LIGHT

BY

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BIBLE SAYS

- And God said, “Let there be light,” and there was light. 4 God saw that the light was good, and he separated the light from the darkness. 5 God called the light “day,” and the darkness he called “night.”

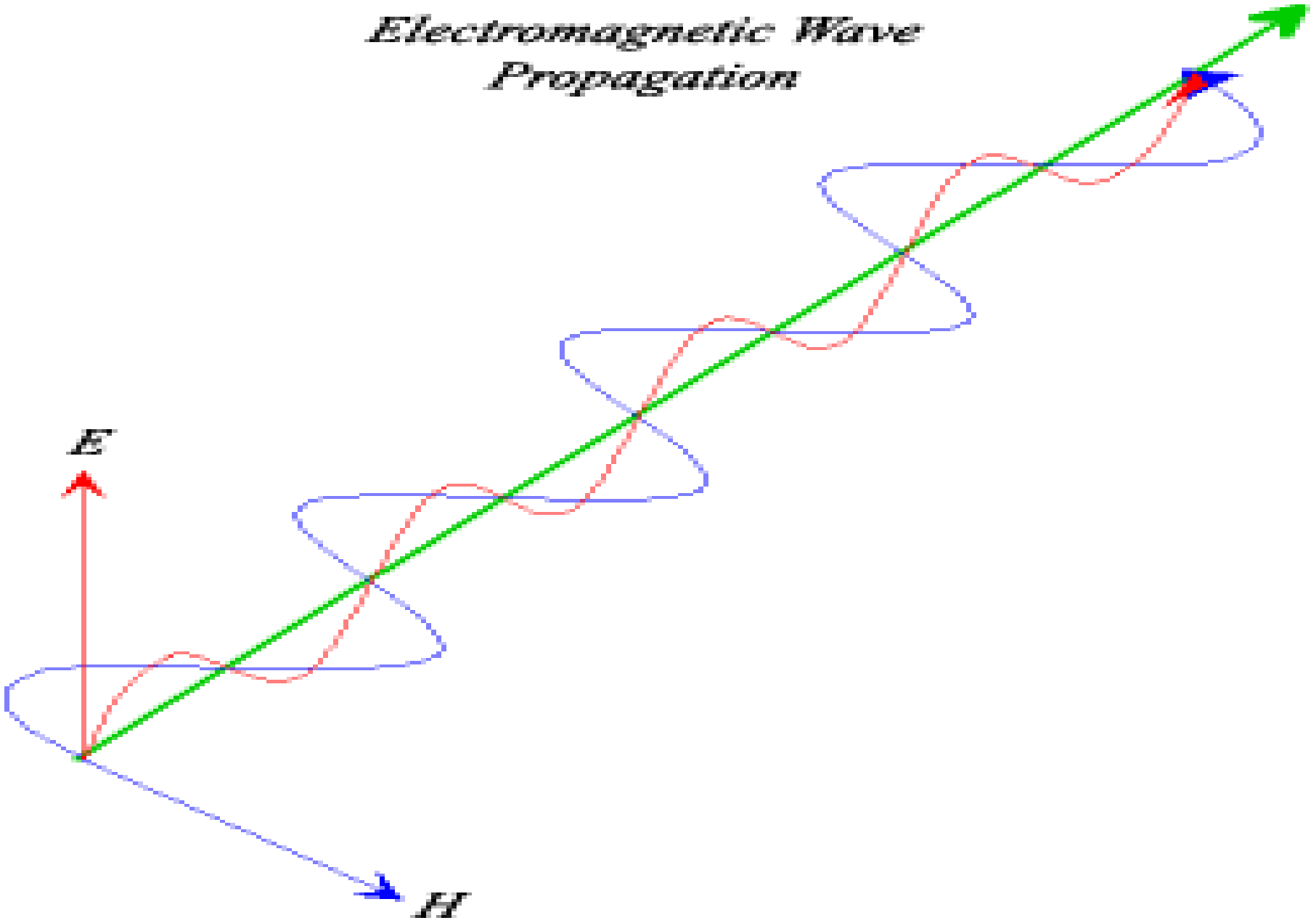
WHAT IS LIGHT?

- Agent which stimulates our sense of sight

- Light is a transverse electromagnetic wave.

THEORIES

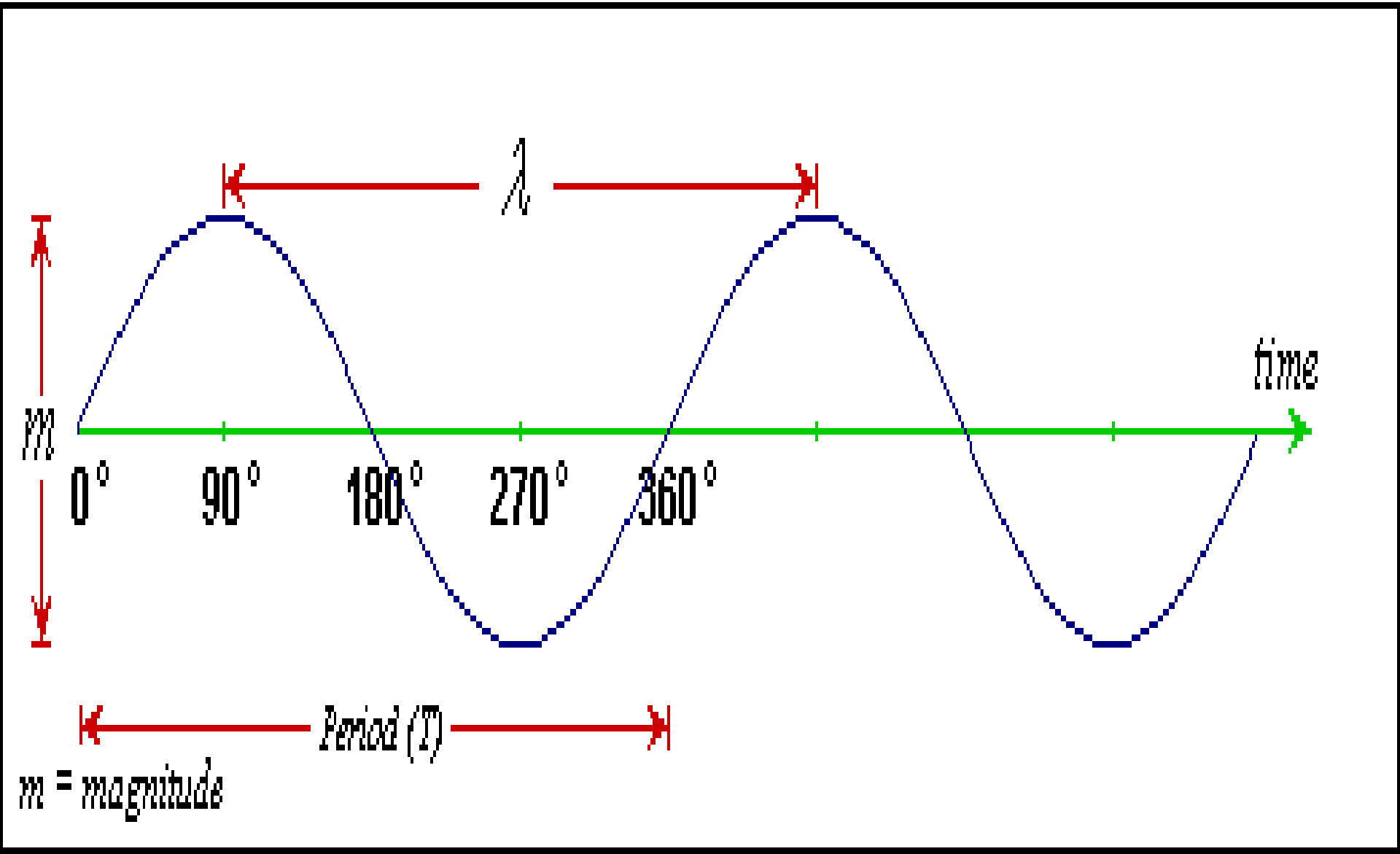
- Corpuscular theory – Newton
- Wave theory – Huygen
- Electromagnetic theory – Maxwell
- Quantum theory – Max Planck & Einstein


Electromagnetic Wave
Propagation
E
H

ELECTROMAGNETIC WAVES SHARE SIX PROPERTIES

- Polarization
- Superposition
- Reflection
- Refraction
- Diffraction
- Interference

WAVE NATURE



- Wavelength x Frequency = Speed

The Speed Of Light

- The speed of light in a vacuum is a universal constant, about 300,000 km/s

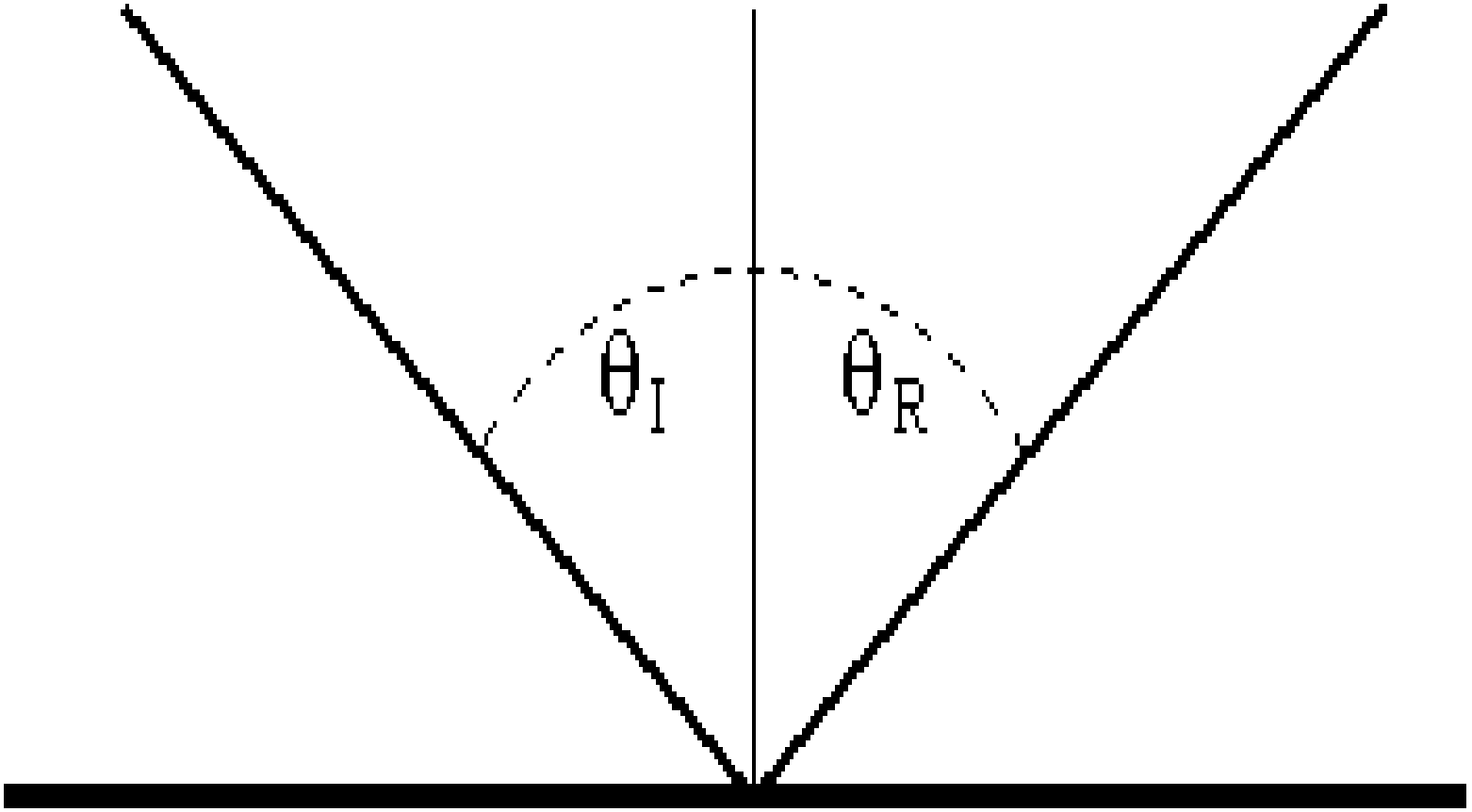
  It takes approximately 8.3 min for light from the sun to reach the earth

PROPERTIES OF LIGHT

- Reflection
- Refraction
- Dispersion
- Diffraction

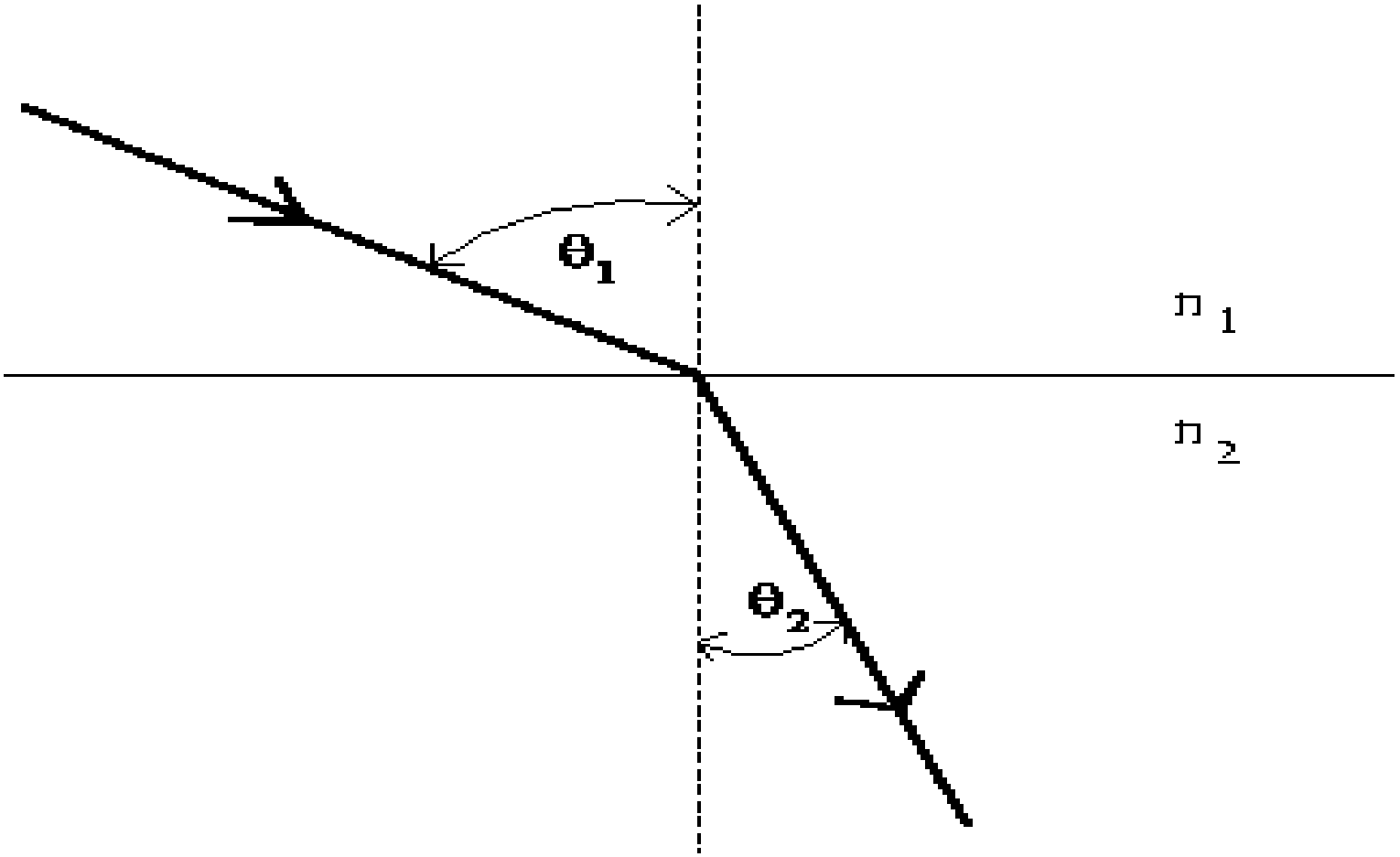
REFLECTION

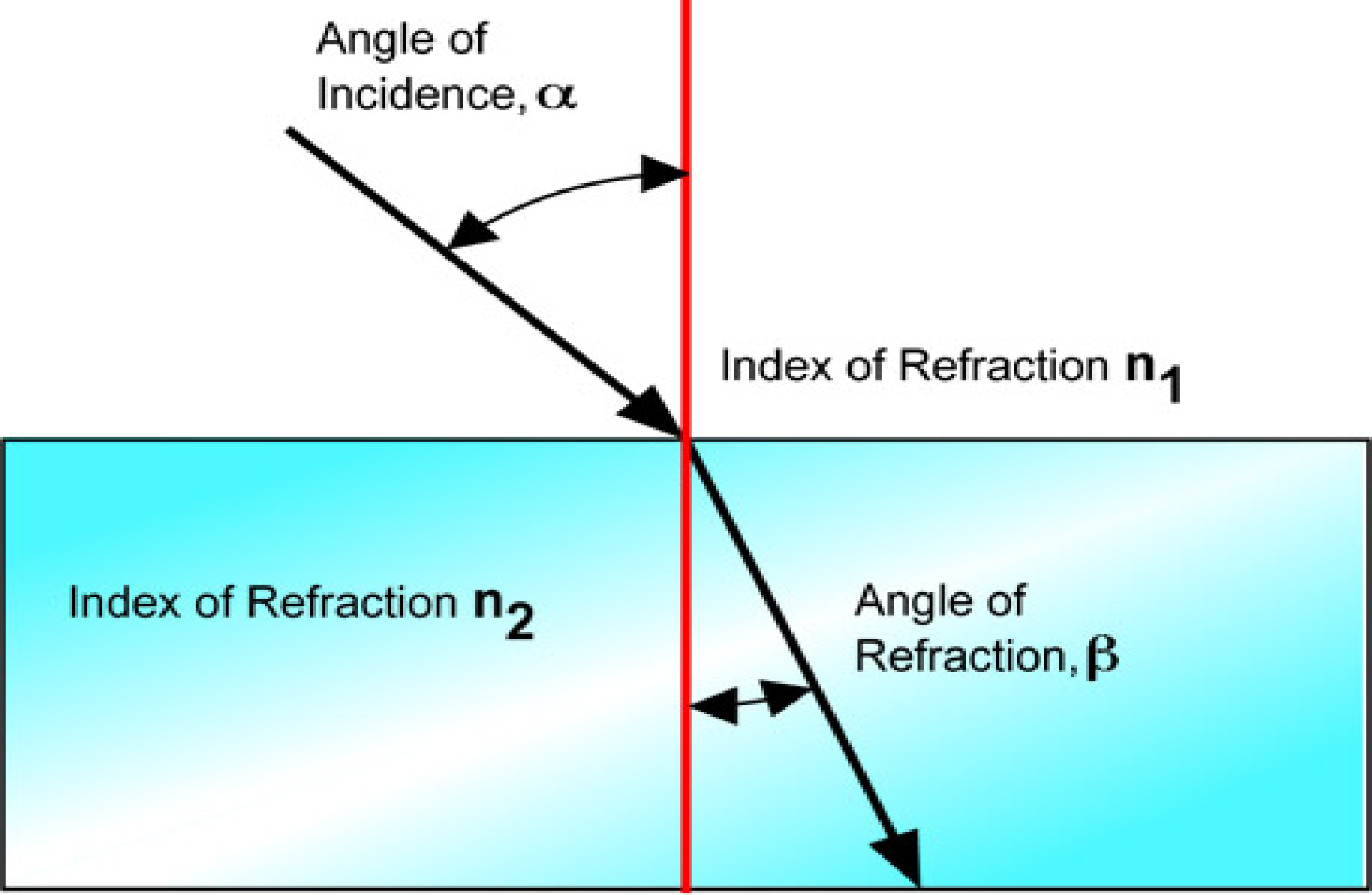
when light is reflected, θ 1 = θ R



REFRACTION

Refraction is the bending of light as it passes between materials of different density.



