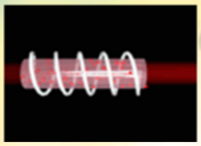
Physics Academy

Al-Azhar University - Gaza

Laser Physics



Laser System: He-Ne laser

Lecture 16

Dr. Hazem Falah Sakeek
www.hazemsakeek.com
www.physicsacademy.org

Laser System

درسنا في المحاضرات السابقة فكرة عمل الليزر بشكل عام مع التركيز على العوامل المؤثرة على الليزر. والآن سوف نخصص دراستنا على عدة أنظمة لليزر تختلف باختلاف المادة **Active medium** ويمكن تقسيم أنظمة الليزر إلى خمسة أقسام هي على النحو التالي:-

- The **state of matter of the active medium**: solid, liquid, gas, or plasma.
- The **spectral range of the laser wavelength**: visible spectrum, Infra-Red (IR) spectrum, etc.
- The **excitation (pumping) method of the active medium**: Optic pumping, Electric pumping, etc.
- The **characteristics of the radiation emitted from the laser**.
- The **number of energy levels which participate in the lasing process**.

سوف نعتمد على النوع الأول والذي يقسم الليزر حسب المادة **Active medium** والذي يحدد الخواص التالية:

- **Laser Wavelength.**
- **Preferred pumping method.**
- **Order of magnitude of the laser output.**
- **The efficiency of the laser system.**

We saw that the **two basic requirements for laser action** are:

- **Population Inversion** between the upper and lower laser energy levels.
- **The active medium must be transparent to the output wavelength.**

تجدر الإشارة هنا إلى أن **active medium** هي التي تحدد خواص الليزر ولهذا السبب تعود تسمية الليزر حسب المادة المستخدمة.

Laser types

[1] Gas lasers:

Atom Gas:

- Helium-Neon Laser (He-Ne).
- Metal Vapor Laser (Copper, Gold).
- Helium Cadmium Laser (He-Cd).
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Ion Gas:

- Argon Ion Laser (Ar^+).
- Krypton Laser (Kr^+).
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Molecular Gas:

- Carbon Dioxide Laser (CO_2).
- Nitrogen Laser (N_2).
- Excimer Laser.
- Chemical Laser.
- Far Infra-Red Laser (FIR).

[2] Solid State lasers:

- Ruby Laser.
- Neodimium YAG and Nd Glass Laser.
- Color Center Laser.
- Titanium Sapphire Laser.
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[3] Diode Laser (Semiconductor Laser, Injection Laser).

[4] Dye Laser (Liquid).

[5] Special Lasers:

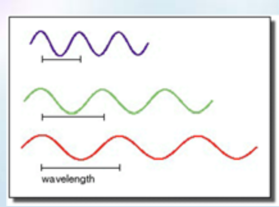
- Free Electron Laser (FEL).
- X Ray Laser.

WAVELENGTHS OF MOST COMMON LASERS

Argon fluoride (Excimer-UV)	0.193
Krypton chloride (Excimer-UV)	0.222
Krypton fluoride (Excimer-UV)	0.248
Xenon chloride (Excimer-UV)	0.308
Xenon fluoride (Excimer-UV)	0.351
Helium cadmium (UV)	0.325
Nitrogen (UV)	0.337
Helium cadmium (violet)	0.441
Krypton (blue)	0.476
Argon (blue)	0.488
Copper vapor (green)	0.510
Argon (green)	0.514
Krypton (green)	0.528
Frequency doubled Nd YAG (green)	0.532
Helium neon (green)	0.543
Krypton (yellow)	0.568
Copper vapor (yellow)	0.570

Helium neon (yellow)	0.594
Helium neon (orange)	0.610
Gold vapor (red)	0.627
Helium neon (red)	0.633
Krypton (red)	0.647
Rohodamine 6G dye (tunable)	0.570-0.650
Ruby ($CrAlO_3$) (red)	0.694
Gallium arsenide (diode-NIR)	0.840
Nd:YAG (NIR)	1.064
Helium neon (NIR)	1.15
Erbium (NIR)	1.504
Helium neon (NIR)	3.39
Hydrogen fluoride (NIR)	2.70
Carbon dioxide (FIR)	9.6
Carbon dioxide (FIR)	10.6

Key: UV = ultraviolet (0.200-0.400 μm)
VIS = visible (0.400-0.700 μm)
NIR = near infrared (0.700-1.400 μm)



