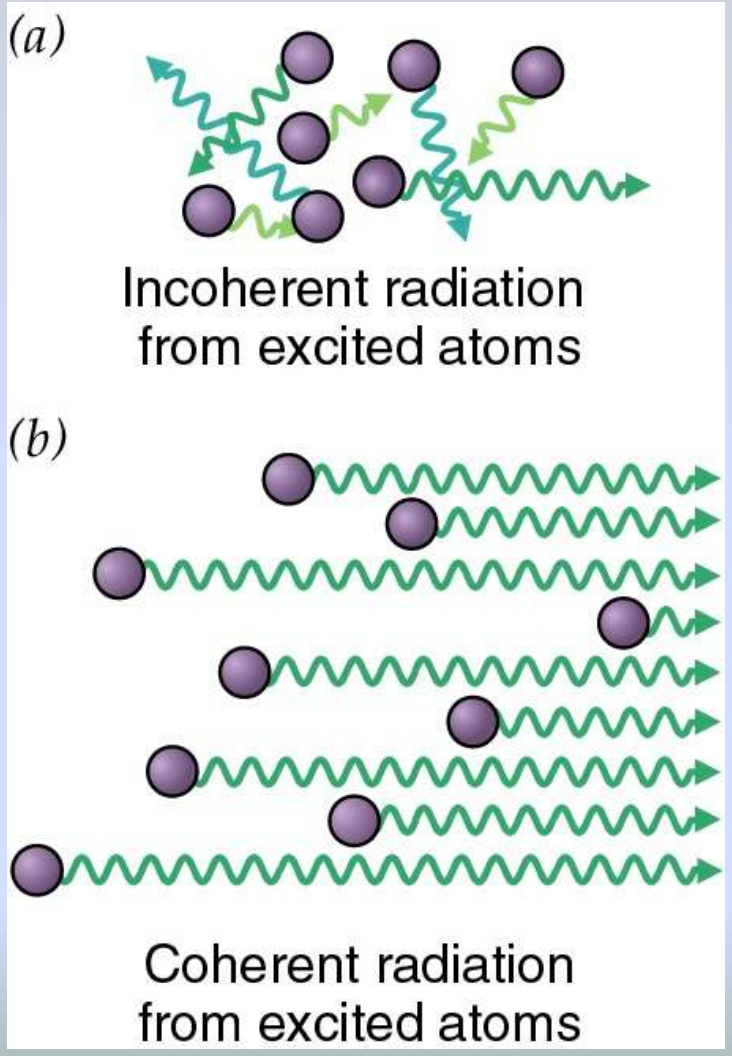
He-Ne Laser

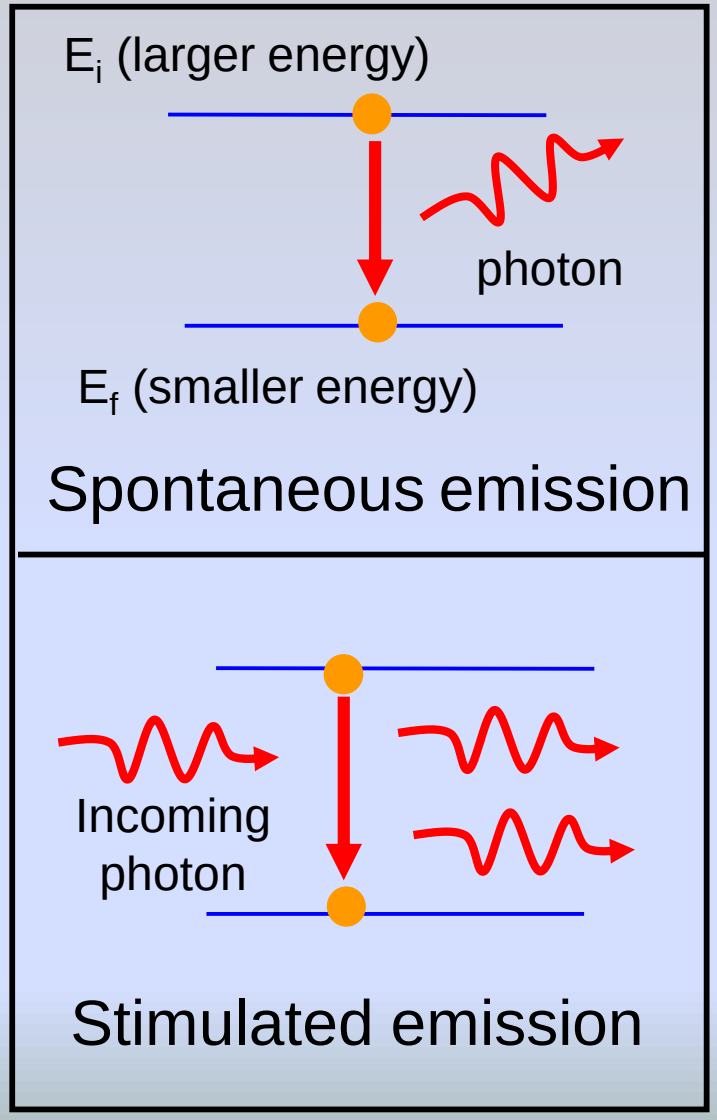
LASERS → a device that controls the way that energized atoms release photons.