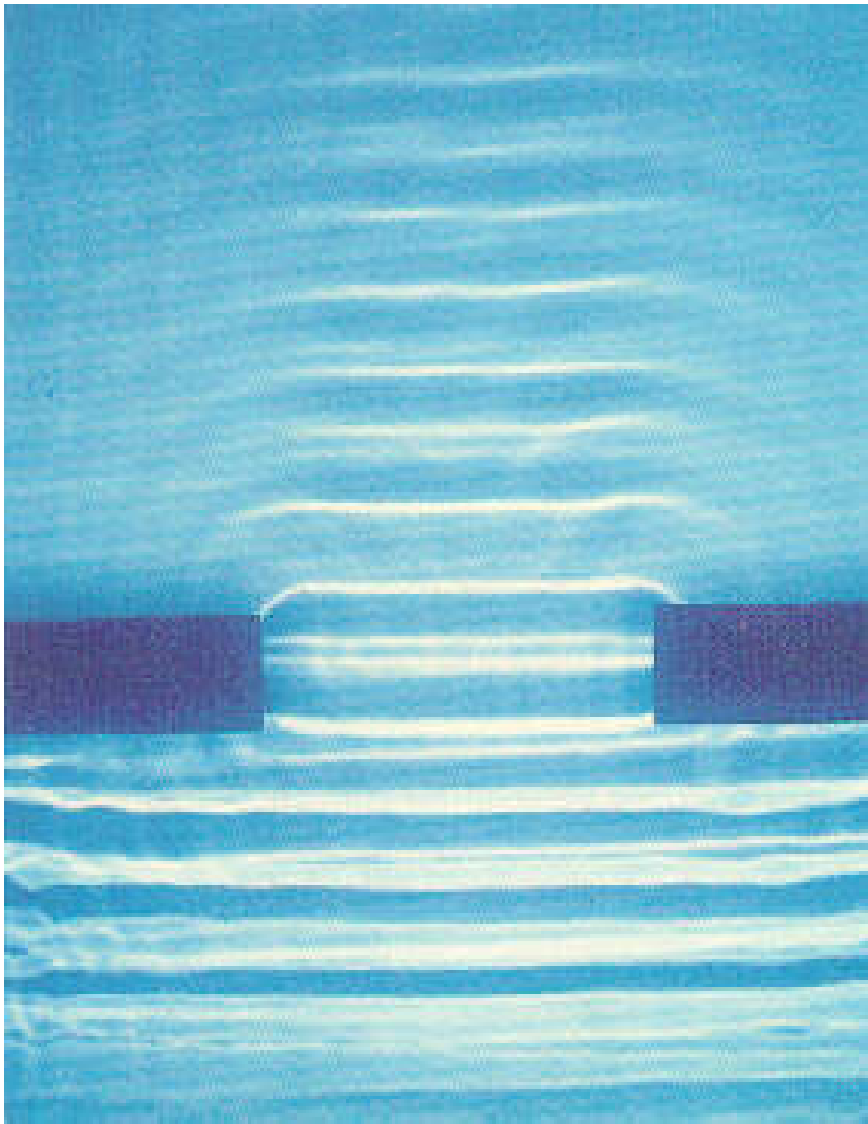


n_1 sine α = n_2 sine β

DIFFRACTION

- Diffraction is the apparent "bending" of light waves around obstacles in its path.

Water waves in a ripple tank

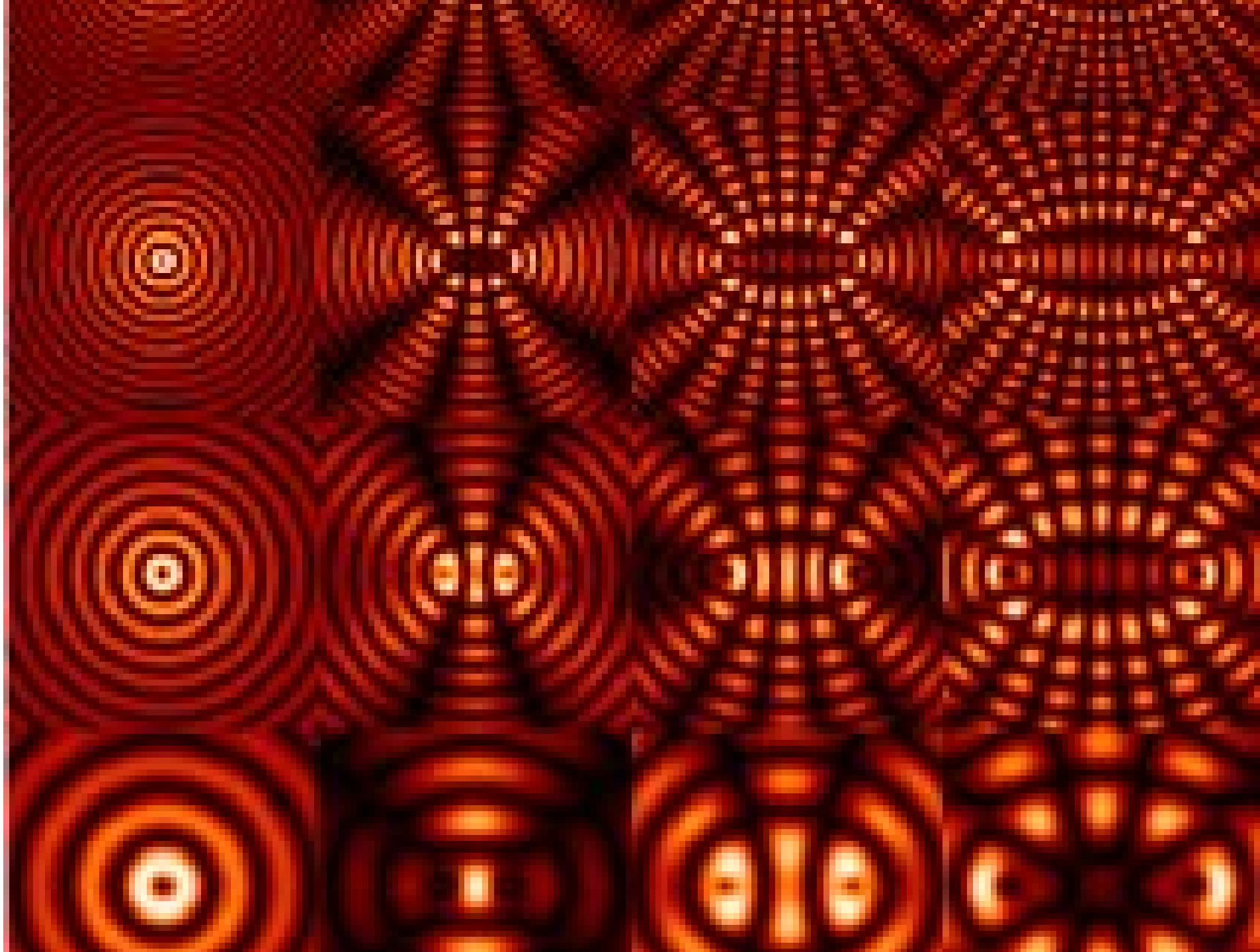


INTERFERENCE

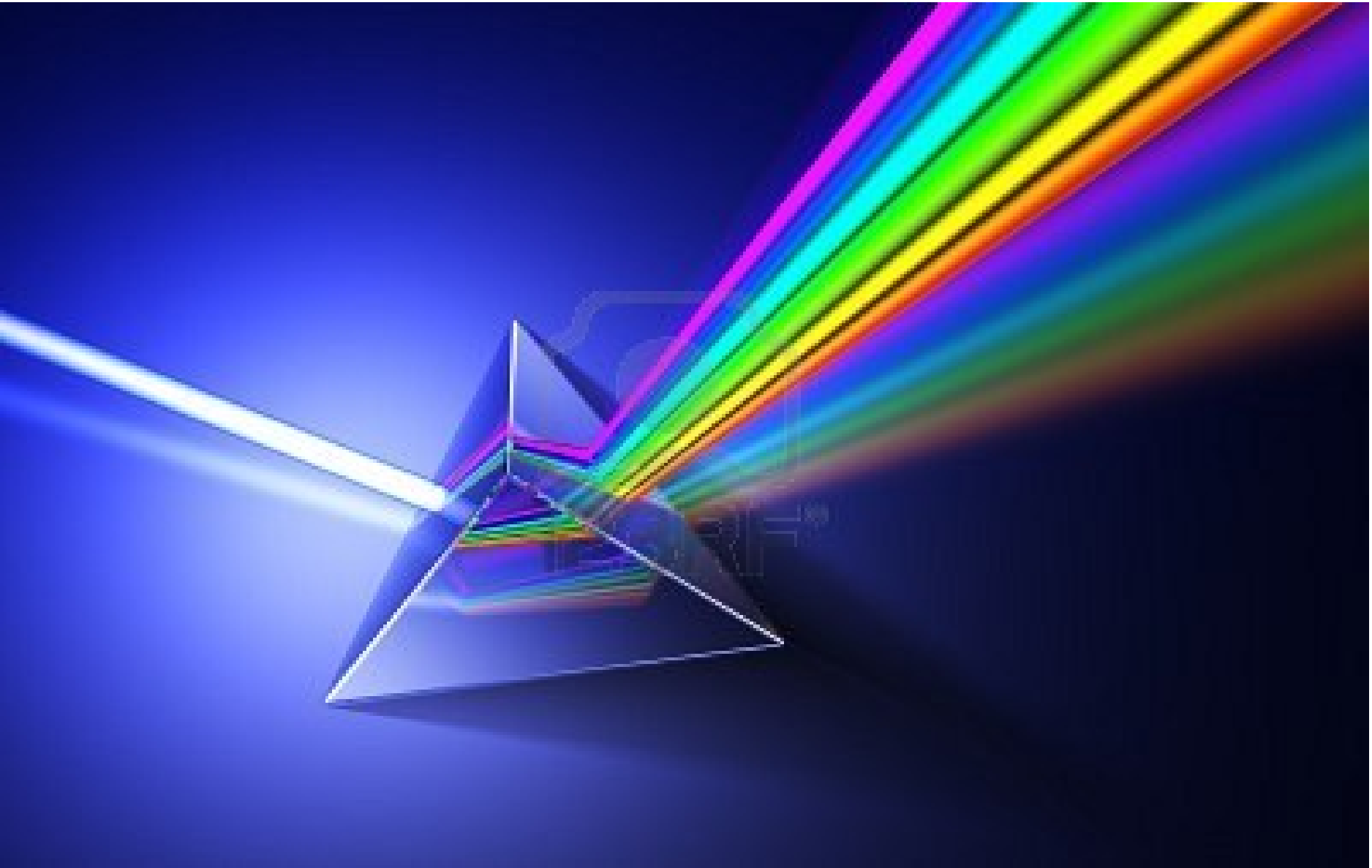
phenomenon in which two waves superimpose to form a resultant wave of greater or lower amplitude.

refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency.

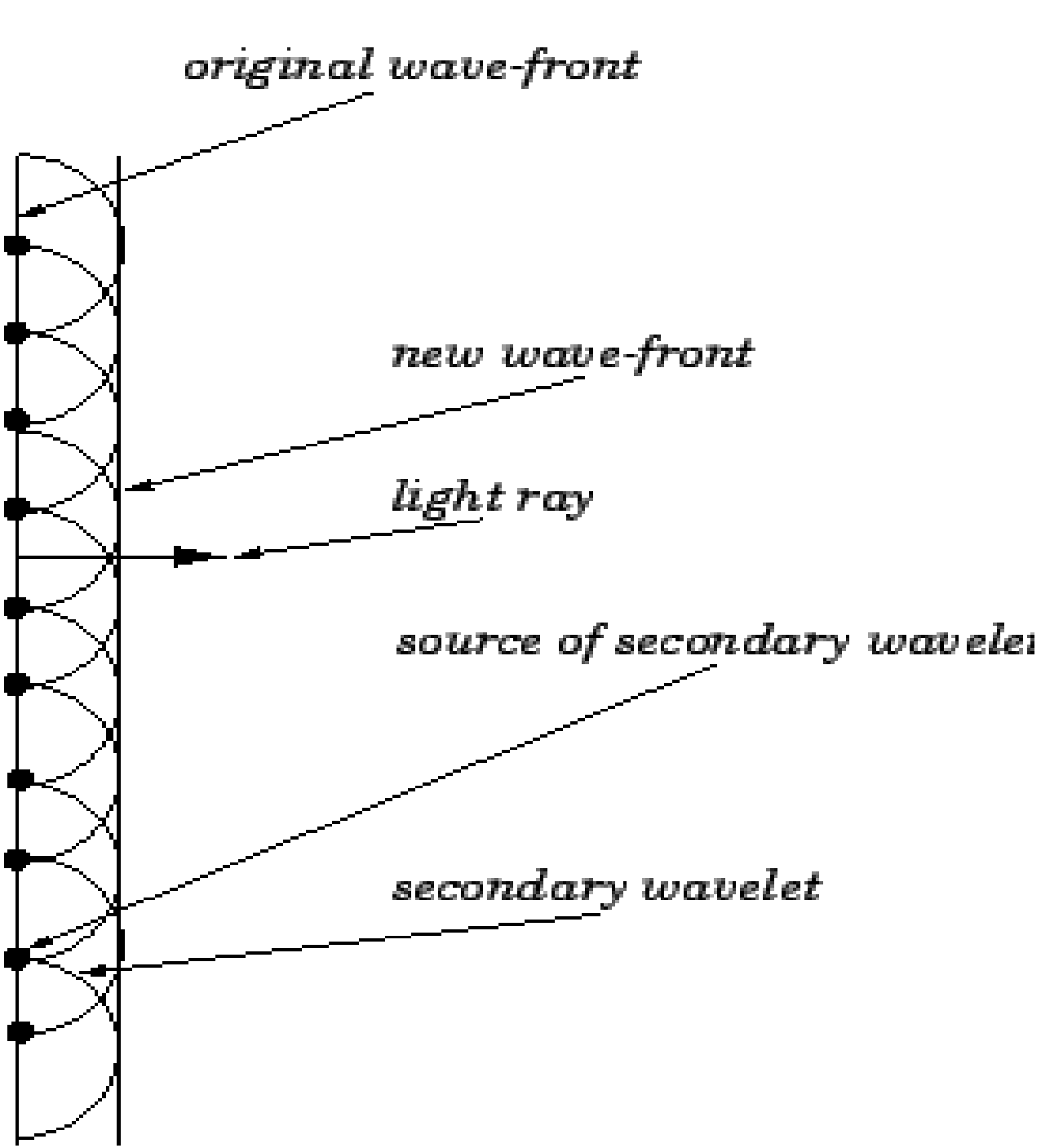
Interference effects can be observed with all types of waves, for example, light, radio, acoustic, and surface water waves

