<u>Modern Physics</u>

LASER :

The term "laser" originated as an acronym for "**light amplification by stimulated emission of radiation**"

It is a beam of light which is coherent, monochromatic, highly directional and very intense.

Energy Level:

In an atom, the electrons are confined to well defined energy states. These states are called as energy level.

There are three type of energy levels:

1. **Ground level:** This refers to the lowest energy state in the system (E1). The completely de-excited atoms would occupy this level.

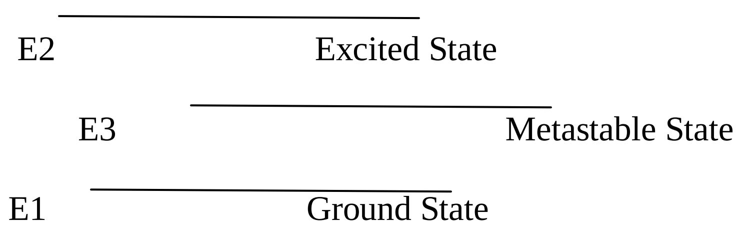


Figure: Energy levels

2. Excited level: Any level above the ground state is excited state (E2). The atom can stay in excited state only for a very short time varying from 10-8to 10-10s. After this time the atom will lose its energy in the form of radiations and come back to ground state.

3. Metastable level: This level lies in between the excited and ground levels (E3). Its lifetime is 100 times more than excited state and atom can stay in this state for a longer time.

The Emission Process

When a material is energized by some radiations, the atoms of the material get excited to the higher state from ground state. These excited atoms may lose energy and come back to ground state. The energy loss may be in the form of heat, light or X-rays etc. This process may takes place in two ways:

I. Spontaneous Emission:

Spontaneous emission is the process of light emission in which the atoms in excited state (E1) comes back to ground state (E0) after 10-8 seconds, without any external radiation(see Fig.).The atoms in excited state, release radiation of energy hν = E1 - E0 in the form of photons. These photons are emitted in random directions.

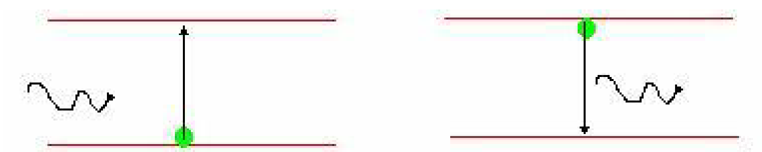


Figure : Spontaneous emission process

II. Stimulated Emission:

If excited atom is irradiated with a photon having energy hν = E1 - E0 before spontaneous emission process, then the excited atom will lose the energy in the form of two photon This process occurs in such a way that the incident photon and the emitted photon are found to be moving with same momentum and phase. This kind of emission is called stimulated emission.

Population Inversion:

In a material, when the number of atoms in excited state (N2) becomes more than the number of atoms in ground state (N1), this condition is known as Population Inversion. This condition is must for stimulated emission.

Characteristics of Laser

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

a) Coherence

The photons emitted from ordinary light sources have different phases and hence noncoherent. While in Laser all the emitted photons have same phase or constant phase
If excited atom is irradiated with a photon having energy hν = E1 - E0 before spontaneous emission process, then the excited atom will lose the energy in the form of two photon This process occurs in such a way that the incident photon and the emitted photon are found to be moving with same momentum and phase. This kind of emission is called stimulated emission difference. Thus the laser light is highly coherent in nature. Because of this coherence, a large amount of power can be concentrated in a narrow space.

b) Monochromatic

In laser, all the photons emitted have the same frequency, or wavelength. Hence, the laser light has single wavelength or color. Therefore, laser light covers a very narrow range of frequencies or wavelengths. Hence the light emitted by a laser is highly monochromatic.

c) Directionality

In ordinary light sources (lamp, torch), photons will travel in random direction. Therefore, these light sources emit light in all directions. But, in laser, all photons will travel in same direction. Therefore, laser emits light only in one direction. This is called directionality of laser light. As a result, 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 by less than 2 cm.

d) High Intensity

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. Even a 1 milliwatt laser would appear many thousand times more intense than 100 Watt ordinary lamp.

Applications of Lasers:

- Laser welding: Lasers can be used for spot welding, seam welding, inert gas laser welding and welding of non-metals.
- Laser cutting: Metals can be cut with output power of at least 100 W to 500 W. Wide range of materials can be cut e-g. paper, cloth, plywood, glass, ceremics, sheet metal like steel, titanium, aluminium etc.
- Laser drilling: Lasers are used for fine drilling.
- Lasers are used for accurate measurement of the order of 0.1 m to the extent of distant object.
- Lasers are used to produce thermonuclear fusion.
- These are used to study the chemical process, nature of chemical bonds, structure of molecule and scattering.
- Long distance communication by using optical fibre and laser is very efficient.
- In medicine, lasers are used to study many biological samples, treatment of lever and to remove tumors.
- Laser is used for printing. Laser printers are very fast and efficient. The quality is very high.
- In computers, we use laser disc. In CD writer, a tiny laser beam burns spot on the compact disc.

