Modern Telecommunication Systems
Lecture 2

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Optical Principles

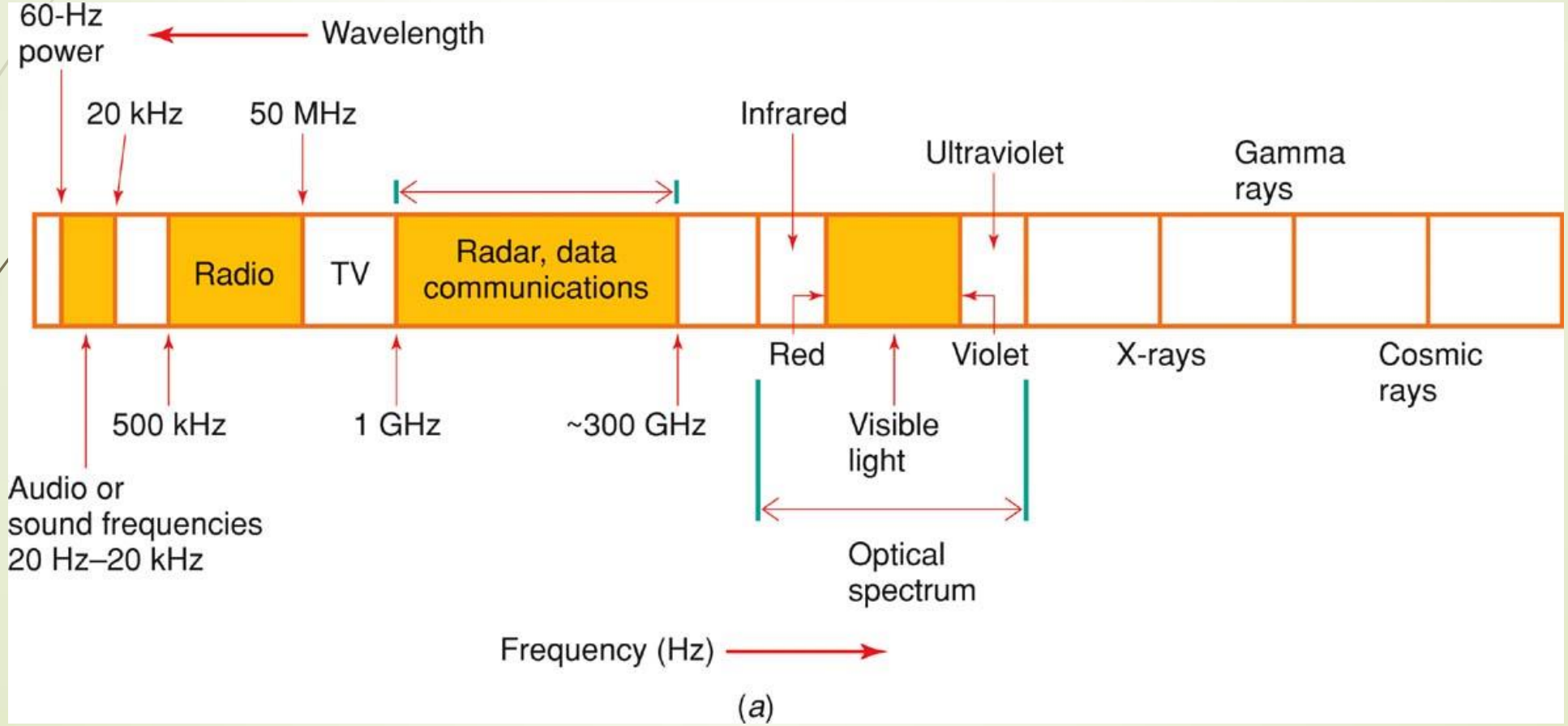
- Optical communication systems use light to transmit information from one place to another.
- Light is a type of electromagnetic radiation like radio waves.
- Today, infrared light is being used increasingly as the carrier for information in communication systems.
- The transmission medium is either free space or a light-carrying cable called a fiber-optic cable.
- Because the frequency of light is extremely high, it can accommodate very high rates of data transmission with excellent reliability.