- Light Amplification by Stimulated Emission of Radiation
- First we must understand the difference between **incoherent** and **coherent** radiation
- Ordinary light sources (light bulbs, fluorescent lights, etc) produce incoherent light
- lasers produce coherent light all atoms radiate in the same manner

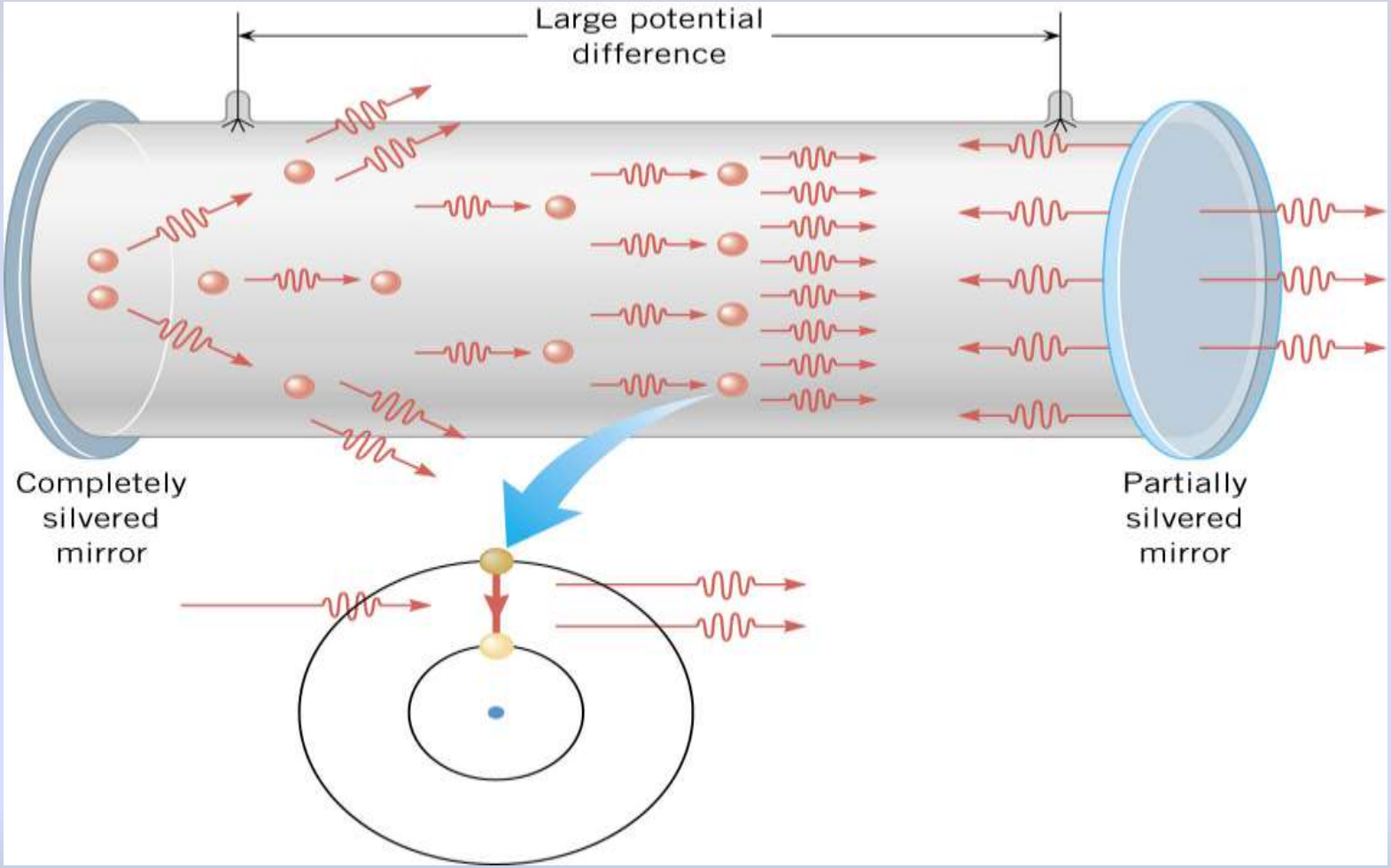


Spontaneous *vs* Stimulated Emission

- Coherent radiation is produced when an atom undergoes stimulated emission.
- Spontaneous emission occurs when an electron makes an unprovoked transition to a lower energy level
- Stimulated emission occurs when an incoming photon induces the electron to change energy levels **amplification**



A Helium-Neon (HeNe) Laser



What is a gas laser?

•A gas laser is a type of laser in which a mixture of gas is used as the active medium or laser medium. Gas lasers are the most widely used lasers.

