
  - repeater every 2km or 3km
- Limited distance
- Limited bandwidth (1MHz)
- Limited data rate (100MHz)
- Susceptible to interference and noise

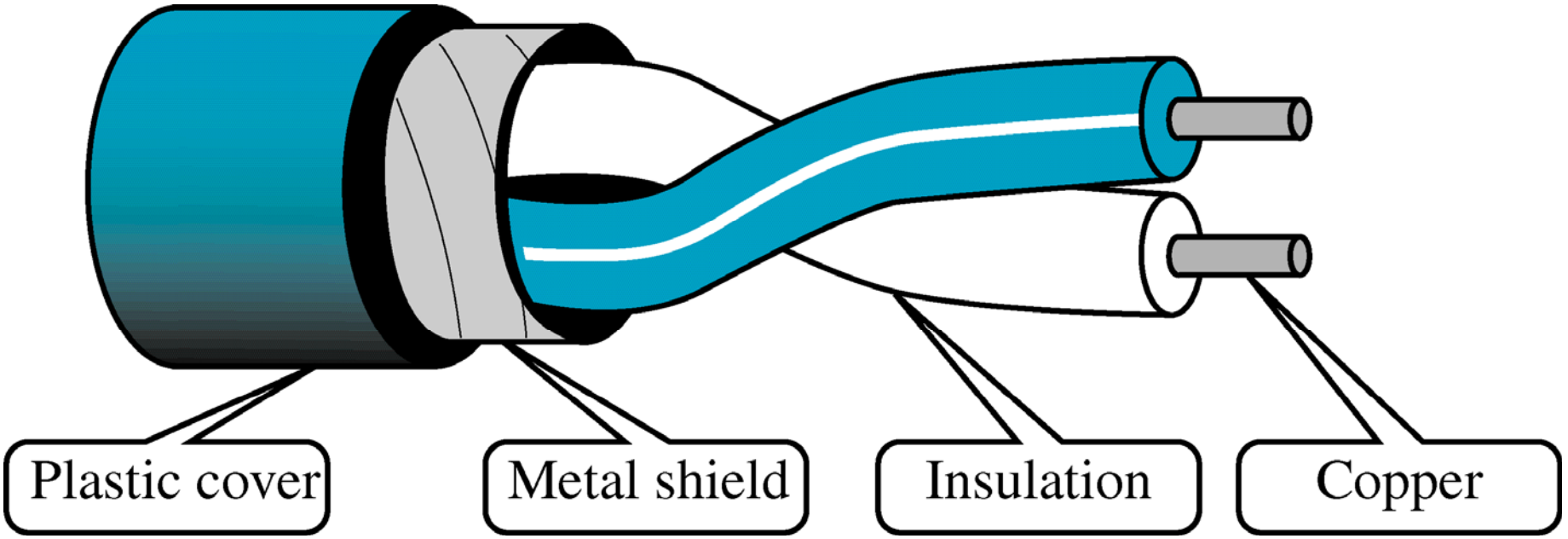
Unshielded and Shielded TP

- Unshielded Twisted Pair (UTP)
  - Ordinary telephone wire
  - Cheapest
  - Easiest to install
  - Suffers from external EM interference
- Shielded Twisted Pair (STP)
  - Metal braid or sheathing that reduces interference
  - More expensive
  - Harder to handle (thick, heavy)