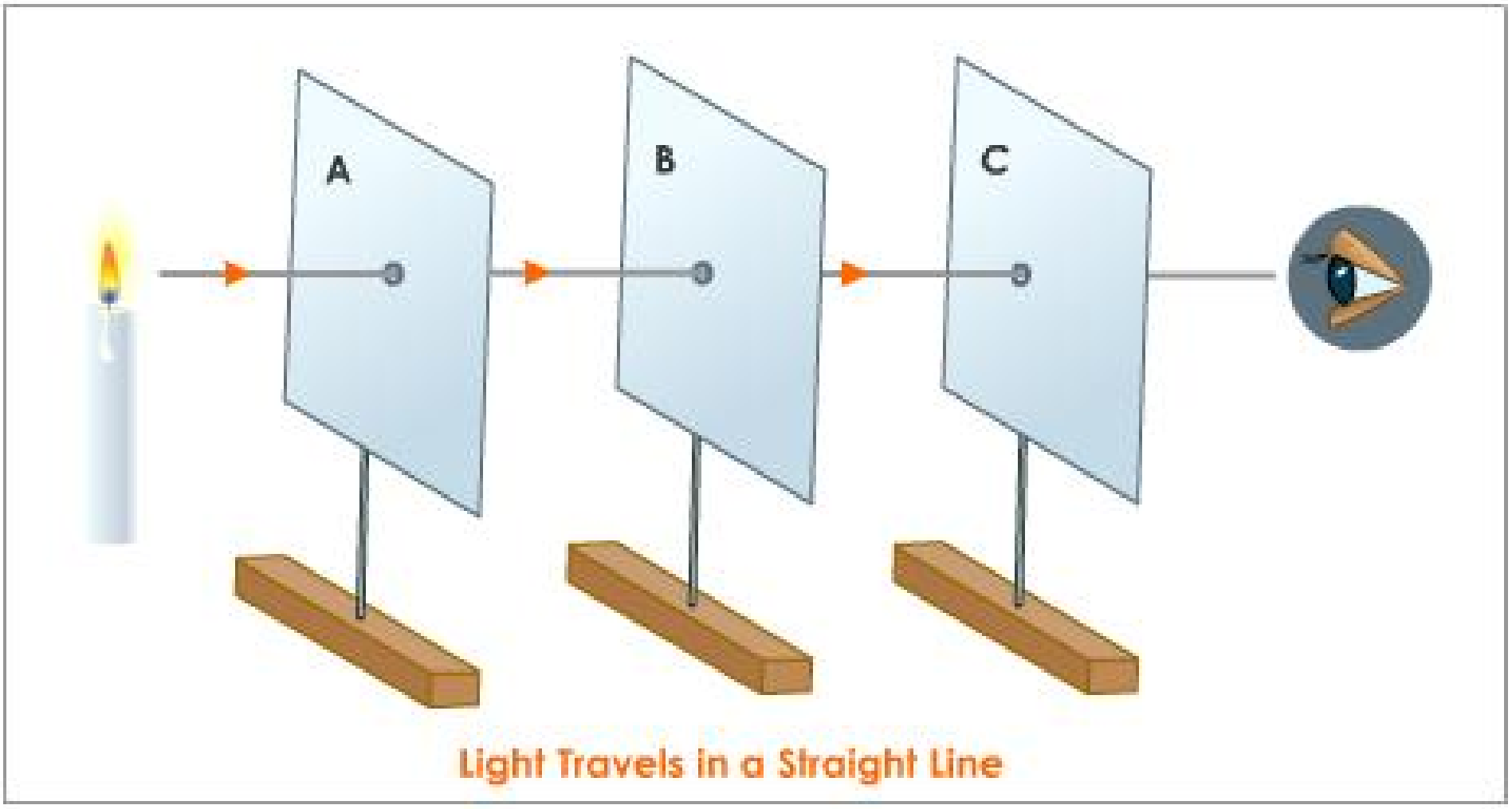


DISPERSION



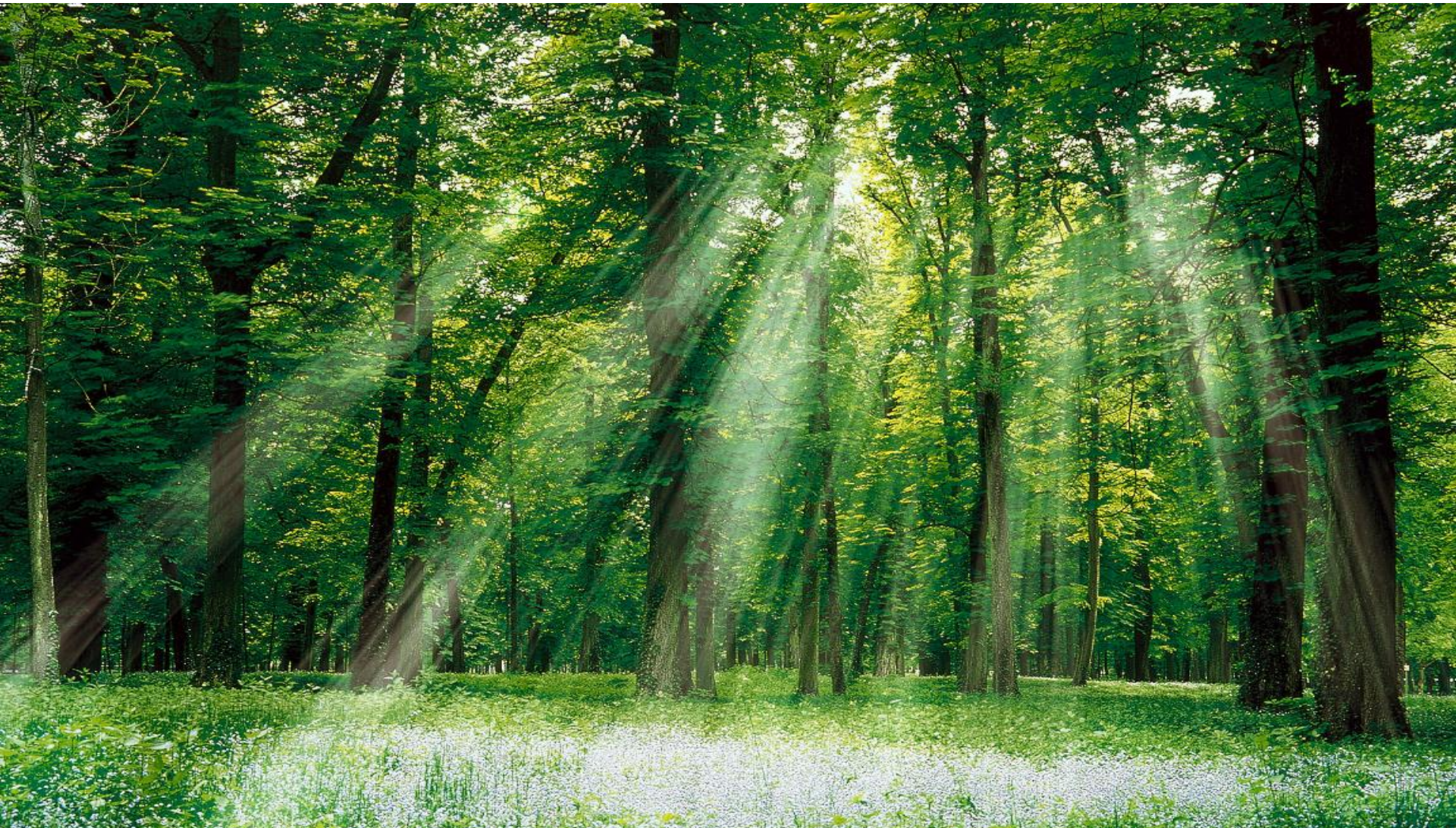
- The velocity of light in a material, and hence its refractive index depends on the wavelength of the light. In general, n varies inversely with wavelength: it is greater for violet than red.


original wave-front
new wave-front
light ray
source of secondary wavele
secondary wavelet



In a homogenous transparent medium, light travels in a straight line and this is known as rectilinear propagation of light.

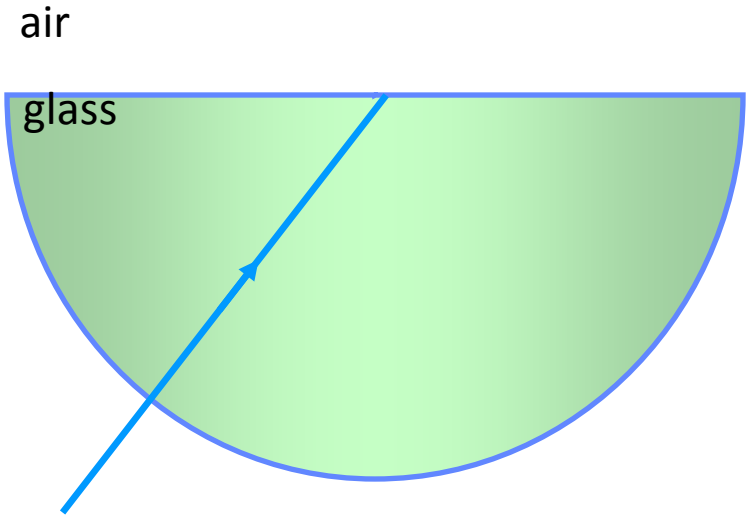
RECTILINEAR PROPAGATION OF LIGHT



Total internal reflection

1 Internal reflection

A light ray hits the inside face of a semicircular block as follows.

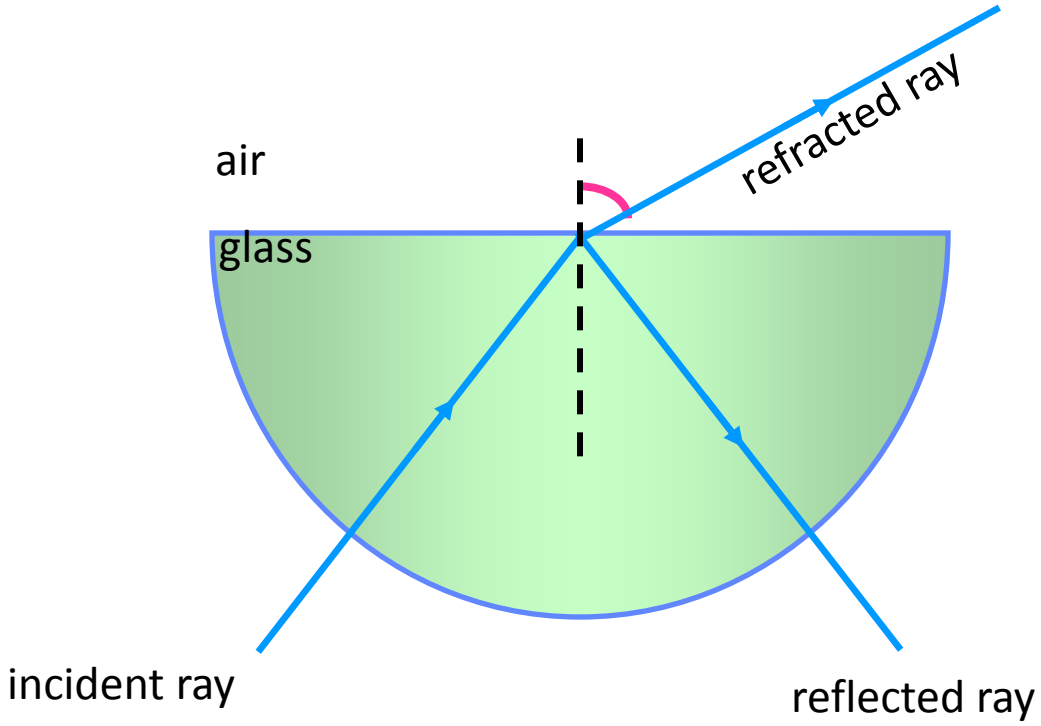


What will happen?

1 Internal reflection

For a small angle of incidence

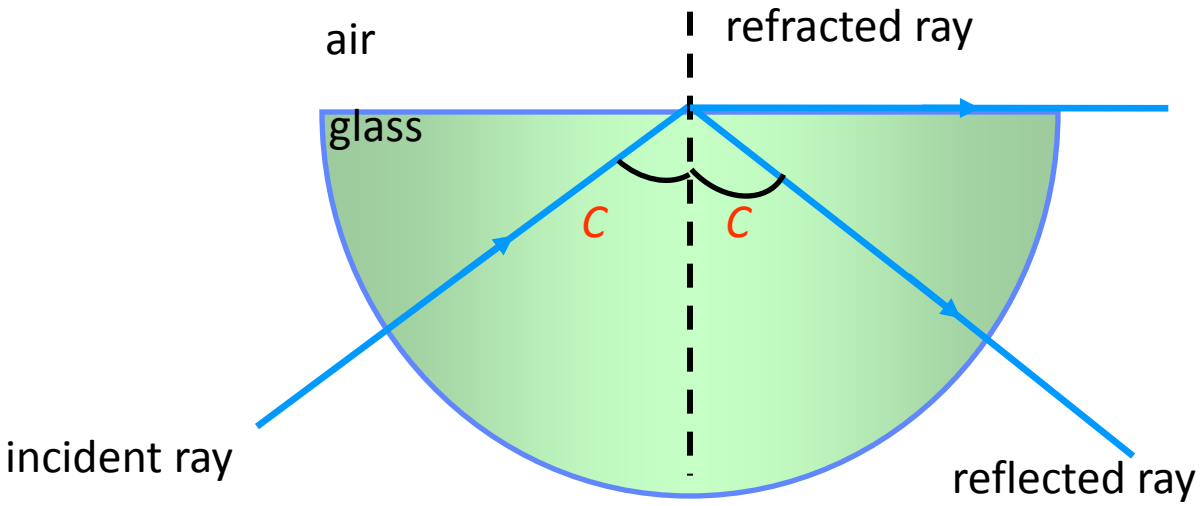
- The incident ray splits into 2 rays.
  - angle of refraction < 90°



1 Internal reflection

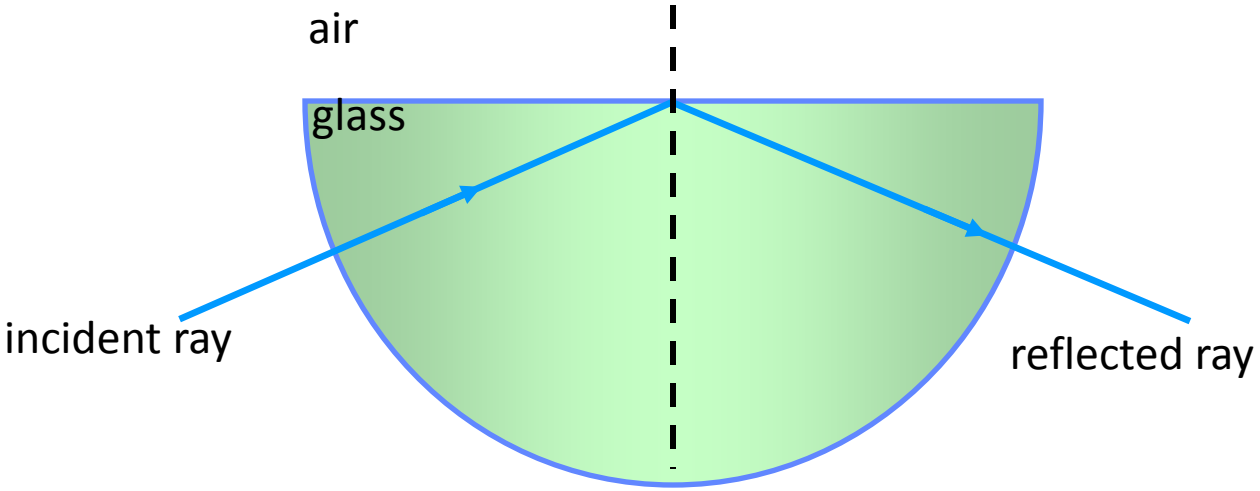
- as angle of incidence ↑, angle of refraction ↑

- eventually, angle of refraction = 90°
- angle of incidence = critical angle *C*



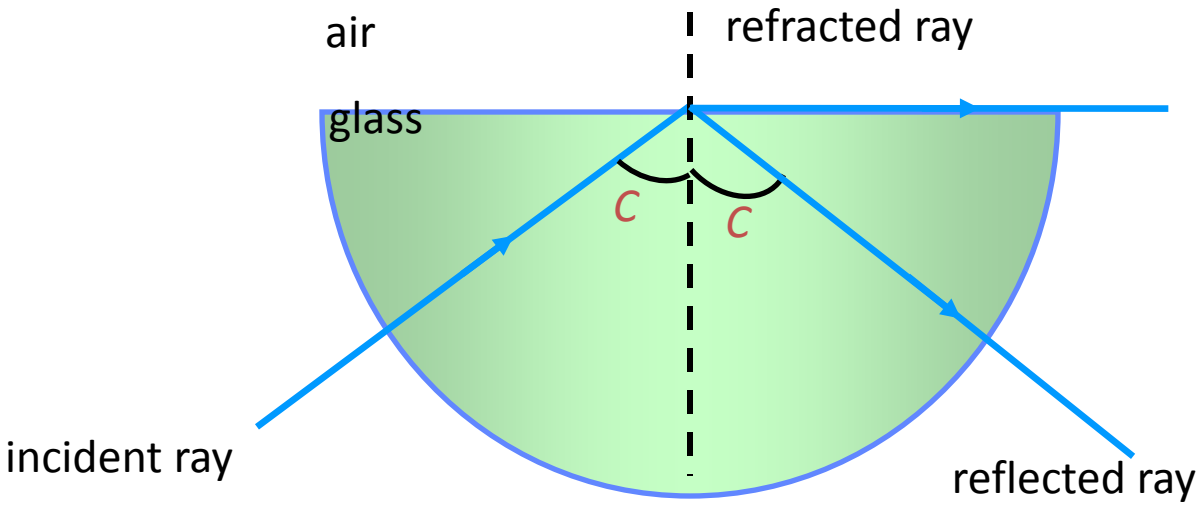
1 Internal reflection

Therefore, if angle of incidence > *C*, the light ray is totally reflected inside.



This is called total internal reflection.

Critical angle and refractive index



$$n = \frac{\sin 90^{o}}{\sin C}$$

$$\Rightarrow n = \frac{1}{\sin C} \quad \text{or} \quad C = \sin^{-1}\left(\frac{1}{n}\right)$$

What does this LIGHT do for us?

HOME

- Energy-saving fluorescent lamps
- Infrared remote controls
- TV flat panel / large screen
- Optical fibers for cable TV
- Compact disc players
- IR motion sensors for home security
- Video disk players
- Alarm clock , radio with LED display
- IR noncontact “ear” thermometers
- Infrared remote headphones

Car

– Infrared security systems
– Optical monitors for antilock brakes
– Optical fiber dashboard displays
– LED traffic signals
– Laser traffic radar
– Solar-powered emergency services

Store

– Supermarket bar-code scanners
– Credit card holograms

Medical

– Laser surgery
– Medical diagnosis tools
– Microscope

OFFICE

- – Optical scanners
- – Fax machines
- – Optical fiber telephone cables
- – Optical data storage
- – Laser printers
- – Photocopiers
- – Overhead slide projectors
- – Video teleconferences
- – Laser pointers
- – Computer active matrix displays
- – Computer displays
- – Infrared remote connections
- – Special optical computers

MANUFACTURING

- – Laser welding and cutting
- – Optical stereo-lithography
- – Machine vision
- – Image recognition for quality control
- – Nondestructive testing
- – Optical inspection of labeling and packaging
- – Laser fabric cutting machines

OTHER

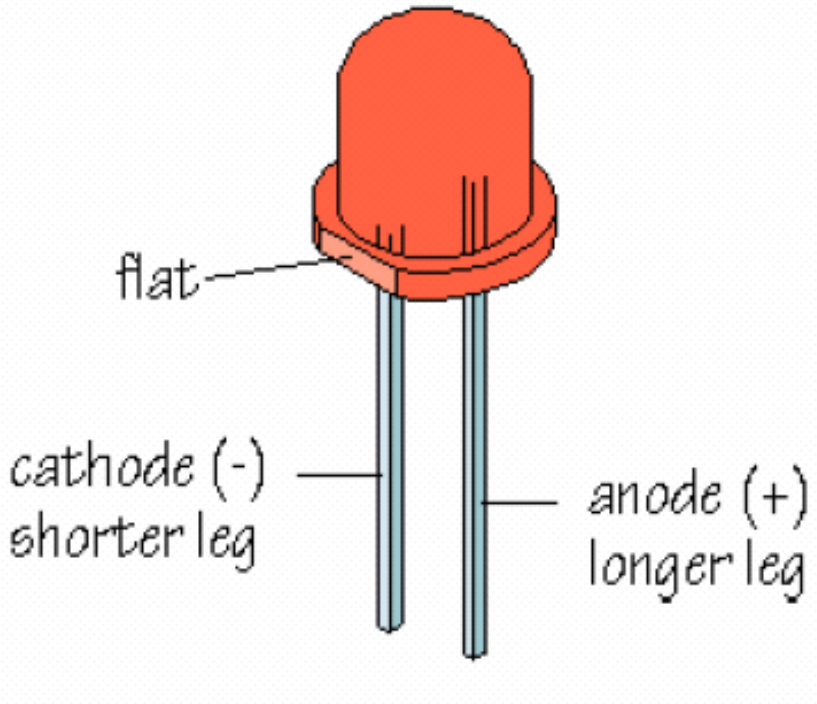
- – Laser light shows
- – Digital cameras
- – Night vision goggles
- – Missile guidance
- – Laser weapons
- – Surveillance cameras
- – Surveying—alignment and range finders
- – Computer-generated optical elements
- – Art gallery holography exhibits

THE MOST IMPORTANT SOURCES

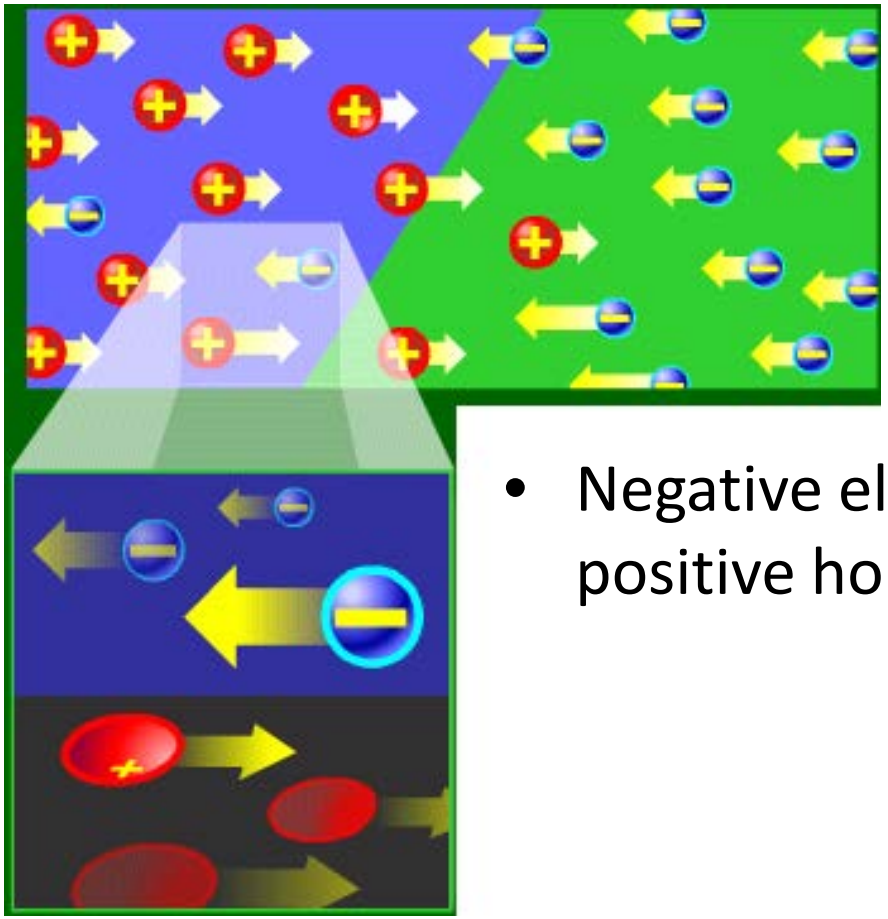
- Fiber Optics
- LED
- LASER

What is an LED?