Optical Principles

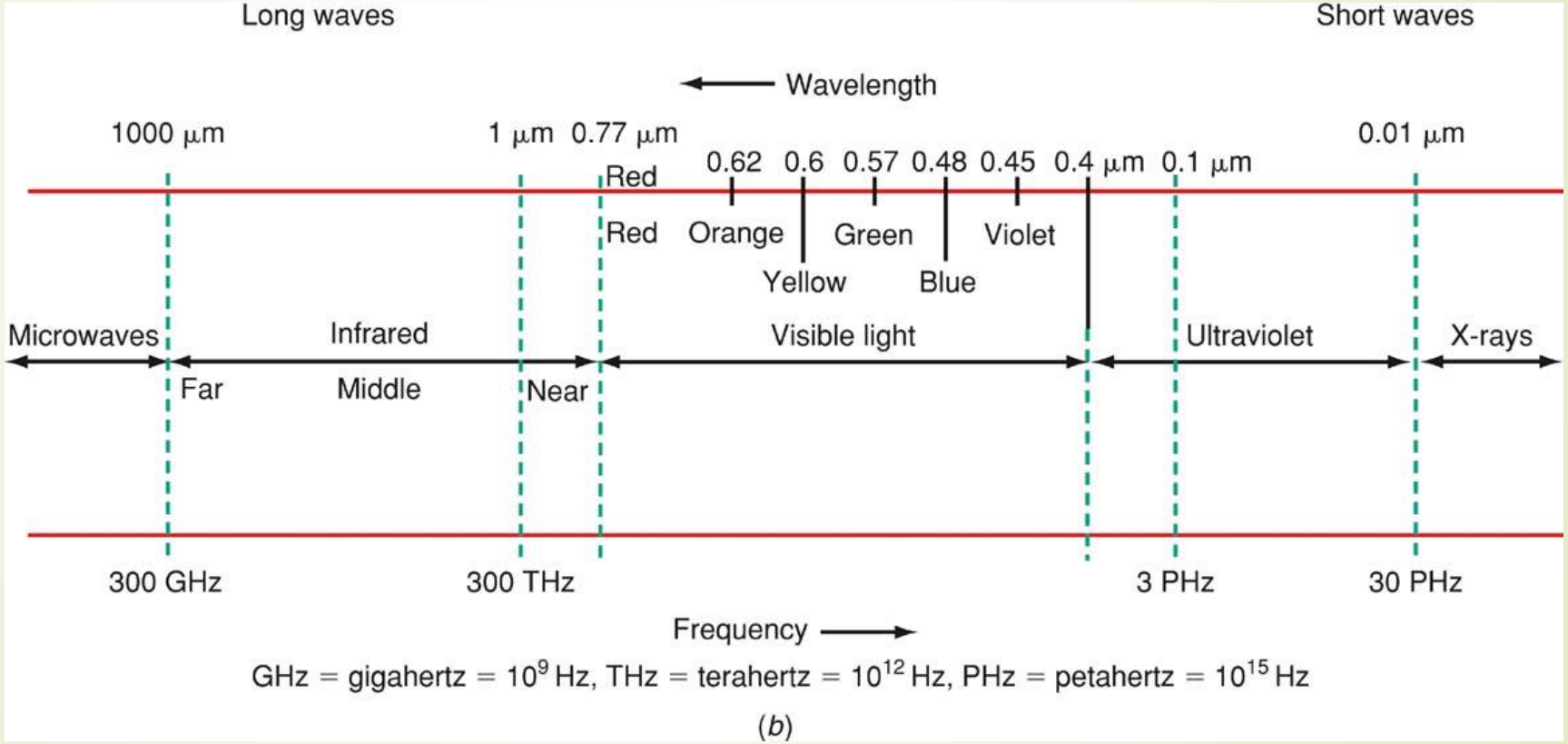
Light

- Light, radio waves, and microwaves are all forms of electromagnetic radiation.
- Light frequencies fall between microwaves and x-rays.
- The optical spectrum is made up of infrared, visible, and ultraviolet light.

Optical Principles



Optical Principles



Optical Principles

Light

- Light waves are very short and are usually expressed in nanometers or micrometers.
- Visible light is in the 400 to 700 nm range.
- Another unit of measure for light wavelength is the **angstrom (Å).** One angstrom is equal to 10^{-10} m.

Optical Principles

Light: Speed of Light

- Light waves travel in a straight line as microwaves do.
- The **speed of light** is approximately 3x10^8m/s in free space (in air or a vacuum).
- The speed of light depends upon the medium through which the light passes.

Optical Principles

- Optics is study of light. Geometric optics and physical optics are the two main branches of optics.
- Geometric optics is concerned with study of light beam while the physical optics deals with study of wave nature of light.
- Light can be processed or manipulated in many ways.
- Lenses are widely used to focus, enlarge, or decrease the size of light waves from some source.

Optical Principles

Reflection

- If an object does not emit its own light, it must reflect light in order to be seen.
- When light rays strike a reflective surface, the light waves are thrown back or reflected. This is called reflection.
- Light reflects from a smooth surface at the same angle as it hits the surface.