Unshielded Twisted-Pair Cable



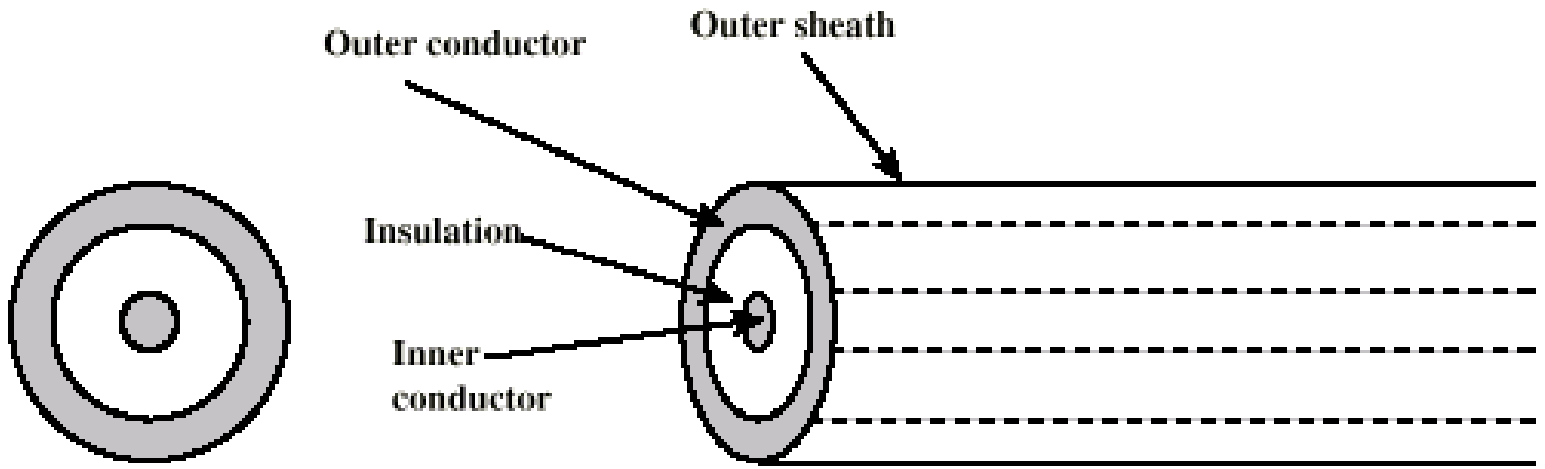
Shielded Twisted-Pair Cable



UTP Categories

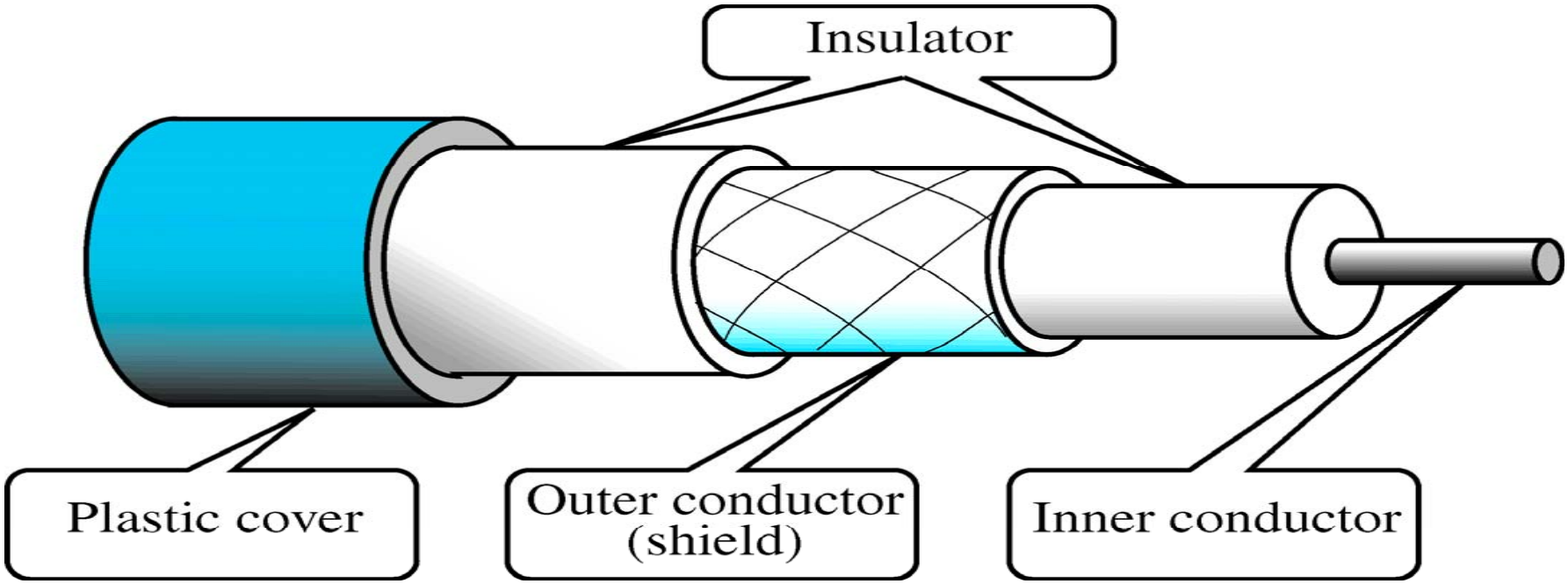
- Cat 3
  - up to 16MHz
  - Voice grade found in most offices
  - Twist length of 7.5 cm to 10 cm
- Cat 4
  - up to 20 MHz
- Cat 5
  - up to 100MHz
  - Commonly pre-installed in new office buildings
  - Twist length 0.6 cm to 0.85 cm

Coaxial Cable



—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

Coaxial Cable



Coaxial Cable Applications

- Most versatile medium
- Television distribution
  - Ariel to TV
  - Cable TV
- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
  - Being replaced by fiber optic
- Short distance computer systems links
- Local area networks

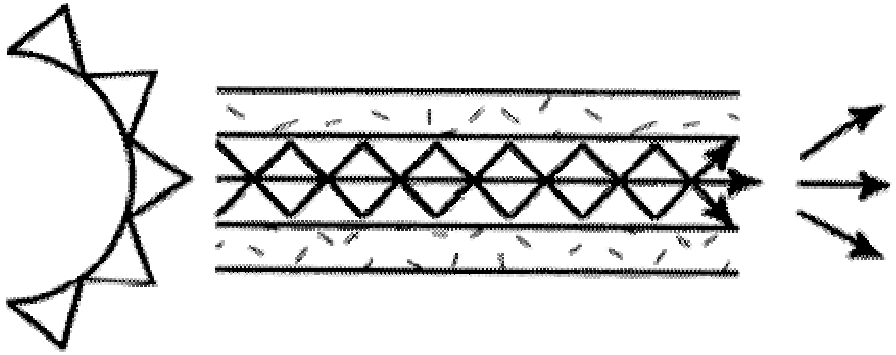
Coaxial Cable - Transmission Characteristics

