Applied Physics (WBSCTE) Sem-II

LASER (Unit-5)

By Priyabrata Banerjee, Lecturer in Physics , Bankura Government Polytechnic

- **Full form of LASER**- **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

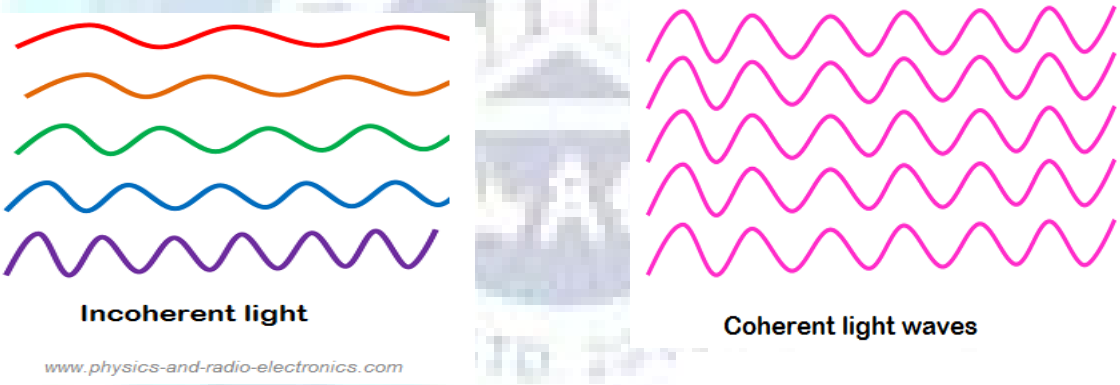
- **Properties of LASER:**

Laser light has four unique characteristics that differentiate it from ordinary light:

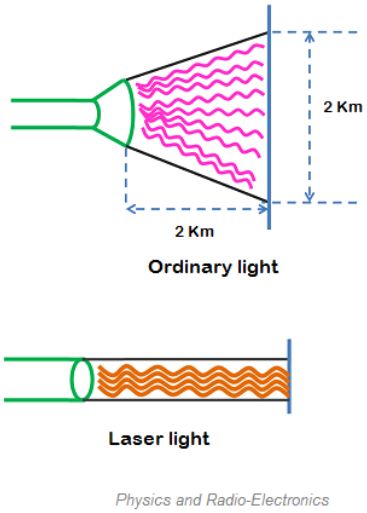
a)Coherence

In ordinary light sources (lamp, sodium lamp and torch light), the electron transition occurs naturally. In other words, electron transition in ordinary light sources is random in time. The photons emitted from ordinary light sources have different energies, frequencies, wavelengths, or colors. Hence, the light waves of ordinary light sources have many wavelengths. Therefore, photons emitted by an ordinary light source are out of phase.

In laser, the electron transition occurs artificially. In other words, in laser, electron transition occurs in specific time. All the photons emitted in laser have the same energy, frequency, or wavelength. Hence, the light waves of laser light have single wavelength or color. Therefore, the wavelengths of the laser light are in phase in space and time. In laser, a technique called stimulated emission is used to produce light.



Thus, light generated by laser is highly coherent. Because of this coherence, a large amount of power can be concentrated in a narrow space.



b) Directionality

In conventional light sources (lamp, sodium lamp and torchlight), photons will travel in random direction. Therefore, these light sources emit light in all directions.

On the other hand, in laser, all photons will travel in same direction. Therefore, laser emits light only in one direction. This is called directionality of laser light. The width of a laser beam is extremely narrow. Hence, a laser beam can travel to long distances without spreading.If an ordinary light travels a distance of 2 km, it spreads to about 2 km in diameter. On the other hand, if a laser light travels a distance of 2 km, it spreads to a diameter less than 2 cm.