Optical Principles

Reflection

- The **law of reflection** states that if the light ray strikes a smooth surface at some angle A from the normal, the reflected light ray will leave the surface at the same angle B to the normal.
- In other words, the angle of incidence is equal to the angle of reflection.
- A light ray from the light source is called an **incident ray.**

Optical Principles

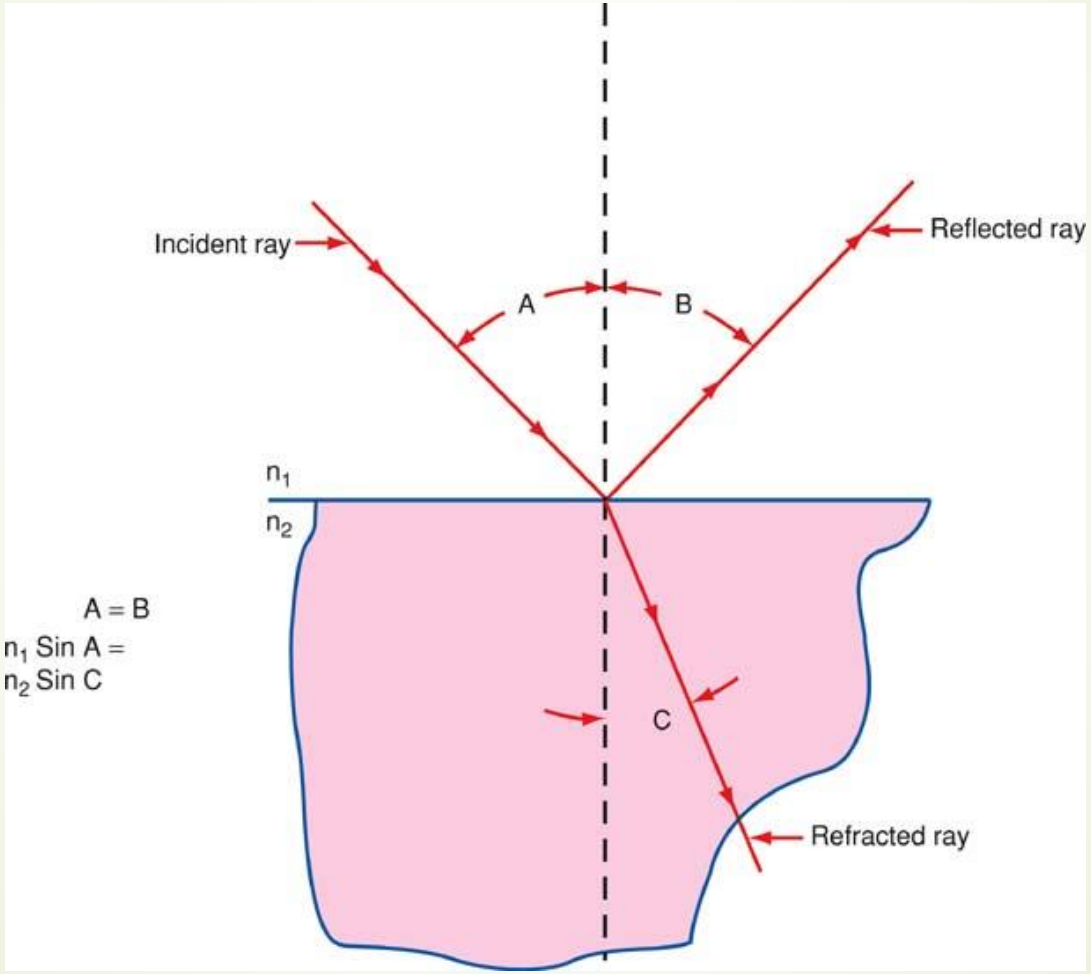
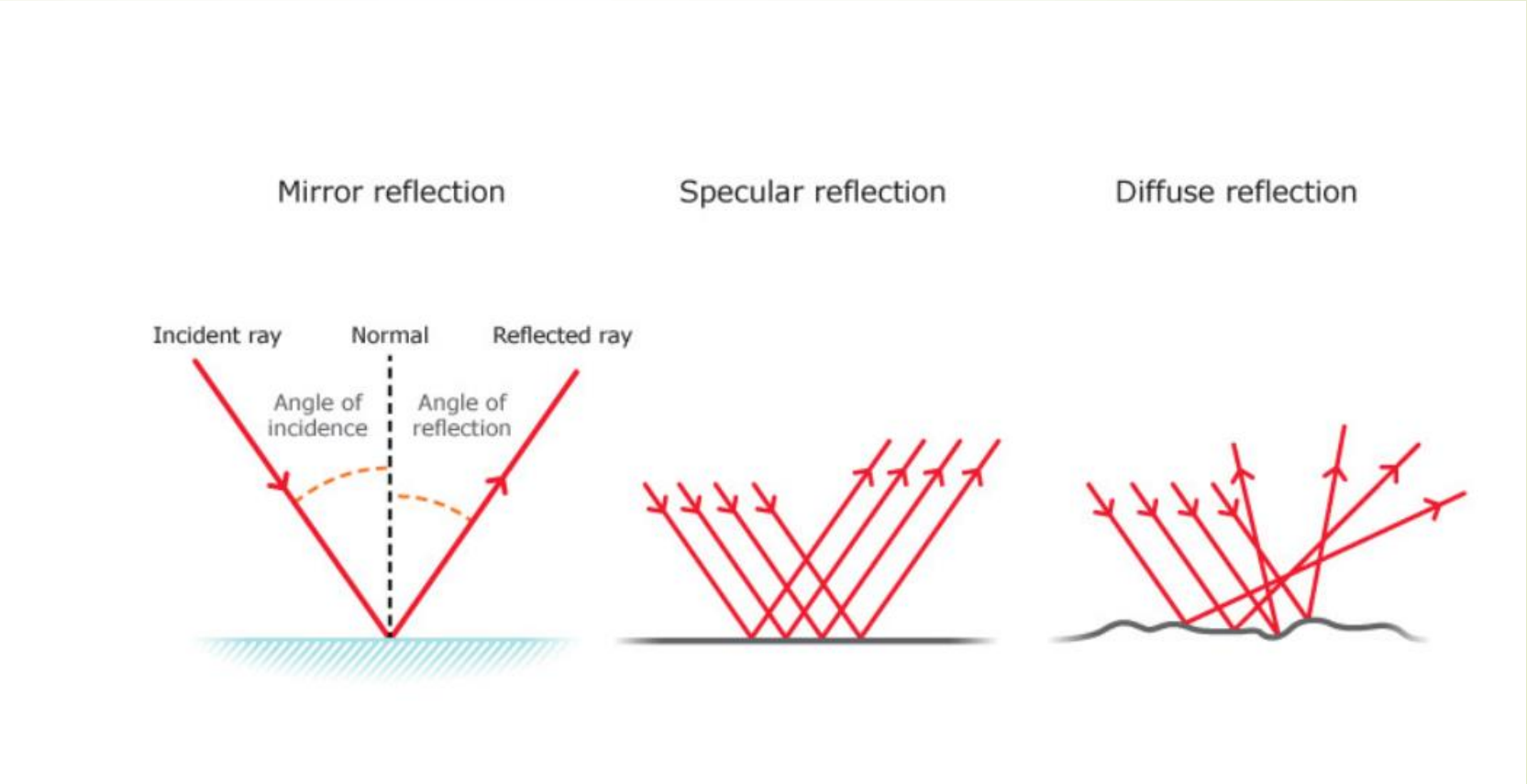