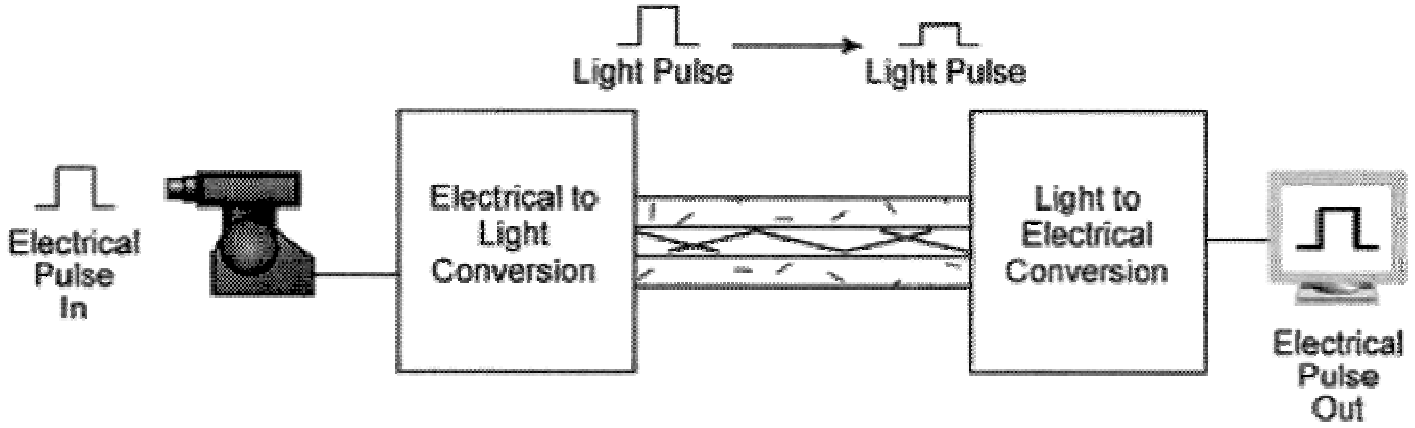
- Analog
  - Amplifiers every few km
  - Closer if higher frequency
  - Up to 500MHz
- Digital
  - Repeater every 1km
  - Closer for higher data rates

Optical fiber

- Other guided media use metallic cables that transmit signals in the form of current
- Made of glass or plastic
- Transmit signals in the form of light

Optical fiber

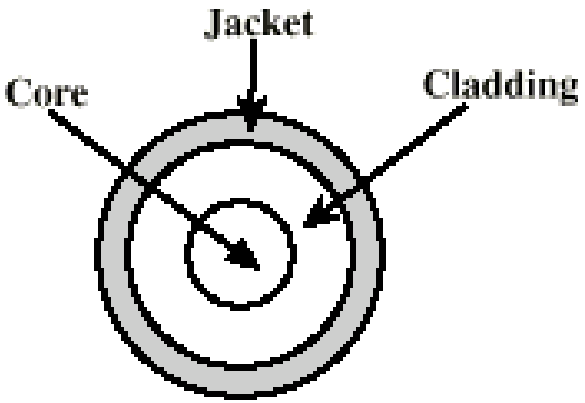




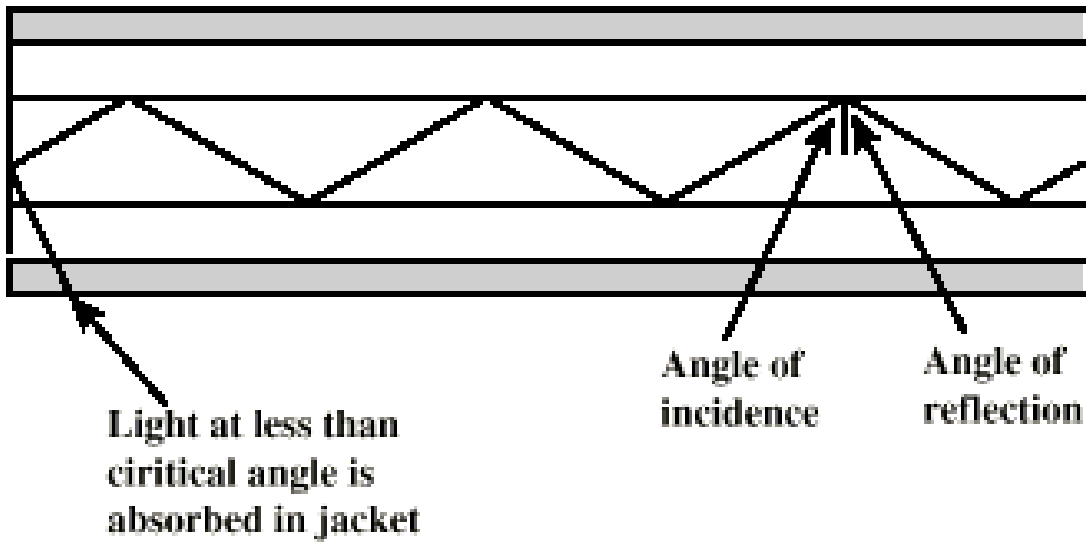
Physical Description

- Cylindrical shape
- Thin flexible medium
- Consists of three concentric sections:
  - The core
  - The cladding
  - The jacket
- Core
  - Innermost section
  - Consists of one or more very thin fibers
  - Made of glass or plastic
  - Diameter 8 to 100 μm

