Assist.Prof. Dr. Muhanad rasheed

Al-Rasheed University College

TYPES OF LASER

Laser Level systems for lasing (2-level, 3-level, 4-level Systems)

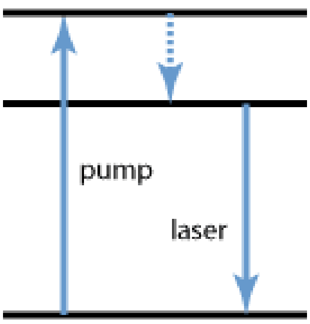
1. Two level laser system

A Two-Level System Cannot Achieve a Population Inversion because a population inversion cannot be achieved in a two-level scheme of operation. The energy being used to pump the atoms into the upper laser state has an equal probability of stimulating them back down.

Thus, For laser amplification one requires at least three or more energy levels.

2. Three level laser system

The 3-level lasers are the first type of lasers discovered. In a 3-level laser, at least half the population of electrons must be excited to the higher energy state to achieve population inversion.



With sufficiently intense pumping it is possible to reach a population of the upper laser level which is well above 50%, and thus higher than that of the lower laser level (the ground state); a **population inversion** is reached. However, pumping with high **optical intensity** is required. That's why Pure three-level laser gain media are seldom used.

A popular example of a three-level laser medium is **ruby** ($Cr^{3+}:Al_2O_3$), as used by Maiman for the first laser.

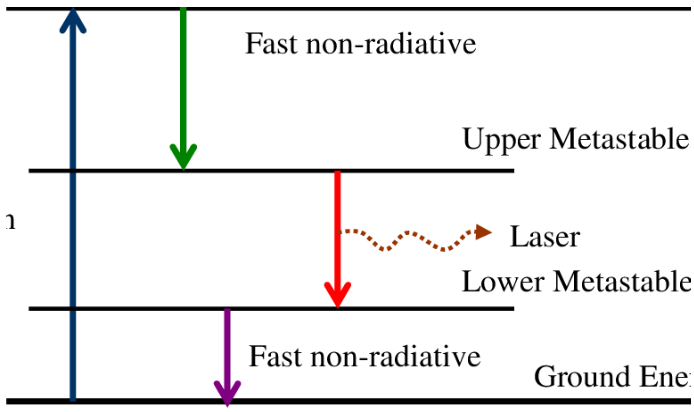
1. **Four level laser system**

In this system, optical pumping from the ground state (E_1) into the pump band (E_4) excites the atoms.

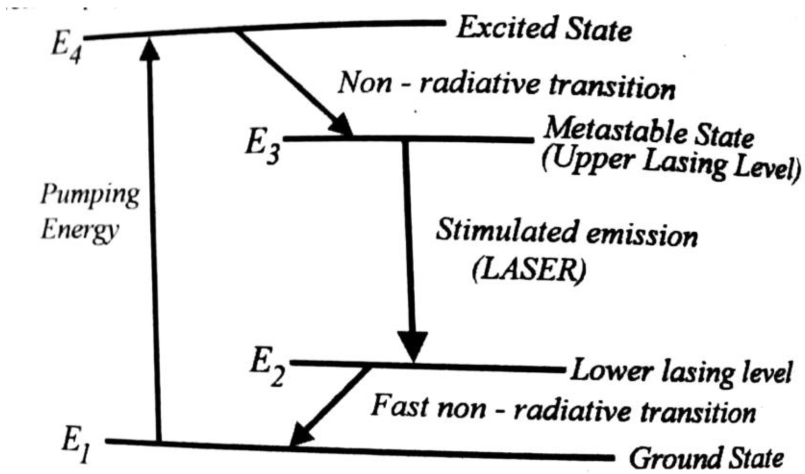
From this level the atoms decay by a fast, radiationless transition into the level 3 (E_3). The lifetime of the laser transition from $E_3 – E_2$ is long compared to that of $E_4 – E_3$, a population accumulates in this level 3 (lasing level).

Here the atoms relax and start to create laser transitions through spontaneous and stimulated emissions into level 2 (E_2). At this level, like level 4 has a fast decay into the ground state.

Since only a small number of atoms need to be excited in the upper lasing level E_3 to form population inversion, it proves that a 4-level laser is much more efficient and practical than the 3-level laser.