c) Monochromaticity

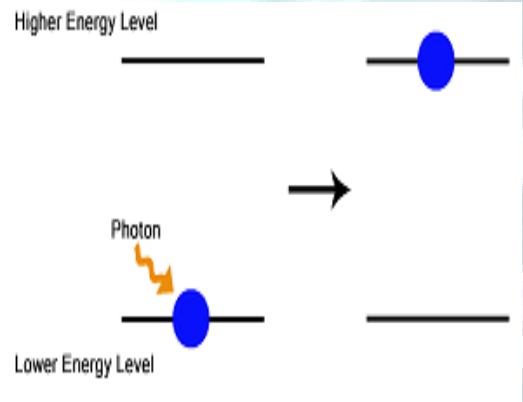
Monochromatic light means a light containing a single color or wavelength. The photons emitted from ordinary light sources have different energies, frequencies, wavelengths, or colors. Hence, the light waves of ordinary light sources have many wavelengths or colors.

On the other hand, in laser, all the emitted photons have the same energy, frequency, or wavelength. Hence, the light waves of laser have single wavelength or color. Therefore, laser light covers a very narrow range of frequencies or wavelengths.

d) High Intensity

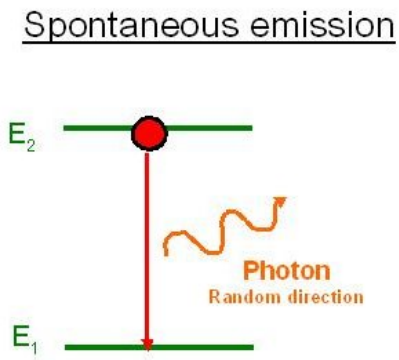
You know that the intensity of a wave is the energy per unit time flowing through a unit normal area. In an ordinary light source, the light spreads out uniformly in all directions.In laser, the light spreads in small region of space and in a small wavelength range. Hence, laser light has greater intensity when compared to the ordinary light.

➢ Absorption:



If a photon interacts with an orbital electron, given the appropriate conditions, the photon is absorbed by the electron. When this occurs the electron moves to a higher energy level. Such an event is called **absorption**. When an electron moves to a higher energy level it is said to be in an excited state.

➢ Spontaneous emission:



Occurs when an electron that is in an excited state spontaneously transit to a lower energy state. When this occurs, a photon is emitted. The energy of the photon is equal to the energy difference between the two energy levels. All forms of luminescence are the result of spontaneous emissions of light.

➢ Metastable state:

Metastable state is an excited state of an atom or other system with a longer lifetime than the other excited states. However, it has a shorter lifetime than the stable ground state but longer than that of the normal excited states. Atoms in the metastable state remain excited for a considerable time in the order of 10^{-3}seconds. A large number of excited atoms are accumulated in the metastable state.

➢ Population inversion:

A **population inversion** occurs while a group of atoms or molecules exists in a state in which **more members** of the atoms or molecules in higher, **excited states than in lower energy states**.