- Light-emitting diode
- Semiconductor
- Has polarity

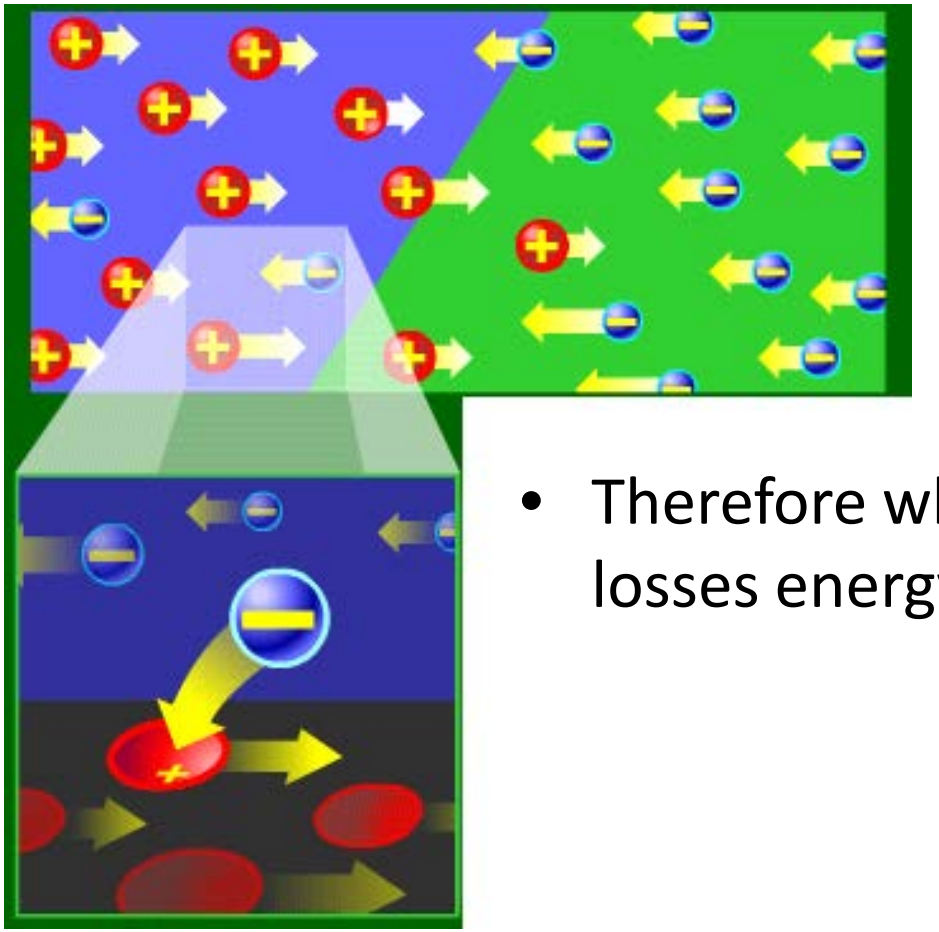


LED: How It Works



- When current flows across a diode
- Negative electrons move one way and positive holes move the other way

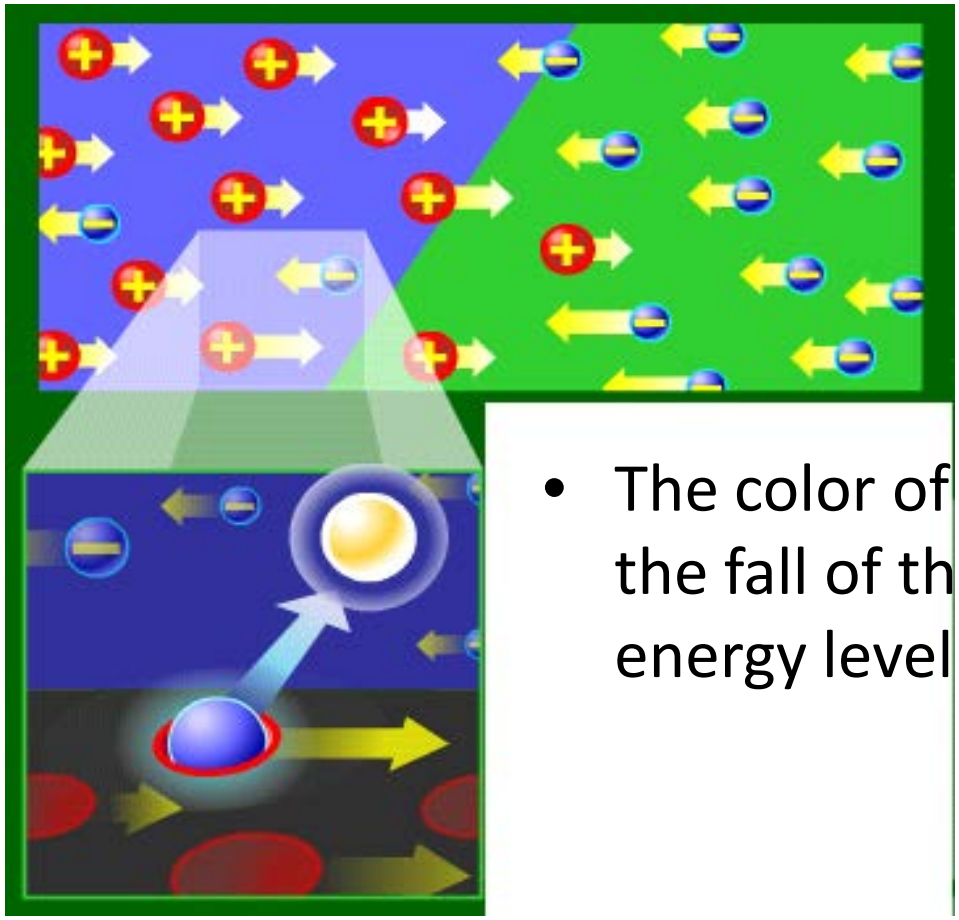
LED: How It Works



- The holes exist at a lower energy level than the free electrons

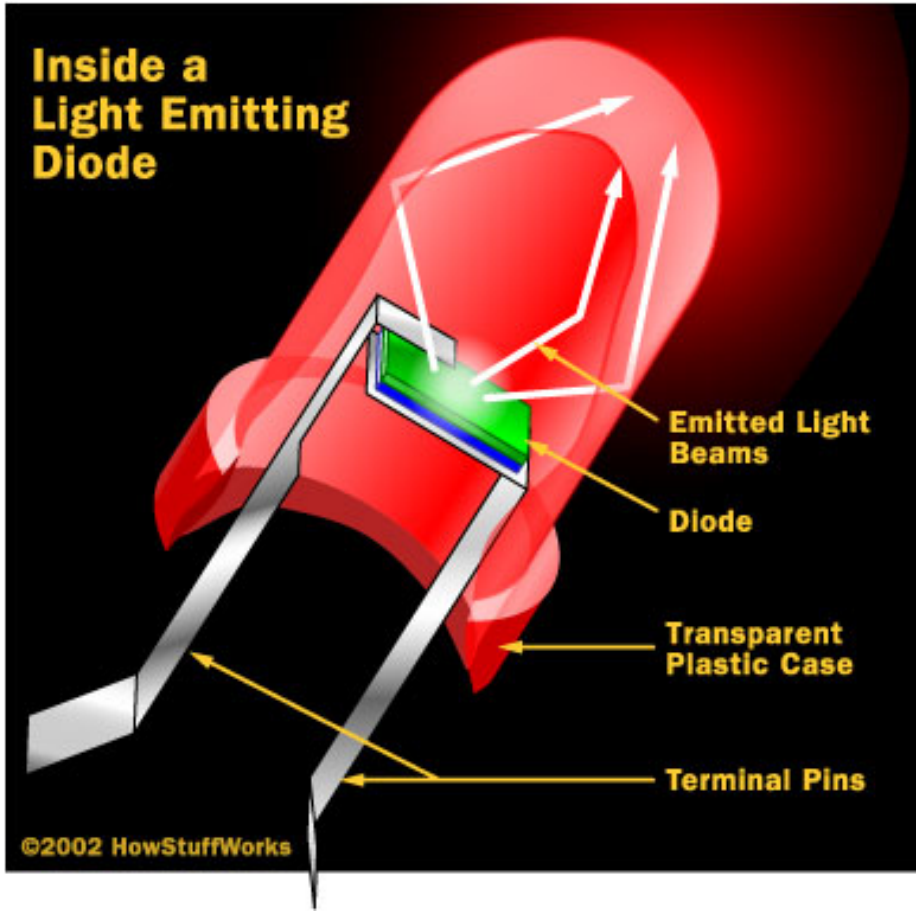
- Therefore when a free electrons falls it losses energy

LED: How It Works



- This energy is emitted in a form of a photon, which causes light
- The color of the light is determined by the fall of the electron and hence energy level of the photon

Inside a Light Emitting Diode



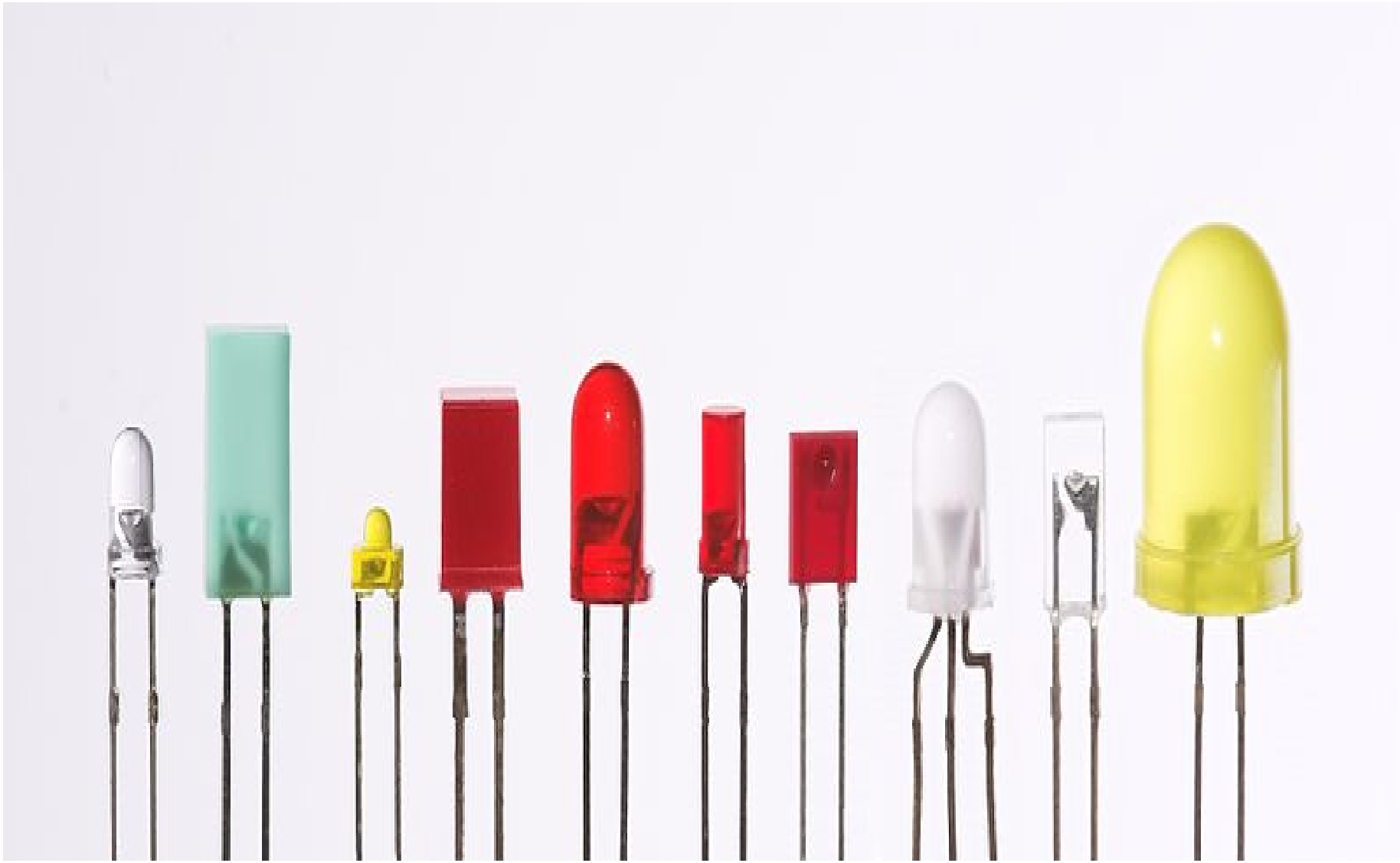
1. Transparent Plastic Case
2. Terminal Pins
3. Diode

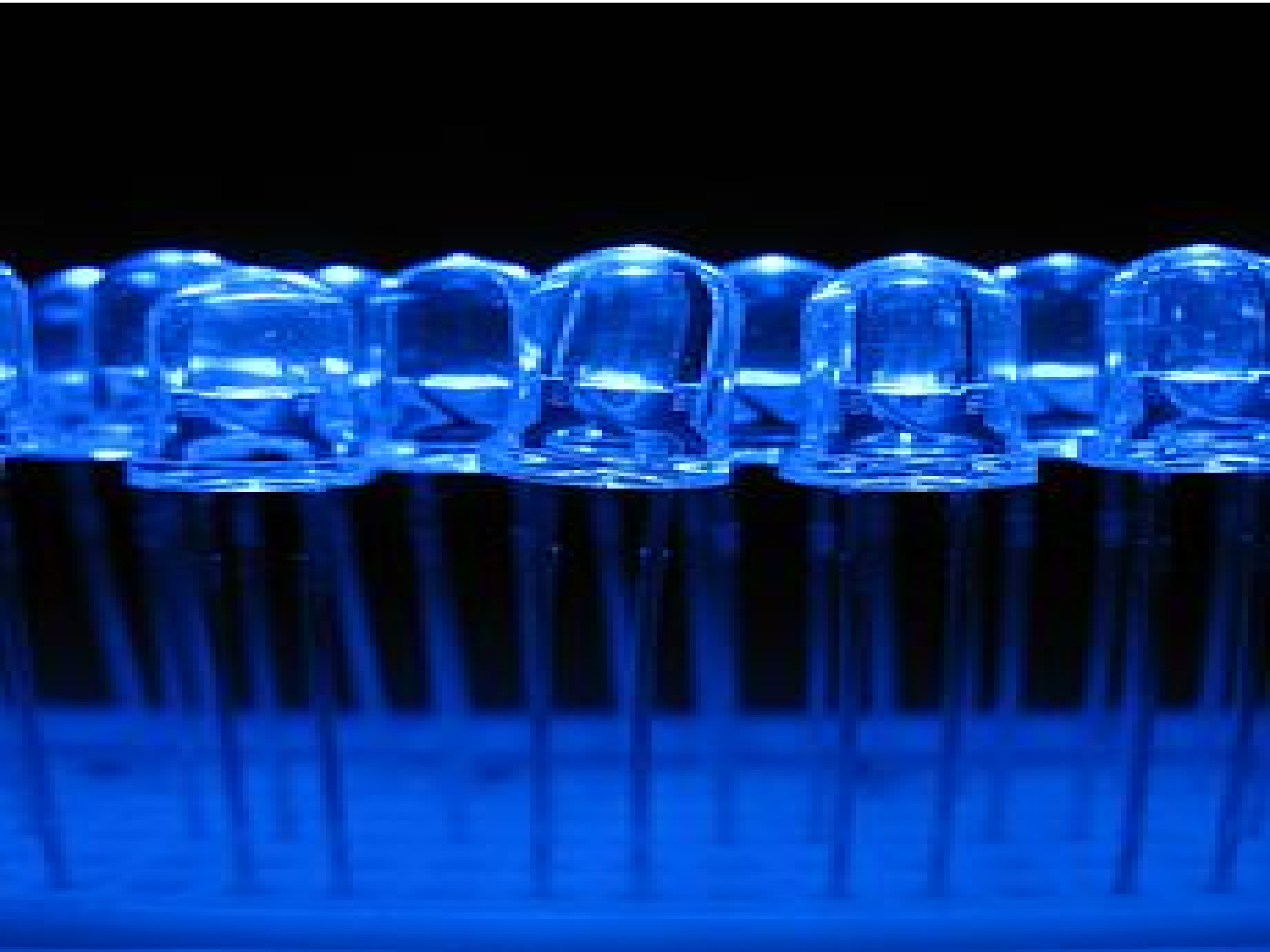
- The wavelength of the light emitted, and thus its color depends on the band gap energy of the materials forming the *p-n junction*. In silicon or Germanium diodes, the electrons and holes recombine by a *non-radiative transition*, which produces no optical emission, because these are indirect bandgap materials. The materials used for the LED have a direct bandgap with energies corresponding to near-infrared, visible, or near-ultraviolet light.
- LED development began with infrared and red devices made with Gallium Arsenide. Advances in materials science have enabled making devices with ever-shorter wavelengths, emitting light in a variety of colors.

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate.

Most materials used for LED production have very high refractive indices. This means that much light will be reflected back into the material at the material/air surface interface. Thus, light extraction in LEDs is an important aspect of LED production, subject to much research and development.

