AL- Mustaqpal University
Science College
Dep. Medical physics

Medical physics
Third Stage

Lec 7

Lasing action

م . م علي سـلمان حمادي

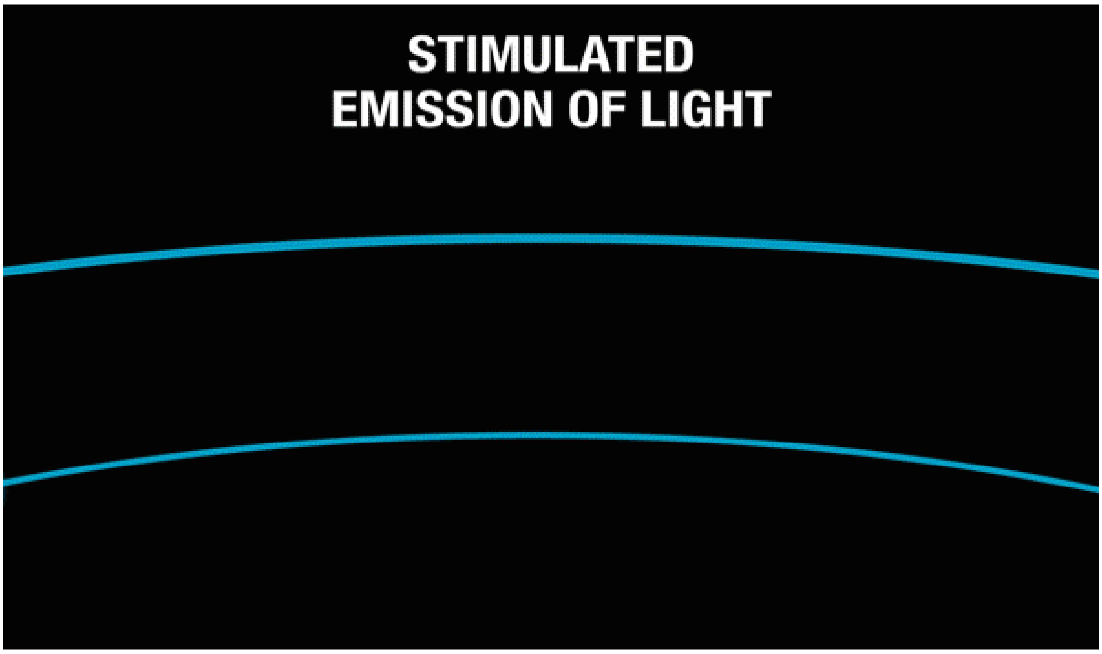
Lasing action

These excited electrons can move from a lesser energy orbit to a greater energy orbit around the nucleus of an atom. After that when they return back to their normal state which is the ground state, the electrons will emit photons in order to lose that energy. This process is known as the lasing action.

A laser is created when electrons in the atoms in optical materials like glass, crystal, or gas absorb the energy from an electrical current or a light. That extra energy “excites” the electrons enough to move from a lower-energy orbit to a higher-energy orbit around the atom’s nucleus.

A laser takes advantage of the quantum properties of atoms that absorb and radiate particles of light called photons. When electrons in atoms return to their normal orbit—or “ground” state—either spontaneously or when “stimulated” with a light or other energy source, even another laser in some cases, they emit more photons.

Light moves in waves. Ordinary visible light, say from a household light bulb or a flashlight, comprises multiple wavelengths, or colors, and are incoherent, meaning the crests and troughs of the light waves are moving at different wavelengths and in different directions.



In a laser beam, the light waves are “coherent,” meaning the beam of photons is moving in the same direction at the same wavelength. This is accomplished by sending the energized electrons through an optical “gain medium” such as a solid material like glass, or a gas.

The particular wavelength of light is determined by the amount of energy released when the excited electron drops to a lower orbit. The levels of energy introduced can be tailored to the material in the gain medium to produce the desired beam color.

A mirror on one side of the laser’s optical material bounces the photon back toward the electrons. The space between mirrors, or the “cavity,” is designed so the photon desired for the particular type of optical gain medium are fed back into the medium to stimulate the emission of an almost exact clone of that photon. They both move in the same direction and speed, to bounce off another mirror on the other side to repeat the cloning process.