Figure Illustrating reflection and refraction at the interface of two optical materials.

Optical Principles

- Light reflects from a smooth surface at the same angle as it hits the surface. This is called specular reflection.
- For a rough surface, reflected light rays scatter in all directions. This is called diffuse reflection.



Optical Principles

Refraction

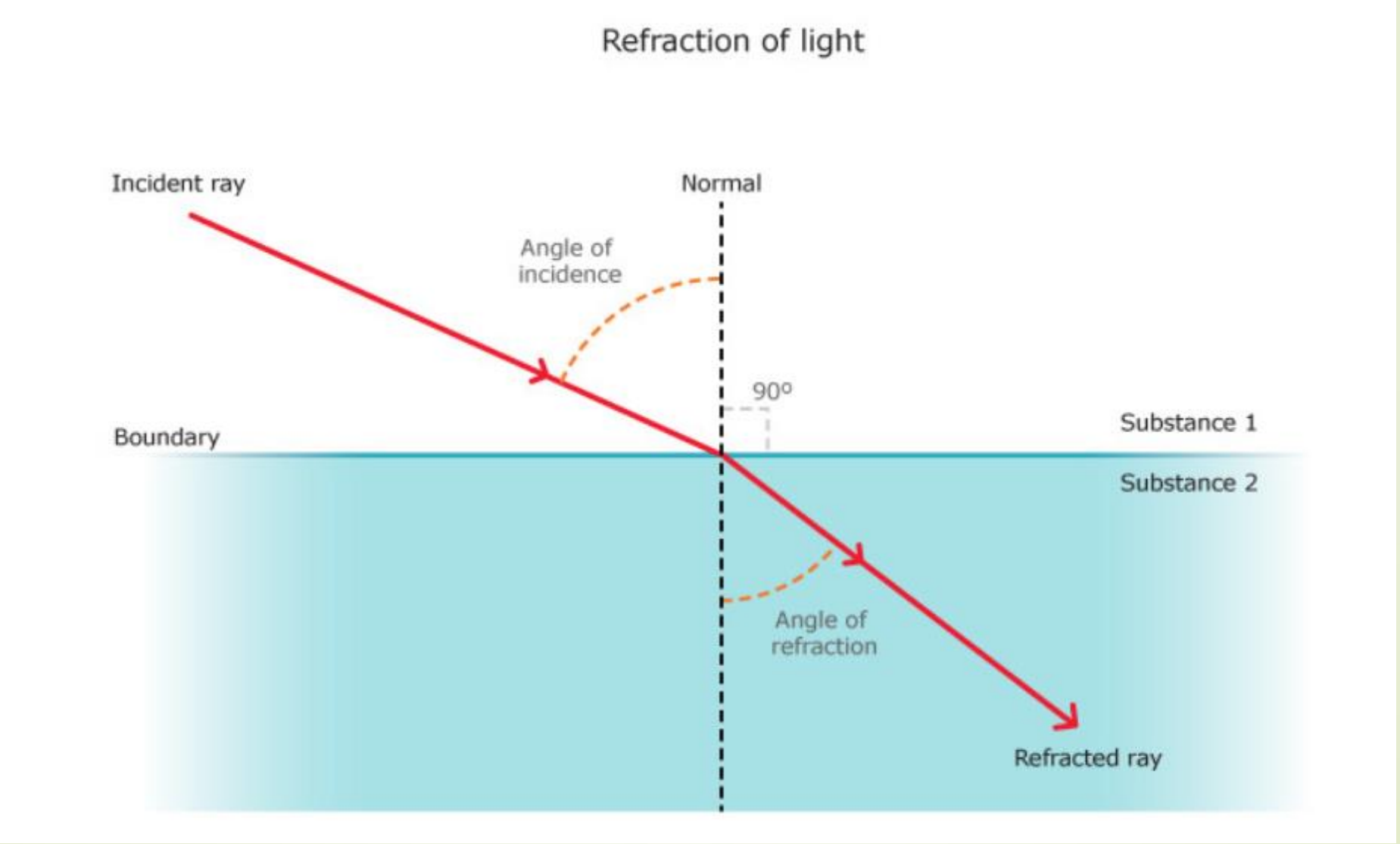
- Refraction of light is the change in direction (bending of light rays) when it passes from one medium to another medium.
- Refraction occurs because light travels at different speeds in different materials.