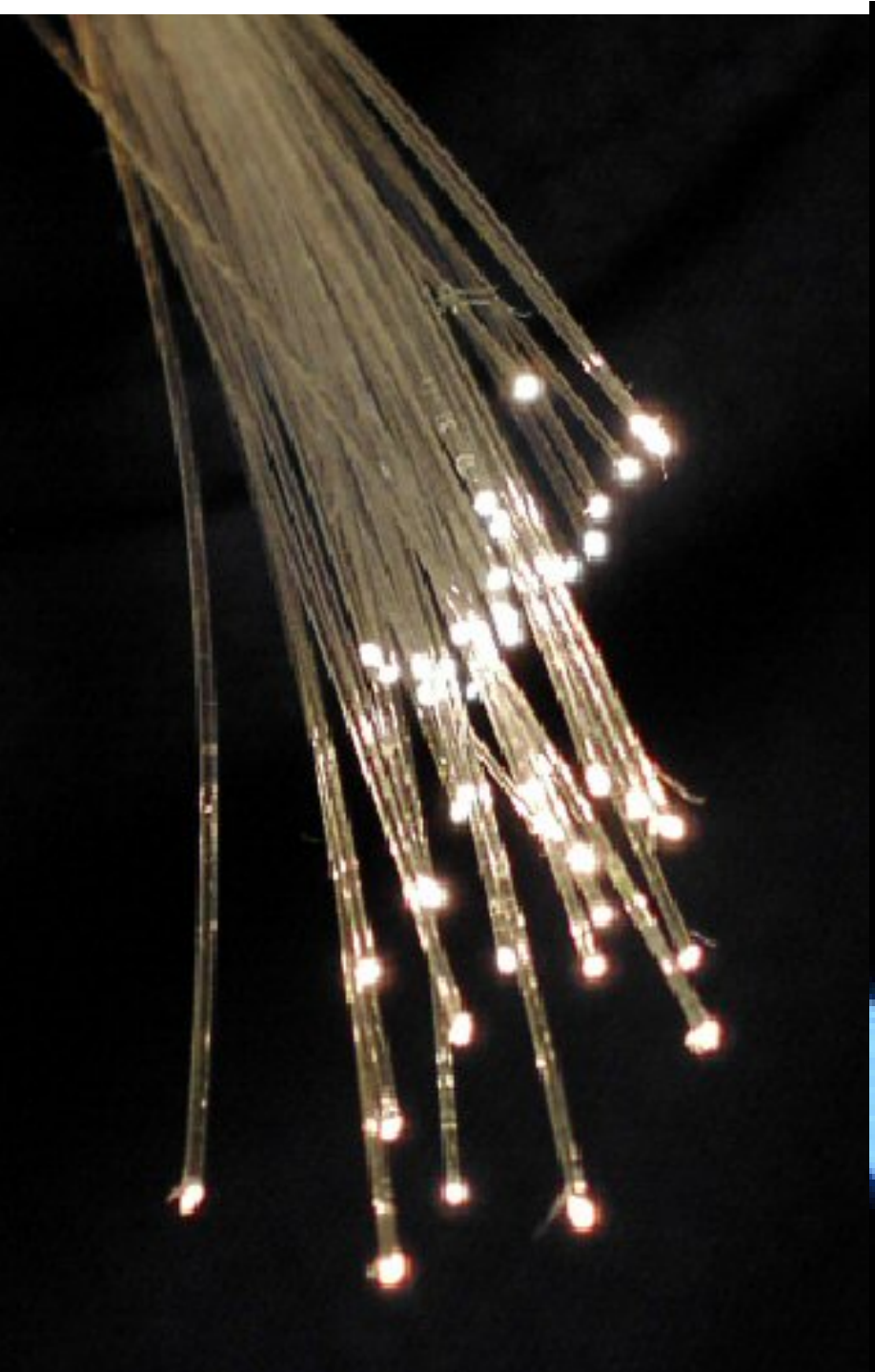
TYPES OF LED’S

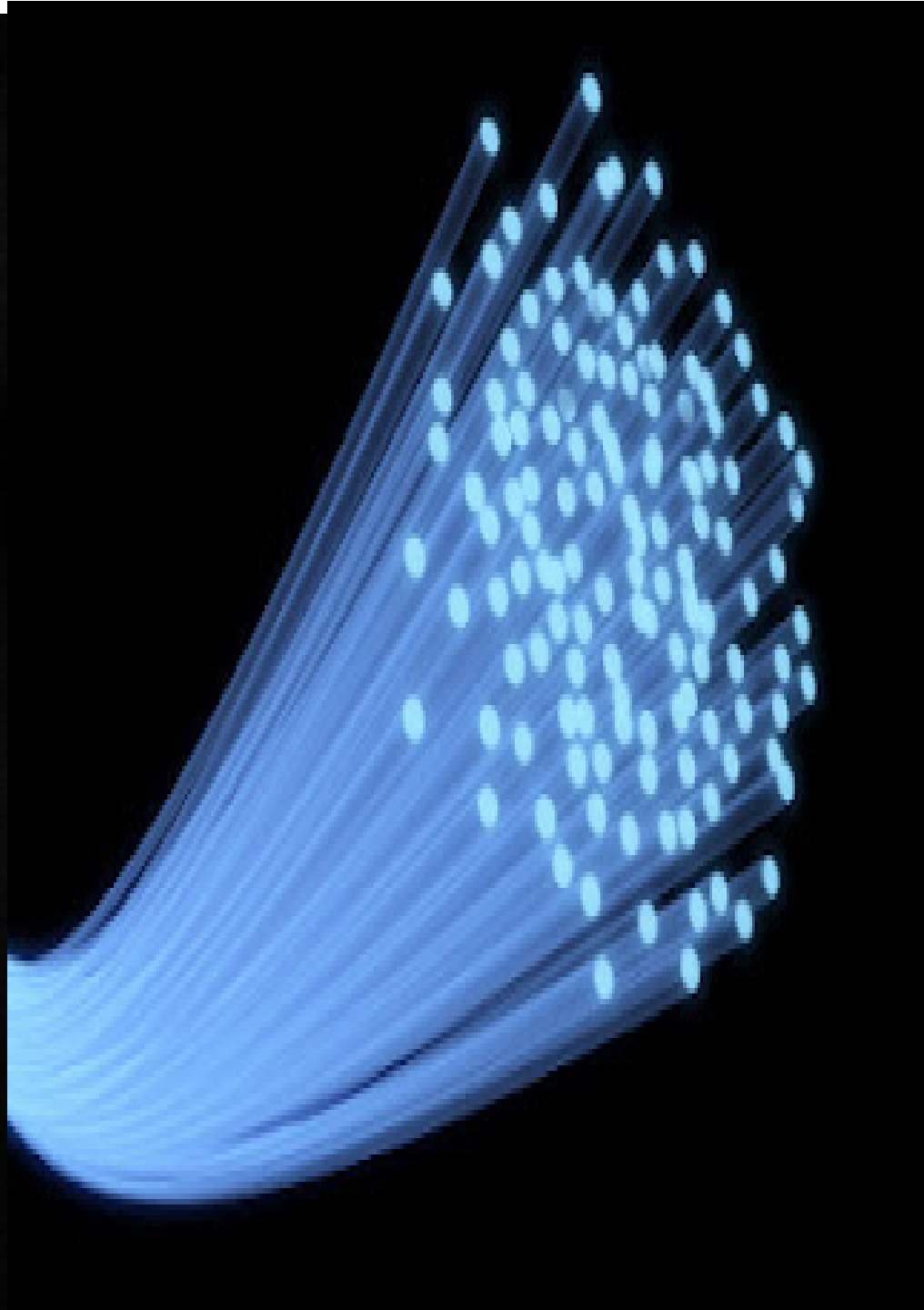




USES OF LED

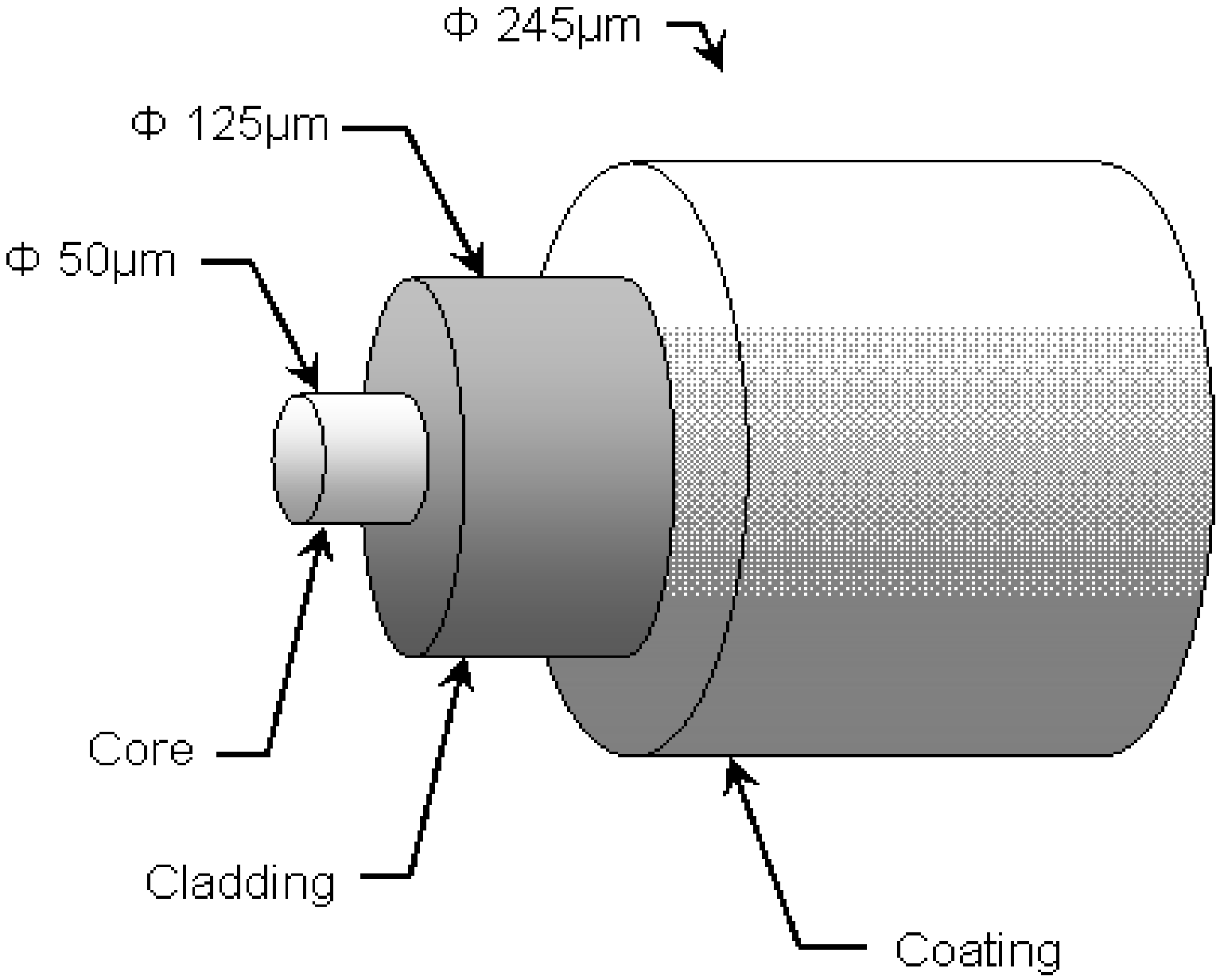
- Decorative lamps
- Pen drive
- All electronic appliances





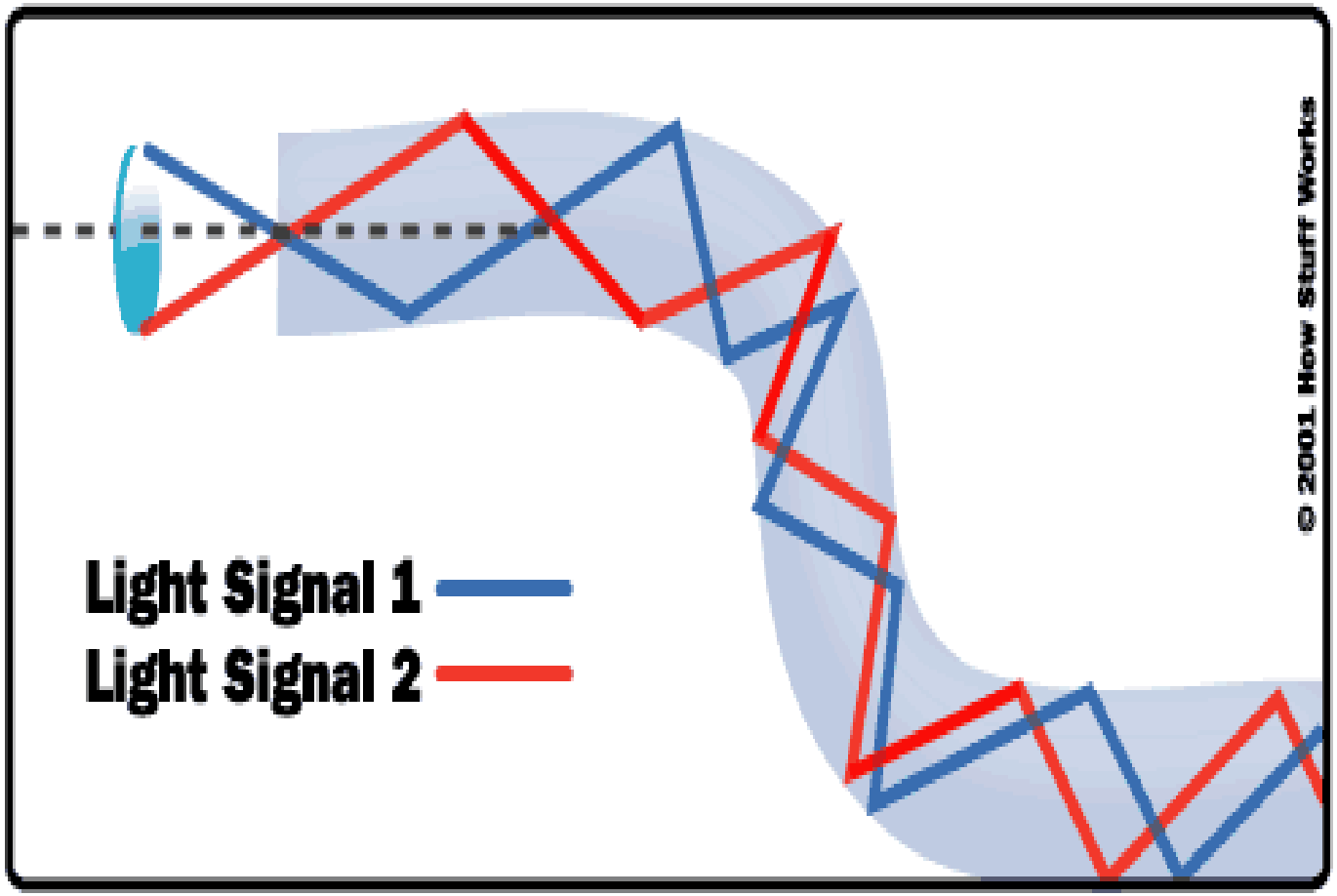
AREAS OF APPLICATION

- Telecommunications
- Local Area Networks
- Cable TV
- CCTV
- Optical Fiber Sensors
- Endoscopy


Φ 245μm
Φ 125μm
Φ 50μm
Core
Cladding
Coating

How Does Optical Fibre Transmit Light??

Total Internal Reflection in Fiber



Fibre Optics Relay Systems has

-Transmitter

-Optical Fibre

-Optical regenerator

-Optical Receiver

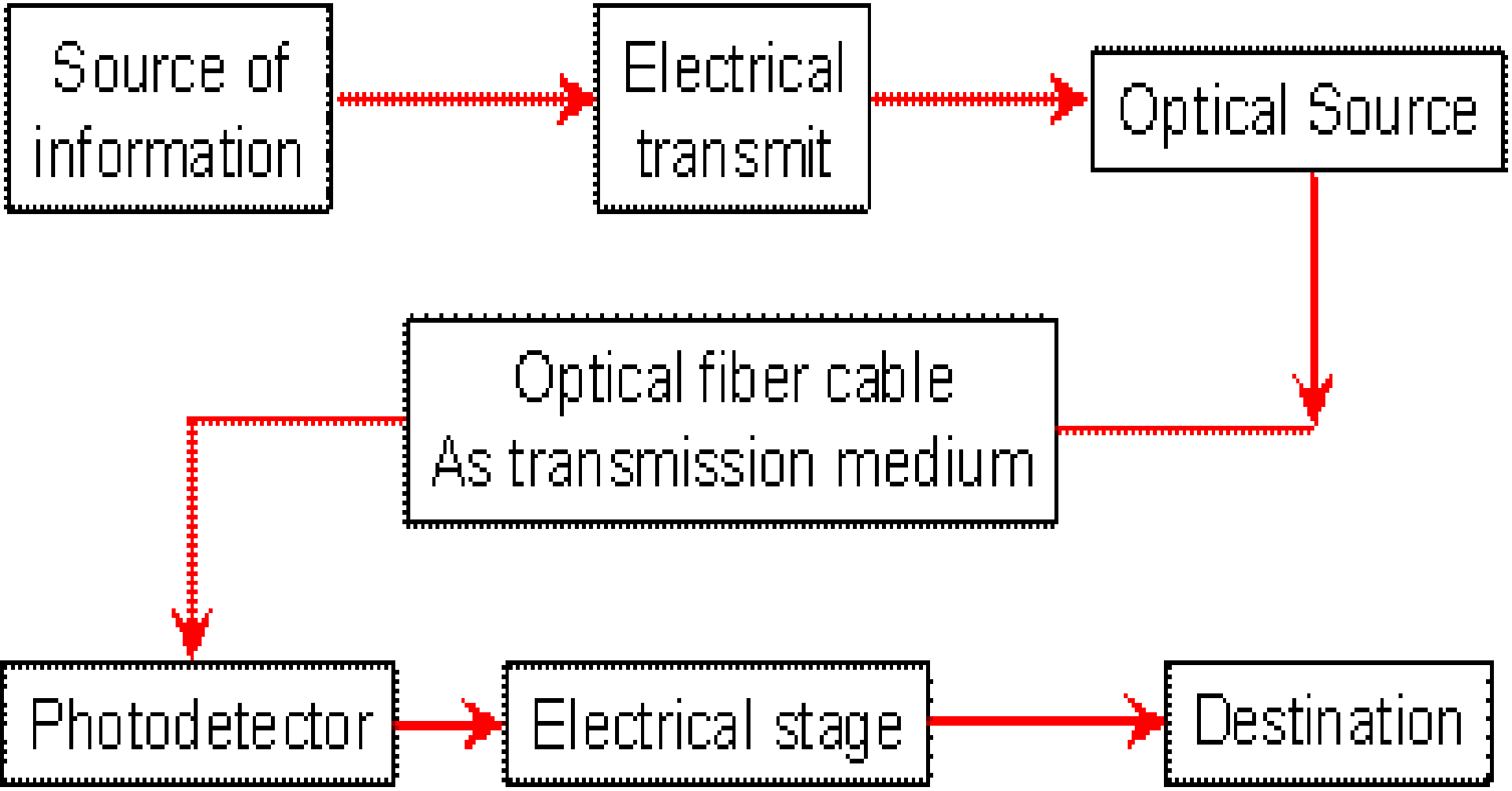
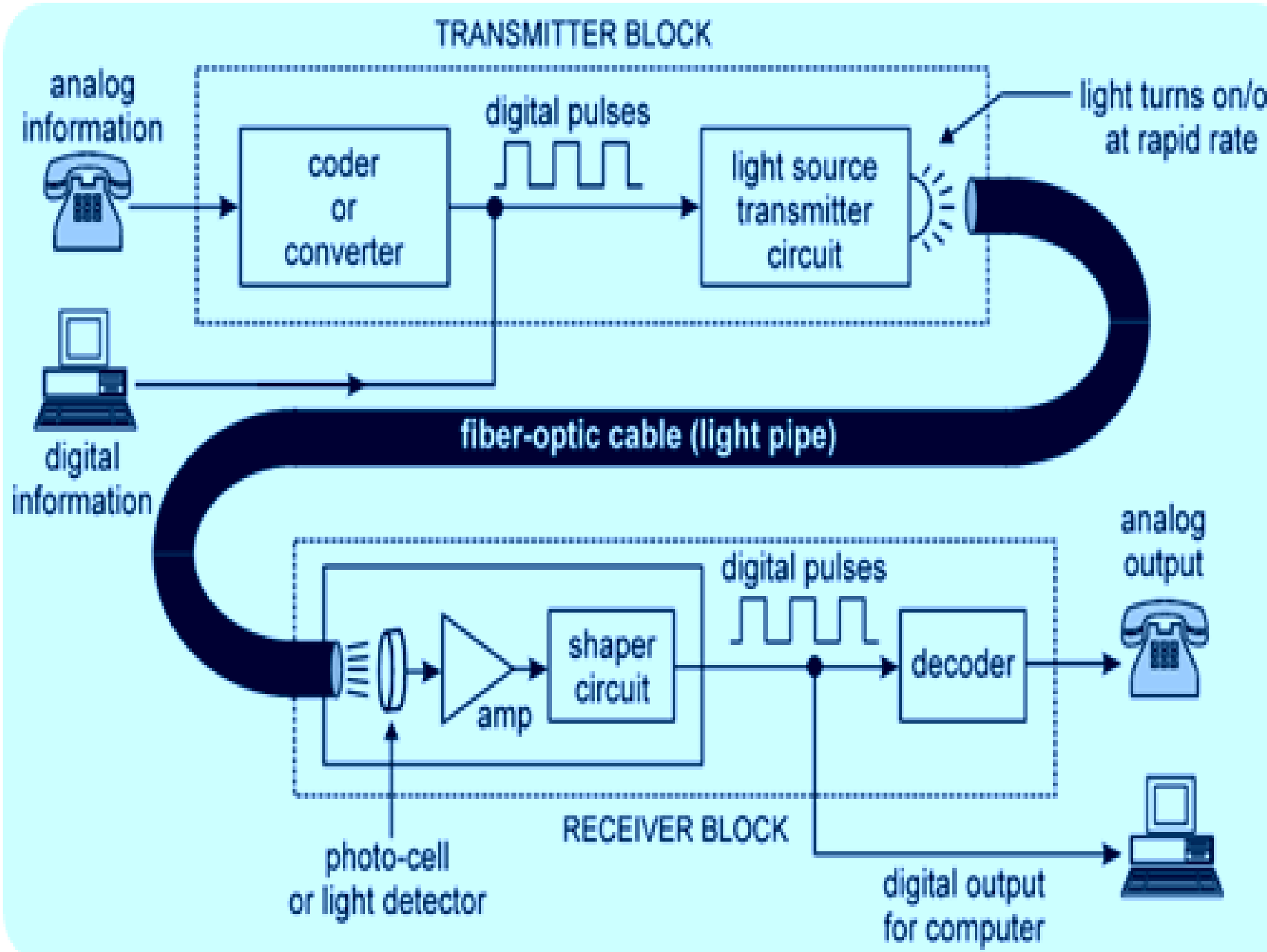