•Gas lasers range from the low power helium-neon lasers to the very high power carbon dioxide lasers. The helium-neon lasers are most commonly used in college laboratories whereas the carbon dioxide lasers are used in industrial applications.

•The main advantage of gas lasers over solid state lasers is that they are less prone to damage by overheating so they can be run continuously.

What is helium-neon laser?

•It was built in 1961 by Ali Javan, Bennett, and Herriott at Bell Telephone Laboratories.

•These lasers have many industrial and scientific uses and are often used in laboratory demonstrations of optics.

•In He-Ne lasers, the optical pumping method is not used instead an electrical pumping method is used. The excitation of electrons in the He-Ne gas active medium is achieved by passing an electric current through the gas

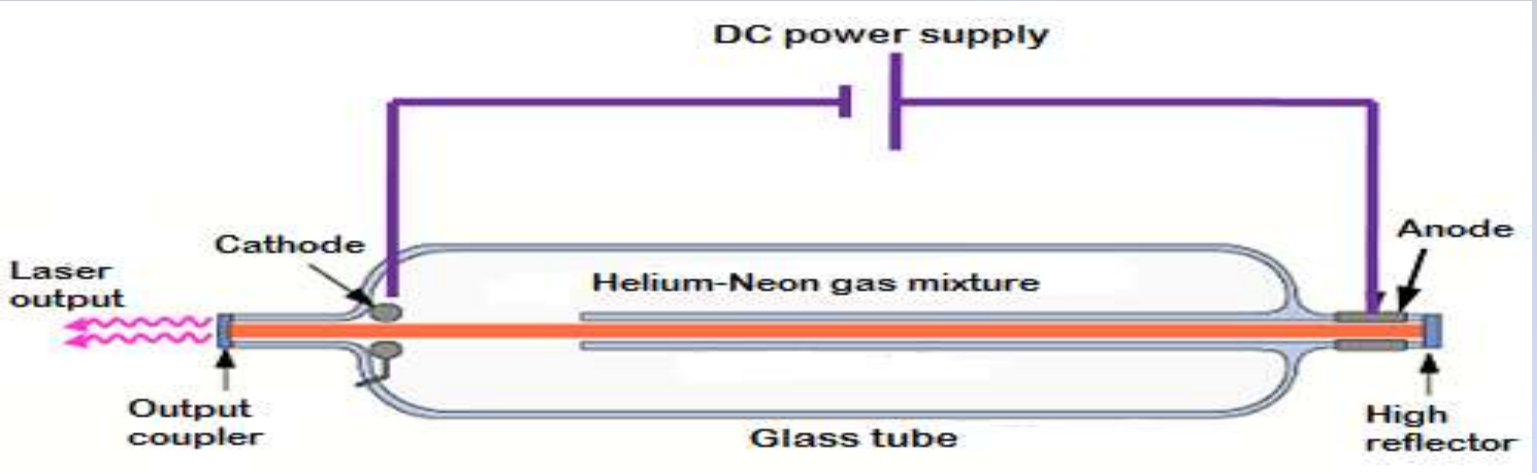
•The helium-neon laser operates at a wavelength of 632.8 nanometers (nm), in the red portion of the visible spectrum.

Helium-Neon laser construction

The helium-neon laser consists of three essential components:

- Pump source (high voltage power supply)
- Gain medium (laser glass tube or discharge glass tube)
- Resonating cavity

Pump Source



•Population inversion is the process of achieving more electrons in the higher energy state as compared to the lower energy state.
•After achieving population inversion, more electrons will remain in the higher energy state than the lower energy state.
In order to achieve population inversion, we need to supply energy to the gain medium or active medium
•In helium-neon lasers, a high voltage DC power supply is used as the pump source. A high Voltage DC supplies electric current through the gas mixture of helium and neon.

Discharge Glass Tube

•The gain medium of a helium-neon laser is made up of the mixture of helium and neon gas contained in a glass tube at low pressure. The partial pressure of helium is 1 mbar whereas that of neon is 0.1 mbar.
•The gas mixture is mostly comprised of helium gas. Therefore, in order to achieve population inversion, we need to excite primarily the lower energy state electrons of the helium atoms.
•In He-Ne laser, neon atoms are the active centers and have energy levels suitable for laser transitions while helium atoms help in exciting neon atoms.
•Electrodes (anode and cathode) are provided in the glass tube to send the electric current through the gas mixture. These electrodes are connected to a DC power supply.

Resonating Cavity

•The glass tube is placed between two parallel mirrors. These two mirrors are silvered or optically coated.

•The left side mirror is partially silvered and is known as output coupler whereas the right side mirror is fully silvered and is known as the high reflector.