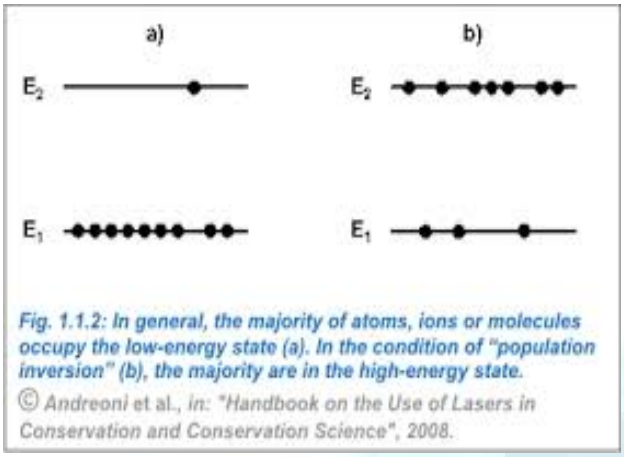


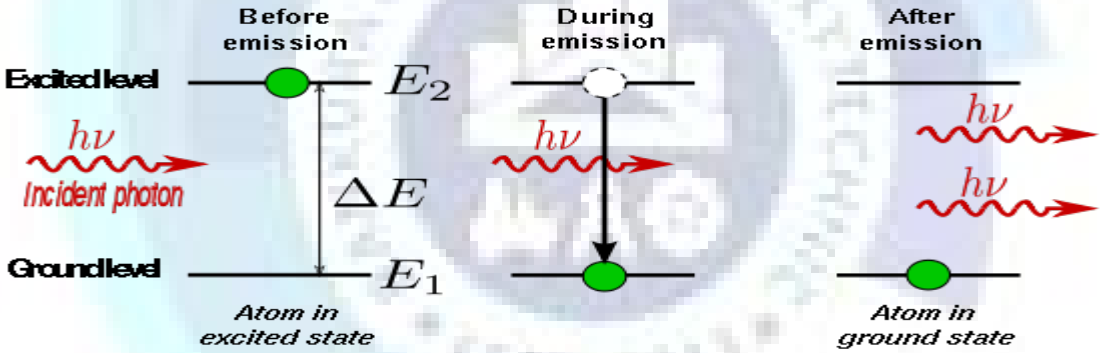
Fig. 1.1.2: In general, the majority of atoms, ions or molecules occupy the low-energy state (a). In the condition of "population inversion" (b), the majority are in the high-energy state.
© Andreoni et al., in: "Handbook on the Use of Lasers in Conservation and Conservation Science", 2008.

It is called an "inversion" because in many familiar and commonly encountered physical systems, this is not possible. This concept is of fundamental importance in laser science because the production of a population inversion is a necessary step in the workings of a standard laser.

The population of metastable state can exceed the population at a lower level thereby establishing population inversion in a lasing medium. Population inversion could not be created without a metastable state.

➢ Stimulated emission:

If an atom is already in the excited state, it may be agitated by the passage of **a photon** that has a frequency ν corresponding to the energy gap ΔE of the excited state to ground state transition. In this case, the excited atom relaxes to the ground state, and it produces a second photon of frequency ν. The original photon is not absorbed by the atom, and so the result is **two photons** of the same frequency are emitted. This process is known as **stimulated emission**.

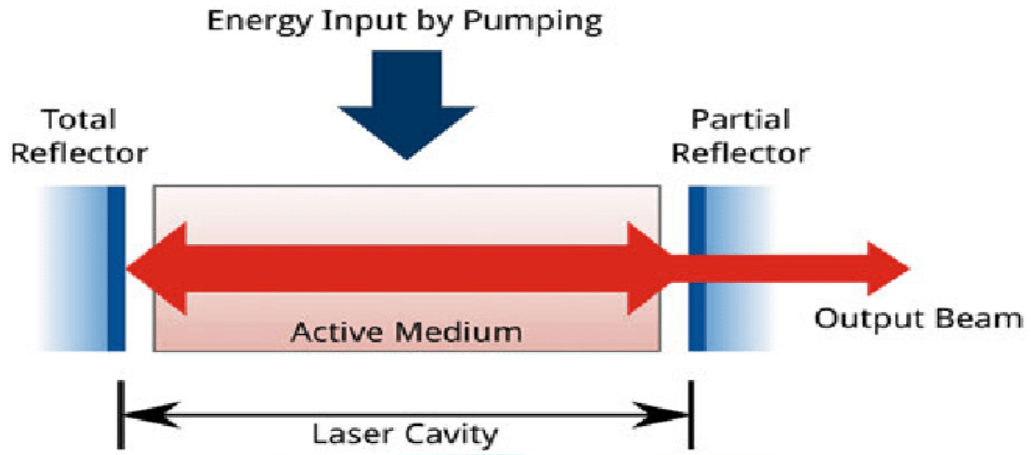


 # Click the bellow links for videos on Spontaneous and stimulated emission

https://youtu.be/lqNVpD4zKyw

https://youtu.be/2Oswmij538Q

➢ Basic LASER production system:



a) Pumping source

The *pump source* is the part that provides energy to the laser system. Examples of pump sources include electrical discharges, flashlamps, arc lamps, light from another laser, chemical reactions and even explosive devices.

e.g A helium–neon (HeNe) laser uses an electrical discharge in the helium-neon gas mixture, a Nd:YAG laser uses either light focused from a xenon flash lamp or diode lasers.

b) Gain medium / Laser medium/Active medium

Within the context of laser physics, a laser gain medium is a medium which can amplify the power of light (typically in the form of a light beam). Such a gain medium is required in a laser to compensate for the resonator losses, and is also called an *active laser medium*.

