Medical Physics Module
Semester 1

Session 5
Lecture 9

Physics of light in medicine

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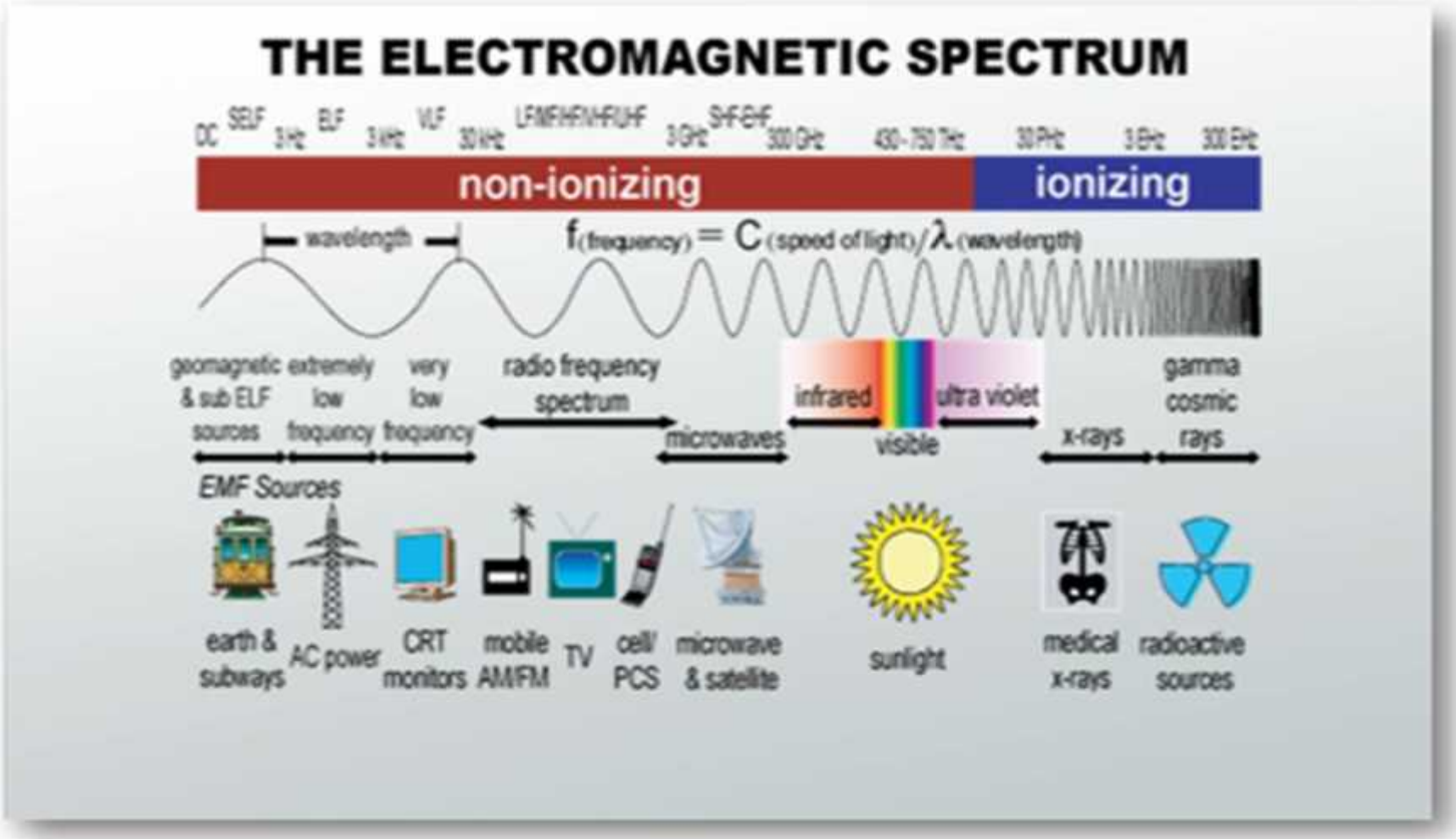
Objectives

- Definition.
- Knowledge of the physical properties of light.
- To get information about applications of light in medicine.
- To get information about the principle of using laser in medicine.

Definition:

Light is a form of electromagnetic radiation.

Human eye has the capability to detect or sense some part of the complete electromagnetic spectrum.


THE ELECTROMAGNETIC SPECTRUM
DC
SELF
3 Hz
ELF
3 kHz
VLF
30 kHz
LF MF HF VHF UHF
3 GHz
SHF EHF
300 GHz
430 - 750 THz
30 PHz
3 EHz
300 EHz
non-ionizing
ionizing
wavelength
f (frequency) = C (speed of light) / λ (wavelength)
geomagnetic & sub ELF sources
extremely low frequency
very low frequency
radio frequency spectrum
microwaves
infrared
visible
ultra violet
x-rays
gamma cosmic rays
EMF Sources
earth & subways
AC power
CRT monitors
mobile AM/FM
TV
cell/ PCS
microwave & satellite
sunlight
medical x-rays
radioactive sources

Light behaves both as a wave and a particle.

As a wave it produces interference and diffraction.

