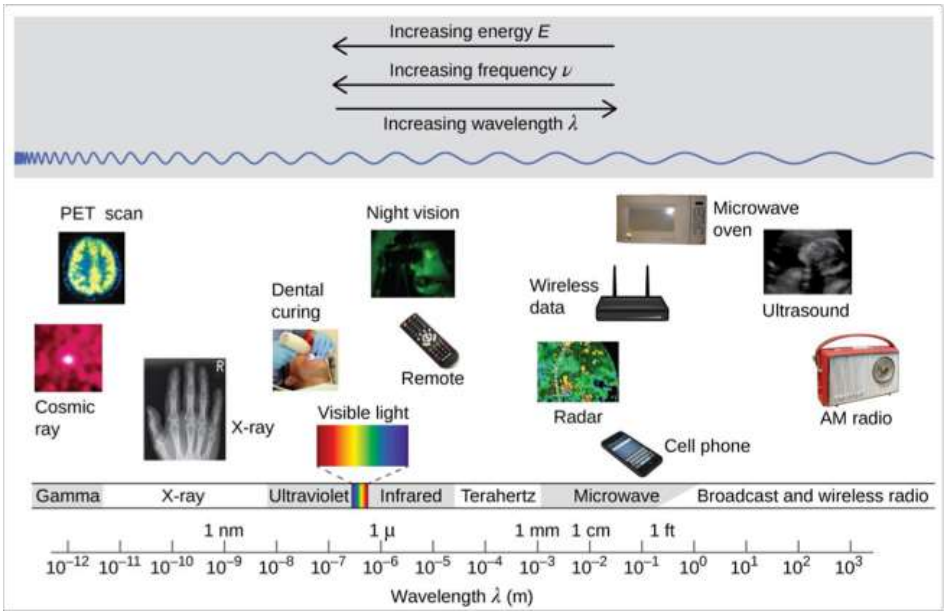
Light in Medicine

○ Introduction to Light

- Light is a form of electromagnetic radiation.
- Speed of light = 3 x 10^8 m/s
- Light represents energy transfer from the source to the observer.



○ Spectrum of light

Before the beginning of the nineteenth century, light was considered to be a stream of particles.In view of other developments in the 20thcentury, light must be regarded as having a dual nature.

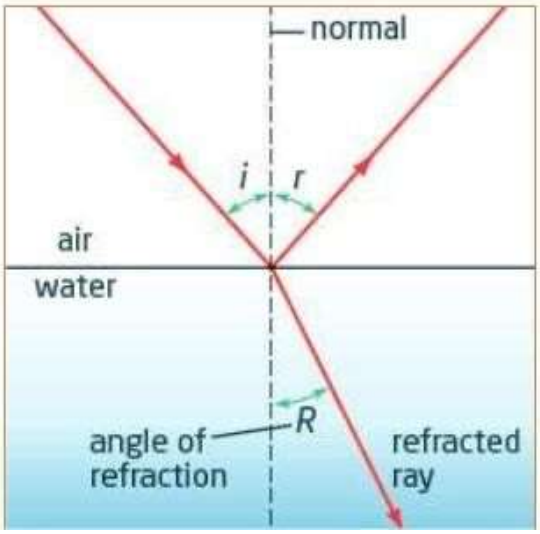
Light has some interesting properties, many of which are used in medicine:

1. The speed of light changes when it goes from one material into another. The ratio of the speed of light in a vacuum to its speed in a given material is called the index of refraction. If a light beam meets a new material at an angle other than perpendicular, it bends, or is reflected. This property permits light to be focused and is reason we can read and see objects clearly.