Source of information
Electrical transmit
Optical Source
Optical fiber cable As transmission medium
Photodetector
Electrical stage
Destination

FIGURE 9.


TRANSMITTER BLOCK
analog information
digital pulses
coder or converter
light source transmitter circuit
light turns on/off at rapid rate
digital information
fiber-optic cable (light pipe)
analog output
digital pulses
shaper circuit
amp
decoder
RECEIVER BLOCK
photo-cell or light detector
digital output for computer

TRANSMITTER SECTION

- its main function is to transmit the information signals like voice, video or computer in the form of light signals.
- the information at input is converted into digital signals by coder or converter circuit. This circuit is actually ADC .
- it converts analog signals into proportional digital signals. If the input signals are computer signals, they are directly connected to light source transmitter circuit.

Contd...

- The light source block is a powerful light source. It is generally a FOCUS type LED or low intensity laser beam source or in some cases infrared beam of light is also used. The rate, at which light source turns ON/OFF, depends on frequency of digital pulses. Thus, its flashing is proportional to digital input.
- digital signals are converted into equivalent light pulses and focused at one end of fiber-optic cable.

FIBER–OPTIC CABLE

- when light pulses are fed to one end of fiber-optic cable, they are passed on to other end. The cable has VERY LESS attenuation *(***loss due to absorption of light waves by scattering, non linear scattering, material absorption** and **fiber bends** *)* over a long distance.
- Its bandwidth is large; hence, its information carrying capacity is high.

RECEIVER SECTION

- At receiving end, a light detector or photocell is used to detect light pulses. It is a transducer, which converts light signals into proportional electrical signals.
- These signals are amplified and reshaped into original digital pulses, *(while reshaping, distortion & noise are filtered out)* with the help of shaper circuit.

Contd...

- Then the signals are connected to decoder. It is actually ADC circuit *(Analog to Digital Converter)*, which converts digital signals into proportional analog signals like voice, video or computer data.
- Digital signals for computer can be directly taken from output of shaper circuit.

Contd...

this total unit is used for fiber optic communication system. However if the distance between transmitter and receiver is very large, then REPEATER UNITS are used.

- Due to repeaters signals attenuation is compensated. For this, light signals at far end are converted into electrical signals, amplified and retransmitted. Such repeater unit is also called RELAY STATION.

ADVANTAGES OF OPTICAL FIBRE

- Thinner
- Less Expensive
- Higher Carrying Capacity
- Less Signal Degradation& Digital Signals
- Light Signals
- Non-Flammable
- Light Weight

BENEFITS OF OPTICAL FIBER COMMUNICATION SYSTEM

- Some of the innumerable benefits of optical fiber communication system are:
- Immense bandwidth to utilize
- Total electrical isolation in the transmission medium
- Very low transmission loss,
- Small size and light weight,
- High signal security,
- Immunity to interference and crosstalk,
- Very low power consumption and wide scope of system expansion etc.

Testing of Optical Fiber

- Tensile Strength
- Refractive Index Profile
- Fiber Geometry
- Information Carrying Capacity
- Operating temperature/humidity range
- Ability to conduct light under water
- Attenuation

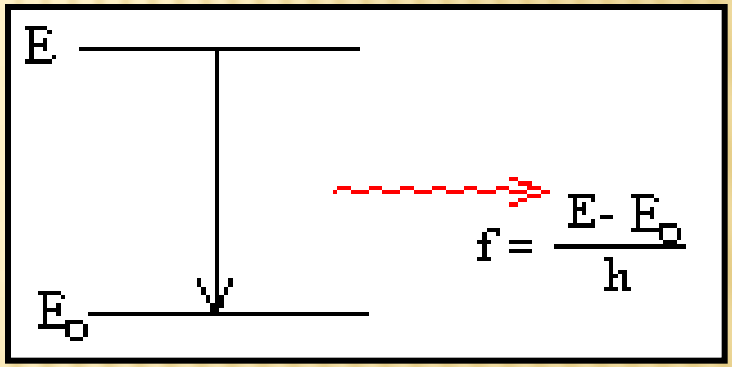
1950s Laser-Eyed Monster

WHAT IS LASER?

- **A laser is a device that produces a beam of monochromatic light in which all the waves are in phase or are coherent.**

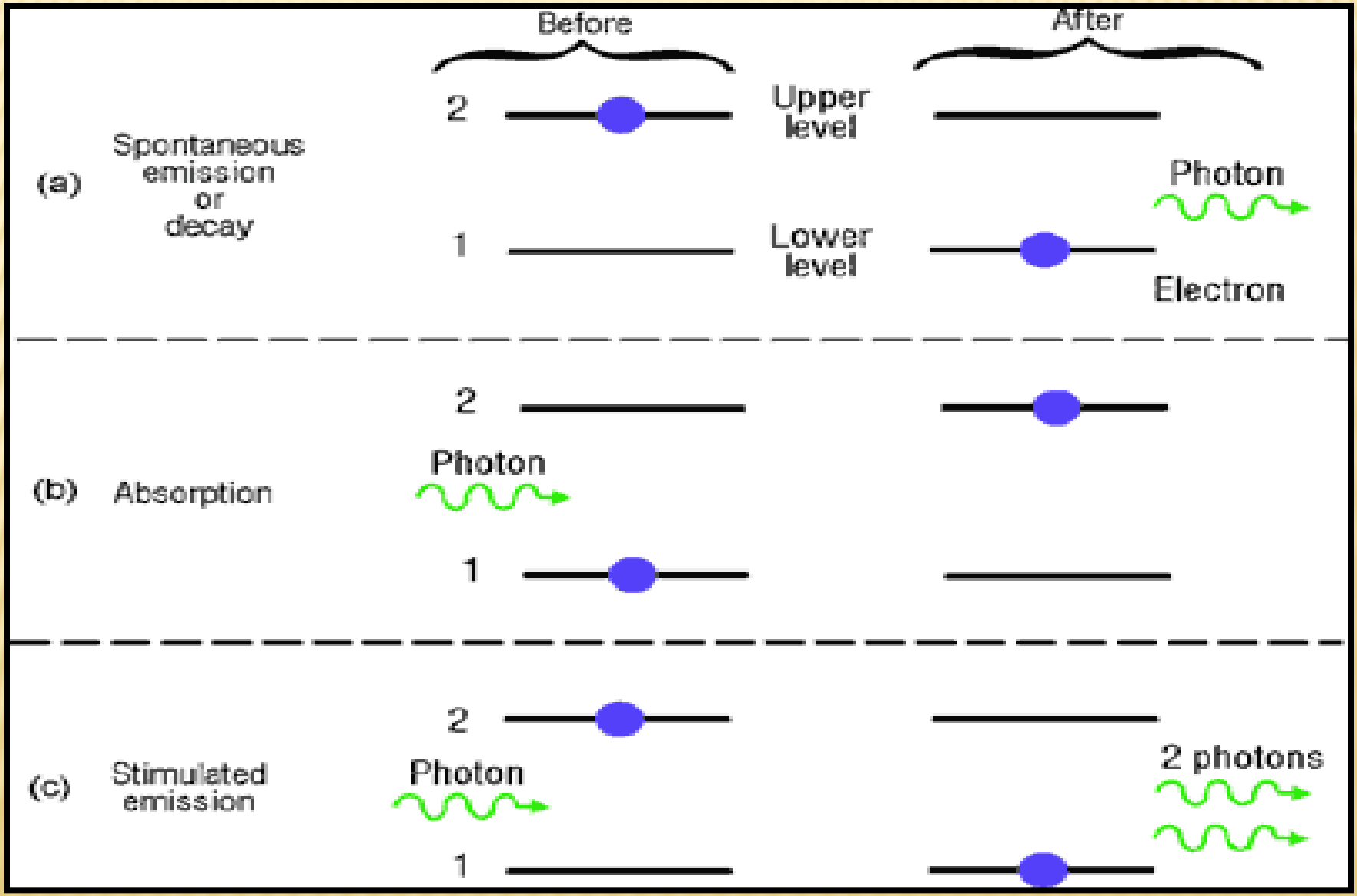
► If an atom or molecule lies in an energy state that is higher than the lowest, or ground level state, it can spontaneously drop to a lower level without any outside stimulation.

► One possible result of dropping to a reduced energy state is the release of the excess energy (equaling the difference in the two energy levels) as a photon of light.



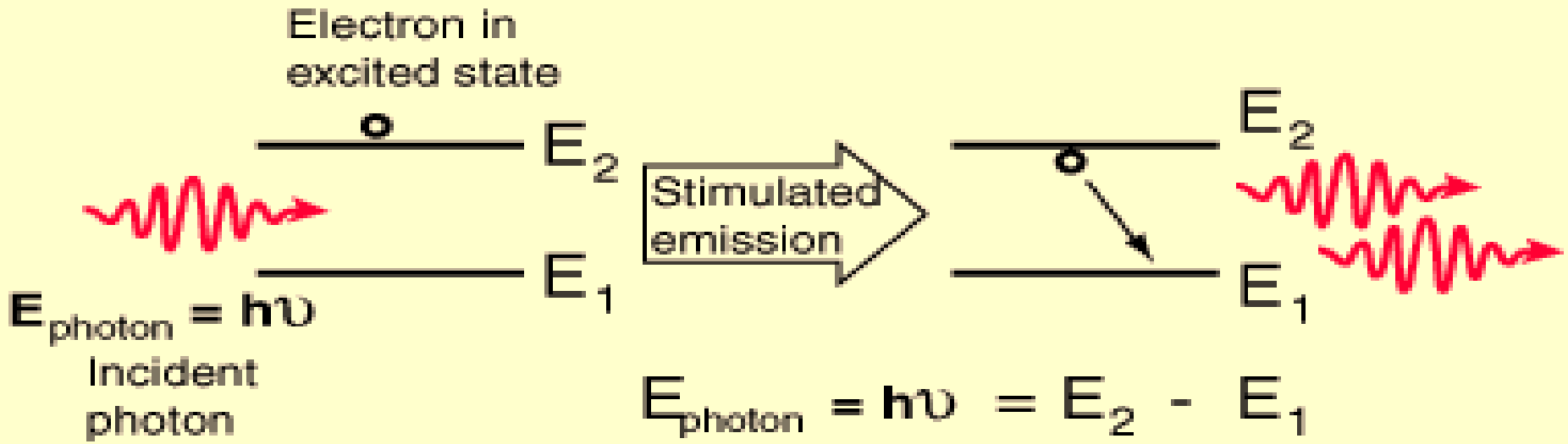
► Excited atoms or molecules have a characteristic spontaneous emission time, which is the average time that they remain in the excited higher energy state before they drop to a lower energy level and emit a photon.

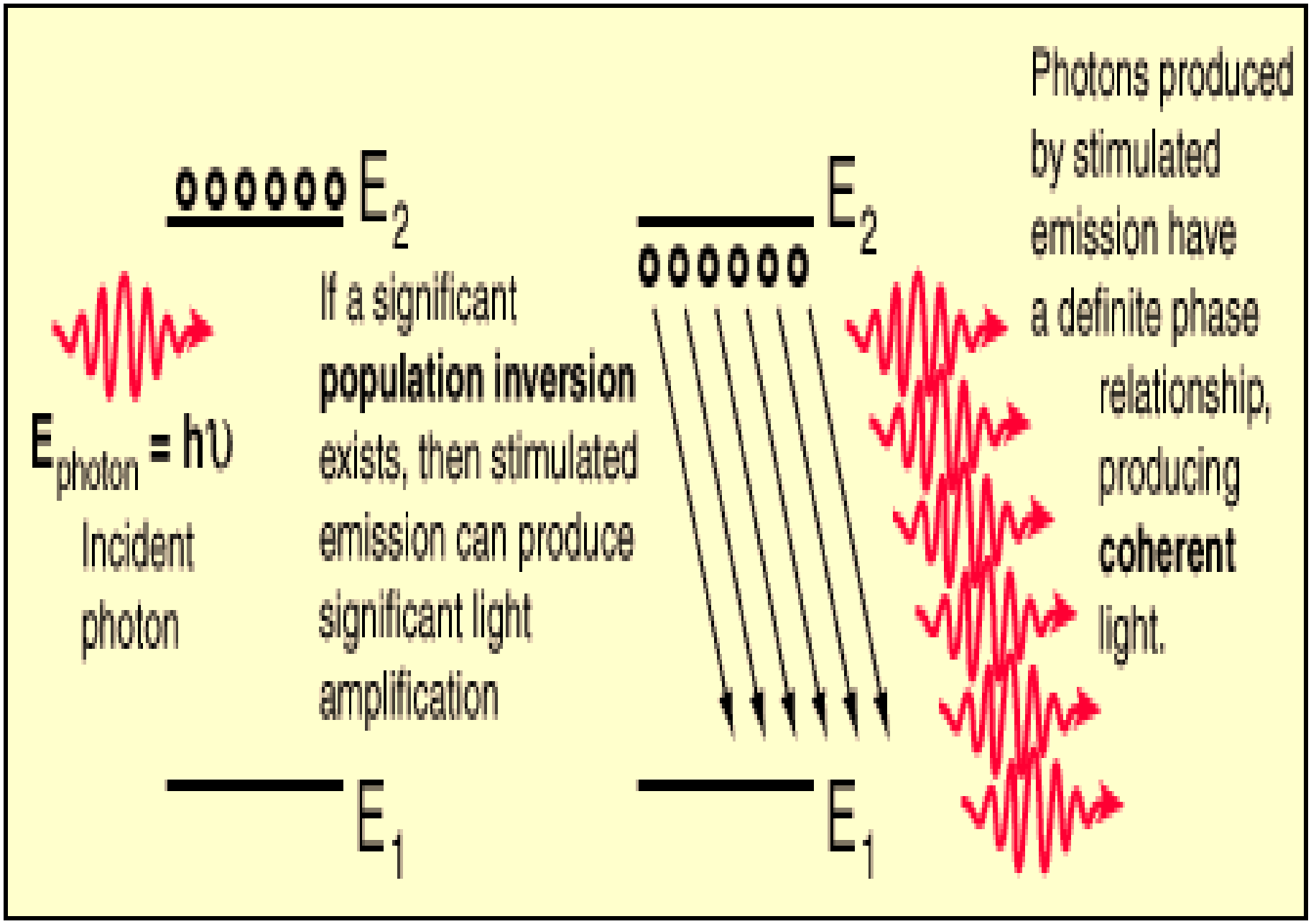
Spontaneous and Stimulated Processes



While in the excited state, if the atom is illuminated with an incoming photon having exactly the same energy as the transition that would spontaneously occur, the atom may be stimulated by the incoming photon to return to the lower state and simultaneously emit a photon at that same transition energy.

- A single photon interacting with an excited atom can therefore result in two photons being emitted.