•The fully silvered mirror will completely reflect the light whereas the partially silvered mirror will reflect most part of the light but allows some part of the light to produce the laser beam

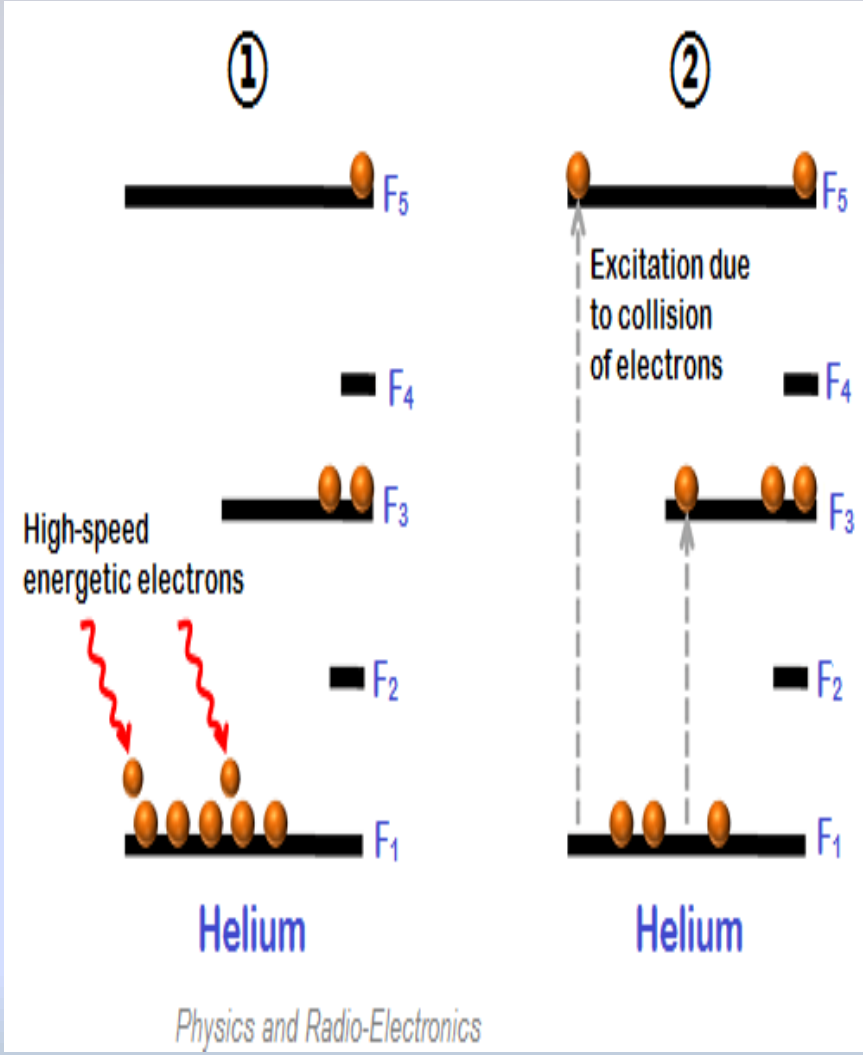
Working of helium-neon laser

•The gas mixture in helium-neon laser is mostly comprised of helium atoms.

•When the power is switched on, a high voltage of about 10 kV is applied across the gas mixture.

•In the process of flowing through the gas, the energetic electrons transfer some of their energy to the helium atoms in the gas.

• As a result, the lower energy state electrons of the helium atoms gain enough energy and jumps into the excited states or metastable states.



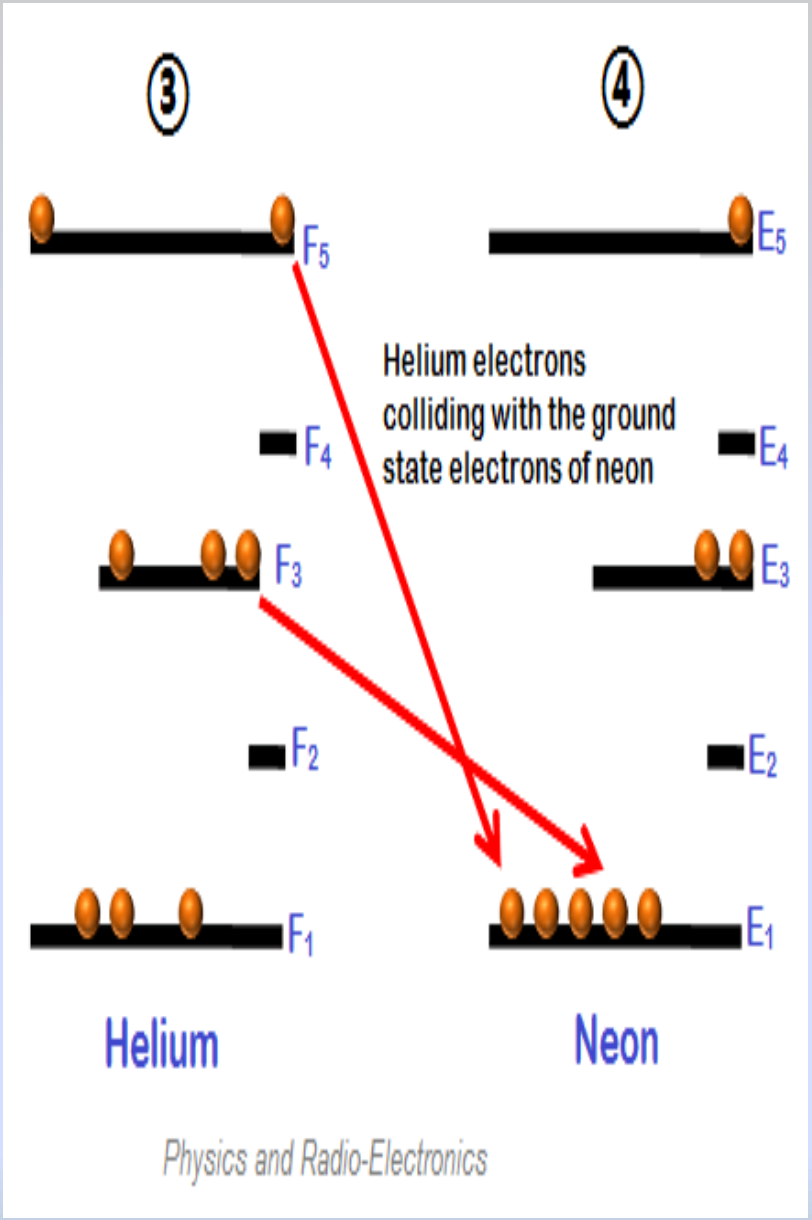
•The metastable state electrons of the helium atoms cannot return to ground state by spontaneous emission.