Fast non-radiative
Upper Metastable
Laser
Lower Metastable
Fast non-radiative

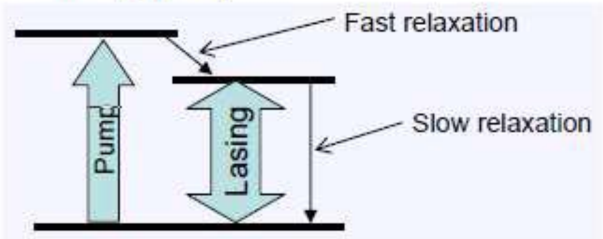


E4
Excited State
Non - radiative transition
E3
Metastable State
(Upper Lasing Level)
Pumping Energy
Stimulated emission
(LASER)
E2
Lower lasing level
Fast non - radiative transition
E1
Ground State

Impossible to invert two 2 level system:

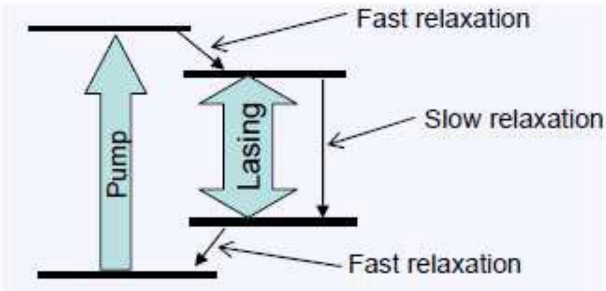
3-level system

requires strong pump



4-level system

best



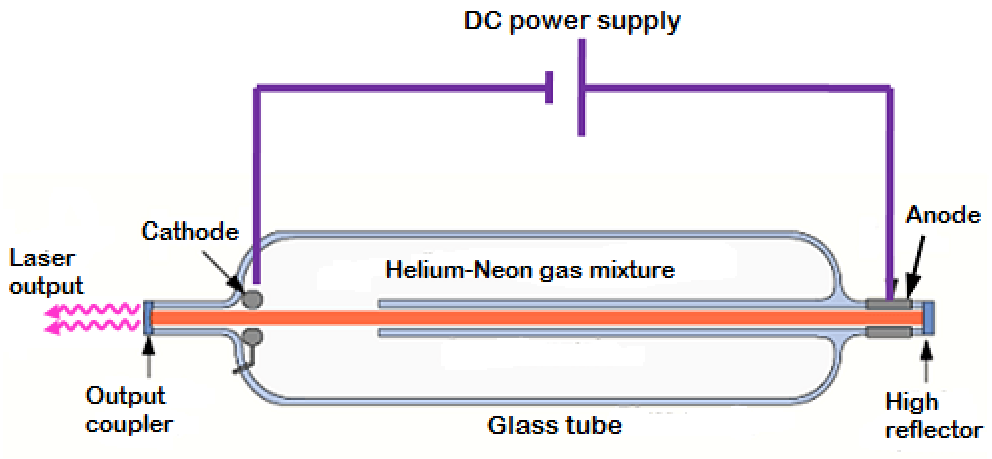
TYPES OF LASER

The different types of laser can be classified depending on the nature of the active medium as follows:

1. **Gas Lasers**
2. **Solid-state Lasers**
3. **Liquid Lasers**
4. **Semiconductor Lasers**
5. **Fiber Lasers**

1. Gas Lasers

A gas laser is a laser in which an electric current is discharged through a gas inside the laser medium to produce laser light. In gas lasers, the laser medium is in the gaseous state filled in a glass tube.



Gas lasers are used in applications that require laser light with very high beam quality and long coherence lengths. The glass tube filled with the mixture of gases acts as an active medium or laser medium. Examples of gas lasers include carbon dioxide (CO2) lasers, helium–neon (He-Ne) lasers, argon lasers, krypton lasers, and Excimer lasers.

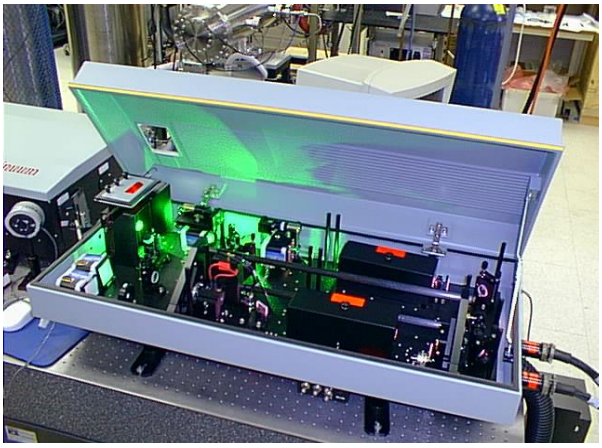
Gas lasers are used in a wide variety of applications, including laser surgery,

holography, spectroscopy, barcode scanning, air pollution measurements, and material processing.