As a particle it can be absorbed by a single molecule

Properties of Light

1- The speed of light when it goes from one material into another given by equation:

$$n = c / v$$

c: Speed of light in vacuum

v: Speed of light in material

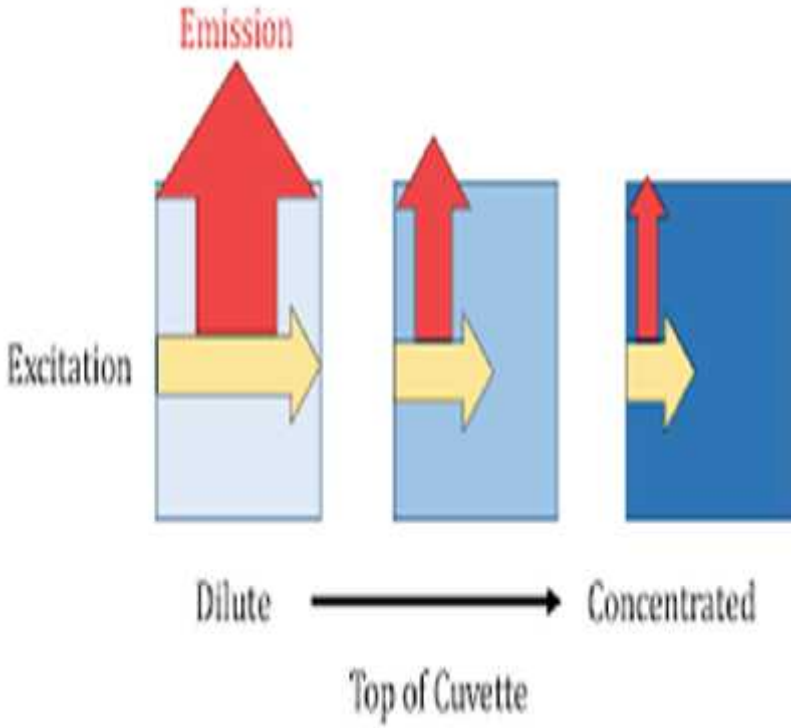
n: Refractive index

When light is absorbed, its energy generally appears as heat.

This property is the basis for the use IR light to heat tissues.

Also the heat produced by laser beams is used to weld and to coagulate small blood vessels.

Some time when a light photon is absorbed, a lower energy light photon is emitted. This property is known as *fluorescence*.


Emission
Excitation
Dilute
Concentrated
Top of Cuvette

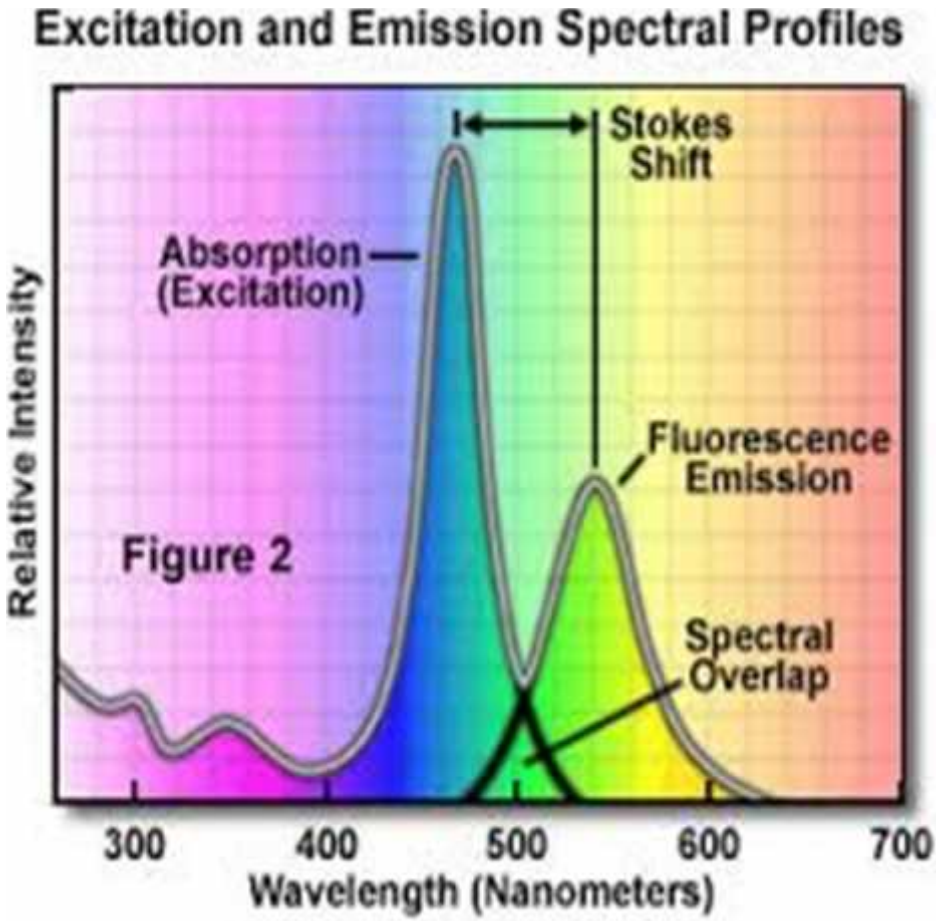

Excitation and Emission Spectral Profiles
Stokes Shift
Absorption (Excitation)
Fluorescence Emission
Spectral Overlap
Relative Intensity
300
400
500
600
700
Wavelength (Nanometers)

Figure 2

2. Light is reflected to some extent from all surfaces.

There are two types of reflection:

A- Diffuse reflection: occurs when rough surface scatter the light in many direction.

B- Specular reflection: it is obtained from very smooth surface such as mirrors.

3. Refraction: When light passes through a substance or medium, light gets bend on the basis of the wavelength or frequency. This phenomenon is termed as the refraction. It follows *Snell's Law* of refraction.

4. Light transmittance is defined as the ratio of the intensity of the Incident light on the substance to the intensity of light which passes through the substance or comes out from the substance.

SNELL'S LAW

The ratio of the sine of the incident angle to the sine of the refracted angle is constant.