• They can return to ground state by transferring their energy to the lower energy state electrons of the neon atoms.

•The energy levels of some of the excited states of the neon atoms are identical to the energy levels of metastable states of the helium atoms.

• Let us assume that these identical energy states are $F_3 = E_3$ and $F_5 = E_5$.

• E_3 and E_5 are excited states or metastable states of neon atoms.

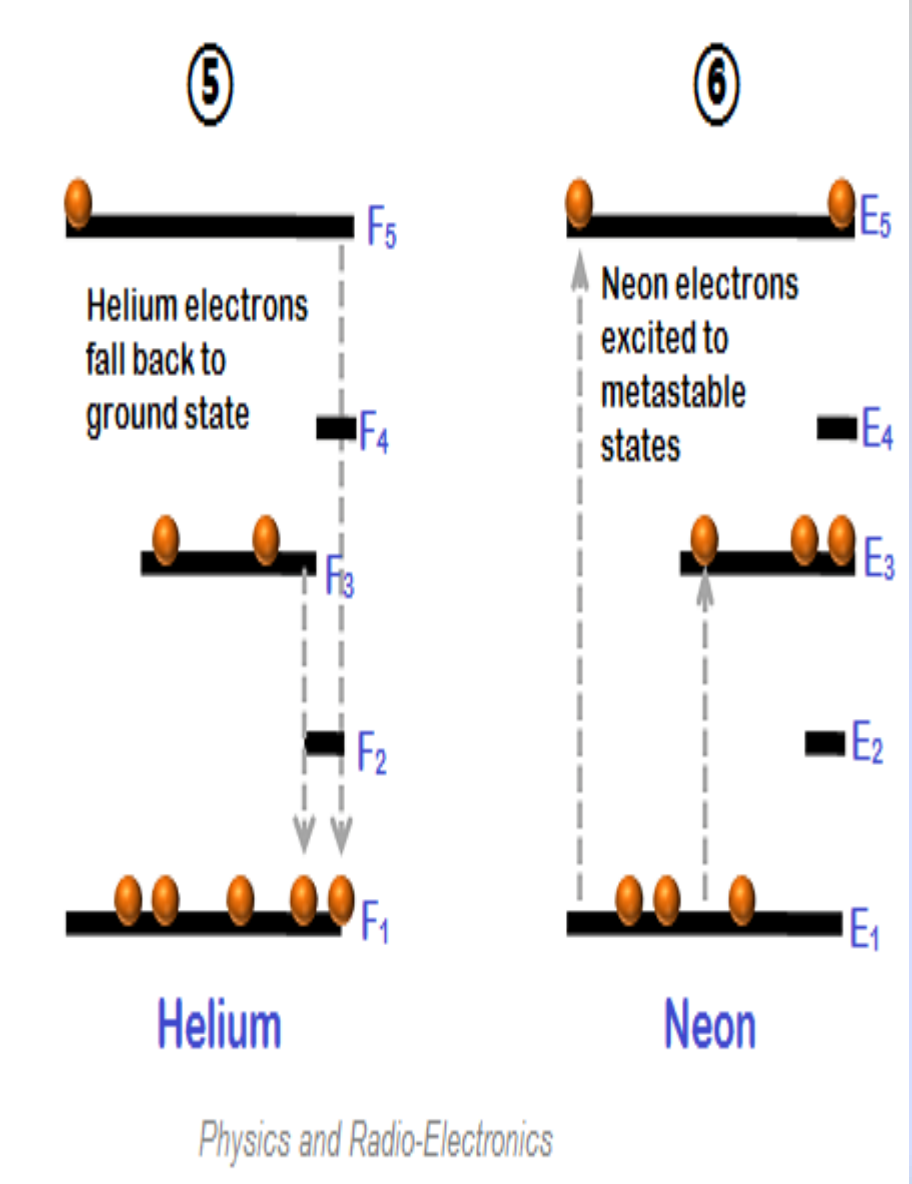


•When the excited electrons of the helium atoms collide with the lower energy state electrons of the neon atoms, they transfer their energy to the neon atoms.