Optical Principles

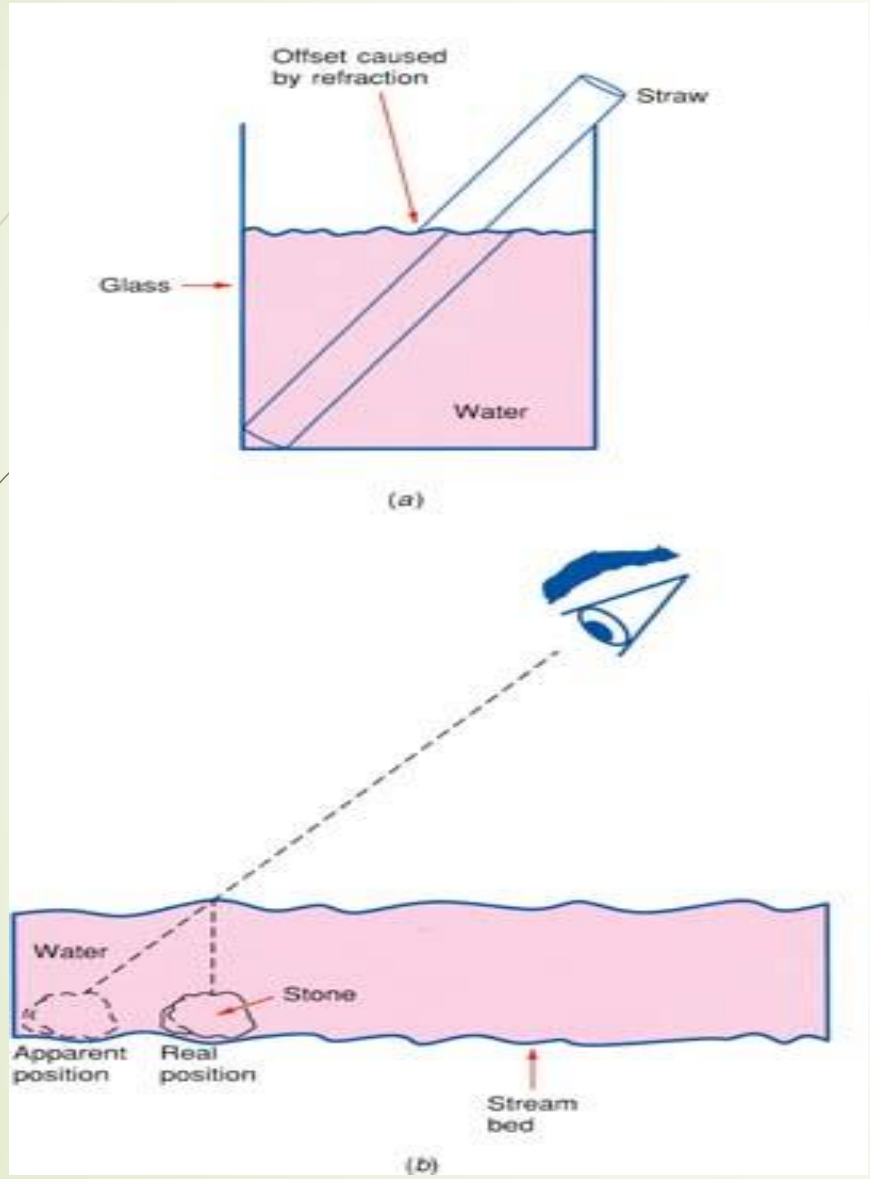
Refraction

- The amount of bending depends on two things:
  - Change in speed – if a substance causes the light to speed up or slow down more, it will refract (bend) more.
  - Angle of the incident ray – if the light is entering the substance at a greater angle, the amount of refraction will also be more noticeable. On the other hand, if the light is entering the new substance from straight on (at 90° to the surface), the light will still slow down, but it won't change direction at all.

