Assist.Prof. Dr. Muhanad rasheed

Al-Rasheed University College

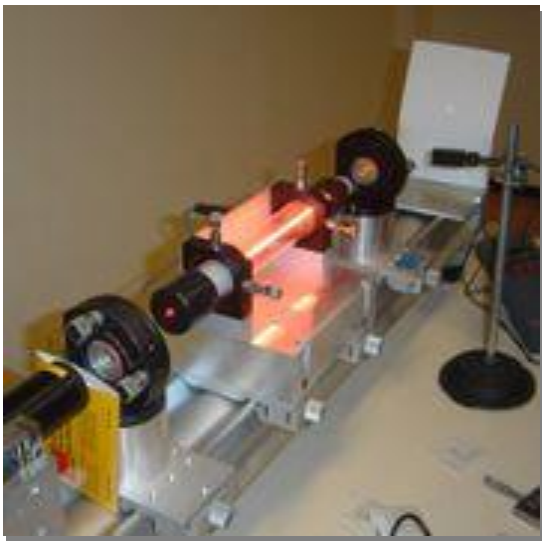
DEP. OF MEDICAL INSTUMENTATION TECHNIQUES ENGINEERING

# Medical Laser system

## Lecture 1 : اساسيات الليزر

Laser Principles (Fundamentals)

# Laser Principles (Fundamentals)



The term " L A S E R " is an acronym formed from :

L : Light A : Amplification by S : Stimulated

E : Emission of R : Radiation

## 1. Light as Electromagnetic Waves

- In 1864 , Maxwell made the major advance in understanding the nature of light .
- He combined several former works of many scientists ,e.g. , Faraday, Oersted & Henry on electricity and magnetism into a set of equations called Maxwell's equations .
- He deduced the existence of a transverse electromagnetic wave whose speed in vacuum (free space) is given by :

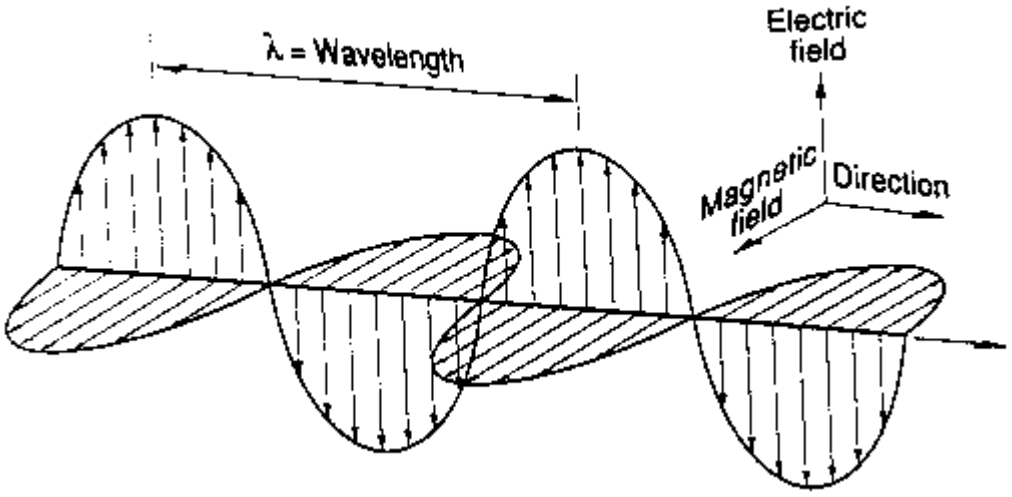
$$C = (1/ \epsilon_0 \mu_0)^{1/2}$$

Where $\epsilon_0$ is the permittivity of free space $= 8.854 \times 10^{-12}$ farad/m