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

n_1 = index of refraction of the incident medium
n_2 = index of refraction of the second medium

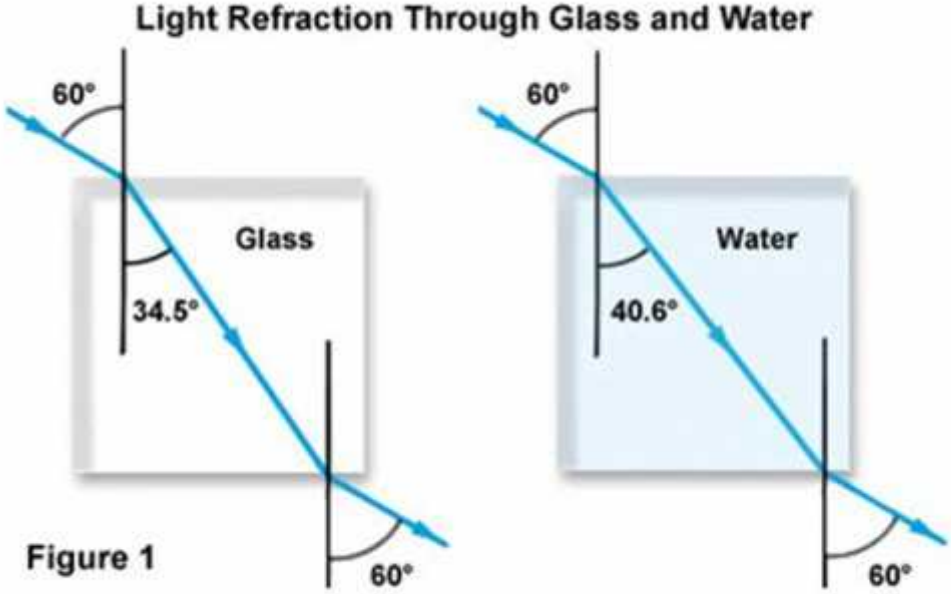


Figure 1

Measurement of Light and its Units:

The three general categories of light-UV, Visible, and IR- are defined in terms of their wavelengths. Wavelength of light used to be measured in

Microns $1\ \mu m = 10^{-6}\ m$

Angstroms $1A = \circ\ 10^{-10}\ m$

Nanometer $1nm = 10^{-9}\ m$

Ultraviolet light has wavelengths from (100 to 400) nm

Visible light has wavelengths (400 to 700) nm

IR light has wavelengths from (700 to 10000)nm.

Each of these categories subdivided according to wavelength.

Ultraviolet UV-A has wavelengths from 320 – 400 nm

UV-B has wavelengths from 290- 320 nm

UV-C has wavelengths from 100- 290 nm

IR radiation can be subdivided into:

IR –A : has wavelengths (760 -1400 nm) (It is most penetrating radiation).

IR –B : has wavelengths (1400 nm - 3 μm) penetrates only into tissue because it is heavily absorbed by water.

IR - C : has wavelengths (3 μm -1000 μm) is absorbed very well and does not penetrate the eye or skin.

Visible light is measured in *photometric* units

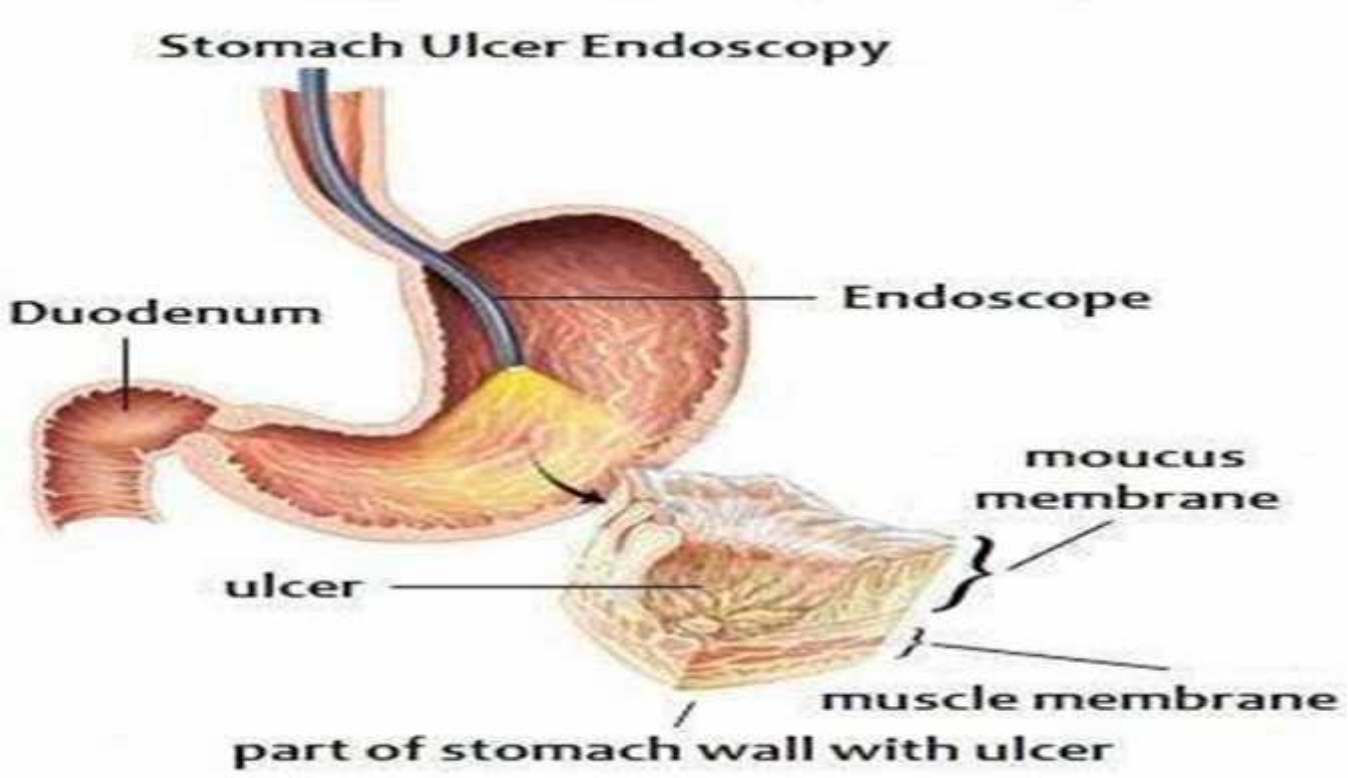
- ✓ **Illuminance the quantity of light striking a surface**
- ✓ **Luminace the intensity of a light source .**