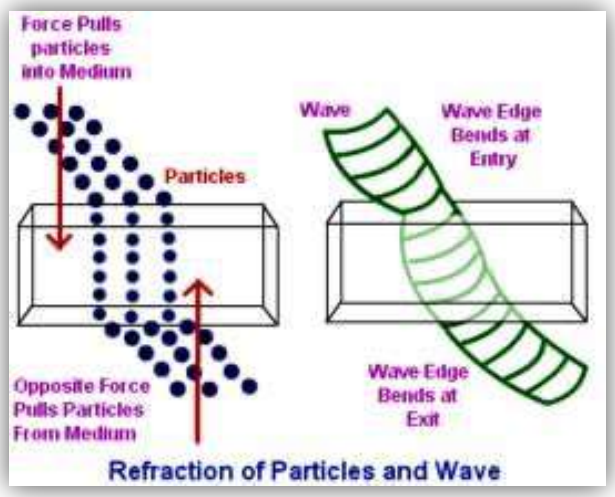
ANGLE OF REFRACTION

- **Refracted ray:** ray of light that is bent when entering a second medium

- **Angle of refraction:** angle between the normal and refracted ray



2. Light behaves both as a wave and as a particle.



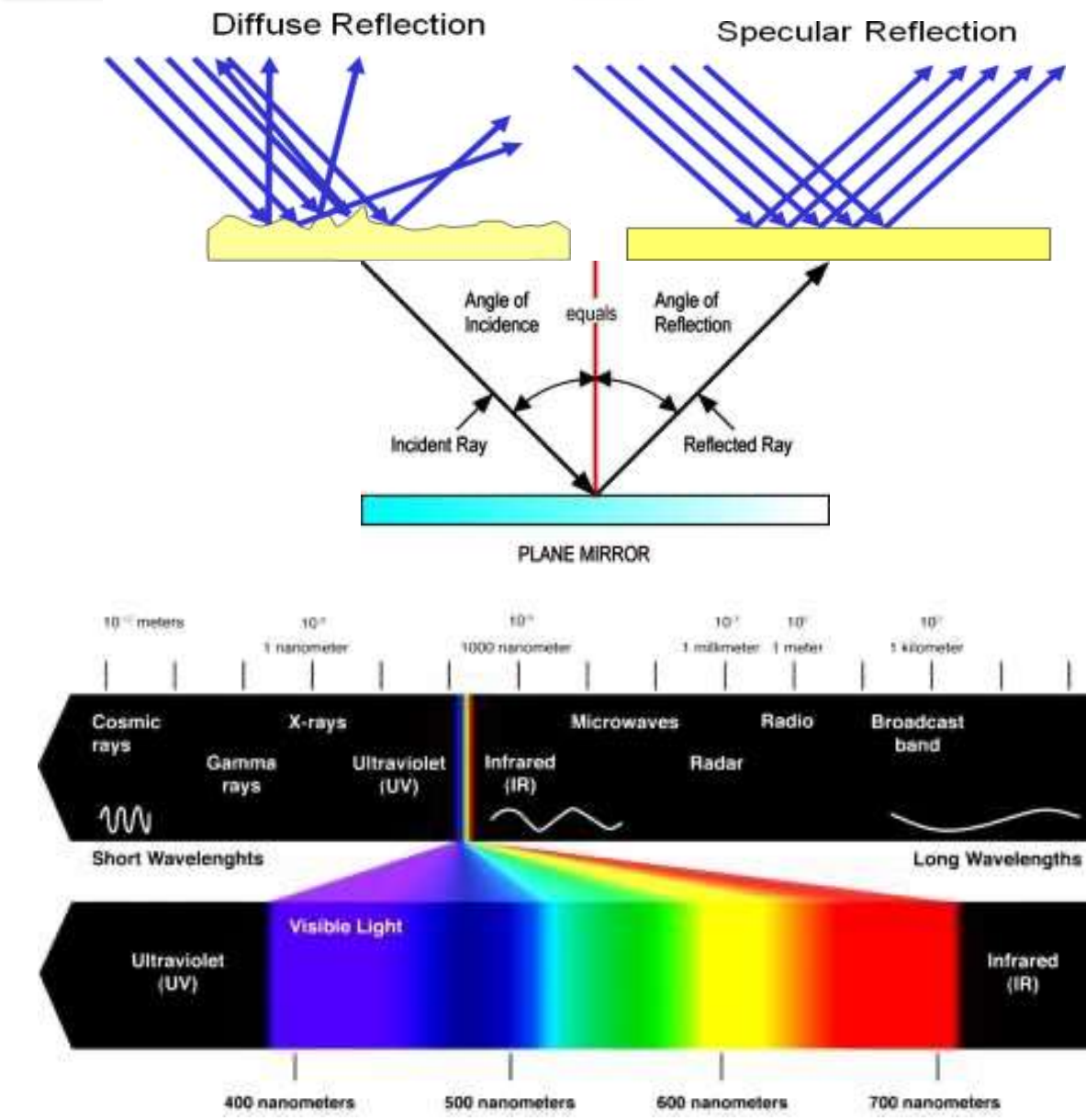
- Like a wave, it produces interference, diffraction, which are of minor importance in medicine.
- As a particle, it can be absorbed by a single molecule. when the alight photon is absorbed in its energy in various ways.