& $\mu_0$ is the permeability of free space $= 4\pi \times 10^{-7}$ henry/m

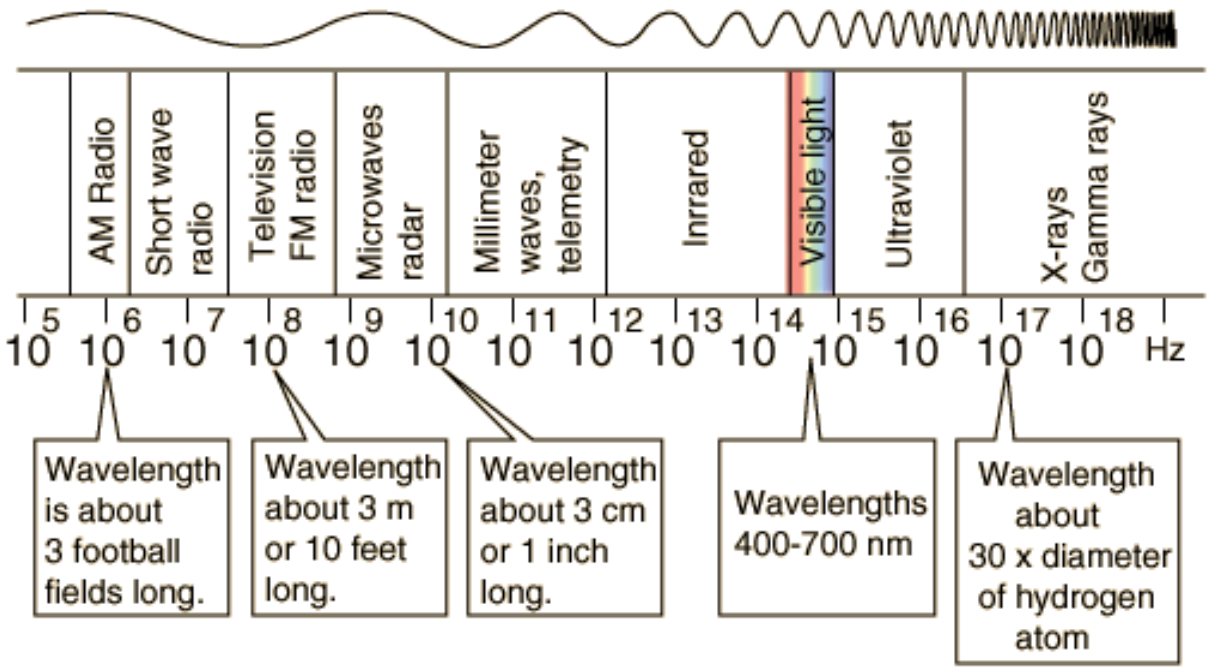
- He observed that the speed of this wave measured depending on $\epsilon_0$ & $\mu_0$ agreed almost exactly with the speed of light as measured by Fizeau $= 2.99792 \times 10^8$ m/sec .
- Accordingly , Maxwell proposed that light is an example of an electromagnetic wave .

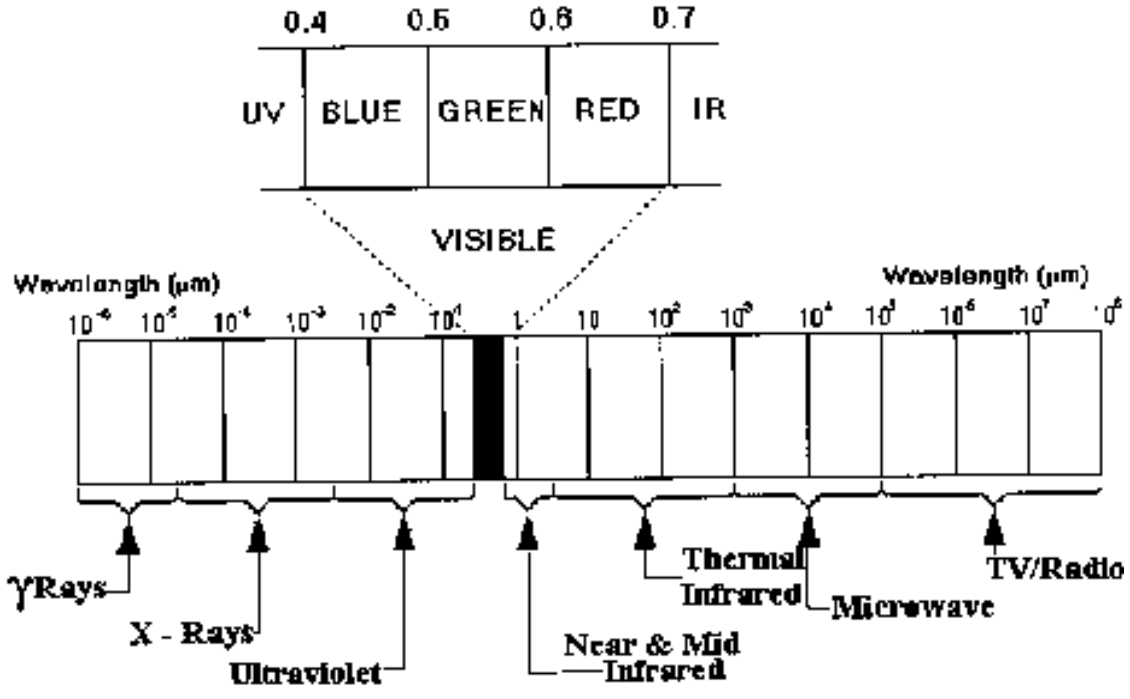
It is now acceptable that light wave is consisting of an electric and magnetic components vibrating at right angles to each other and to the direction of propagation