The gain medium is the major determining factor of the wavelength of operation, and other properties, of the laser. The gain medium is excited by the pump source to produce a population inversion, and it is in the gain medium where spontaneous and stimulated emission of photons takes place, leading to the phenomenon of optical gain, or amplification.

c) Optical resonator

The optical resonator, or optical cavity, in its simplest form is two parallel mirrors placed around the gain medium, which provide feedback of the light. The mirrors are given optical coatings which determine their reflective properties. Typically, one will be a high reflector, and the other will be a partial reflector.

Light from the medium, produced by spontaneous emission, is reflected by the mirrors back into the medium, where it may be amplified by stimulated emission. The light may reflect from the mirrors and thus pass through the gain medium many hundreds of times before exiting the cavity.

 # click the below link for detail video

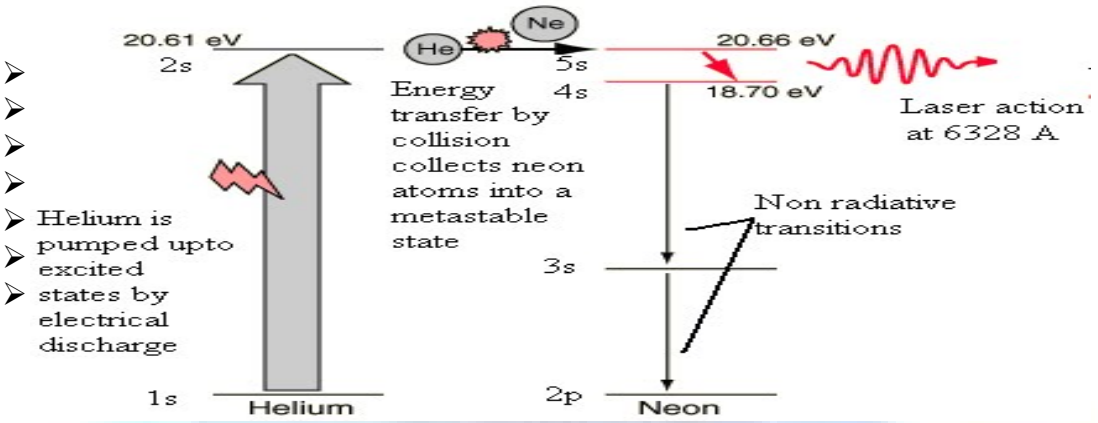
https://youtu.be/McNsx1o552o

- **He-Ne LASER:**

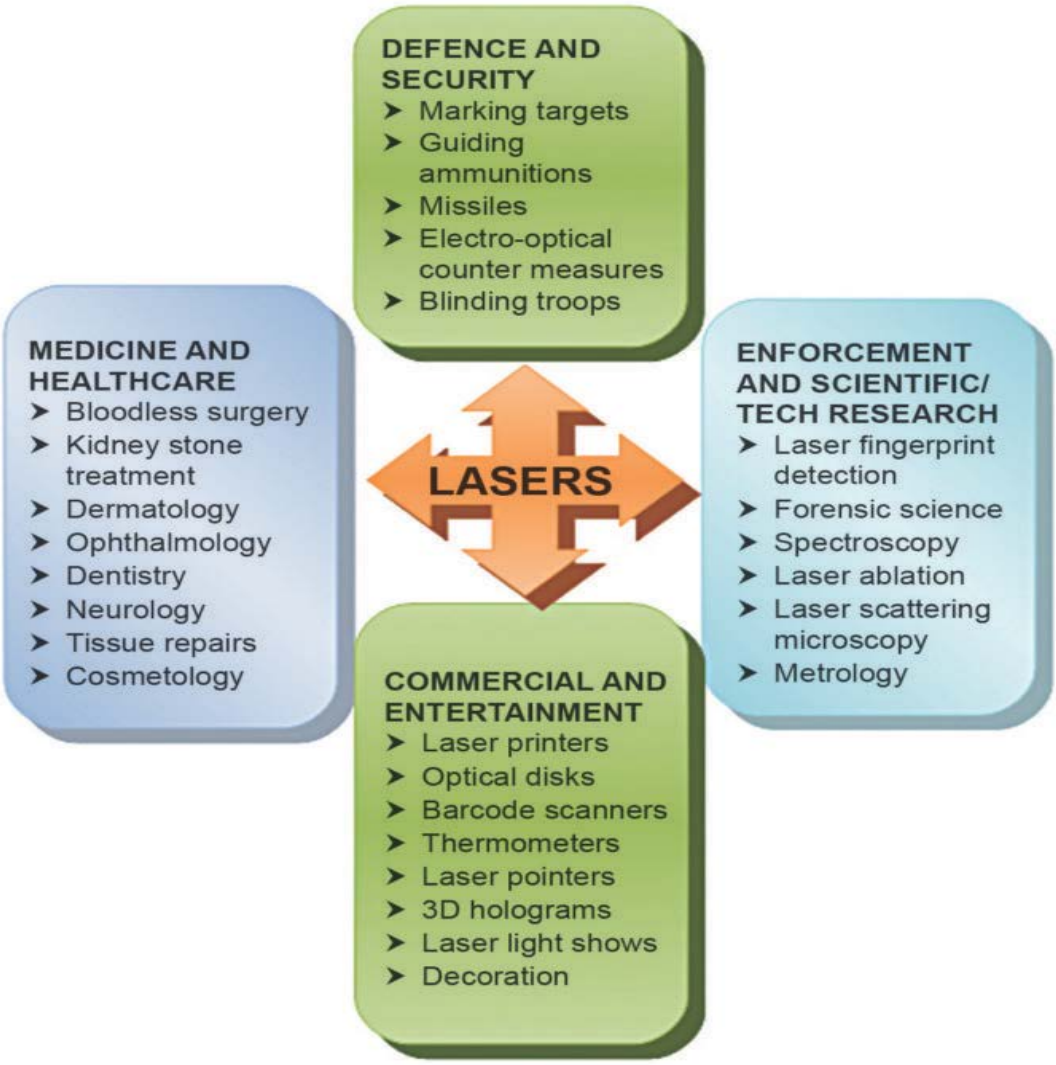
Click the bellow links for detail video

https://youtu.be/RyY4PEpV2RQ

https://youtu.be/nNUmUoVRbTU



- **Applications of LASER:**



Applied Physics (WBSCTE) Sem-II

Holography (Unit-5)

By Priyabrata Banerjee, Lecturer in Physics , Bankura Government Polytechnic

- **Holography** is based on the principle of interference. A hologram captures the interference pattern between two or more beams of coherent light (i.e. laser light). One beam is shone directly on the recording medium and acts as a reference to the light scattered from the illuminated scene.

A hologram is a physical structure that diffracts light into an image. The term 'hologram' can refer to both the encoded material and the resulting image.