It can cause a chemical change in the molecule that in turn can cause an electrical change. This is basically what happens when a light photon is absorbed in one of the sensitive cells of the retina (the light-sensitive part of the eye). The chemical change in a particular point of the retina triggers an electrical signal to the brain to inform it that a light photon has been absorbed at that point.

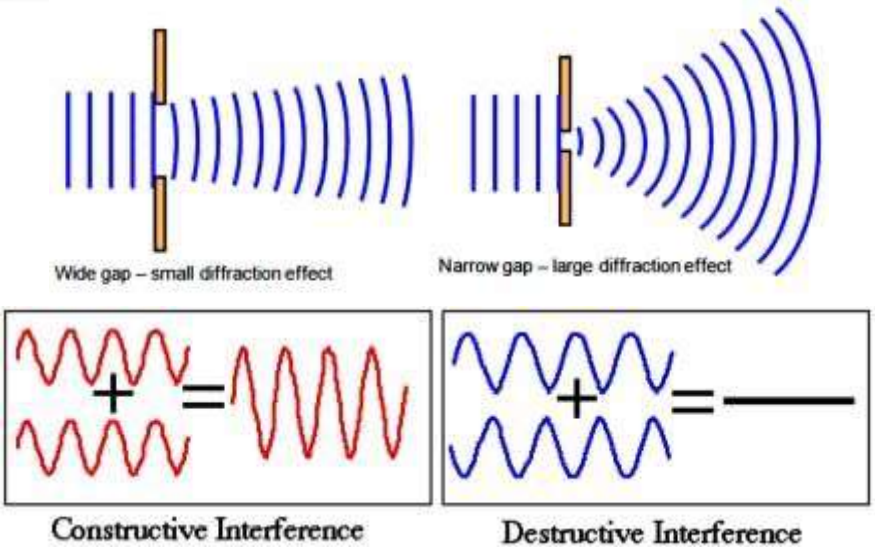
3. When light is absorbed its energy generally appears as heat. This property is the basis for the use in medicine of IR light to heat tissues. Also, the heat produced by laser beams is used to "weld" a detached retina to the back ofthe eyeball and to coagulate small blood vessels in the retina.

4. Sometimes when a light photon is absorbed, a lower energy light photon is emitted. This property is known as fluorescence. Certain materials fluoresce in the presence of UV light, sometimes called "black light" and give off visible light. The amount of fluorescence and the color of the emitted light depend on the wavelength of the UV light and on the chemical composition of the material that is fluorescing. One way fluorescence is used in medicine is in the detection of porphyria, a condition in which the teeth fluoresce red when irradiated with UV light.

5. Light is reflected to some extent from all surfaces. There are two types of reflection diffuse and specular as shown in figure below. Diffuse reflection occurs when rough surfaces scatter the light in many directions. Specular reflection is a more useful type of reflection; it is obtained from very smooth shiny surfaces such as mirrors where the light is reflected at an angle that is equal to the angle at which it strikes the surface. Mirrors are used in many medical instruments. One simple instrument is a mirror that is held at the back of a patient's throat to look at his vocal folds.

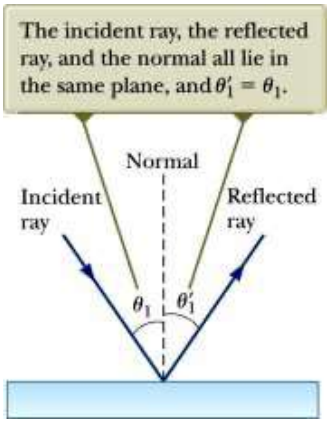


Ray optics: (Sometimes-called geometric optics) involves the study of the propagation of light. It uses the assumption that light travels in a straight-line path in a uniform medium and changes its direction when it meets the surface of a different medium.



- Law of Reflection

- The normal: is a line perpendicular to the surface.
- The angle of reflection is equal to the angle of incidence.
- $\theta_1` = \theta_1$This relationship is called the Law of Reflection.
- The incident ray, the reflected ray and the normal are all in the same plane.



- Refraction of Light

When a ray of light traveling through a transparent medium encounters a boundary leading into another transparent medium, part of the energy is reflected and part enters the second medium and changes its direction of propagation at the boundary.This bending of the ray is called refraction.