Refraction


Refraction of light
Incident ray
Normal
Angle of incidence
90°
Boundary
Substance 1
Substance 2
Angle of refraction
Refracted ray

Optical Principles



Examples of the effect of refraction.

Optical Principles

Refraction

- The amount of refraction of the light of a material is usually expressed in terms of the **index of refraction n.**
- This is the ratio of the speed of light in air to the speed of light in the substance.
- It is also a function of the light wavelength.

Optical Communication Systems

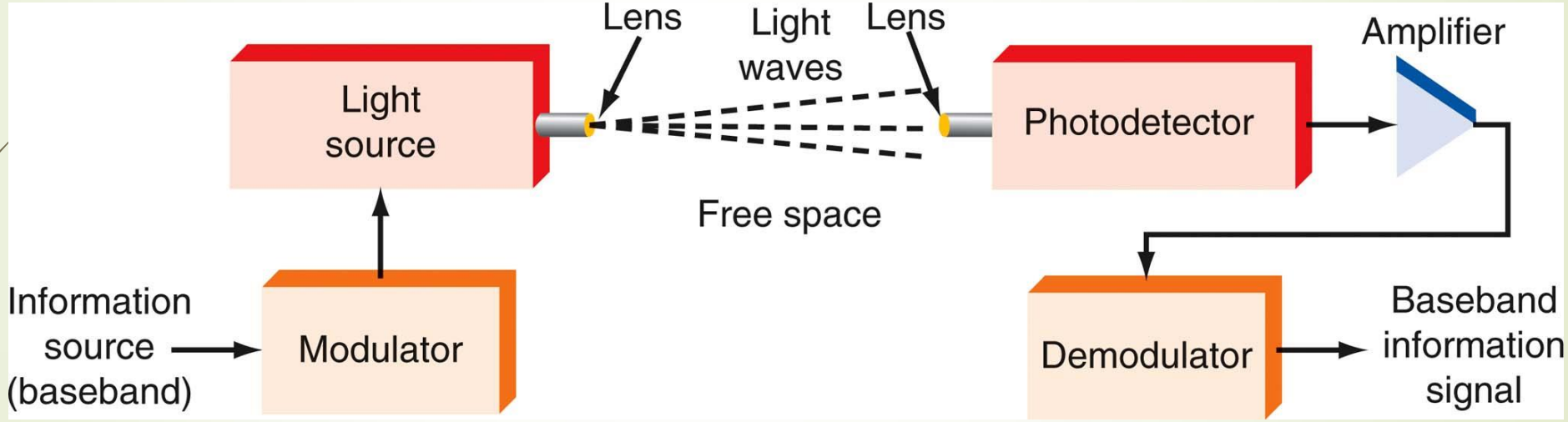
- Optical communication systems use light as the carrier of the information to be transmitted.
- The medium may be free space as with radio waves or a special light “pipe” or waveguide known as fiber-optic cable.
- Using light as a transmission medium provides vastly increased bandwidths.

Optical Communication Systems

Light Wave Communication in Free Space

- An optical communication system consists of:
  - A light source modulated by the signal to be transmitted.
  - A photodetector to pick up the light and convert it back into an electrical signal.
  - An amplifier.
  - A demodulator to recover the original information signal.

Optical Communication Systems



Free-space optical communication system.