•The lower energy state electrons of the neon atoms gain enough energy from the helium atoms and jumps into the higher energy states or metastable states (E_3 and E_5)

•The excited electrons of the helium atoms will fall into the ground state.

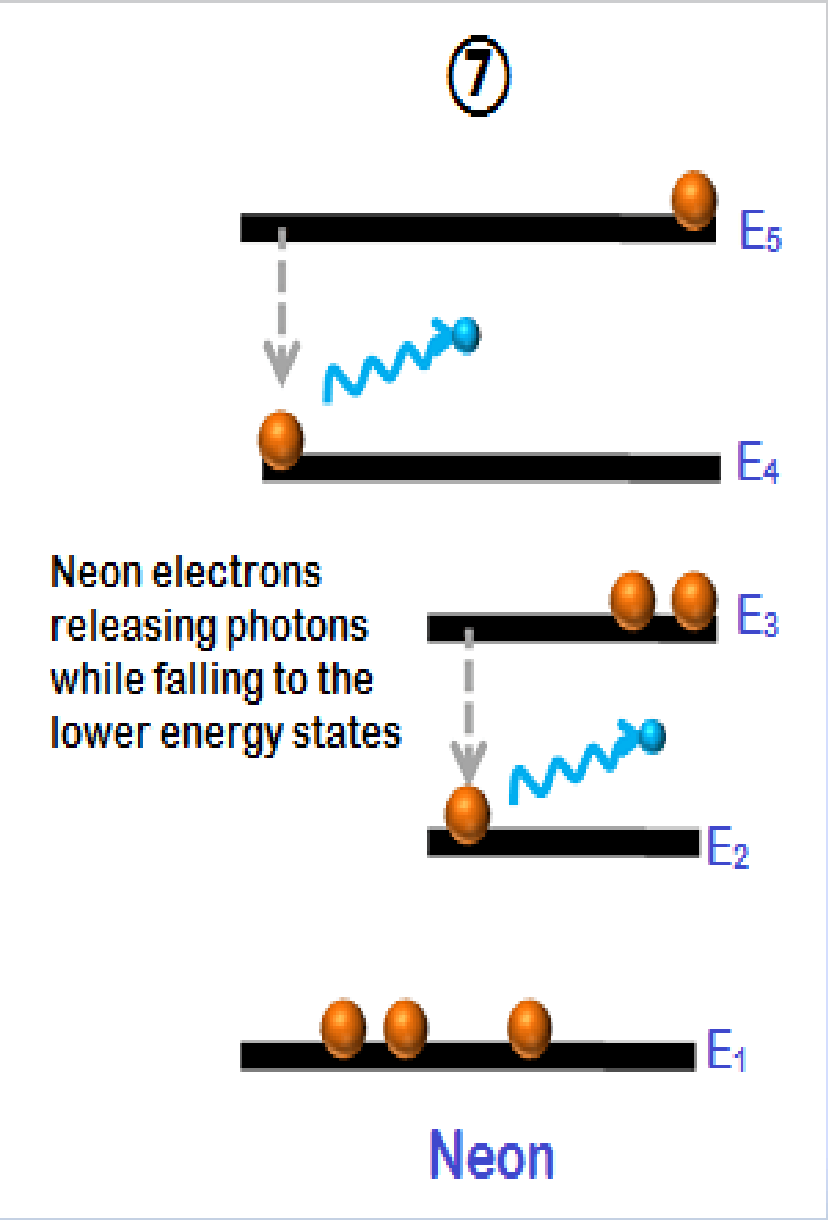
•Thus, helium atoms help neon atoms in achieving population inversion.



•Millions of ground state electrons of neon atoms are excited to the metastable states. The metastable states have the longer lifetime.

•A large number of electrons will remain in the metastable states and hence population inversion is achieved.

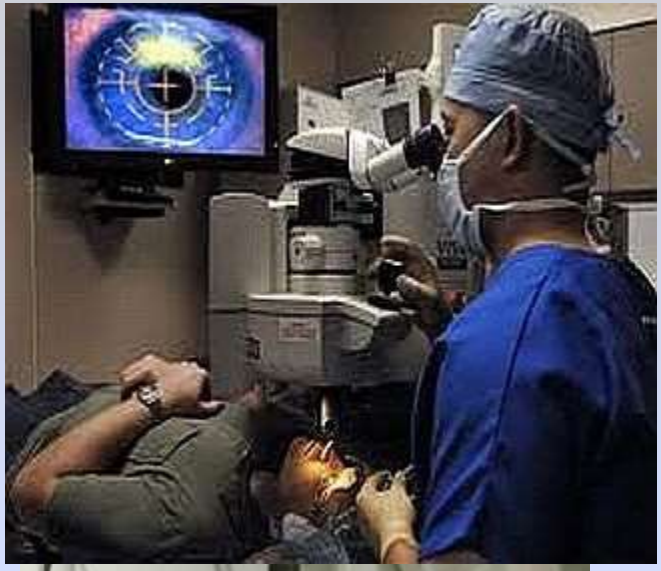
•After some period, the metastable states electrons (E_3 and E_5) of the neon atoms will spontaneously fall into the next lower energy states (E_2 and E_4) by releasing photons or red light. This is called spontaneous emission.