The angle of refraction depends upon the material and the angle of incidence.

$$\frac{\sin \theta_2}{\sin \theta_1} = \frac{v_2}{v_1}$$

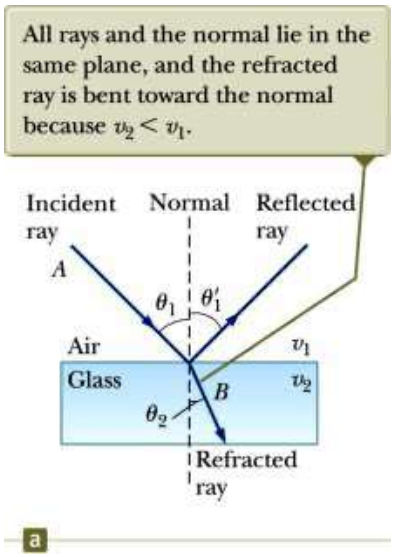
Where:

-v_1 is the speed of the light in the first medium.

-v_2 is its speed in the second medium.

-$\theta_1$is the angle of incidence ray.

-$\theta_2$is the angle of refraction ray.



The speed of light in any material is less than its speed in vacuum. The index of refraction, n, of a medium can be defined as

For a vacuum, n = 1
We assume n = 1 for air also

For other media, n > 1
n is a dimensionless number greater than unity and is not necessarily an integer.

Snell's Law of Refraction

$n_1 \sin \theta_1 = n_2 \sin \theta_2$

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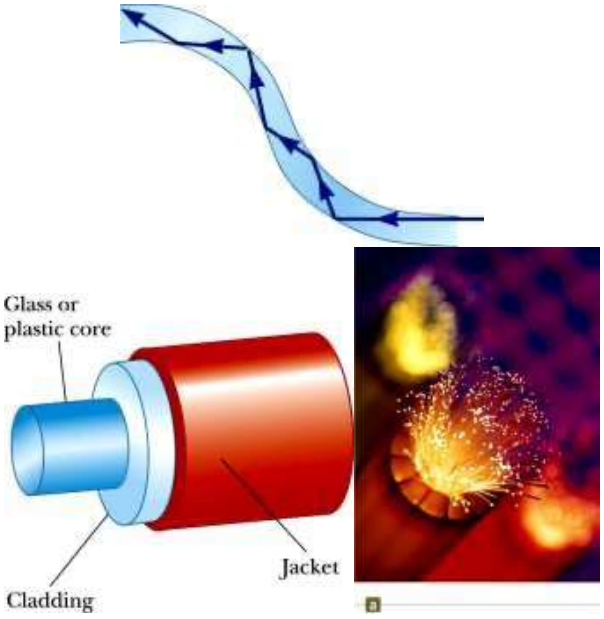
- **Fiber Optics**

An application of internal reflection. Plastic or glass rods are used to "pipe" light from one place to another.

Applications include:1)Medical examination of internal organs
2)Telecommunications

The transparent core is surrounded by cladding.The cladding has a lower n than the core. This allows the light in the core to experience total internal reflection. The combination is surrounded by the jacket. A flexible light pipe is called an optical fiber.