OPTICAL FIBRE

An optical fibre consists of a very thin core made of glass or silica having a radius of the order of micrometers (10-6 m). The core is covered by a thin layer of cladding material of lower refractive index. Such optical fibres can transmit a light beam from one end to the

other without significant energy loss. These are generally made from transparent materials such as glass (silica) or glass like polymers.
The branch of physics dealing with the propagation of light through optical fibres is known as **fibreoptics.**

Principle: It is based on the phenomenon of total internal reflections at the glass or silica boundary. The light will reach at other end even if the fibre is bend or twisted.
If ray of light travelling from a denser medium into a rarer medium, and the angle of incidence is greater than the critical angle, the ray is totally reflected back into the same media. This phenomenon is called as **total internal reflection.**

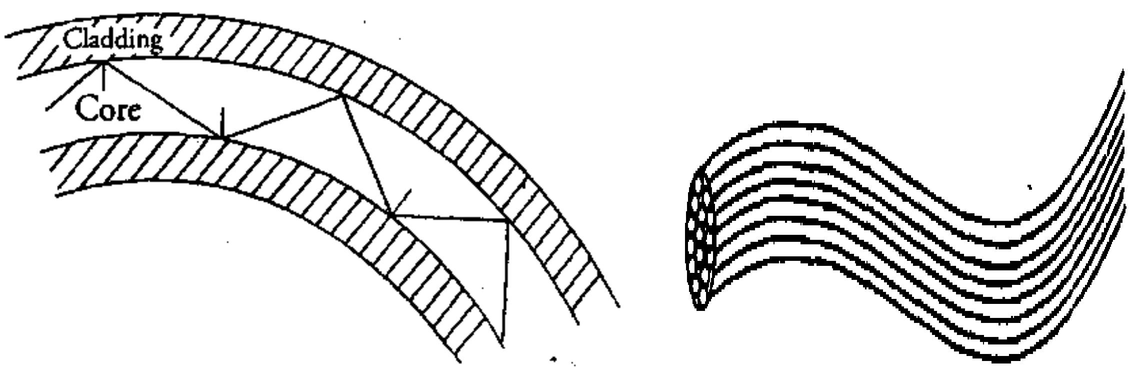
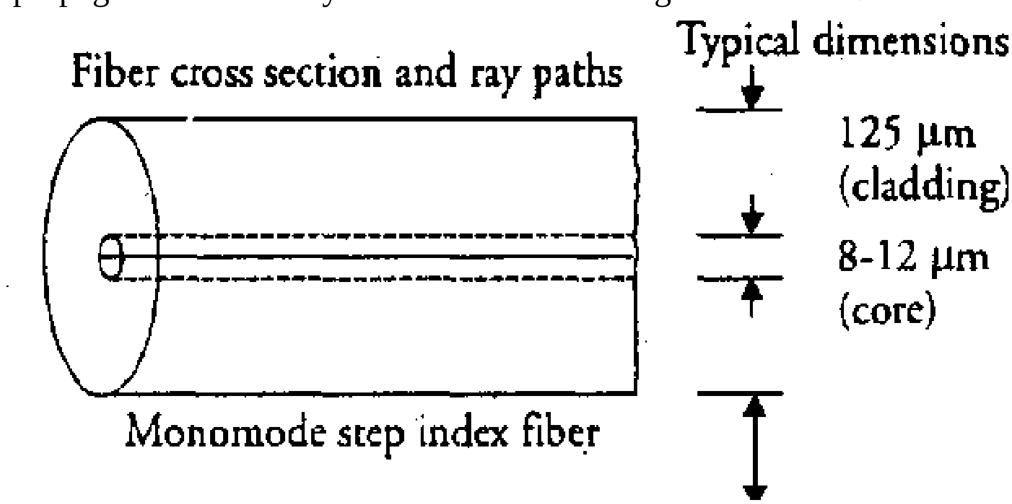


Figure : Schematic of optical fibre

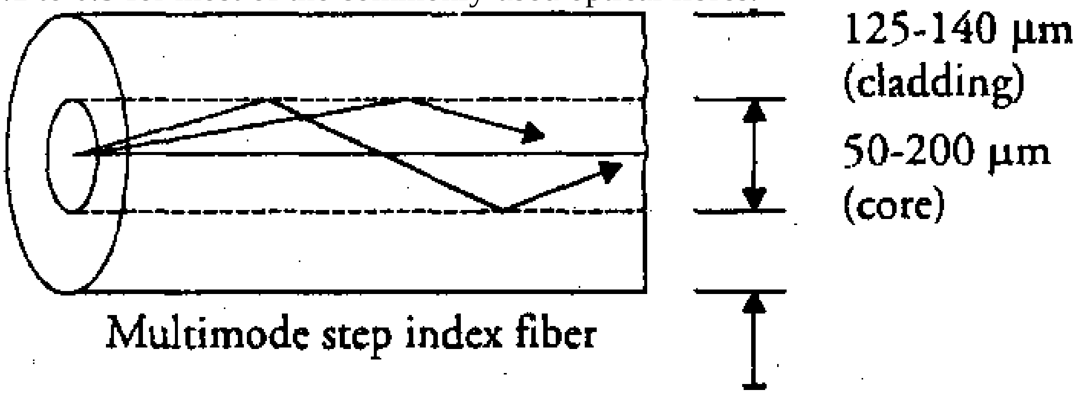
Fibre Types: On the basis of mode of propagation the fibre can be classified as:

Monomode fibre: It has a very narrow core of diameter about 8-12 μm or less and the cladding is relatively big 125 μm As the name implies, monomode fibre sustains only one mode of propagation that is why it is also known as single mode fibre.



Multimode fibre: It has a core of relatively large diameter such as 50-200 μm as shown in As the name suggests the multimode fibre contain many hundreds of modes of propagation simultaneously. The signals do not intermix with each other. This is most commonly used optical fibre.

Numerical Aperture (NA): It is the light collecting ability of an optical fiber. It depends on difference in refractive index of core and cladding. Generally, value of NA ranges from 0.1 to 0.5 for most of the commonly used optical fibres.



Applications of Optical Fibres:

With the help of light pipes made up of flexible optical fibres, it is possible to examine the inaccessible parts of equipment or of the human body. For example in endoscopy, a patient's stomach can be viewed by inserting one end of a light pipe into the stomach through mouth.

- Optical fibres are also used for transmitting and receiving electrical signals that are converted to light by transducers.
- These are used as transmission medium to transmit communication signals at high data rates over long distances. For example, more than 100000 telephone signalsat data rate of Gigabits/sec can be simultaneously transmitted through a typical single pair of optical fibre.
- Optical fibres are also being extensively used for cable TV networks and local area networks (LAN) in premises. The quality of the signals transmitted with optical fibres is much better than other conventional methods.

NANOTECHNOLOGY

It is the branch of technology that deals with use of nanomaterials with dimensions less than 100 nanometres, especially the manipulation of individual atoms and molecules.

Nanomaterials:

These are materials with any dimension in the nanoscale (1 nm to 100 nm). These materials are very reactive and exhibit unique physical, chemical and biological properties due to high surface-to-volume ratio.

Example: Carbon nanotube, nanoparticle, quantum dots, nanoplymers, nanoshell, nanopores,nanorod, nanowires, nanopowder, fullerene, etc.

Applications of Nanotechnology

Nanomaterials are of interest because of their unique optical, magnetic, electrical, and other properties. These emergent properties have the potential for great impacts in electronics, medicine, and other fields.

Medicine: Nanotechnology based drugs are being used to treat dangerous diseases like cancers and prevent health issues more effectively, as customized nanoparticles can deliver drugs directly to diseased cells in the body. New nanoparticles based chemotherapy drugs that can be delivered directly to cancer cells for better treatment are under development.

- **Electronics:**Electronic devices made with nano-fabrication techniques help in reducing weight and power consumption. This also improves display screens on electronic devices and increasing the density of memory chips. Nanotechnology can help to reduce the size of transistors and other components used in integrated circuits.
- **Food Industry**: Developing new nanomaterials will not only make a difference in the taste of food, but also in improve the food production, nutrient value and preservation.
- **Fuel Cells:** Nanotechnology is being used to reduce the cost of catalysts, used in fuel cells to produce hydrogen ions from fuel such as methanol. Nanomaterials are also being developed to improve the efficiency of membranes used in fuel cells.
- **Solar Cells:** Nanotechnology based solar cells can be manufactured at significantly lower cost with better efficiency as compared to conventional solar cells.
- **Space:** Advancements in development of nano- composites make lightweight spacecrafts. Carbon nanotubes based cableshave been proposed for the space elevators.
- **Fuels:**Nanotechnology can be used for production of fuels from low grade raw materials which are economical and also increase the efficiency of engines.
- **Catalyst:**Nanoparticles have a greater surface area to interact with the reacting chemicals than catalysts made up of larger particles. This allows more chemicals to interact with the catalyst simultaneously and hence makes the catalyst more effective.
- **Chemical Sensors:** Nanotechnology based sensors can detect very small amounts of chemical vapors. Various types of nanostructures such as carbon nanotubes, grapheme,zinc oxide nanowires can be used as detecting elementsin nanotechnologybased sensors.
- **Fabric:** Making composite fabric with nano-sized particles or fibres allows improvement of fabric properties without a significant increase in weight, thickness, or stiffness.
- **Environment:** Nanotechnology is being used in cleaning water and existing pollution,improving manufacturing methods to reduce the generation of new pollution,and making alternative energy sources more cost effective.