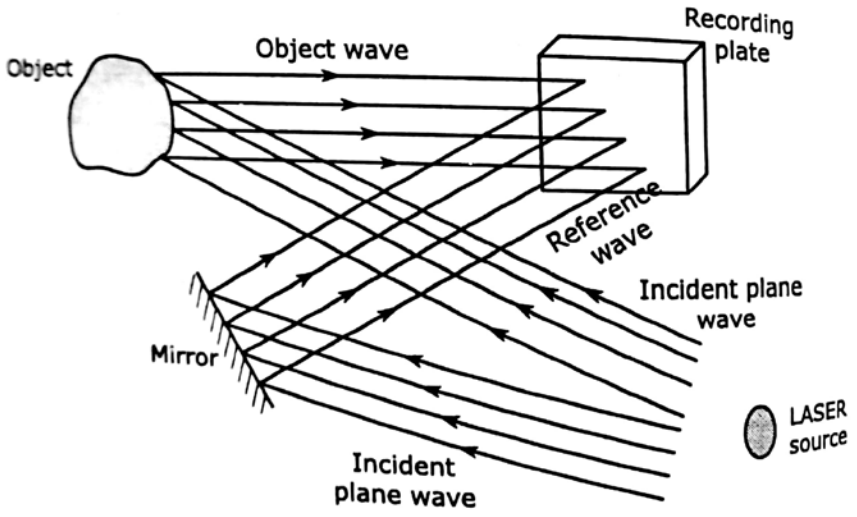
A holographic image can be seen by looking into an illuminated holographic print or by shining a laser through a hologram and projecting the image onto a screen.

(Two photographs of a single hologram taken from different viewpoints)

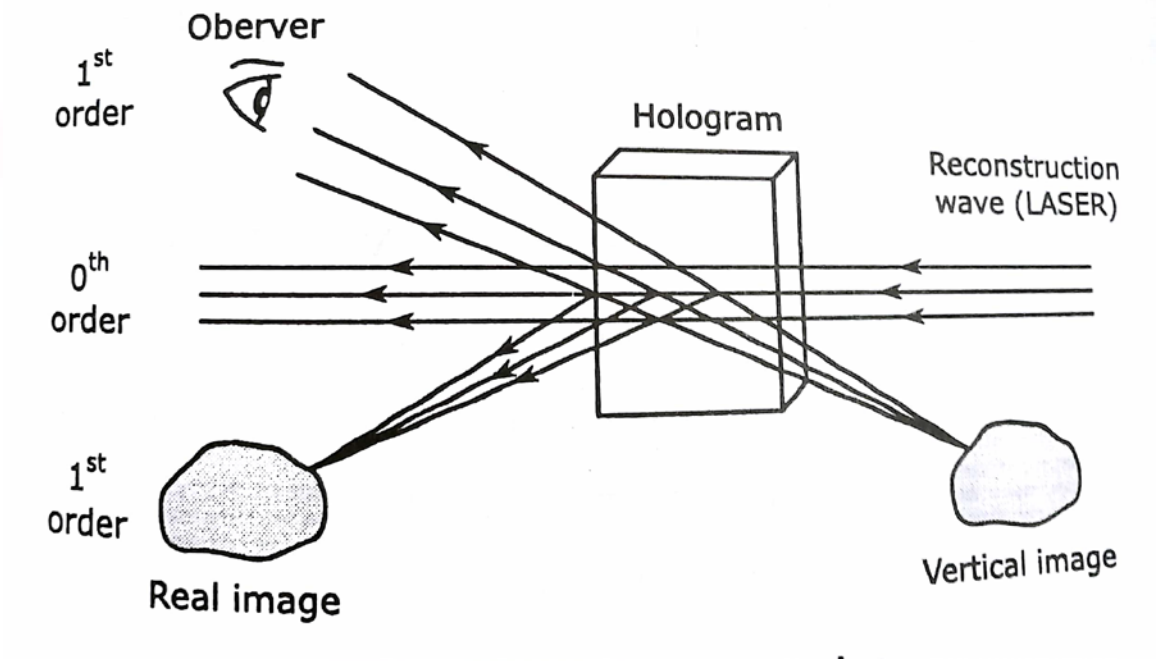
Comparison between

photography	holography
2D image of 3D object	3D image of 3D object
Intensity variation only recorded	Intensity and phase variation recorded
Recorded film is called photograph	Recorded film is called hologram
Point to point recording of the intensity of light	Each point of the film receives light from all parts of the object
When cut into pieces, each piece gives partial information only	Each piece gives full information of object

➢ **Recording of Holographic plate: (Key process- Interference of light)**



➢ **Reconstruction of Hologram (Key process- Diffraction of light)**



 # Click the link for detail video

https://youtu.be/WoMLI1bVSck

➢ **Application of Holography:**