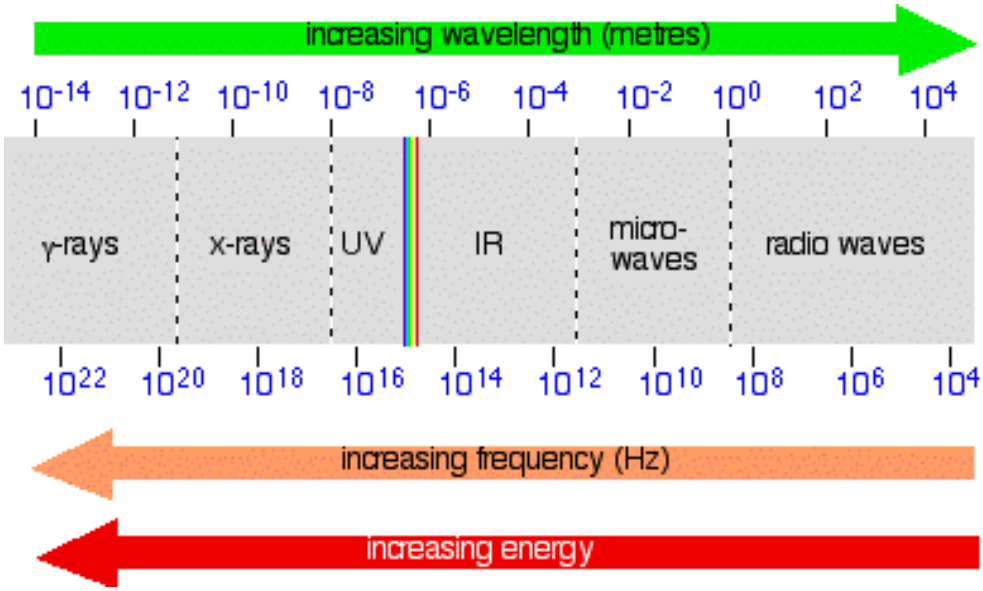

1. Visible light is only a small portion of the electromagnetic spectrum . All of the e/m waves are transverse waves having the same speed as light in free space (vacuum) ; However , they are differing only in wavelengths. There is a huge difference between wavelengths of

radio waves (hundreds of meters in length ) to gamma-rays (tiny wavelength on the order of $\lambda = 10^{-12}$m). So, that's why these waves behave differently.




**The electromagnetic spectrum**




The main color regions of the spectrum are approximately:

| color region | wavelength (nm) |
|---|---|
| violet | 380 - 435 |
| blue | 435 - 500 |
| cyan | 500 - 520 |
| green | 520 - 565 |
| yellow | 565 - 590 |
| orange | 590 - 625 |
| red | 625 - 740 |

2. In 1900, Max Plank announced at a meeting of the German Physical society that he was able to derive the correct blackbody radiation spectrum only by making the assumption that atoms emitted light discrete energy chunks rather than in a continuous manner. Thus, quanta and quantum mechanics were born.

3. According to Plank, the energy E of a quantum of electromagnetic(e/m) radiation is proportional to frequency of the radiation ( v ) ,

$$E = h\,v \qquad \text{.....(1)}$$

where h is the Plank's constant ($6.63\times 10^{-34}$ J.S) .

4. Five years later, Albert Einstein offered an explanation of the photoelectric effect, the emission of the electrons from a metal surface when irradiated with light. Central to his explanation was the conception of light as a stream of small bundles of energy which he called "photons" whose energy is related to frequency by Plank's equation (eq. 1).
5. As mentioned before , the photon energy (E) α frequency (V)

$$E = h\upsilon \ \ldots \upsilon = \frac{c}{\lambda} \ \ldots E = \frac{h\,c}{\lambda} \ OR \quad \lambda = \frac{c}{\upsilon} \ \text{.....(1)}$$

Where λ is the wavelength in free space (vacuum) ,

υ is the frequency

c is the speed of light in free space ≈ $3 \times 10^8$ m/s

But in other media , the speed (c) is modified to (v) ,

ولكن اذا اخترق الضوء وسطا اخروليس في الفراغ فان سرعته في تلك المادة تتحول من الرمز c الى الرمز v

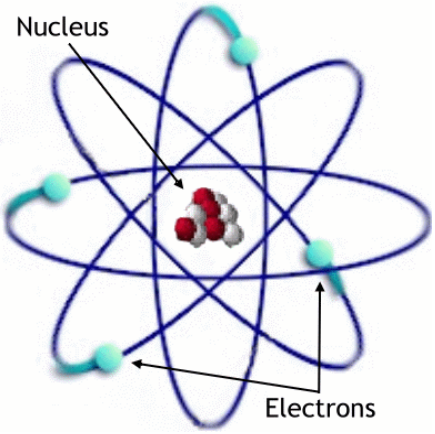
$$\frac{c}{V} = \frac{\lambda}{\lambda'} = n \qquad \text{.....(2)}$$

v = speed of light or e/m wave in the medium .