1. Solid-State Lasers

Solid-state lasers use a solid (crystals or glasses) mixed with a rare earth element as their source of optical gain. The mixed element is typically neodymium, chromium, erbium, thulium, or ytterbium.

The most known solid-state laser is the ruby laser, since it is the first laser ever constructed. The Nd:YAG laser (neodymium-doped yttrium aluminum garnet) is also common in material processing applications.

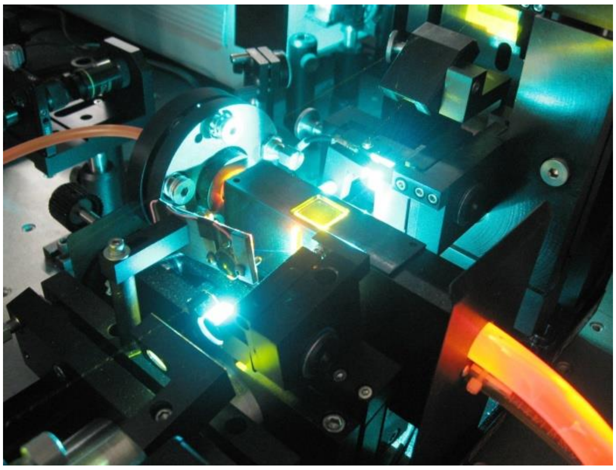


Solid-state lasers are also used for various medical applications, including tattoo and hair removal, tissue ablation, and kidney stone removal.

2. Liquid Lasers

A Liquid lasers use an organic dye in liquid form as their gain medium. They are also known as dye lasers and are used in laser medicine, spectroscopy, birthmark removal, and isotope separation.

One of the advantages of dye lasers is that they can generate a much wider range of wavelengths, making them good candidates to be tunable lasers, meaning that the wavelength can be controlled while in operation.



2. Semiconductor Laser

Laser diodes, also called diode lasers and semiconductor lasers, are similar to regular diodes in that they have a positively-negatively (PN) charged junction. Although most semiconductor lasers are diode lasers, a few of them are not. This is because there are semiconductor lasers that do not use the diode structure, such as optically pumped semiconductor lasers.

Laser diodes can be classified as solid-state lasers since their gain medium is solid. However, they are in a category of their own because of their PN junction.

Laser diodes are often used as energy sources to pump other lasers. These lasers are referred to as diode-pumped lasers. In these cases. Laser diodes are extremely common. They are used in barcode readers, laser pointers, laser printers, laser scanners, and several other applications.

3. Fiber Lasers

A fiber laser is a special type of solid-state laser that is a category of its own. In fiber lasers, the gain medium is an optical fiber (silica glass) mixed with a rare-earth element.

The light guiding properties of the optical fiber are what makes this type of laser so different: the laser beam is straighter and smaller than with other types of lasers, making it more precise. Fiber lasers are also good electrical efficiency, low maintenance and low operating costs.
Fiber lasers are used in a range of applications, including material processing (laser cleaning, texturing, cutting, welding, marking), medicine, and directed energy weapons.

Examples of fiber lasers used for these applications include ytterbium and erbium-doped fiber lasers.

Laser Radiation Properties

- Laser radiation is *nearly monochromatic ;* Monochromatic refers to **a single wavelength, or "one color" of light.** Laser radiation contains a narrow band of wavelengths and can be produced closer to monochromatic than light from other sources.
- Laser radiation is **highly** *directional*. The radiation is produced in a beam that is spatially narrow and has low divergence relative to other light sources.
- Laser radiation is ***highly coherent***, which means the waves of light emitted have a constant relative phase. The waves of light in a laser beam are thought of as in phase with one another at every point. The degree of coherence is proportional to the range of wavelengths in the light beam, or the beam's monochromaticity. Laser radiation has both *spatial* **and** *temporal* **coherence**, characterized by the ***coherence length*** and the ***coherence time***.

Laser Output

Laser output can be :

i. Continuous (CW) : characterized by their *average power*

ii. pulsed. Characterized by peak power, Irradiance (Intensity, or power density)

Irradiance (power density) = power per unit area = power/area = Watt/ cm^2 = W/cm^2

<u>Laser Pulse width (duration)</u>

Pulse Width (PW) is the elapsed time between the rising and falling edges of a single pulse.