Optical Fiber



—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight



Light at less than ciritical angle is absorbed in jacket

Fiber Construction

- Cladding
  - A Core is surrounded by cladding--- the fiber
  - Glass or plastic coating
  - Optical properties different from the core
  - The interface between the core and cladding acts as a reflector
- Jacket
  - The entire cable is encased in an outer jacket
  - One or a bundle of cladded fibers are surrounds by the jacket
  - Can be made of several materials—Teflon coating, plastic coating, fibrous plastic, metal tubing and metal mesh.
  - To protect against moisture, crushing, and other environmental damages

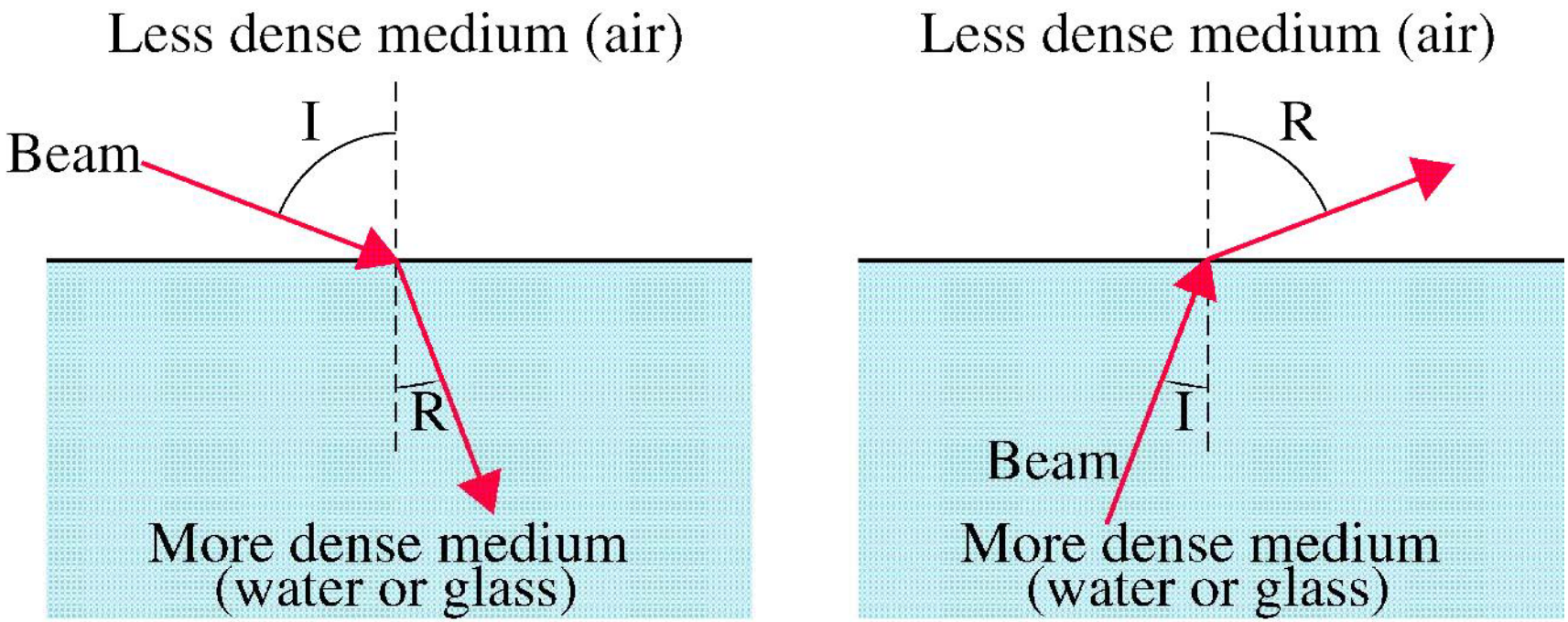
Several aspects of nature of light

- The nature of light
  - Light is a form of electromagnetic energy
  - The speed of light in a vacuum is 3,00,000 kms/s
  - The speed of light depends on the density of the medium
  - The higher the density, the slower the speed

Refraction

- Light travels in a straight line as long as it is move through a single uniform substance
- If a ray of light traveling through one substance suddenly enters another (more or less dense) substance its speed changes suddenly
- Causing the ray to change direction
- This change is called **refraction**
- The change of direction is depends on the change in density(**index of refraction**).
- The ratio of the **speed of light in a material** to the **speed of light in a vacuum** is called the **Index of Refraction.** Therefore, the measure of the optical density of a material is the index of refraction of that material.