Optical Communication Systems

Light Wave Communication in Free Space: Light Sources

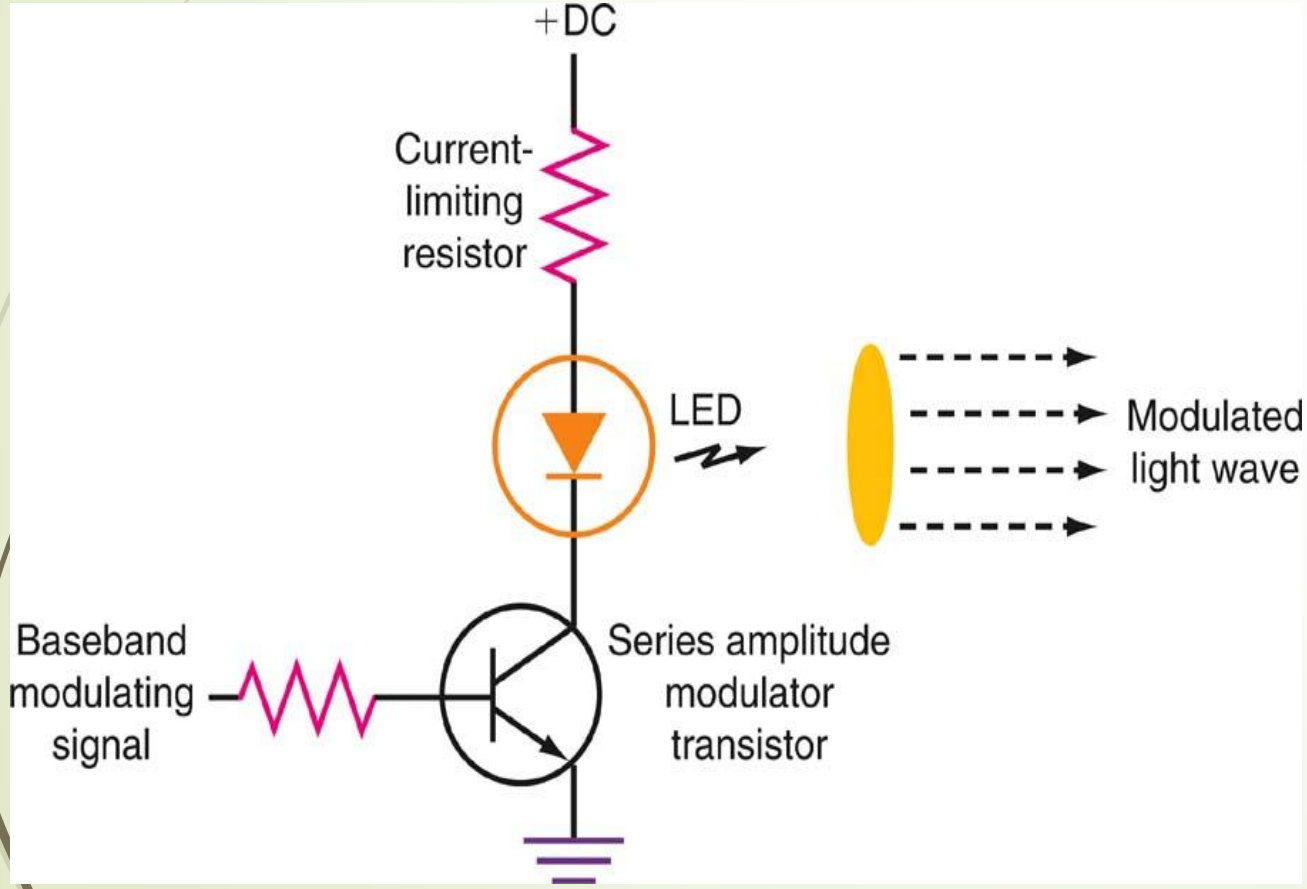
- A transmitter is a light source.
- Other common light sources are light-emitting diodes (LEDs) and lasers.
- These sources can follow electrical signal changes as fast as 10 GHz or more.
- Lasers generate monochromatic, or single-frequency, light that is fully coherent; that is, all the light waves are lined up in sync with one another and as a result produce a very narrow and intense light beam.

Optical Communication Systems

Light Wave Communication in Free Space: Modulator

- A modulator is used to vary the intensity of the light beam in accordance with the modulating baseband signal.
- Amplitude modulation, also referred to as intensity modulation, is used where the information or intelligence signal controls the brightness of the light.
- A modulator for analog signals can be a power transistor in series with the light source and its dc power supply.

Optical Communication Systems



A simple light transmitter with series amplitude modulator.
Analog signals:
transistor varies its conduction and acts as a variable resistance.
Pulse signals:
Transistor acts as a saturated on/off switch.

Optical Communication Systems

Light Wave Communication in Free Space: Receiver

- The modulated light wave is picked up by a photodetector.
- This usually a photodiode or transistor whose conduction is varied by the light.
- The small signal is amplified and then demodulated to recover the originally transmitted signal.
- Light beam communication has become far more practical with the invention of the laser.
- Lasers can penetrate through atmospheric obstacles, making light beam communication more reliable over long distances.

Optical Communication Systems

Fiber-Optic Communication System

- Fiber-optic cables many miles long can be constructed and interconnected for the purpose of transmitting information.
- Fiber-optic cables have immense information-carrying capacity (wide bandwidth).
- Many thousands of signals can be carried on a light beam through a fiber-optic cable.