Two become four, four become eight and so on until the photons are amplified enough for them to all move past the mirrors and the optical material in perfect unison. And that unison gives the laser its power. Laser beams can stay sharply focused over vast distances, even to the moon and back.

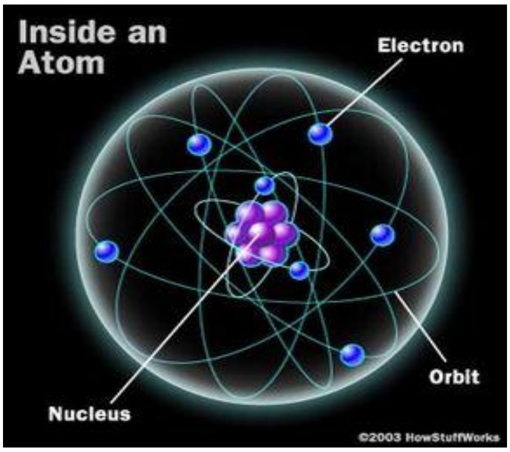
1. A basic laser, like this red ruby laser, consists of a rod made of ruby crystals with a mirror on each end, and a flash tube.
2. A burst of light from the flash tube adds energy inside the rod, exciting the ruby atoms and producing light particles called photons.
3. The photons strike the atoms, creating more and more photons bouncing back and forth between the mirrors within the rod.
4. The number of photons become so great that they pass through one of the mirrors, which is partially reflective, and the laser beam emerges.

Today, lasers come in many sizes, shapes, colors, and levels of power, and are used for everything from surgery in hospitals, to bar code scanners at the grocery store, and even playing music, movies, and video games at home. You might have undergone LASIK surgery, which corrects vision by using a tiny laser to reshape the cornea of eye. Some lasers, such as ruby lasers, emit short pulses of light. Others, like helium–neon gas lasers or liquid dye lasers, emit light that is continuous. NIF, like the ruby laser, emits pulses of light lasting only billionths of a second. Laser light does not need to be visible. NIF beams start out as invisible infrared light and then pass through special optics that convert them to visible green light and then to invisible, high-energy ultraviolet light for optimum interaction with the target.

Atoms are constantly in motion. They continuously vibrate, move and rotate. Even the atoms that make up the chairs that we sit in are moving around. Solids are actually in motion! Atoms can be in different states of excitation. In other words, they can have different energies. If we apply a lot of energy to an atom, it can leave what is called the ground-state energy level and go to an excited level. The level of excitation depends on the amount of energy that is applied to the atom via heat, light, or electricity.

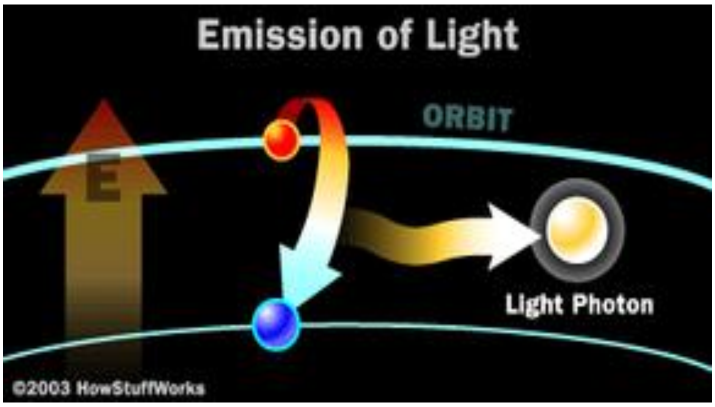
Above is a classic interpretation of what the atom looks like.

This simple atom consists of a nucleus (containing the protons and neutrons) and an electron cloud. It's helpful to think of the electrons in this cloud circling the nucleus in many different orbits.



If we apply some heat to an atom, we might expect that some of the electrons in the lower-energy orbitals would transition to higher-energy orbitals farther away from the nucleus. This is a highly simplified view of things, but it actually reflects the core idea of how atoms work in terms of lasers. Once an electron moves to a higher-energy orbit, it eventually wants to return to the ground state. When it does, it releases its energy as a photon — a particle of light.