(UV & IR) radiation can be measured in *radiometric units*

- ➢ **Irradiance the quantity of light striking a surface**
- ➢ **Radiance the intensity of a light source**

Applications of Visible Light in Medicine

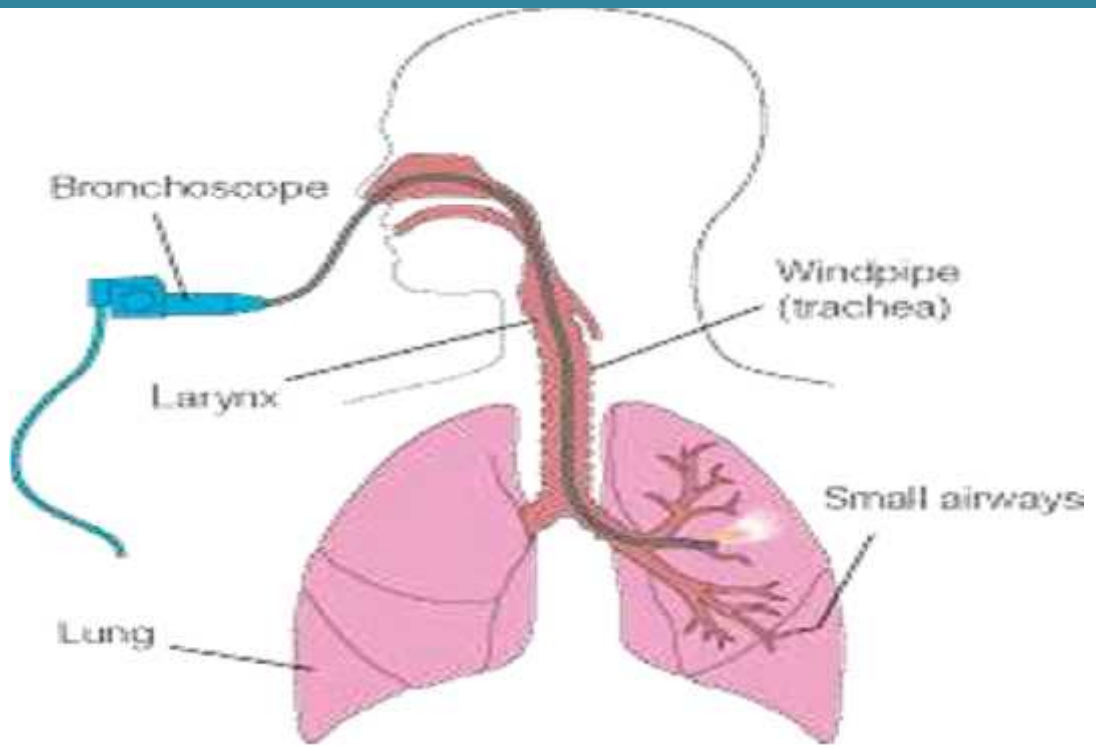
❖ Endoscope :A number of instruments are used for viewing internal body cavities.



❖ Cytoscopes: Are used to examine the bladder.

❖**Bronchoscope: Are used for examining the air passages into lungs. Some endoscopes are rigid tubes with a light source to illuminate the area of interest.**

Flexible endoscopes can be used to obtain information from regions of the body that cannot be examined with rigid endoscopes, such as the small intestine and much of large intestine.



Applications of UV and IR Light in Medicine:

UV photons have energies greater than visible and IR light. Because of their higher energies, UV photons are more useful than IR photons.

-UV can kill germs and used to sterilize medical instruments.

-UV produces more reaction in the skin some of these reactions are beneficial, and some are harmful.

Two types of IR photography are used in medicine:

- **Reflective IR photography, which uses wavelength of (700 - 900 nm)to show patterns of viens just below the skin.**
- Emissive IR photography uses the long IR heat waves emitted by the body that give an indication of the body temperature, is usually called thermograph.

0-2	No danger to the average person
3-5	Little risk of harm from unprotected sun exposure
6-7	High risk of harm from unprotected sun exposure
8-10	Very high risk of harm from unprotected sun exposure
11+	Extreme risk of harm from unprotected sun exposure

