LASER

The light emitted from an ordinary light source is incoherent, because the radiation emitted from different atoms has no definite phase relationship with each other. For interference of light, coherent sources are essential. Two independent sources cannot act as coherent sources. For experimental purposes, from a single source, two coherent sources are obtained. In recent years, some sources have been developed, which are highly coherent known as LASER. The word 'Laser' is an acronym for Light Amplification by Stimulated

Characteristics of laser

The laser beam (i) is monochromatic. (ii) is coherent, with the waves, all exactly in phase with one another, (iii) does not diverge at all and (iv) is extremely intense

Spontaneous and stimulated emission

An atom may undergo transition between two energy states E1 and E2, if it emits or absorbs a photon of the appropriate energy E2 – E1 = hv.

In a system of thermal equilibrium, the number of atoms in the ground state (N1) is greater than the number of atoms in the excited state (N2). This is called normal population.

Consider a sample of free atoms, some of which are in the ground state with energy E1 and some in the excited energy state with energy E2. If photons of energy hv = E2-E1 are incident on the sample, the photons can interact with the atoms in the ground state and are taken to excited state. This is called stimulated or induced absorption.

The process by which the atoms in the ground state is taken to the excited state is known as pumping. If the atoms are taken to the higher energy levels with the help of light, it is called optical pumping. If the atoms in the ground state are pumped to the excited state by means of external agency, the number of atoms in the excited state (N2) becomes greater than the number of atoms in the ground state (N1). This is called population inversion.

The life time of atoms in the excited state is normally 10-8 second. Some of the excited energy levels have greater life times for atoms (10-3s). Such energy levels are called as the metastable states. If the excited energy level is an ordinary level, the excited atoms return to the lower (or) ground energy state immediately without the help of any external agency. During this transition, a photon of energy E2-E1 = hv is emitted. This is called spontaneous emission.

If the excited state is a metastable state, the atoms stay for some time in these levels. The atoms in such metastable state can be brought to the lower energy levels with the help of photons of energy hv = E2 – E1. During this process, a photon of energy E2 – E1 = hv is emitted. This is known as stimulated emission (or) induced emission.

A photon produced by stimulated emission is called secondary photon (or) stimulated photon. The secondary photon is always in phase with the stimulating photon. These photons in turn stimulate the emission further and the process continues to give a chain – reaction. This is called laser action and by this action all the emitted photons having same energy and same frequency are in phase with each other. Hence, a highly monochromatic, perfectly coherent, intense radiation is obtained in laser.

Conditions to achieve laser action

(i) There must be an inverted population i.e. more atoms in the excited state than in the ground state.
(ii) The excited state must be a metastable state.
(iii) The emitted photons must stimulate further emission. This is achieved by the use of the reflecting mirrors at the ends of the system.

Ruby laser

The Ruby laser was first developed by T. Maiman in 1960. It consists of a single crystal of ruby rod of length 10 cm and 0.8 cm in diameter. A ruby is a crystal of aluminium oxide Al2O3, in which some of aluminium ions (Al3+) are replaced by the chromium ions (Cr3+). The opposite ends of ruby rod are flat and parallel; one end is fully silvered and the other is partially silvered (i.e.) semi-transparent. The ruby rod is surrounded by a helical xenon flash tube which provides the pumping light to raise the chromium ions to upper energy level. In the xenon flash tube, each flash lasts several milliseconds and, in each flash, a few thousand joules of energy are consumed.

The simplified energy level diagram of chromium ions in a ruby laser, indicating appropriate excitation and decay. In normal state, most of the chromium ions are in the ground state E1. When the ruby rod is irradiated by a flash of light, the 5500 Å radiation (green colour) photons are absorbed by the chromium ions which are pumped to the excited state E3. The excited ion gives up part of its energy to the crystal lattice and decay without giving any radiation to the meta stable state E2. Since, the state E2 has a much longer lifetime (10-3s), the number of ions in this state goes on increasing. Thus population inversion is achieved between the states E2 and E1. When the excited ion from the metastable state E2 drops down spontaneously to the ground state E1, it emits a photon of wavelength 6943 Å. This photon travels through the ruby rod and is reflected back and forth by the silvered ends until it stimulates another excited ion and causes it to emit a fresh photon in phase with stimulating photon. Thus, the reflections will amount to the additional stimulated emission – the so-called amplification by stimulated emission. This stimulated emission is the laser transition. Finally, a pulse of red light of wave length 6943 Å emerges through the partially silvered end of the crystal.

Helium – neon laser:

A continuous and intense laser beam can be produced with the help of gas lasers. He – Ne laser system consists of a quartz discharge tube containing helium and neon in the ratio of 1 : 4 at a total pressure of about 1 mm of Hg.

One end of the tube is fitted with a perfectly reflecting mirror and the other end with partially reflecting mirror. A powerful radio frequency generator is used to produce a discharge in the gas, so that the helium atoms are excited to a higher energy level.