Anything that produces light — fluorescent lights, gas lanterns, incandescent bulbs — does it through the action of electrons changing orbits and releasing photons.



Although there are many types of lasers, all have certain essential features. In a laser, the lasing medium is "pumped" to get the atoms into an excited state. Typically, very intense flashes of light or electrical discharges pump the lasing medium and create a large collection of excited-state atoms (atoms with higher-energy electrons). It is necessary to have a large collection of atoms in the excited state for the laser to work efficiently.

In general, the atoms are excited to a level that is two or three levels above the ground state. This increases the degree of population inversion. The population inversion is the number of atoms in the excited state versus the number in ground state.

Once the lasing medium is pumped, it contains a collection of atoms with some electrons sitting in excited levels. The excited electrons have energies greater than the more relaxed electrons. Just as the electron absorbed some amount of energy to reach this excited level, it can also release this energy. The electron can simply relax, and in turn rid itself of some energy. This emitted energy comes in the form of photons (light energy).

<u>The main components</u> that are required to be present in laser devices (laser operating conditions) are:

1) Active medium.

2) Resonator.

3) Pumping technique.

What is meant by (active medium)？

Answer / It is a group of atoms, molecules, or ions of an element, compound, or mixture in a solid, liquid, or gaseous state that has a number of energy levels, including absorption, spontaneous emission, and stimulated emission.

What is meant by resonator?

Answer / It is a resonant cavity with a suitable design consisting of two plane or concave mirrors, both or one of them. One of them is completely reflective of light (100%), and the second has a reflectivity of less than 100%.

What is pumping technology and how is it achieved ?

Answer / It is the technique by which energy can be prepared for the atoms of the active medium to transfer them from the level of stability to the level of irritation. Through it, the pumped energy can be obtained to excite the stable atoms in the medium in order to achieve the appropriate inverse distribution condition that guarantees laser generation.

What are the pumping methods?

Answer /

1- **<u>Optical pumping</u>** : It is used in solid-state and liquid-state lasers... and a high-intensity light source is used.
2- **<u>Electrical pumping</u>** : It is used in gas lasers through electrical discharge... and is also used in semiconductor lasers with a different excitation process.
3- **<u>Chemical pumping</u>** : It is used in chemical lasers such as the **deuterium fluoride laser**... Its efficiency is very high, reaching 200% and 300%, and the energy of the reaction products may greatly exceed the energy needed to cause the chemical reaction.

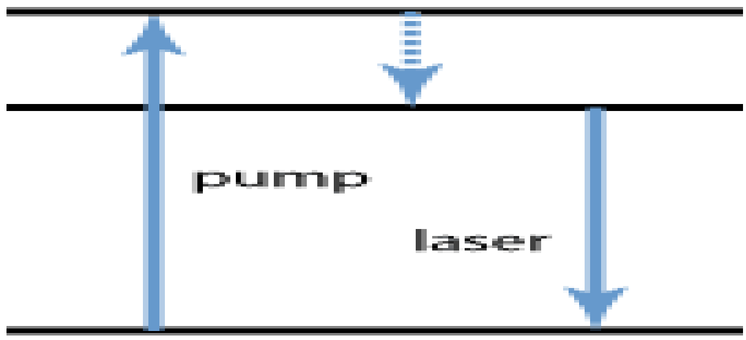
There are two types of laser systems used to complete the inverse distribution process:

1 -The three-level system.

2- The four-level system.

Three - level system

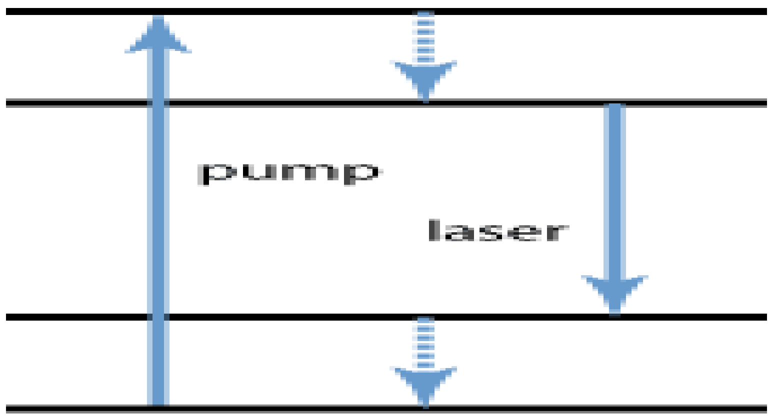
There are three energy levels...the ground energy level (E_1), the middle energy level (semi-stable level) (E_2), and the highest energy level (E_2), in which the atoms are agitated by pumping from the ground level (E_1) to the upper level (E_3)... It quickly falls to the semi-stable level (E_2), and here the inverse distribution between (E_2) and (E_1) will be achieved, and the required laser beam will then be generated.