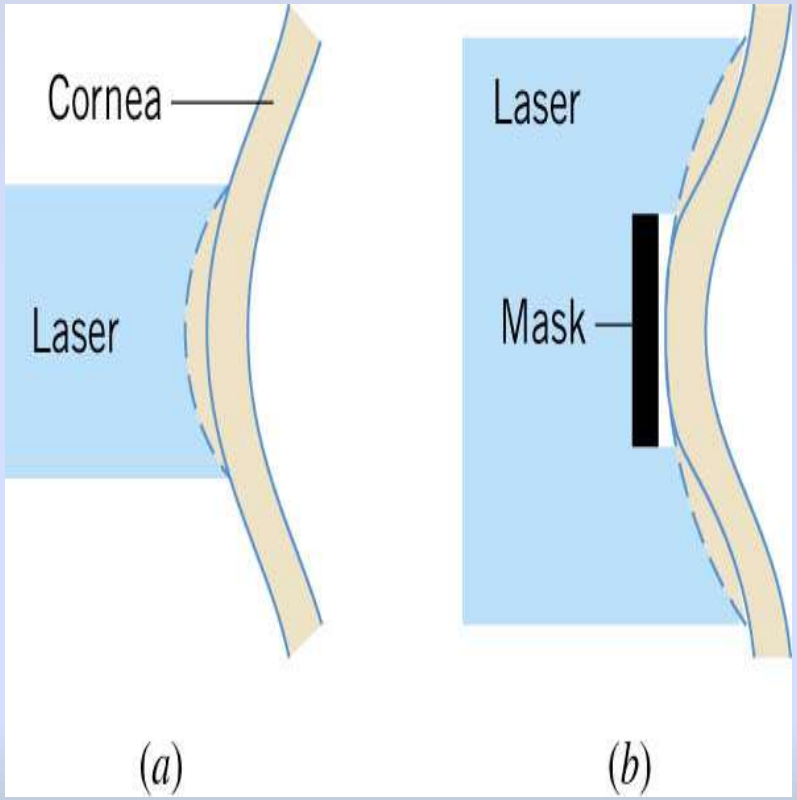
•The light or photons emitted from the neon atoms will moves back and forth between two mirrors until it stimulates other excited electrons of the neon atoms and causes them to emit light. Thus, optical gain is achieved. This process of photon emission is called stimulated emission of radiation.

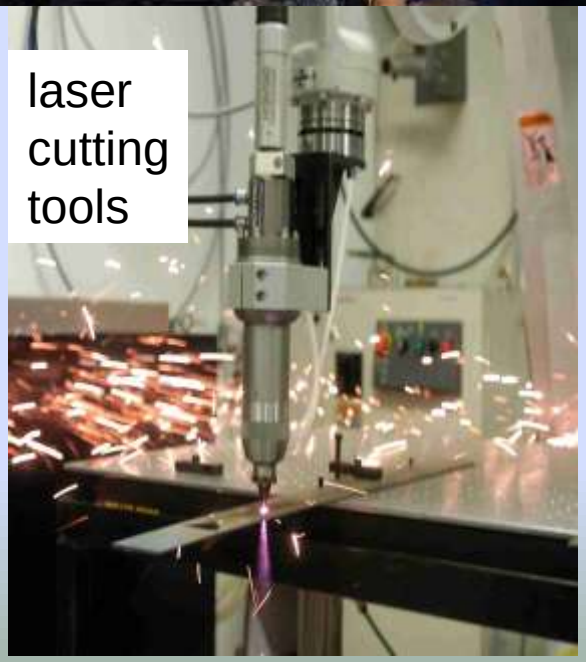
•The light or photons emitted due to stimulated emission will escape through the partially reflecting mirror or output coupler to produce laser light.