Refraction



a. From less dense to more dense medium

b. From more dense to less dense medium

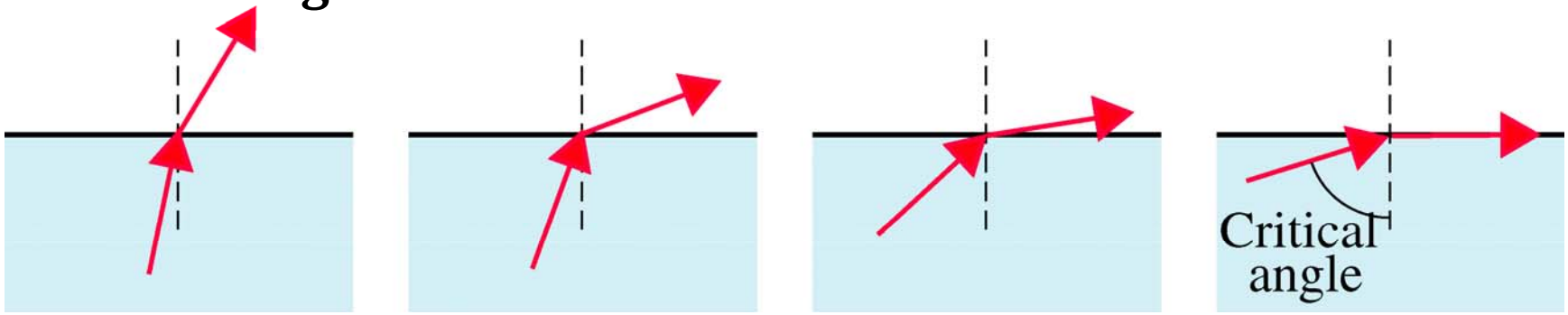
Refraction

- Light beam moving from a medium of less index of refraction into a medium of higher index of refraction is bent toward the vertical axis
- Two angles in relation to the vertical axis:
  - I-incident
  - R-refracted
- When light travels into a more dense medium, I is greater than R.

Critical Angle

- More dense to less dense medium
- Gradually increase the angle of incidence measured from the vertical
- As I increases, so does the R
- R moves away from the vertical and closer and closer to the horizontal
- At some point the change in the I results in a R of 90 degrees
- Refracted beam now lying along the horizontal
- The I at this point is known as the ***Critical angle***

Critical angle



Reflection

- When the I becomes greater than the critical angle ,the reflection occurs
- The light no longer passes into the less dense medium

Total internal reflection

- A **light ray** that is being turned on and off to send data (1s and 0s) into an optical fiber **must stay inside** the fiber until it reaches the far end.
- The ray **must not refract** into the material wrapped around the outside of the fiber.
- A design must be achieved for the fiber that will make the outside surface of the fiber act like a mirror to the light ray moving through the fiber.
- If any light ray that tries to move out through the side of the fiber were reflected back into the fiber at an angle that sends it towards the far end of the fiber,

Total internal reflection

The **laws of reflection and refraction** illustrate how to design a fiber that guides the light waves through the fiber with a **minimum energy loss**. The following two conditions must be met for the light rays in a fiber to be reflected back into the fiber without any loss due to refraction:

- The **core** of the optical fiber has to have a **larger index of refraction** than the material that surrounds it.
- The **angle of incidence** of the light ray is **greater** than the **critical angle** for the core and its cladding.
- When both of these conditions are met, the entire incident light in the fiber is reflected back inside the fiber. This is called **total internal reflection**

Optical Fiber - Benefits

- Greater capacity
  - Data rates of hundreds of Gbps
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
    - The system is not vulnerable to interference, impulse noise, or crosstalk
- Greater repeater spacing
  - 10s of km at least

Optical Fiber - Applications

- Long-haul trunks
  - 1500 km
  - In the telephone network
- Metropolitan trunks
  - 12km
  - Joining telephone exchanges in a metropolitan or city
- Rural exchange trunks
  - 40 to 160km
  - Link towns and villages
- Subscriber loops
  - Fibers that run directly from the central exchange to a subscriber
- LANs
  - Capacity :100 Mbps to 10 Gbps
  - Support 100s or 1000s of stations in a large office building