Four - level system

There are four energy levels... and in it the atoms are excited from the ground level (E_1) to the level (E_4)... and then they quickly fall to the level (E_3). Here the inverted distribution between (E_3) and (E_2) will be achieved, and the required laser beam will be generated.

This system is the best because it requires less pumping energy .



Discussion

1. What is lasing action?

A) Photon split

B) Electron jump

C) Photon emission ☑

D) Energy loss

E) Heat transfer

2. What excites electrons in lasers?

A) Gravity

B) Light or current ☑

C) Sound

D) Pressure

E) Magnet

3. Photon emission occurs when electrons…

A) Ionize

B) Rotate nucleus

C) Drop orbit ☑

D) Split

E) Fuse

4. Ordinary light is…

A) Monochromatic

B) Incoherent ☑

C) Focused

D) Polarized

E) Single color

5. Laser light is…

A) Random

B) Diffuse

C) Coherent ☑

D) Multicolor

E) Weak

6. The gain medium can be…

A) Solid, liquid, gas ☑

B) Only gas

C) Only solid

D) Vacuum

E) Plasma

7. Photon wavelength depends on…

A) Atom size

B) Nucleus spin

C) Energy drop ☑

D) Pressure

E) Gravity

8. Laser cavity contains…

A) Lenses

B) Two mirrors ☑

C) Crystal

D) Coils

E) Filters

9. One mirror is…

A) 0% reflective

B) 25% reflective

C) 50% reflective

D) 100% reflective ☑

E) Transparent

10. The second mirror is…

A) Fully opaque

B) Transparent

C) <100% reflective ☑

D) Absorber

E) No mirror

11. Which process clones photons?

A) Reflection

B) Refraction

C) Stimulated emission ☑

D) Absorption

E) Diffraction

12. Ruby lasers emit…

A) Continuous light

B) Pulses ☑

C) Green light

D) Infrared

E) White light

13. Helium–Neon lasers emit…

A) Pulses

B) Continuous ☑

C) Random light

D) Ultraviolet

E) White

14. What is LASIK surgery using?

A) Ruby rods

B) X-rays

C) Laser beam ☑

D) Heat

E) Ultrasound

15. NIF laser emits…

A) Hours

B) Seconds

C) Nanoseconds

D) Billionths sec ☑

E) Minutes

16. Laser light can be…

A) Only visible

B) Only green

C) Visible & invisible ☑

D) Only UV

E) Only red

17. What is active medium?

A) Nucleus

B) Mirror

C) Pump source

D) Excitable atoms ☑

E) Cavity

18. What is a resonator?

A) Battery

B) Lens

C) Mirror cavity ☑

D) Gas tube

E) Flash tube

19. What is pumping technology?

A) Cooling

B) Heating

C) Energy supply ☑

D) Filtration

E) Detection

20. Optical pumping uses…

A) Sound

B) Light ☑

C) Electricity

D) Heat

E) Gas

21. Electrical pumping uses…

A) Light bulb
B) Flash tube
C) Electric discharge ☑
D) Magnet
E) Vibration

22. Chemical pumping is in…

A) Ruby laser
B) Dye laser
C) Chemical laser ☑
D) Neon laser
E) Fiber laser

23. Max efficiency of chemical lasers?

A) 10%

B) 50%

C) 100%

D) 200–300% ☑

E) 500%

24. Three-level laser has…

A) 2 levels
B) 3 levels ☑
C) 4 levels
D) 5 levels
E) 6 levels

25. Four-level system is better because…

A) More mirrors
B) Faster light
C) Less pumping energy ☑
D) Cheaper
E) No cavity