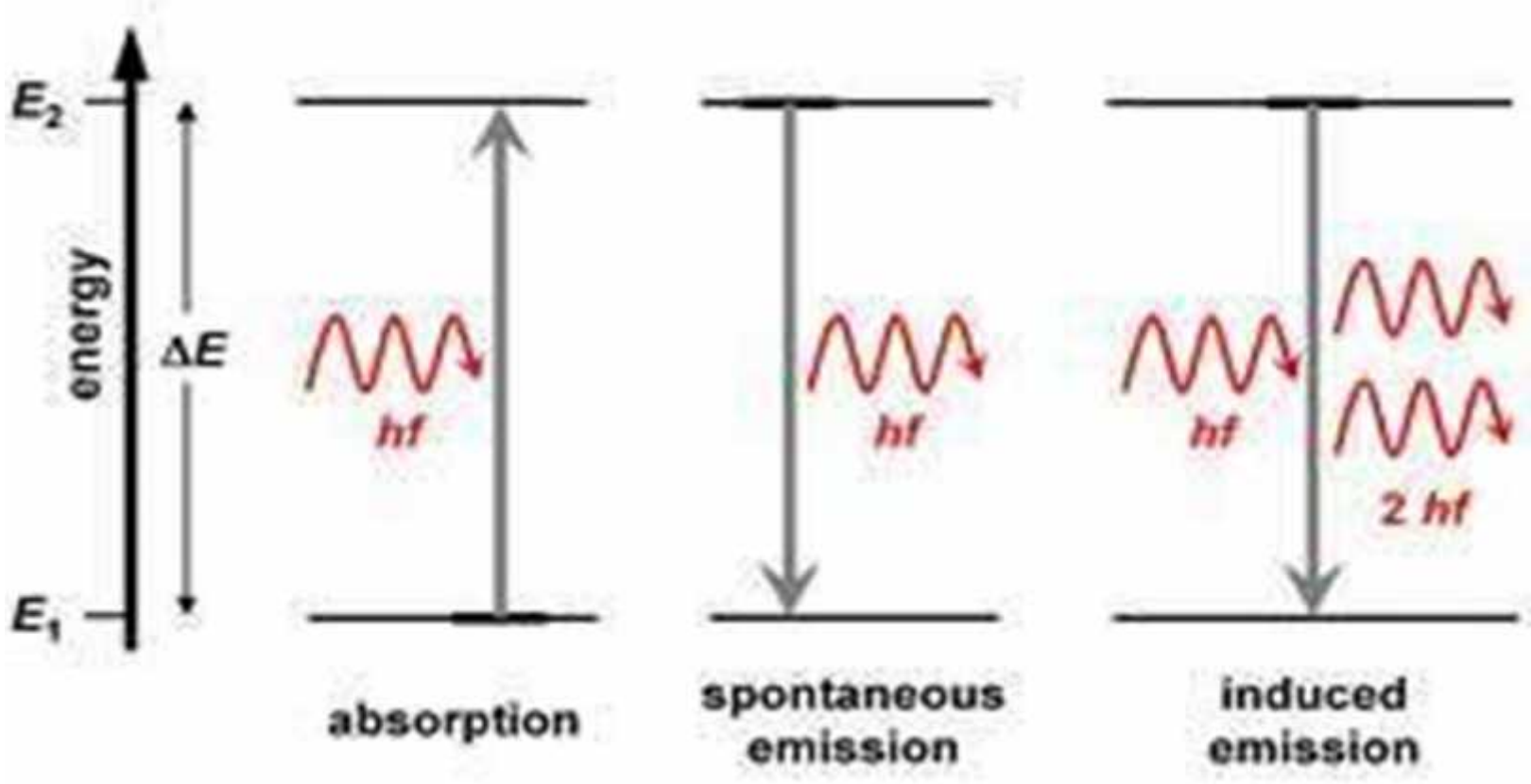
Laser in Medicine

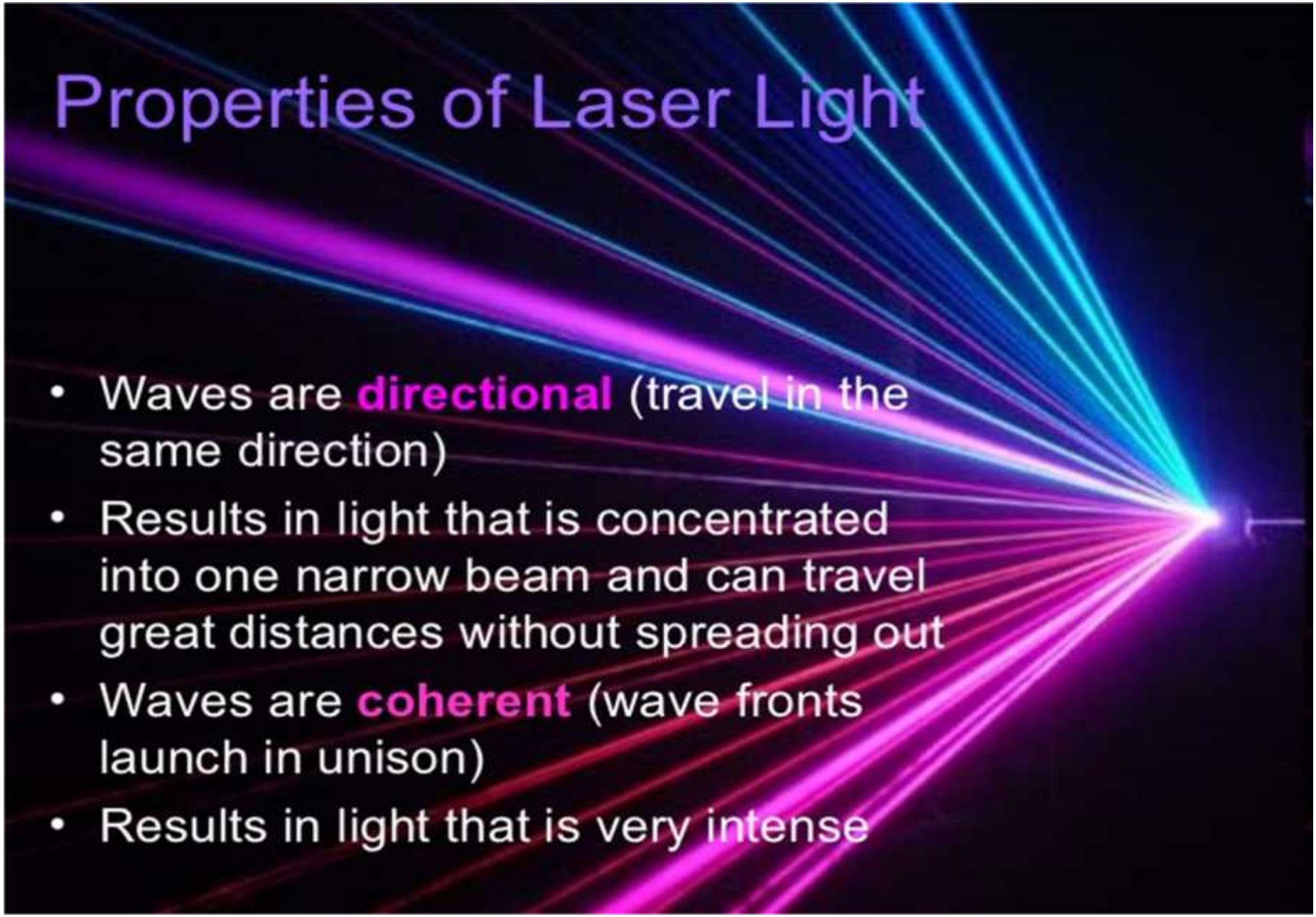
Light Amplification by Stimulated Emission of Radiation