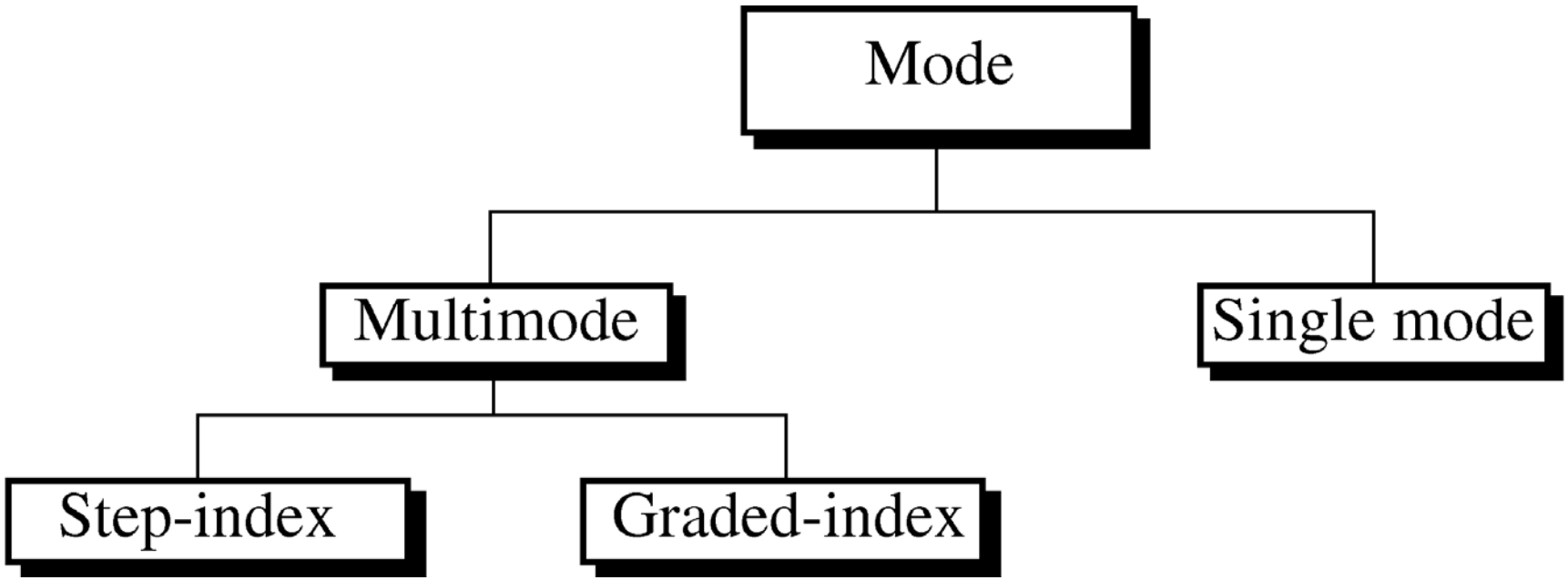
Light sources for optical cable

- The sending device—light source
- The receiving device– photosensitive cell (photodiode)
  - Capable of translating the received light into current usable
- Light Emitting Diode (LED)
  - Cheaper
  - Wider operating temp range
  - Last longer
  - Limited to short distance use
- Injection Laser Diode (ILD)
  - More efficient
  - Supports longer distances
  - Greater data rate

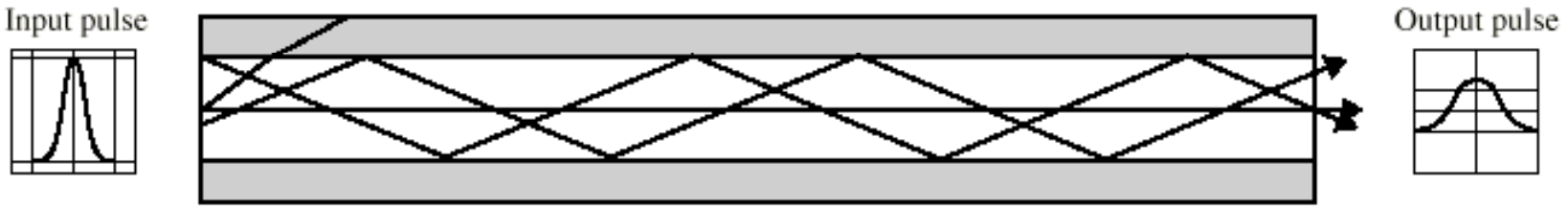
Transmission Characteristics

- Optical fiber transmits a signal-encoded beam of light by means of total internal reflection
- Act as wave guide for 10^{14} to 10^{15} Hz