When an electric discharge passes through the gas, the electron in the discharge tube collides with the He and Ne atoms and excite them to metastable states of energy 20.61 eV and 20.66 eV respectively above the ground state. Some of the excited helium atoms transfer their energy to unexcited Ne atoms by collision. Thus, He atom help in achieving a population inversion in Ne atoms. When an excited Ne atom drops down spontaneously from the metastable state at 20.66 eV to lower energy state at 18.70 eV, it emits a 6328 Å photon in the visible region.

This photon travelling through the mixture of the gas, is reflected back and forth by the reflector ends, until it stimulates an excited neon atom and causes it to emit a fresh 6328 Å photon in phase with the stimulating photon. This stimulated transition from 20.66 eV level to 18.70 eV level is the laser transition. The output radiations escape from the partially reflecting mirror. The neon atoms drop down from the 18.70 eV level to lower state E, through spontaneous emission emitting incoherent light. From this level E, the Ne atoms are brought to the ground state through collision with the walls of the tube. Hence the final transition is radiation less.

Applications of laser

Due to high coherence, high intensity, laser beams have wide applications in various branches of science and engineering.

Industrial applications

i) The laser beam is used to drill extremely fine holes in diamonds, hard sheets etc.
ii) They are also used for cutting thick sheets of hard metals and welding.
iii) The laser beam is used to vapourize the unwanted material during the manufacture of electronic circuit on semiconductor chips.
iv) They can be used to test the quality of the materials.

Medical applications

(i) In medicine, micro surgery has become possible due to narrow angular spread of the laser beam.
(ii) It can be used in the treatment of kidney stone, tumour, in cutting and sealing the small blood vessels in brain surgery and retinal detachment.
(iii) The laser beams are used in endoscopy.
(iv) It can also be used for the treatment of human and animal cancer.

Scientific and Engineering applications

(i) Since the laser beam can stay on at a single frequency, it can be modulated to transmit large number of messages at a time in radio, television and telephone.

(ii) The semiconductor laser is the best light source for optical fiber communication.

(iii) Narrow angular spread of the laser beam makes it a very useful tool for microwave communication. Communication with earth satellites and in rocketry. Laser is also used in accurate range finders for detecting the targets.

(iv) The earth-moon distance has been measured with the help of lasers.

(v) It is used in laser Raman Spectroscopy.

(vi) Laser is also used in holography (three dimensional lensless photography)

(vii) Laser beam can determine precisely the distance, velocity and direction as well as the size and form of the objects by means of the reflected signal as in radar.

Holography

When an object is photographed by a camera, a two-dimensional image of three-dimensional object is obtained. A three-dimensional image of an object can be formed by holography. In ordinary photography, the amplitude of the light wave is recorded on the photographic film. In holography, both the phase and amplitude of the light waves are recorded on the film. The resulting photograph is called hologram.

MASER

The term MASER stands for Microwave Amplification by Stimulated Emission of Radiation. The working of maser is similar to that of laser. The maser action is based on the principle of population inversion followed by stimulated emission. In maser, the emitted photon, during the transition from the metastable state belongs to the microwave frequencies. The paramagnetic ions are used as maser materials. Practical maser materials are often chromium or gadolinium ions doped as impurities in ionic crystals. Ammonia gas is also a maser material. Maser provides a very strong tool for analysis in molecular spectroscopy.

Practice Questions

1. Which of the following are characteristics of laser?
   a. Monochromatic b. Coherent
   c. Extremely intense **d. all the above**
   பின்வருவனவற்றில் எது லேசரின் சிறப்பியல்புகள்?
   a. ஒற்றை நிற ஒளியைக் கொண்டது.
   b. ஓரியல்பு தன்மையுடையது
   c. அதிகச் செறிவு கொண்டது.
   d. அனைத்தும்

2. LASERS used for hair transplantation is
   a. Co_2 laser b. Nd : YAG laser
   c. Ruby laser d. Diode laser
   ரோமங்களை மாற்றுவதற்கு பயன்படும் லேசர்
   a. **Co_2** லேசர் b. Nd : YAG லேசர்
   c. ரூபி லேசர் d. டையோடு லோசர்

3. The Ruby laser was first developed by _____
   a. T. Maiman b. Henry
   c. Newton d. none of the above
   ரூபி லேசரையை முதலில் உருவாக்கியவர் யார்?
   a. T. மெய்மன் b. ஹென்றி
   c. நியூட்டன் d. எதுவுமில்லை

4. He-Ne laser system consists of a quartz discharge tube containing helium and neon in the ratio.
   a. 1:4 b. 4:1 c. 2:7 d. 7:2
   He-Ne லேசரில் குவார்ட்ஸ் குழாய் ஒன்றுள்ளது இதனுள் _____ விகிதத்தில் He-Ne வாயுக்கள் உள்ளன.
   a. 1:4 b. 4:1 c. 2:7 d. 7:2

5. MASER stands for _____
   a. Microwave Amplification by stimulated emission of radiation
   b. Microwave Amplifier by stimulated emission of radio wave.
   c. Microns amplification by stimulated emission of radio wave
   d. None of the above
   MASER என்பதன் விளக்கம் _____.
   a. Microwave Amplification by stimulated emission of radiation
   b. Microwave Amplifier by stimulated emission of radio wave.
   c. Microns amplification by stimulated emission of radio wave
   d. None of the above