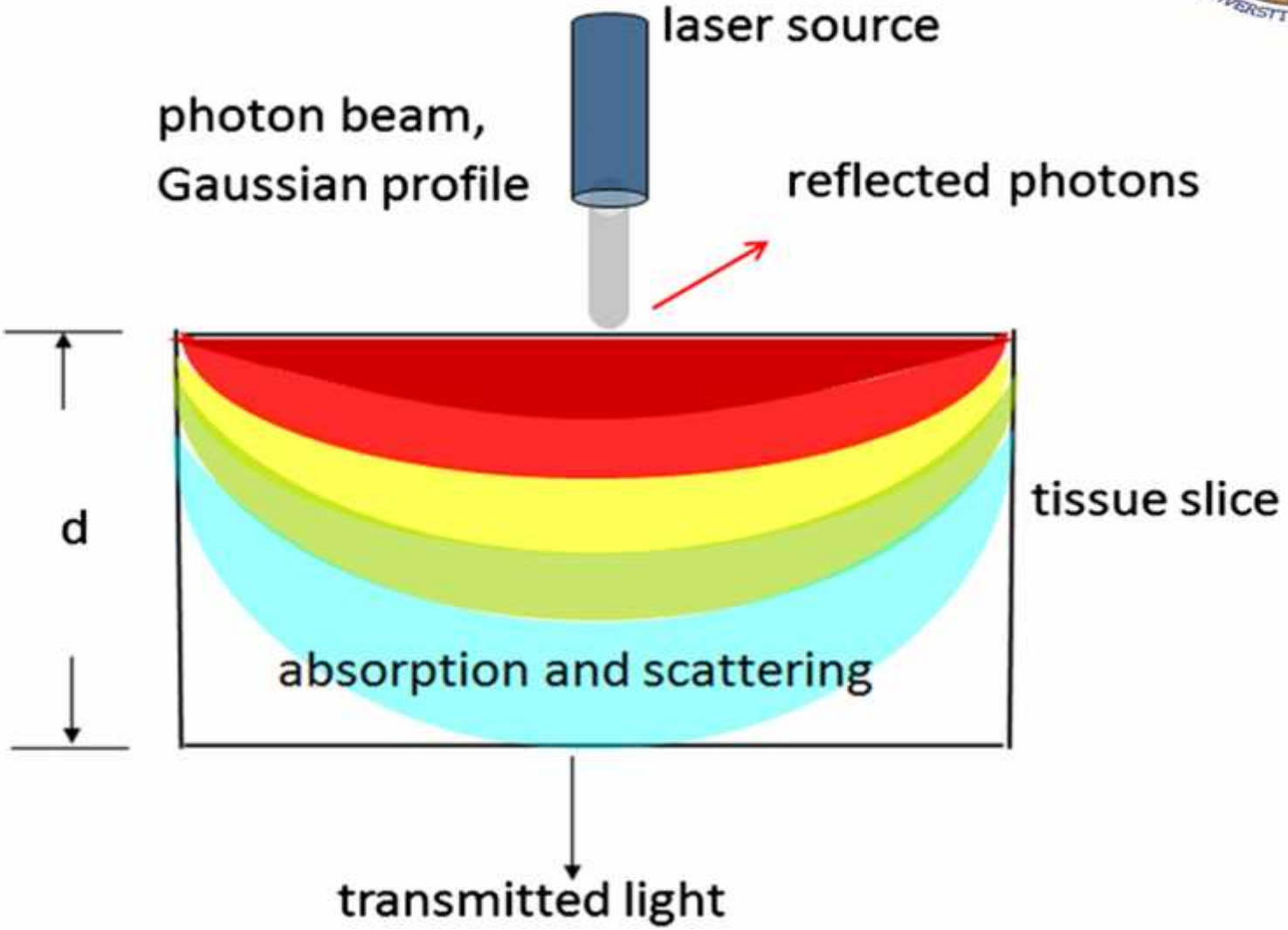
When an electron makes a transition from higher energy to lower energy state, a photon is emitted .

The emission process can be one of two types:

- **Spontaneous Emission.**
- **Stimulated Emission.**


E2
energy
ΔE
E1
hf
absorption
hf
spontaneous
emission
hf
2 hf
induced
emission


Properties of Laser Light
• Waves are directional (travel in the same direction)
• Results in light that is concentrated into one narrow beam and can travel great distances without spreading out
• Waves are coherent (wave fronts launch in unison)
• Results in light that is very intense


laser source
photon beam,
Gaussian profile
reflected photons
d
tissue slice
absorption and scattering
transmitted light

For example, tissue can withstand 70C^{o} for 1 s, in general even the briefest exposure to temperatures above 100C^{o} results in tissue destruction. However, not all laser damage is due to heat.