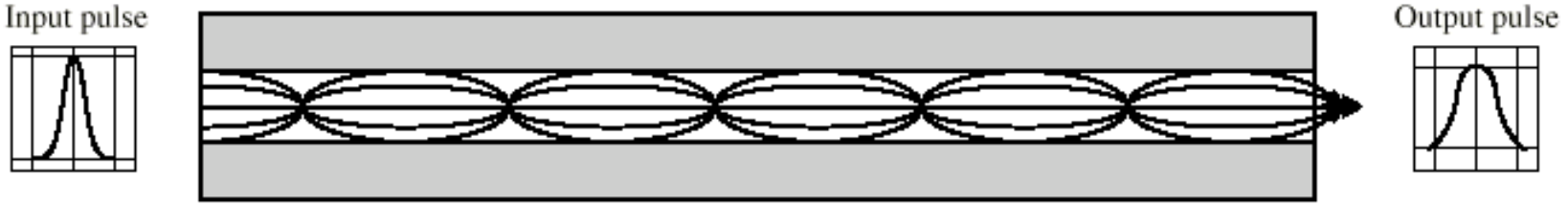
Transmission modes



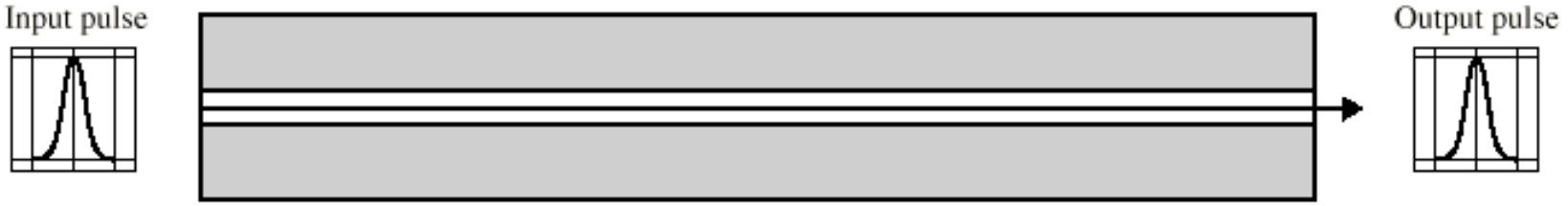
Optical Fiber Transmission Modes



(a) Step-index multimode



(b) Graded-index multimode



(c) Single mode

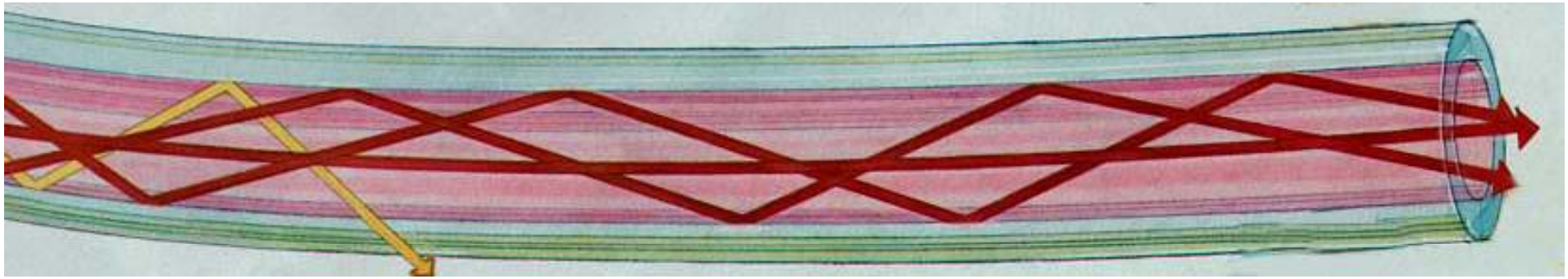
Multimode

- Multiple beams from a light source move through the core in different path

Multimode step index

- The density of the core remains constant from the center to the edges
- A beam of light moves through the constant density in a straight line until it reaches the interfaces of the core and the cladding
- At the interface, there is an abrupt change to a lower density that alters the angle of the beam's motions.
- As multiple path exist, each with different path length and hence time to traverse the fiber. This causes signal elements to spread out in time which limits the data rate.

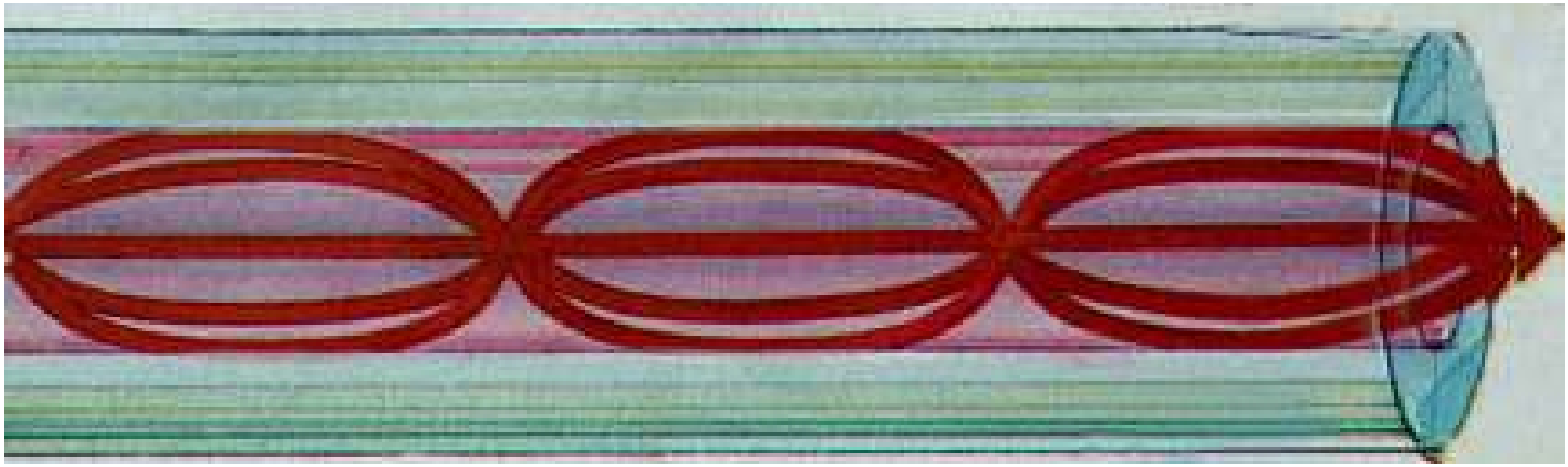
Multimode Step-Index



Multimode graded index

- Index—index of refraction
- One with varying densities
- Density is highest at the center of the core
- Decreases gradually to its lowest at the edge
- Decreases distortion of the signal through the cable