Applications of lasers



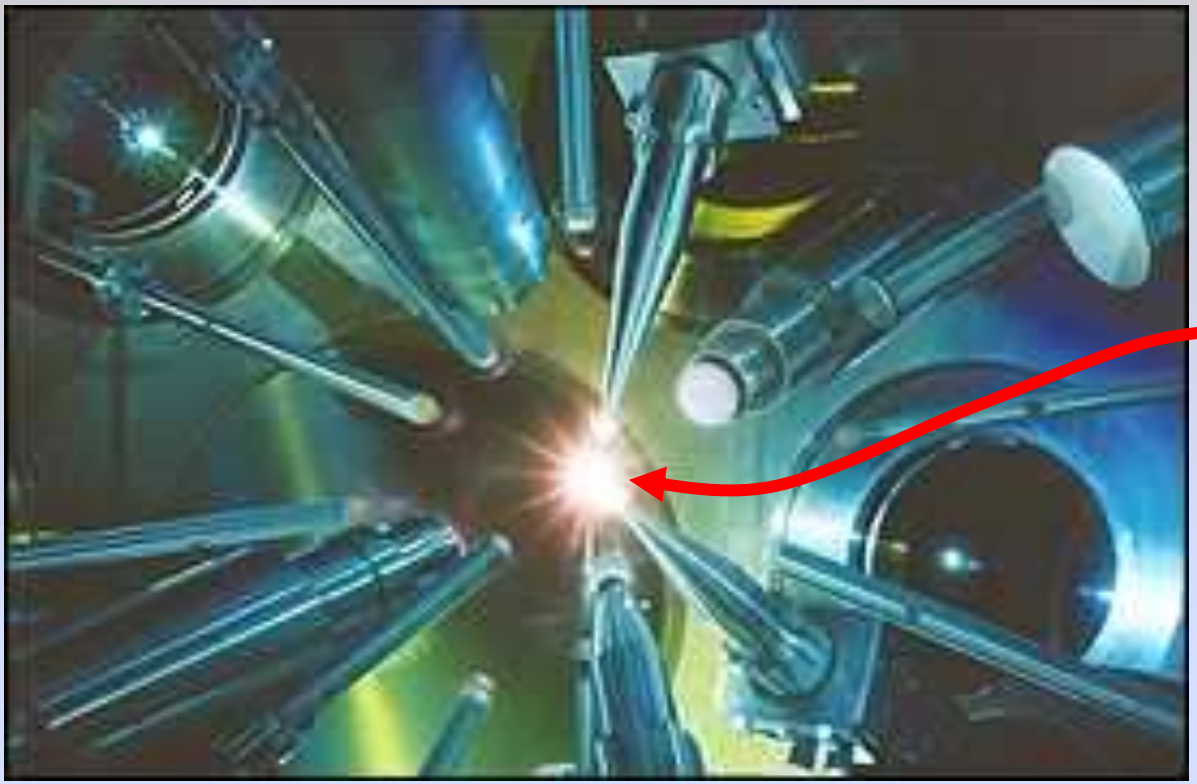
Laser surgery to correct for
(a) nearsightedness, and
(b) farsightedness





laser cutting tools

Laser Fusion Energy



Multiple beams of a powerful laser are focused on a tiny pellet containing fusion fuel. The laser energy compresses the pellet producing a mini-hydrogen bomb that produces energy

Advantages of helium-neon laser

•Helium-neon laser emits laser light in the visible portion of the spectrum.

•High stability

•Low cost

•Operates without damage at higher temperatures

Disadvantages of helium-neon laser

•Low efficiency

•Low gain

•Helium-neon lasers are limited to low power tasks

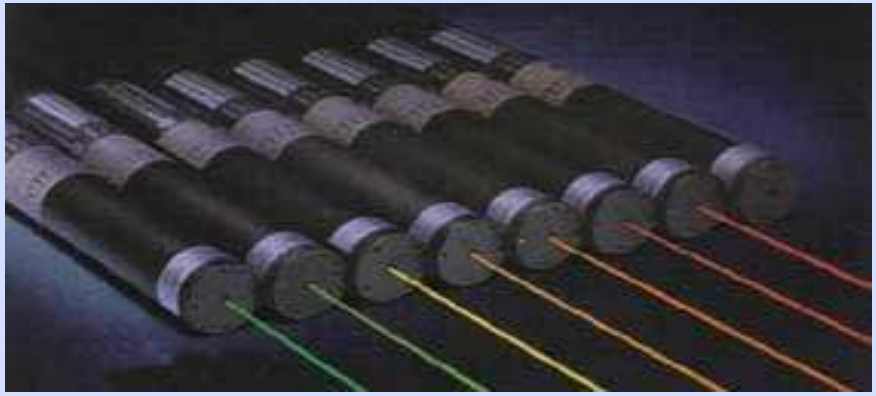
Applications of helium-neon lasers

•Helium-neon lasers are used in industries.

•Helium-neon lasers are used in scientific instruments.

•Helium-neon lasers are used in the college laboratories.

Solid State Laser Diodes



in a variety of different colors

- Diode lasers use semiconductor materials (tiny chips of silicon) as the lasing media
- When current flows through the silicon chip it emits an intense beam of coherent light.
- Diode lasers are used to read the information embedded in the pits in CD's and DVD's, and also to read UPC's in bar code scanners and in laser pointers!

Applications of modern technology

- Laser speed gun: sends out a laser beam that bounces off your car and back; from the time delay it calculated your car's speed
- CD burner: CD coated with a photosensitive dye that darkens when hit with laser light
- Medical imaging methods
  - x-rays
  - CT and CAT scans
  - MRI's (Magnetic Resonance Imaging)

Thanks