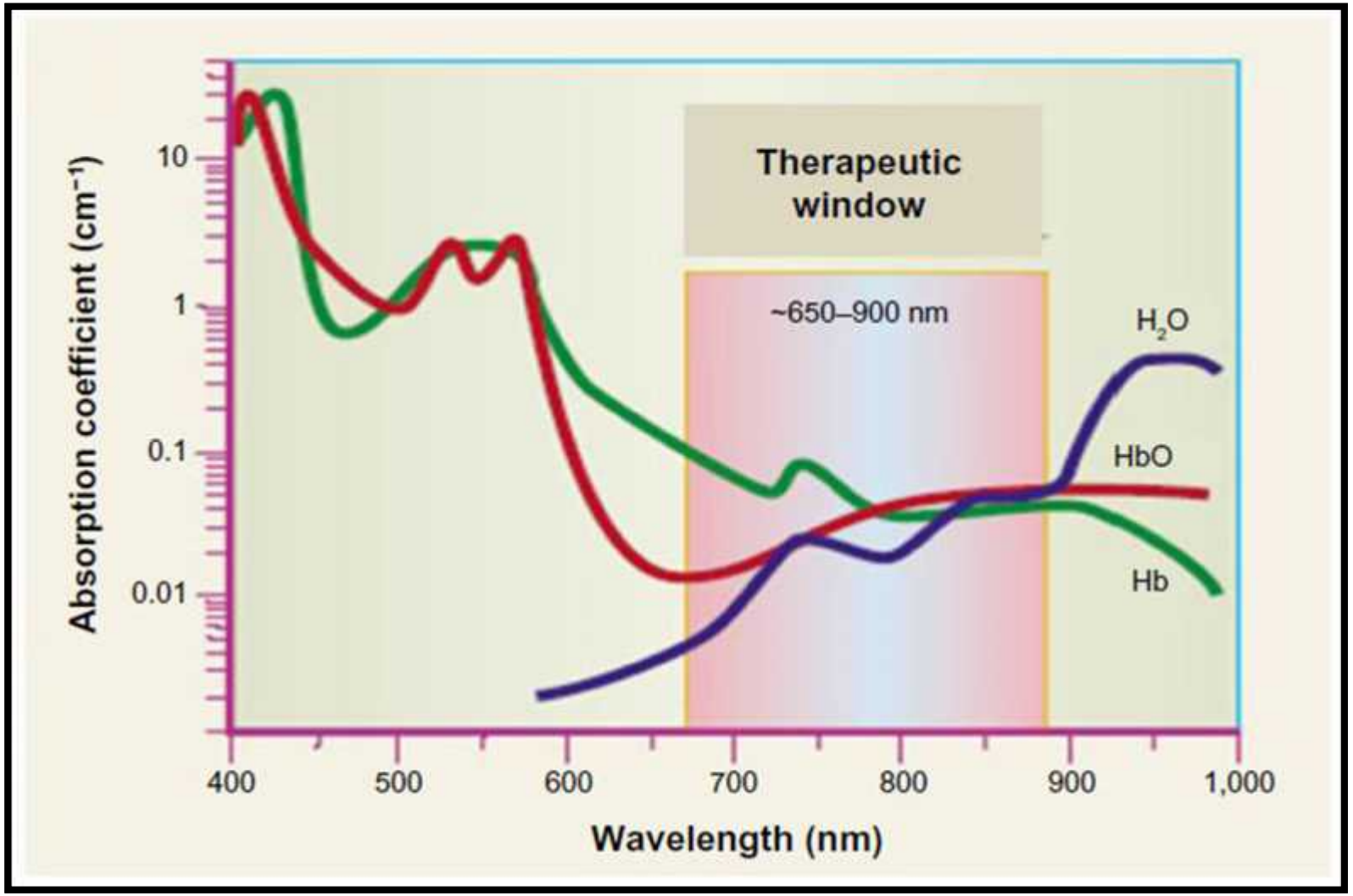
Types of Lasers:

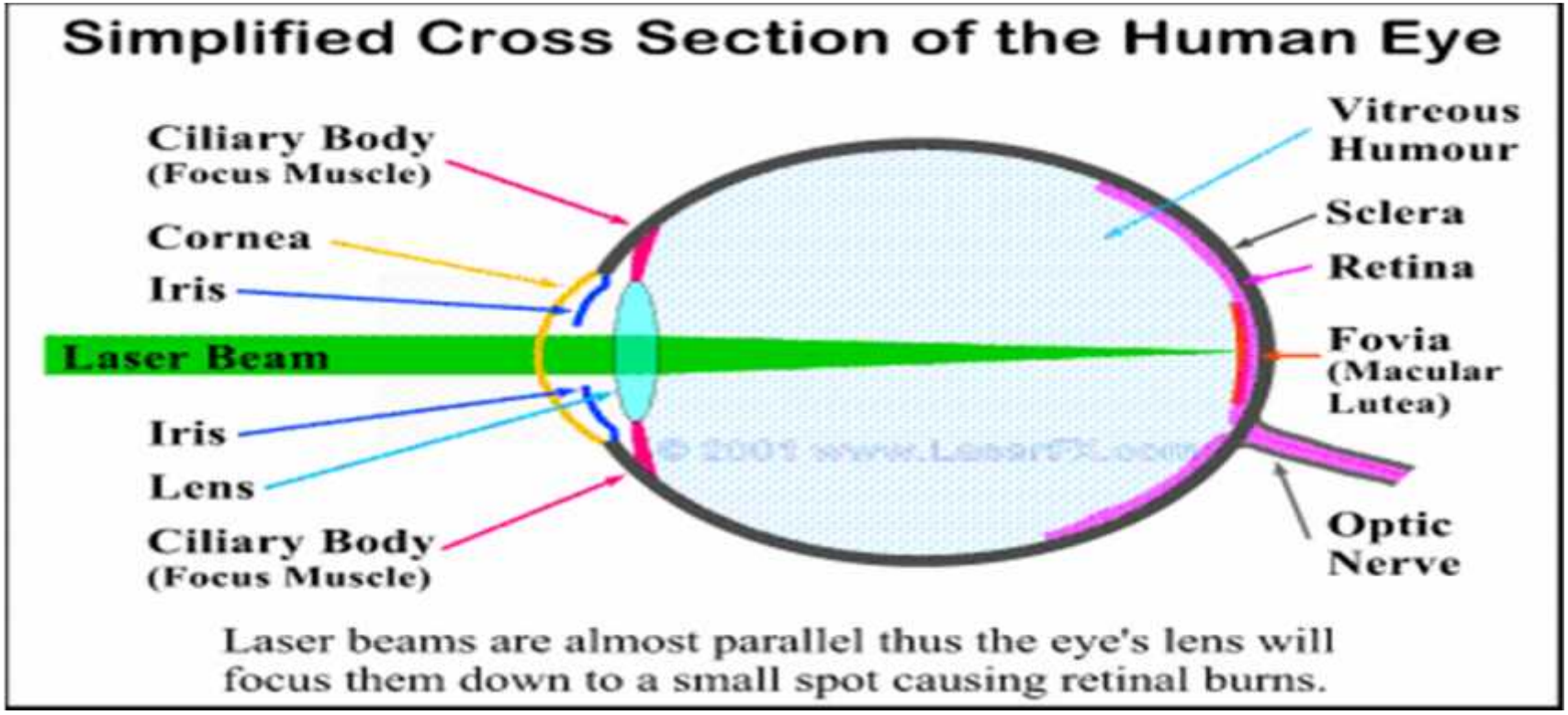
1. Semiconductor diode laser.
2. Solid state laser (Ruby), Nd:YAG.
3. Gas laser (He- Ne).
4. Dye laser.

The energy can be provided in number of ways, including intense of ordinary light and high voltage discharges.

Medical Applications:

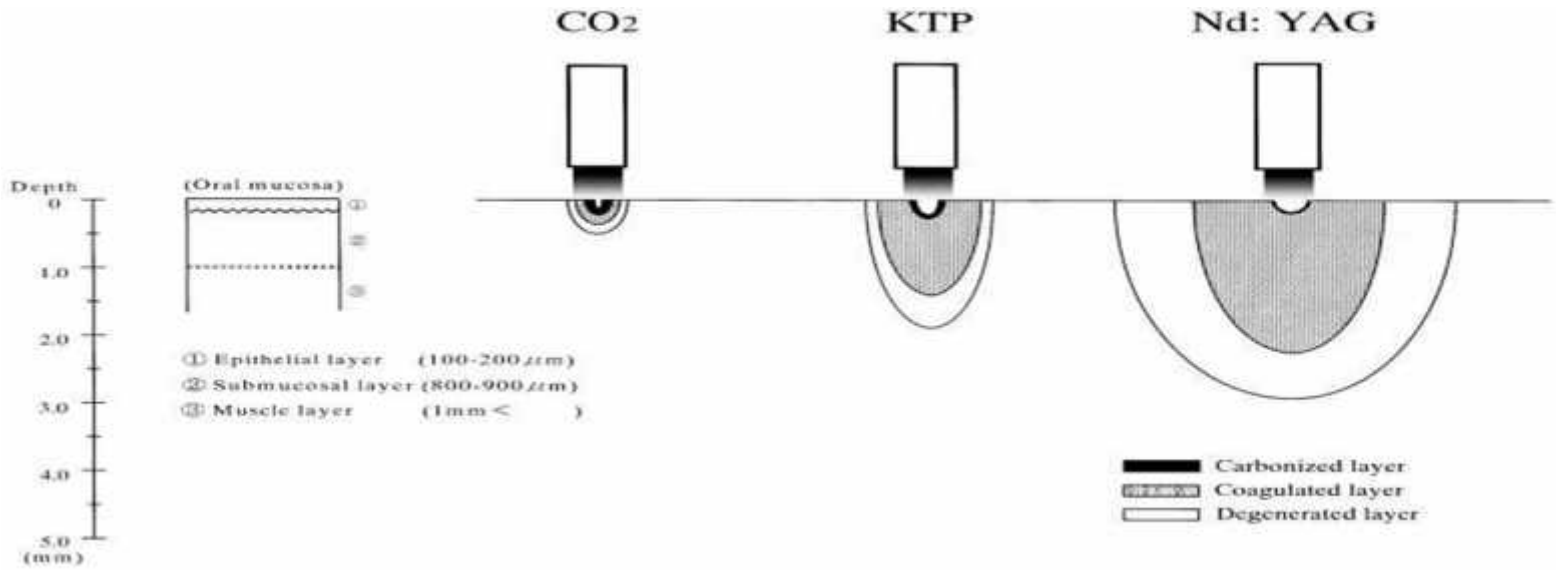
1. **Photocoagulation.**
2. **In Surgery.**
3. **Internal medicine.**
4. **Red spot on the skin of human.**


Therapeutic window
~650–900 nm
H_2O
HbO
Hb
Absorption coefficient (cm^{-1})
10
1
0.1
0.01
400
500
600
700
800
900
1,000
Wavelength (nm)



Medicine lasers are used primarily to deliver energy to tissue, laser energy directed at human tissue causes a rapid rise in temperature and can destroy the tissue.

The laser used in medicine as a bloodless knife for surgery. It can focused by a lens to almost point.



Thank you for your attention