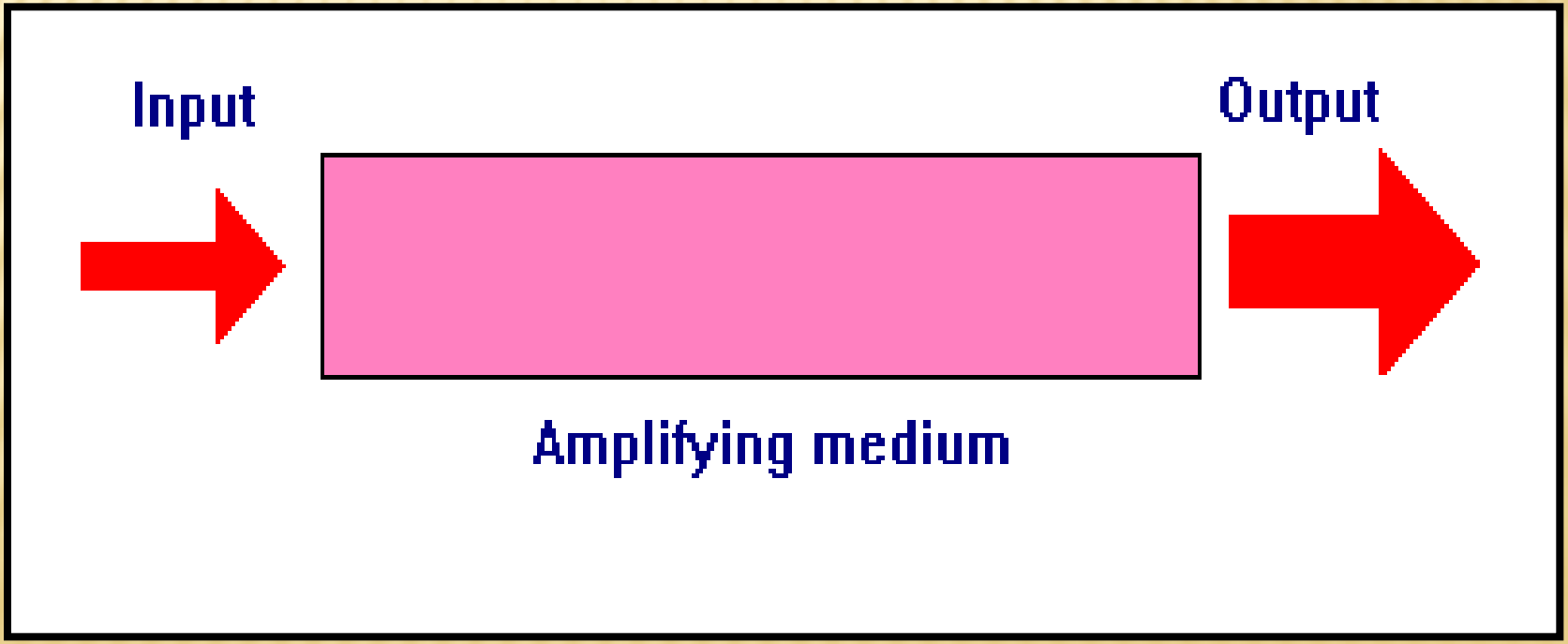



E2
E1
Ephoton = hυ
Incident photon
If a significant population inversion exists, then stimulated emission can produce significant light amplification
E2
E1
Photons produced by stimulated emission have a definite phase relationship, producing coherent light.

All Lasers Contain FOUR Primary Components:

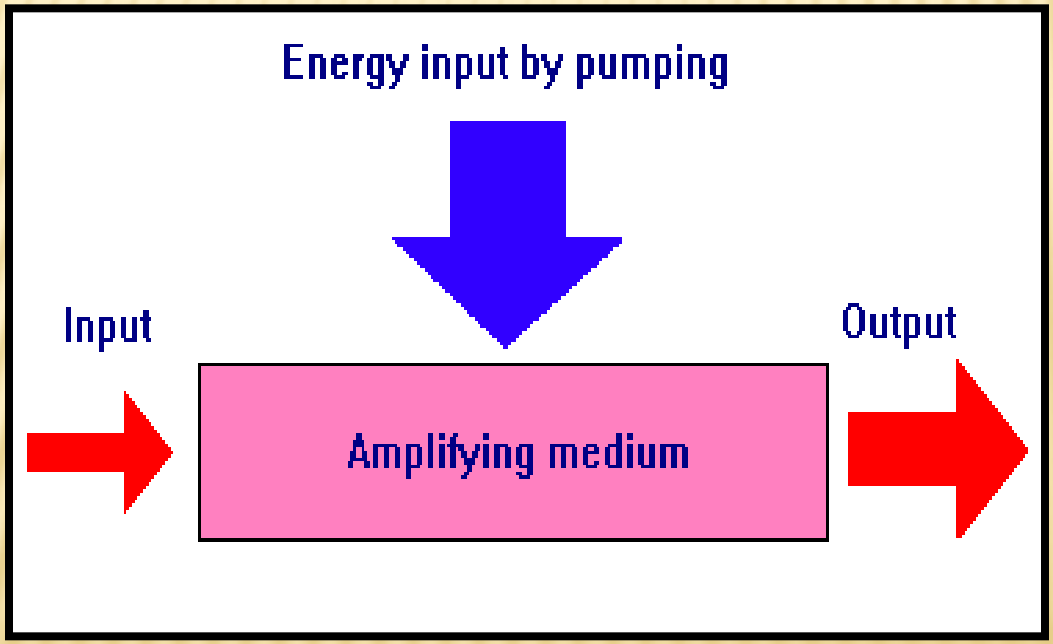
1. *Active Medium:*

- The active medium may be solid crystals such as Ruby or Nd:YAG, liquid dyes, gases like CO_2 or He/Ne, or semiconductors such as GaAs.
- Active mediums contain atoms whose electrons may be excited to an elevated energy level by an external energy source.



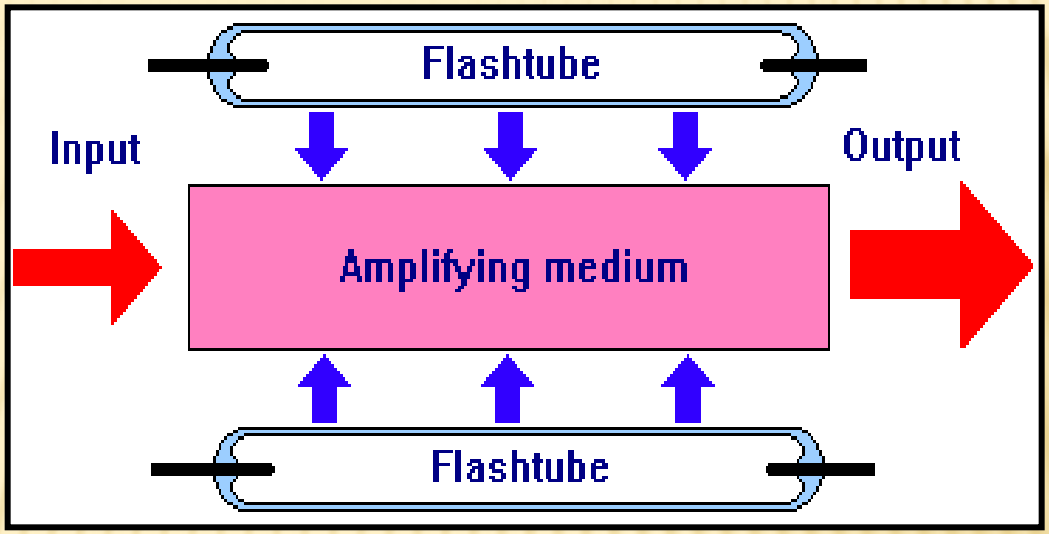
2. Excitation Mechanism:

- Excitation mechanisms pump energy into the active medium by one or more of three basic methods; optical, electrical or chemical

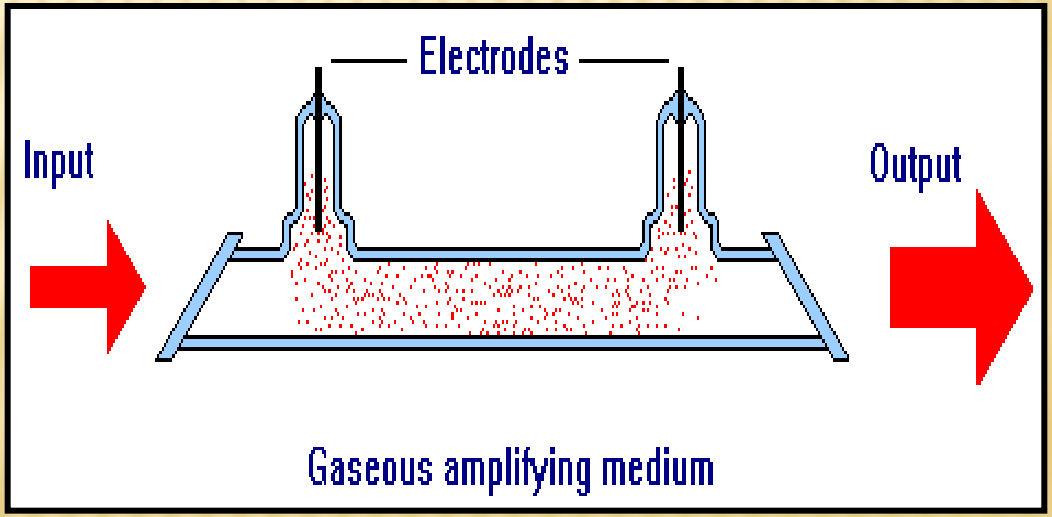


Examples of pumping an amplifying medium:

Optical pumping



Gas Discharge

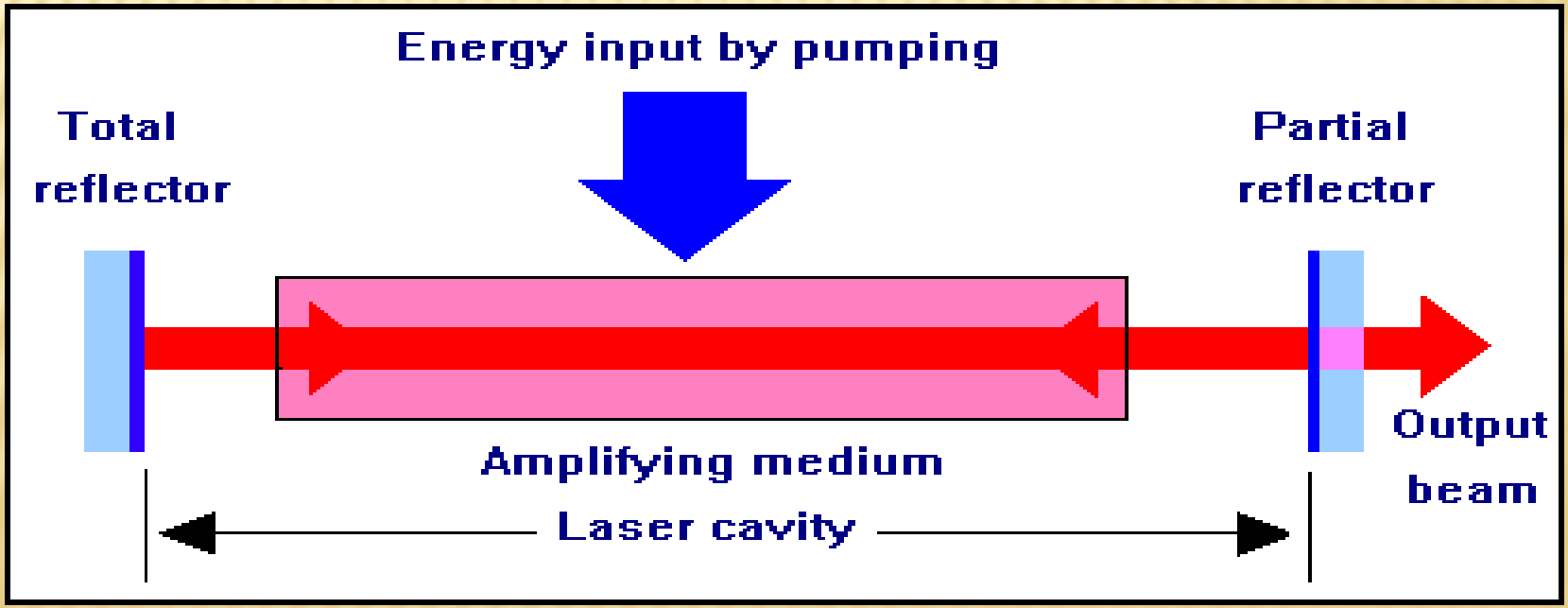


3. High Reflectance Mirror :

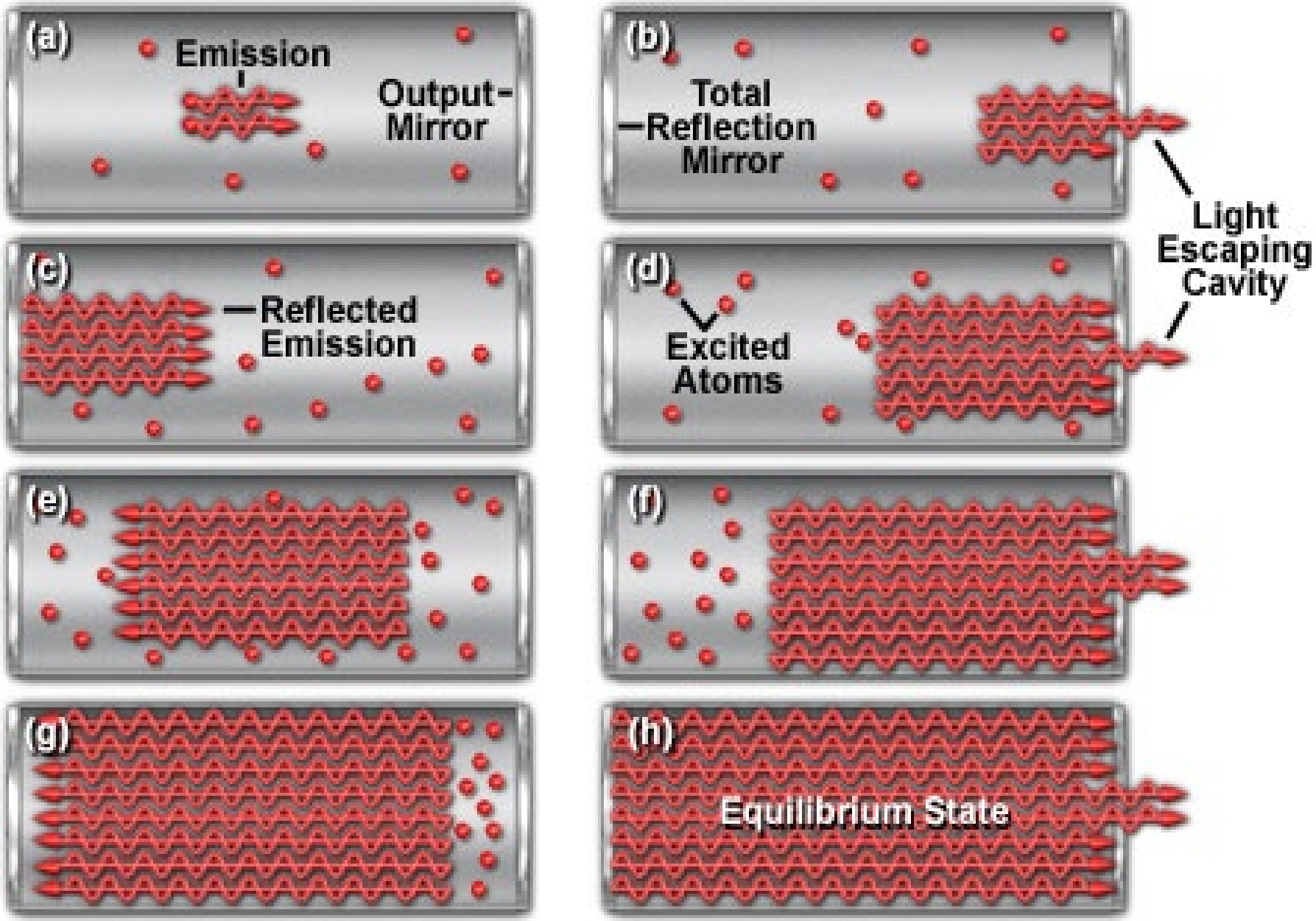
- A mirror which reflects essentially 100% of the laser light.

4. *Mirror Allowing Partial Transmission:*

- A mirror which reflects less than 100% of the laser light and transmits the remainder.



Stimulated Emission in a Mirrored Laser Cavity



Laser Gain

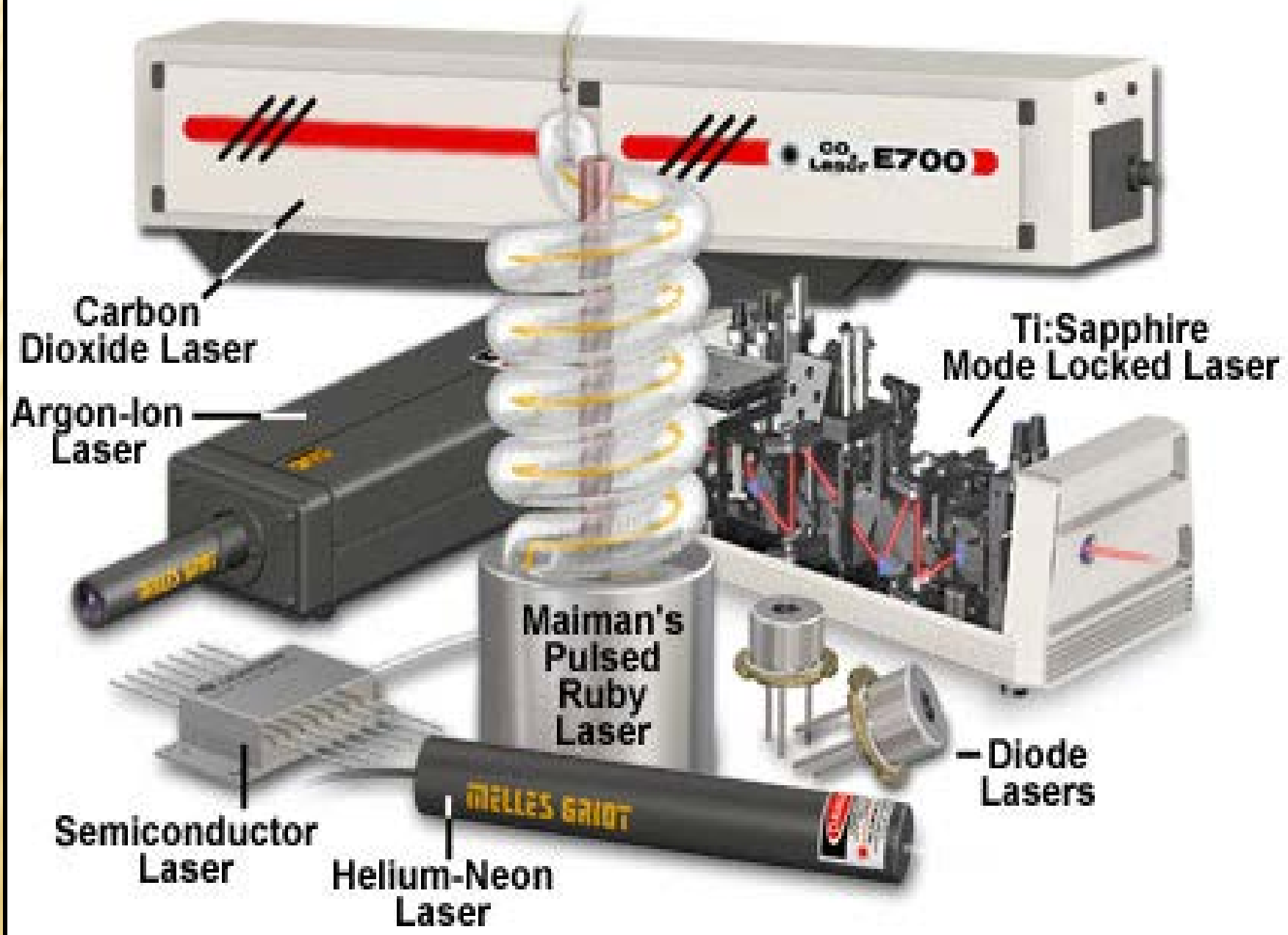
- The output power of the laser at specific moment is determined by two conflicting factors:
  1. Active medium gain - which depends on:
     a) Population Inversion,
     b) Fluorescence line-shape of the spontaneous emission that is related to the lasing transition.
  2. Losses in the laser, which include:
     a) Reflections from end mirrors
     b) Radiation losses inside the active medium due to absorption and scattering.
     c) Diffraction losses - Due to the finite size of the laser components.