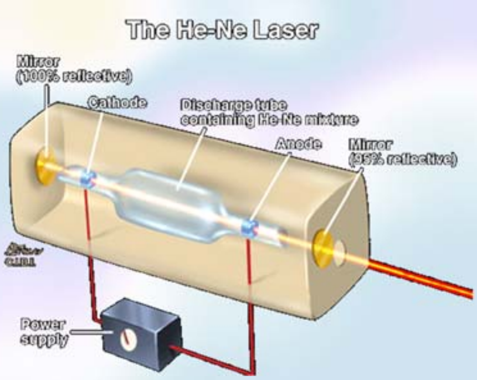
Helium-Neon (He-Ne) Laser

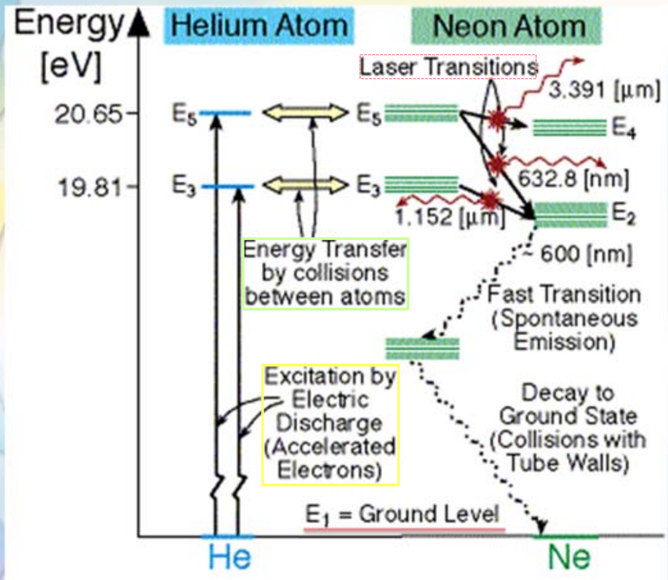
The Helium-Neon laser was the most common laser until the spread of **diode lasers**.

It was first built in 1961 by Ali Javan. The active medium is a noble gas Neon (Ne), and it is a 4 level laser.

- Two **meta-stable energy levels** act as **upper laser levels.**
- The He-Ne laser have two lower laser levels, so quite a few wavelengths can come out of the transitions between these levels.
- **The important wavelengths are:**

  λ_1= (632.8 nm), λ_2=1.152 μ m, λ_3=3.3913 μ m





The energy level diagram of a Helium-Neon laser

The excitation process of the **Neon** atoms is a two stages process:

- The high voltage causes electrons to accelerate from the cathode toward the anode. These **electrons** collide with the He atoms and transfer kinetic energy to them.
- The **excited Helium** atoms collide with the Neon atoms, and transfer to them the energy for excitation.

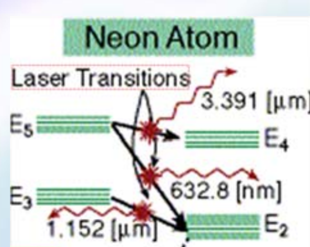
Thus Helium gas does not participate in the lasing process, but increases the excitation efficiency

The role of the Helium gas in He-Ne laser is to increase the efficiency of the lasing process. Two effects make Helium particularly valuable:

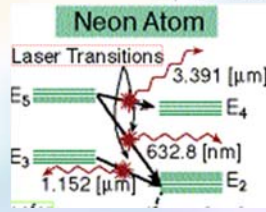
- The direct excitation of Neon gas is inefficient, but the direct excitation of He gas atoms is very efficient.
- An excited state of the He atom (labeled E_5) has an energy level which is very similar to the energy of an excited state of the Neon atom (also labeled E_5).

Red Wavelength out of He-Ne Laser: Most of the applications of He-Ne Laser use the **red wavelength**, because it is the strongest line and it is in the visible region of the spectrum.

As shown in the figure, this red light is emitted when the Neon atom goes from the energy level labeled E_5 to the energy level labeled E_2, a much bigger energy difference than for the other transitions.



A problem with creating this red light is that a Neon atom in state E_5 may also emit 3.3913 μm radiation. This emission decreases the population of the E_5 level, without producing visible radiation.



- **The solution** to this problem is to use a special coating on the laser mirrors which selectively reflect only the red light. This coating causes reflection back into the optical cavity of only the desired (red) wavelength, while all other wavelengths are transmitted out, and not forced to move back and force through the active medium.
- In a similar way, other selective reflecting coating can be used on the mirrors to select other transitions. This procedure allows commercial production of He-Ne lasers at other wavelengths in the visible spectrum. For example, orange, yellow and green He-Ne lasers can be produced, but the laser efficiency is much lower than for the red.

Absorption and Amplification in He-Ne Laser

- He-Ne laser is a 4 level laser, so the lifetime of the **lower laser energy level** needs to be very short.
- In a Neon gas, which is the active lasing gas, the transition (decay) from the lower laser level is not fast enough, but it is accelerated by collisions with the tube walls. Because the number of collisions with the tube walls increase as the tube becomes narrow, the laser gain is inversely proportional to the tube radius. So, **the tube diameter of a He-Ne laser must be as small as possible**.

- The **low gain of the active medium in a He-Ne laser limits the output power to low power**.
- In laboratory prototypes an output power of the order of 100 μW was achieved, but commercial lasers are available only in the output range of 0.5-50 mW.
- The **output coupler** of He-Ne laser is a mirror with coating that transmits about 1% of the radiation to the output. This means that the power inside the optical cavity is a 100 times more than the emitted power.

Commercial He-Ne Lasers:

Wavelength:	632.8 [nm]
Output Power:	0.5-50 [mW]
Beam Diameter:	0.5-2.0 [mm]
Beam Divergence:	0.5-3 [mRad]
Coherence Length:	0.1-2 [m]
Power Stability:	5 [%/Hr]
Lifetime:	>20,000 [Hours]