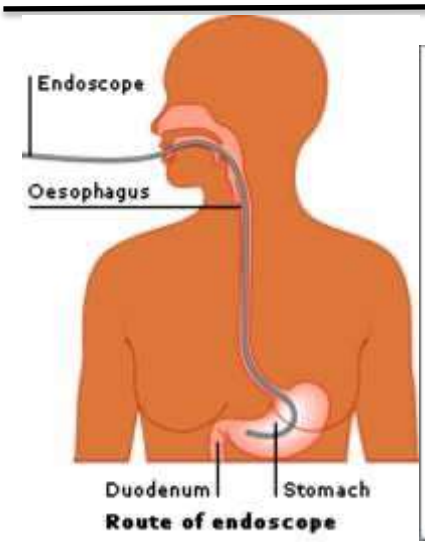
- Medical uses of visible light

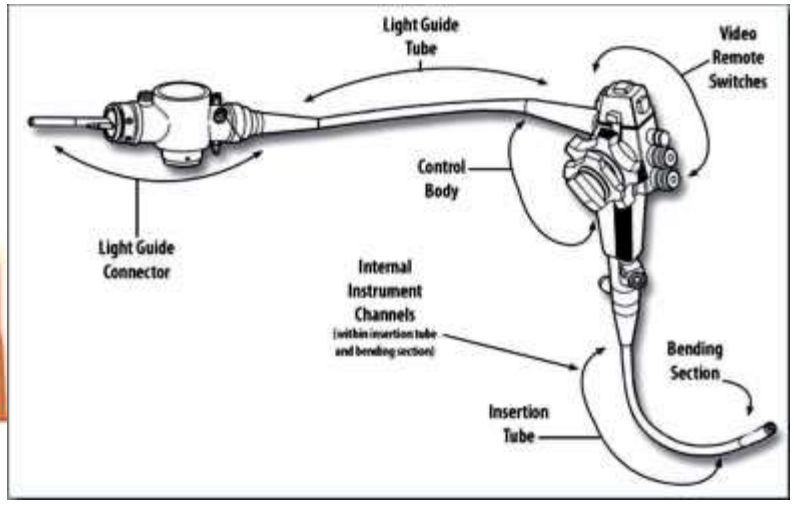
1. Pediatricians use a shine light into the bodies of infants and observe the amount of scattered light produced in order to detect water –head or collapsed lung.
2. Pediatricians use visible light for treating jaundice in premature infants.
3. Light source in endoscope uses to see inside the body.
4. Physician use normal light to examine the skin.
5. The visible light used in the ophthalmoscope for looking into eyes ,and in the otoscope for looking into ears by using a concave mirror to direct light in the body and a hole in the middle of it for the physician to look through.

- **Endoscope**

An endoscope works by inserting a long, thin and bendable tube into the body. On one end is a light source and in most cases also a video camera. The endoscope can be inserted through a natural opening in the body such as the throat or it can be inserted through a cut made in the skin.

An endoscope consists of two or three optical cables. Each cable includes up to 50,000 separate optical fibers that are made from glass or plastic. One or two of these cables will carry light down into the patient's body, this illuminates where the endoscope has been inserted.





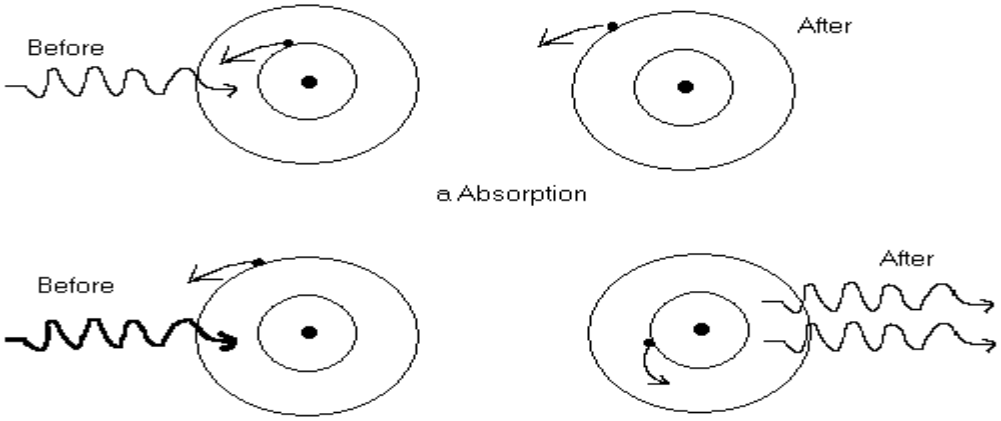
The light is reflected along the walls of the cable into the patient's body. The light does this due to total internal reflection, which means that for this to happen the light ray must be at an angle of 82 degrees (which is the angle required for air to glass to be internally reflected).

The other cable will carry reflected light that shines off the patient's body, this light is the image of the body. The light bounces off the glass walls as it goes up to the physician's eyepiece or into a camera. If the reflected light is carried up to a camera it will then be displayed on a TV monitor.

- ## Laser

Light Amplification by Stimulated Emission of Radiation

In (1917) ,Einstein postulated that: **The incident photons of energies equal exactly to the energy that an excited atom must eject if it falls to its lower energy state**. These incident photons stimulate the excited atom to fall to the lower state and the photon ejected by the atom is in phase with the incident photon that stimulates it to make the transition.



The incident photon and the photon of the atom that it stimulated have the same frequency direction ,and phase i.e. they are coherent.

Kinds of Laser:

1. Pulse Laser: i.e.

(i) Ruby laser **(λ =694 nm**).

(ii) Semiconductor (λ is dependent on the applied current).

(iii) Glass laser.