λ' = wavelength in the medium.

n = refractive index of the medium .

6. Recall the basic structure of the atom , it is a positively charged nucleus surrounded by a cloud of negative electrons . Each of these electrons moves in its own orbit around the nucleus .




Q / Why the electrons do not collapse into the +ve nucleus ?

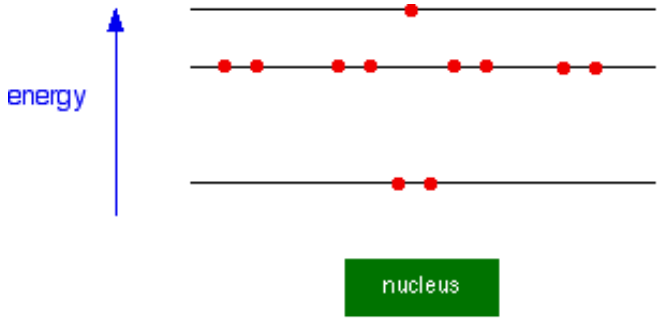
The electrons orbit the nucleus as the planets orbit the sun . The centripetal force required to maintain the electron in its circular orbit is provided by the Coulomb attraction of the +ve nucleus on the -ve electrons ,

$$\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

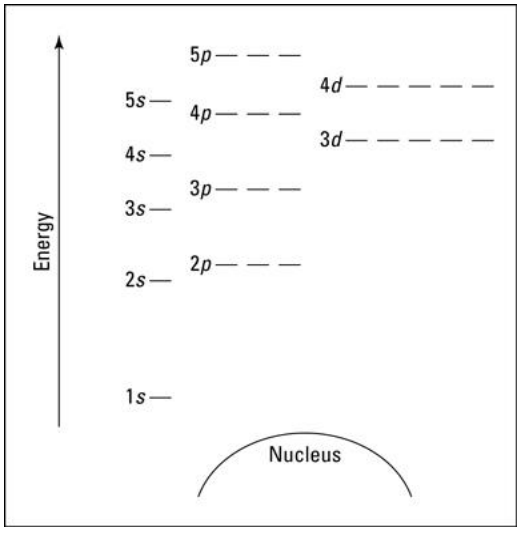
Where m, e , & v are the electron mass , charge and velocity respectively , r is the radius of the orbit and $\epsilon_0$ is the permittivity of the free space .

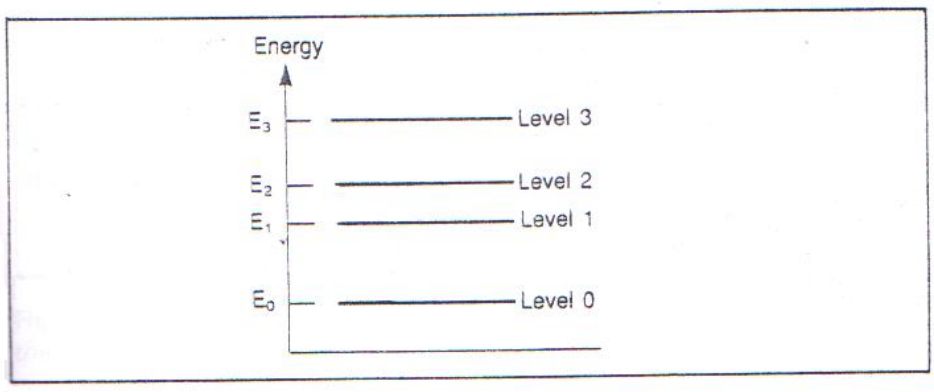
1. When energy is absorbed by the atom , the energy goes to the electrons ; They move faster or if the energy enough , they move to different orbit (level). The most important point is that the atom can absorb only certain amounts of energy and accordingly it can lose energy only in specified amounts because the electron can return only to allowed lower energy orbit (level).

2. This atomic behavior is shown schematically in the following energy-level diagrams. The allowed energies for the atom are represented by different levels on the diagram ,




(not to scale)




*The allowed energy levels for an atom correspond to different orbital configurations of its electrons*

i. An atom in the ground state has an energy $E_0$ , while an atom in the first excited state has an energy $E_1$ and so on .

ii. An atom in the ground-state (level 0) can absorb only certain amount of energy , e.g., the ground-state atom could absorb $(E_1 – E_0)$ and move to the first excited state (level 1)or$(E_2 – E_0)$ and move to the second excited state (level 2) and so on . But the atom cannot absorb an amount of energy less than $(E_1 – E_0)$ nor can it absorb amount of energy between $(E_2 – E_1)$ and $(E_1 – E_0)$ .