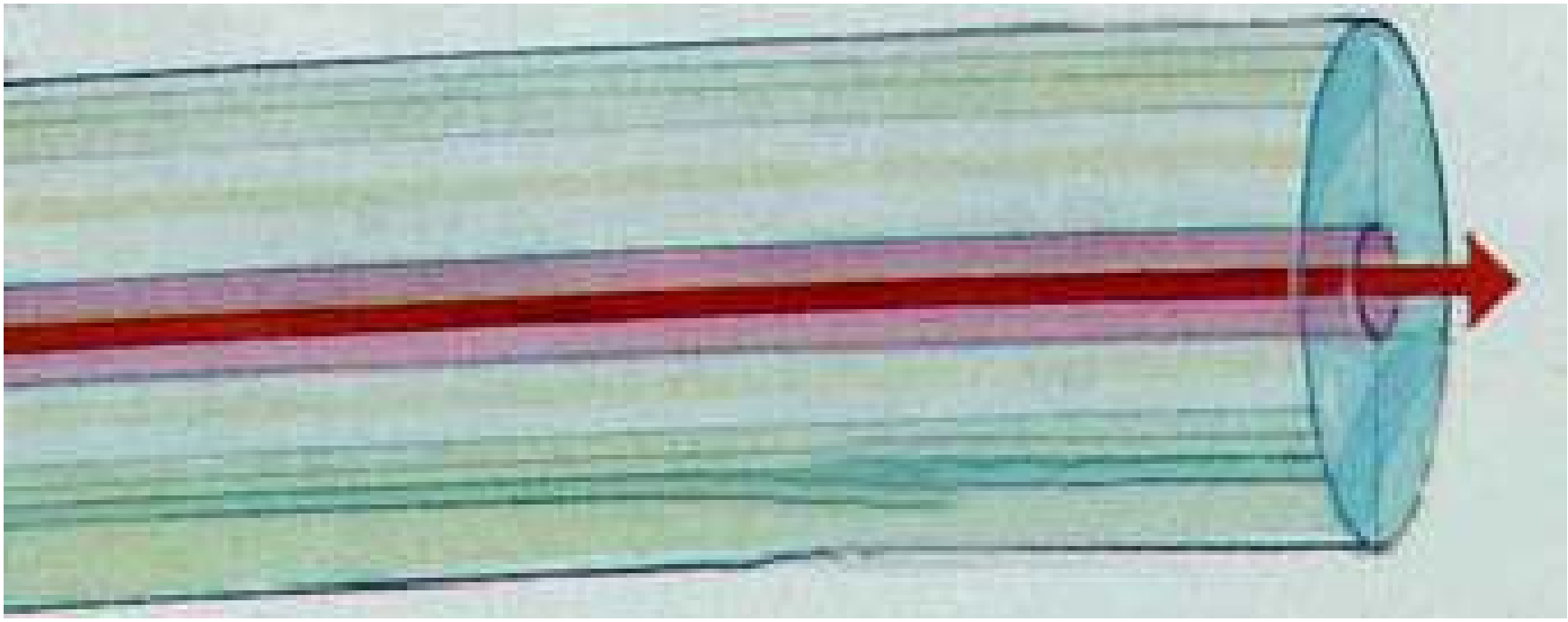
Multimode Graded-Index



Single mode

- Uses step-index fiber
- Highly focused source of light that limits beams to a small range of angles ,all close to the horizontal.
- Manufactured with a much smaller diameter.
- Critical angle :close enough to 90 degrees to make the propagation of beams almost horizontal.
- Propagation of different beams is almost identical.
- Delays are negligible.
- No distortion to the signal.
- Used for long distance applications

Single Mode



Wireless Transmission

- Unguided media
- Transmission and reception via antenna
- Directional
  - Focused beam
  - Careful alignment required
- Omnidirectional
  - Signal spreads in all directions
  - Can be received by many antennae

Frequencies

- 2GHz to 40GHz
  - Microwave
  - Highly directional
  - Point to point
  - Satellite
- 30MHz to 1GHz
  - Omnidirectional
  - Broadcast radio
- 3×10^{11} to 2×10^{14}
  - Infrared
  - Local

Terrestrial Microwave

- Parabolic dish
- Focused beam
- Line of sight
- Long haul telecommunications
- Higher frequencies give higher data rates

Satellite Microwave

- Satellite is relay station
- Satellite receives on one frequency, amplifies or repeats signal and transmits on another frequency
- Requires geo-stationary orbit
  - Height of 35,784km
- Television
- Long distance telephone
- Private business networks

Broadcast Radio

- Omnidirectional
- FM radio
- UHF and VHF television
- Line of sight
- Suffers from multipath interference
  - Reflections

Infrared

- Modulate noncoherent infrared light
- Line of sight (or reflection)
- Blocked by walls
- e.g. TV remote control, IRD port

Required Reading

- Stallings Chapter 4