2. continuous wave laser (cw)e.g. ,gas filled tubes laser

(i) Neon-helium laser **(λ =632.8 nm**)

(ii) Argon laser **(λ =488-514nm)**

- **Ruby Laser:**

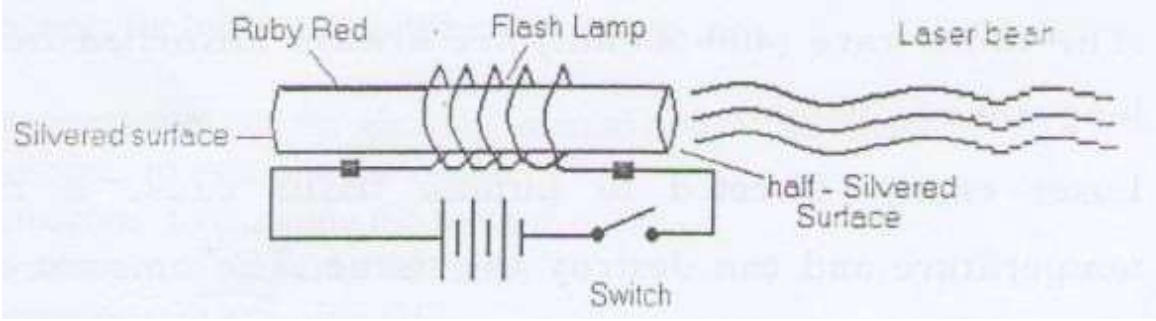
In (1960) T.H. Maiman produced a laser beam from ruby crystal.

* The rod is aluminum oxide crystal with some chromium atoms throughout it (**AL_2O_3 :Cr_2O_3).**

* The active material (**Medium)** in the ruby is the chromium ions **Cr^{+3}.**

* The **color** of the ruby crystal depends on the contents of **Cr^{+3}** on it.

* One end of the rods are covered completely with silver and the other ends are coated partially with silver **to allow light to escape.**



The bright flash causes electrons in the chromium atoms of the rod to gain energy, which is released inside the rod **as red light**

the end of the half – coated end of the rod as a laser beam. The red light is reflected back and forth between the mirrored surfaces at the ends of the rod.

The light causes the chromium atoms to release more light.

The intensity of the red light beam increase and leaves

***A laser beam remains narrow over long distance and can be focused to a spot only a few microns in diameter**.

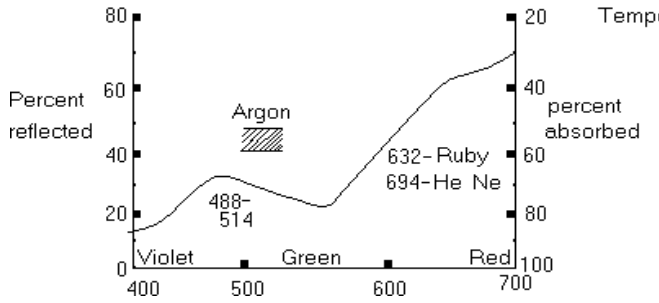
* **When all of the energy of laser is concentrated in such small area , the power density energy (power per unit area) become very large.**

o Laser in Medicine:

In medicine laser are used primarily to deliver energy to tissue.

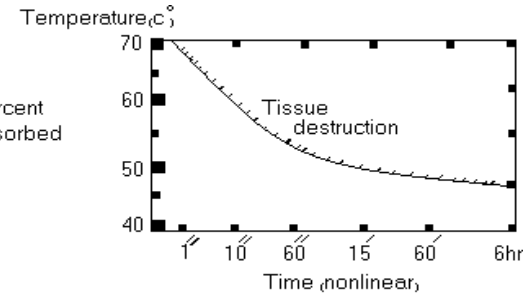
• The laser wave length used should be strongly absorbed by tissue .**The short wave (400-600nm) are always absorbed better than the long wave (≈700nm)**

• Laser energy directed to human tissue cause a rapid rise in temperature and can destroy the tissue .**The amount of damage to living tissue depends on time the tissue is exposed to increased temperature**.



A

The absorbance and reflectance of skin as a function of wavelength.



B

Effects of time and temperature on tissue destruction

1. It is used by surgeons for the painless **removed of eye tumors**

2. It is used as a **(bloodless knife)** in surgery.

3. Repairing retinal tears or holes that develop prior to retinal detachment. **(Photocoagulation).**

4. Treatment of the diabetic ethnography i.e. the complications of diabetes that affect the retina, **(photocoagulation)**.

5. In medical research it is used for special three-dimensional imaging called **(holography)**.