Optical Communication Systems

Fiber-Optic Communication System

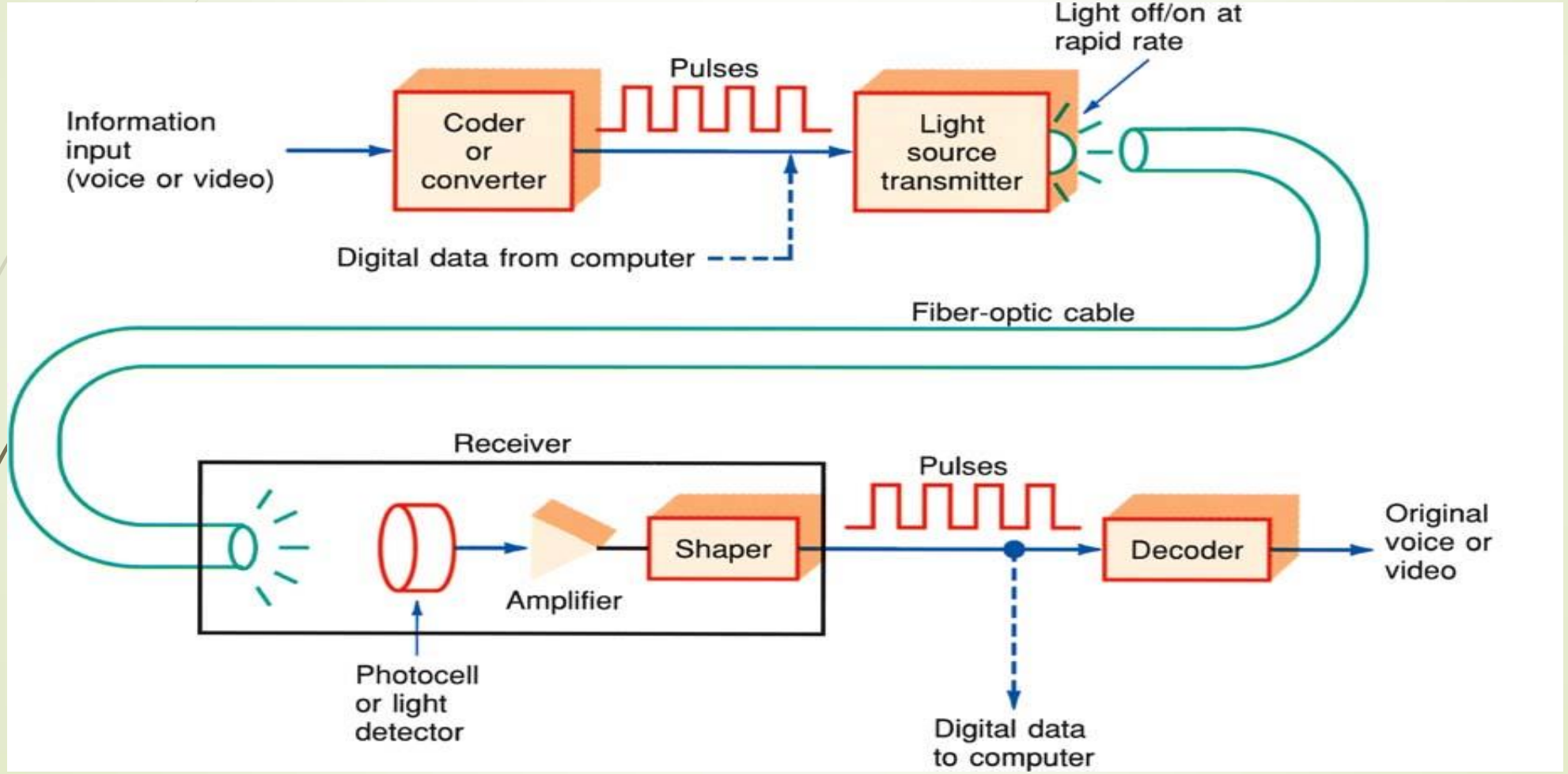
- The information signal to be transmitted may be voice, video, or computer data.
- Information must be first converted to a form compatible with the communication medium, usually by converting analog signals to digital pulses.
- These digital pulses are then used to flash a light source off and on very rapidly.
- The light beam pulses are then fed into a fiber-optic cable, which can transmit them over long distances.

Optical Communication Systems

Fiber-Optic Communication System

- At the receiving end, a light-sensitive device known as a photocell, or light detector, is used to detect the light pulses.
- The photocell converts the light pulses into an electrical signal.
- The electrical signals are amplified and reshaped back into digital form.
- They are fed to a decoder, such as a D/A converter, where the original voice or video is recovered.

Optical Communication Systems



Basic elements of a fiber-optic communication system.

Optical Communication Systems

Applications of Fiber Optics Communication System

- The primary use of fiber optics is in long-distance telephone systems and cable TV systems.
- Fiber-optic networks also form the core or backbone of the Internet.
- Fiber-optic communication systems are used to interconnect computers in networks within a large building, to carry control signals in airplanes and in ships, and in TV systems because of the wide bandwidth.

End Of Slides