Properties of Laser Radiation

- The photon which is emitted in the stimulated emission process is identical to the incoming photon. They both have:
  1. Identical wavelengths (and thus, frequencies) - *Monochromaticity.*
  2. Identical directions in space – *Directionality*.
  3. Identical phase - *Coherence.*

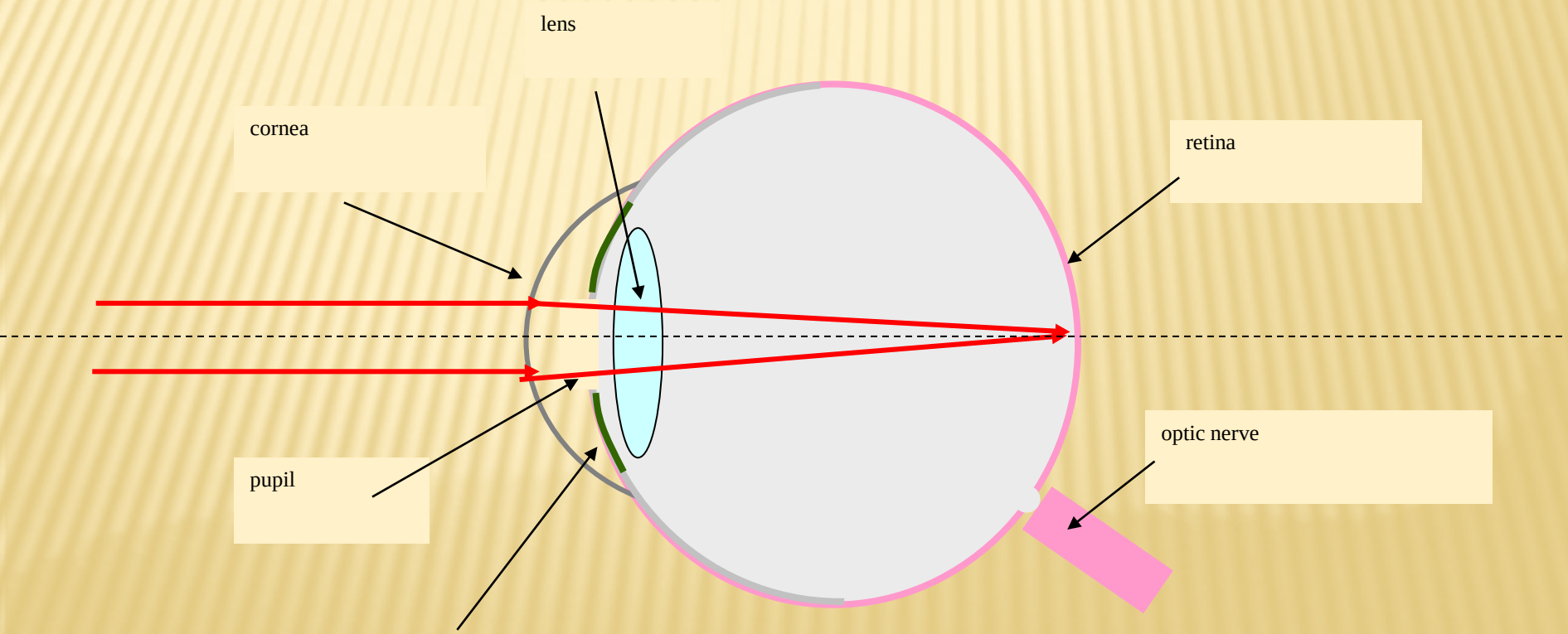
- Laser radiation is characterized by these properties which are not present in other electromagnetic radiation.

Common Laser System Configurations



Laser Eye Hazards

The eye is the part of the body most vulnerable to laser hazards. Changes to the eye can occur at much lower laser power levels than changes to the skin. And, eye injuries are generally far more serious (life altering) than injuries to the skin.



The **cornea** is the outermost, transparent layer. It covers the front of the eye. The cornea can withstand dust, sand, and other assaults from the environment. That's partly because corneal cells replace themselves in about 48 hours. Thus, mild injuries to the cornea are healed quickly.

The **aqueous humor** is a liquid (mostly water) between the cornea and the lens. The water in the aqueous humor absorbs heat, so it protects the internal portion of the eye from thermal (heat) radiation. The index of refraction is approximately 1.33, same as water.

The **lens** of the eye is a flexible tissue that changes shape. In conjunction with the cornea, the lens focuses light on the back of the eye. When the lens changes shape, its focal length changes. This lets the eye focus on both near and far objects.

The **iris** controls the amount of light that enters the eye. The iris is the pigmented or colored part of the eye. It responds to light intensity by adjusting its size. The change in iris size adjusts pupil size and controls the amount of light admitted to the eye.

The **pupil** is the opening in the center of the iris through which light passes. The size of a pupil changes from about 2 mm to 7 mm, according to the brightness of light in the environment. The darker the environment, the larger the pupil. A fully dilated pupil (expanded to admit the greatest amount of light) is considered to be about 7 mm.

The **vitreous humor** is a colorless gel that fills the large area at the center of the eyeball. The vitreous humor helps to maintain the shape of the eye.

The **retina** is the light-sensitive layer located at the back of the eye. The retina contains two types of photoreceptor (light-receiving) cells: rods and cones. These cells convert the optical image produced by the lens into electrical signals. The signals then are transmitted to the brain.

The **fovea** is the most sensitive, central part of the retina. It's the area responsible for the most detailed vision. A foveal lesion caused by laser radiation is a worst-case scenario for vision.

The **optic nerve** carries electrical impulses from the retina to the brain.

Absorption of Light by the Eye

Laser Wavelength Region

IR-C = 1 mm to 1400 nm

IR-B = 3000 nm to 1400 nm

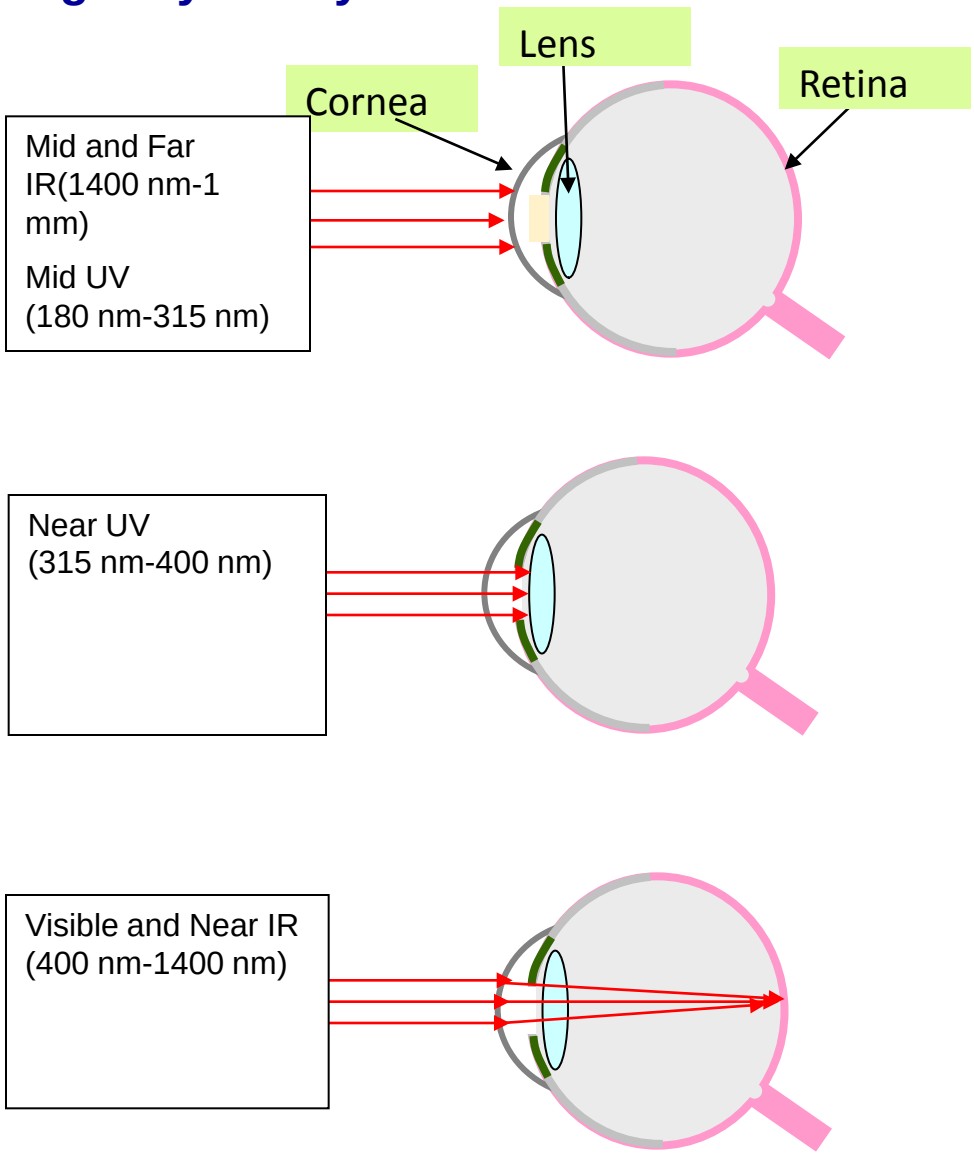
IR-A = 1400 nm to 700 nm

Visible light = 700 nm to 400 nm

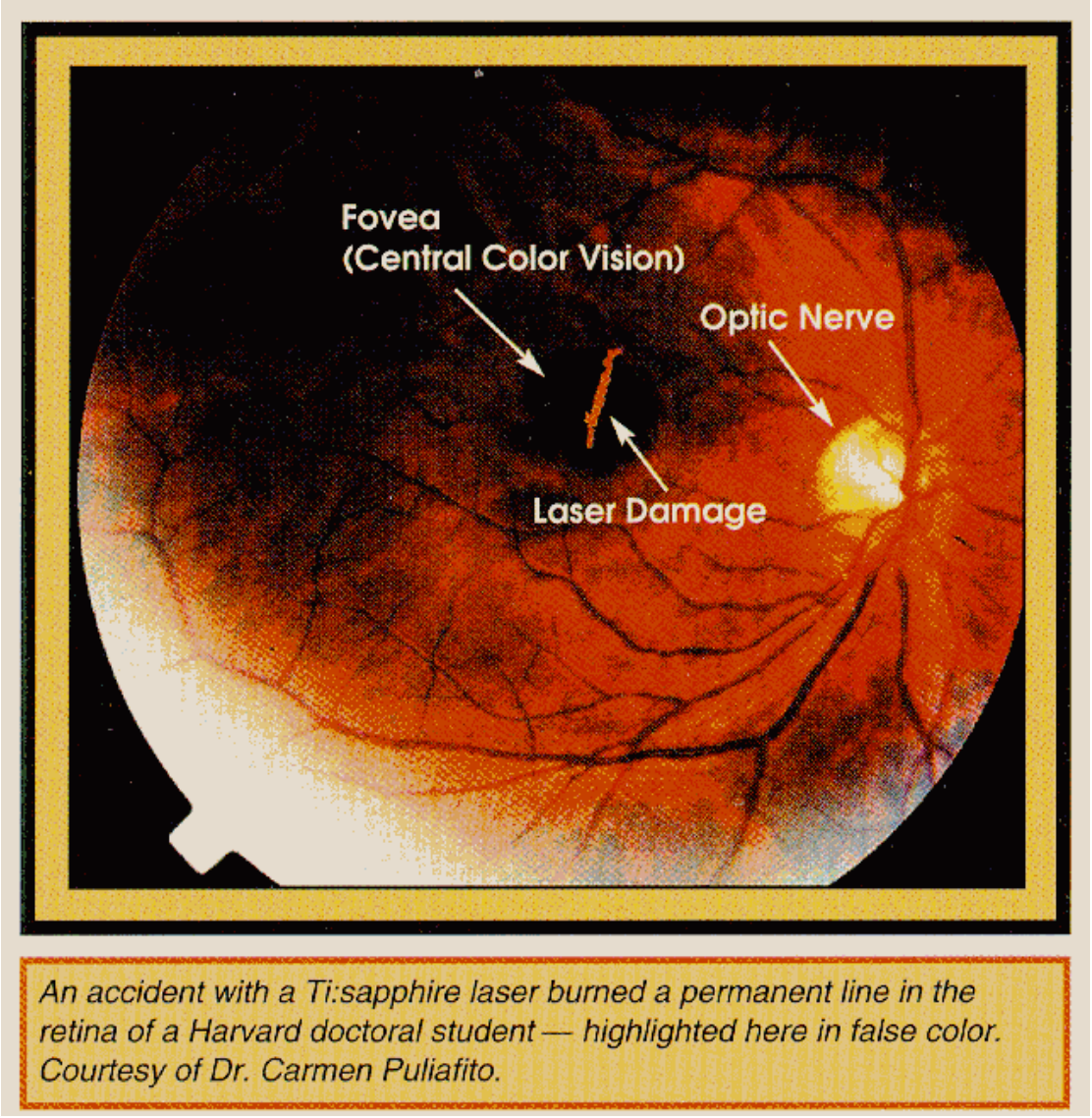
UV-A = 400 nm to 315 nm

UV-B = 315 nm to 280 nm

UV-C = 280 nm to 100 nm



Example of retinal damage due to laser exposure



An accident with a Ti:sapphire laser burned a permanent line in the retina of a Harvard doctoral student — highlighted here in false color. Courtesy of Dr. Carmen Puliafito.

LASER SKIN HAZARDS

- **Thermal hazards (skin burns) from high level of optical radiationelerated aging and risk of skin cancer) due to ultraviolet radiation**

- **Laser safety eyewear**

- **Photochemical hazards (accis *required* when class 3b and 4 lasers are in use.**

It is important to wear safety eyewear *all the time* when using class 3b and 4 lasers.

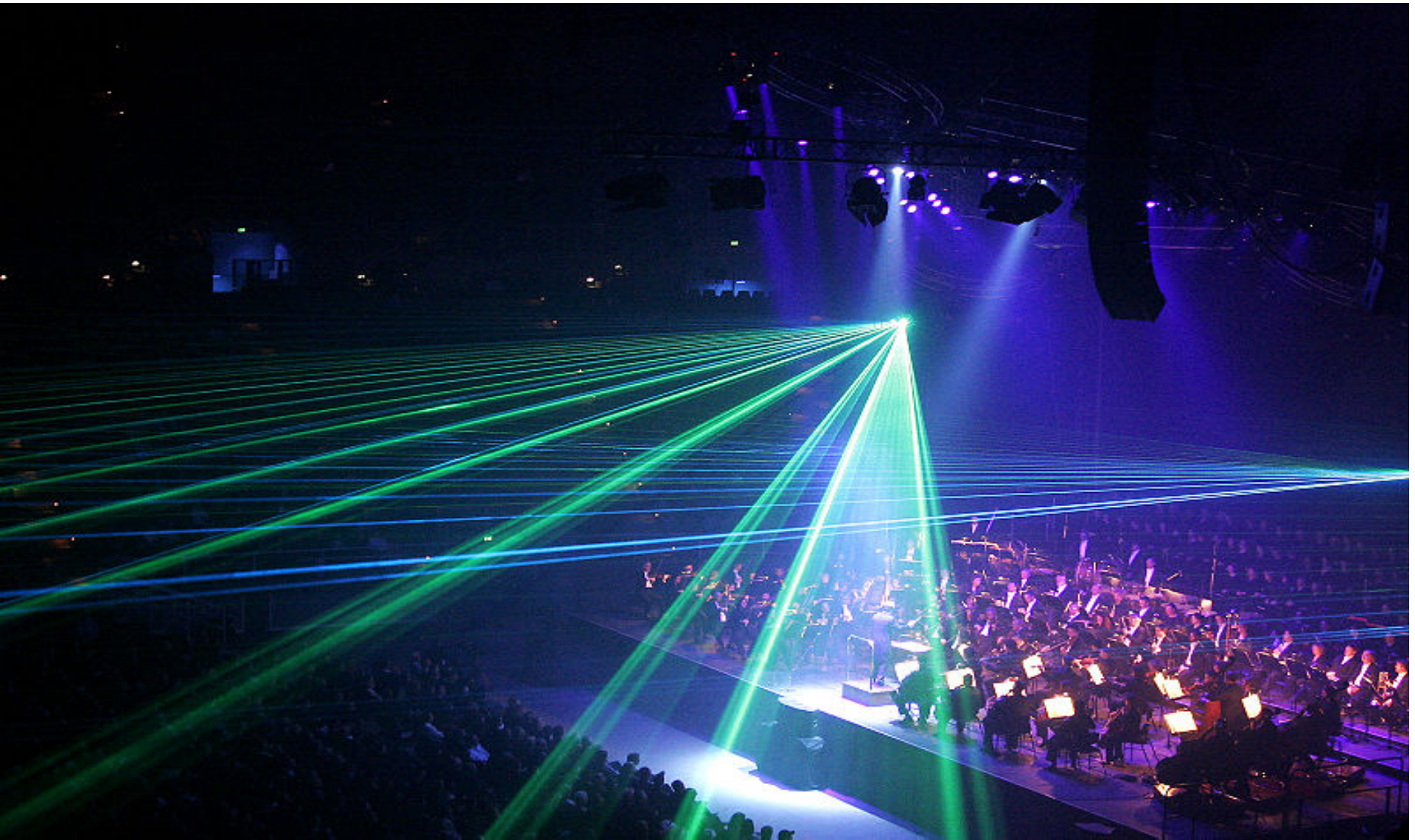
If the eyewear prevents seeing the beam during alignment

CAROL DIDN’T USE HER SAFETY EYEWEAR..

…..NOW SHE DOESN’T NEED IT.

APPLICATIONS OF LASER?

LASER LIGHT SHOW



Argon: 488 nm (Turquoise/Cyan) or 514.5 nm (Cyan) (no longer used for hair removal)

Ruby laser: 694.3 nm (Deep Red) (no longer used for hair removal; only safe for patients with very pale skin) [9]

Alexandrite: 755 nm (Near-Infrared) (most effective on pale skin and not safe on darker skin at effective settings)

Pulsed diode array: 810 nm (Near-Infrared) (for pale to medium type skin)

Nd:YAG laser: 1064 nm (Near-Infrared) (made for treating darker skin types, though effective on all skin types

CONCLUSION

- Light is the natural source , which gives man happiness and a healthy mind
- The generation, transport, manipulation, detection, and use of light are at the heart of photonics.
- Photonics is a critical part of the future and a growing career field.
- To work in photonics, it is necessary to have a basic understanding of the nature of light and its properties.

THANK YOU