Special lecture on LASER

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LASER

LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION

- LASER–A device that generates light by a process called stimulated radiation.
- Laser action can be understood by
  - **Spontaneous emission**
  - **Stimulated emission**
  - **Optical pumping**
  - **Population inversion**

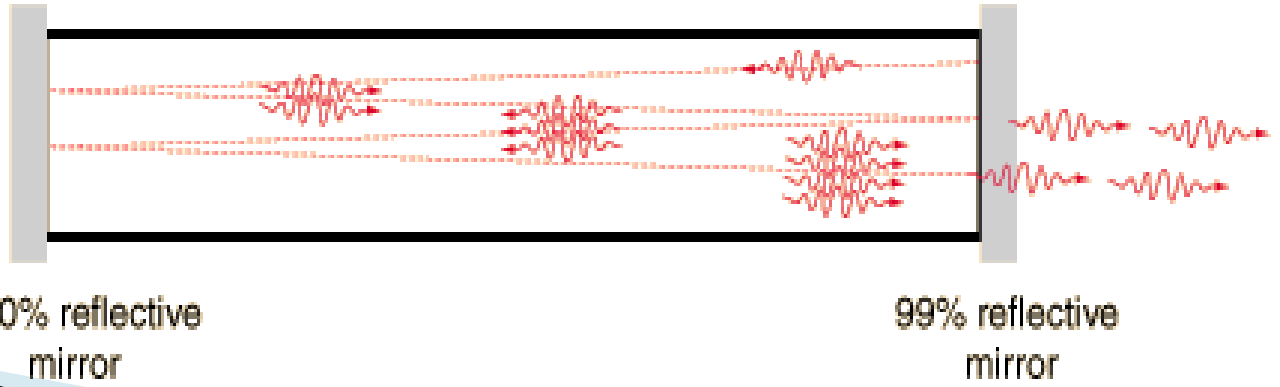
Laser –History

- In 1917, Albert Einstein –theoretical foundations for the laser & maser. (Paper: On the Quantum Theory of Radiation).
- Einstein modified Max Planck's law of radiation, introduced Einstein coefficients for the absorption, spontaneous emission, and stimulated emission of electromagnetic radiation.
- in 1928, by Rudolf W. Ladenburg the phenomena of stimulated emission was confirmed.
- In 1939, Valentin A. Fabrikant predicted the use of stimulated emission to amplify "short" waves.
- In 1947, Willis E. Lamb and R. C. Rutherford found apparent stimulated emission in hydrogen spectra and effected the first demonstration of stimulated emission.
- In 1950, Alfred Kastler (Nobel Prize for Physics 1966) proposed the method of optical pumping& this was experimentally confirmed two years later by Brossel, Kastler, and Winter.
- IN 1958 Townes &Schawlow proposed the actual theory of laser action.

Ref: Laser – Wikipedia

Principle of Laser action

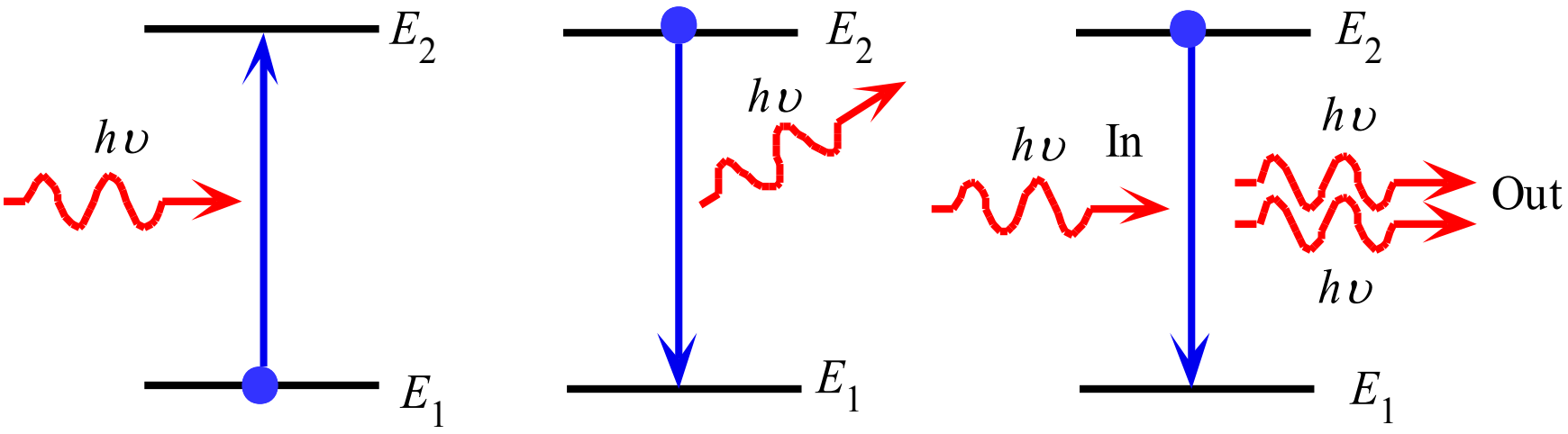
- The light is absorbed or emitted by atoms during their transition from one energy state to another energy state.
- Two types of Transition : Excitation & Absorption
- Excitation:Transfer from normal state of min energy (E_1)to excited/higher state of max energy (E_2)
- Absorption: Transfer from normal state of min energy to excited/higher state of max energy by absorbing a photon of energy $E_2-E_1=\Delta E=h\gamma$



Spontaneous & Stimulated emission

- Spontaneous emission: Atom in the excited state returning to the ground state by emitting a photon of energy $E=h\gamma$ without an external agency. This is a random, uncontrolled process
- Stimulated emission: Atom in the excited state returning to the ground state by emitting a photon of energy $E=h\gamma$ with an external agency. This is a controlled process. The transition depends on the no of incident photons.

Spontaneous & Stimulated emission



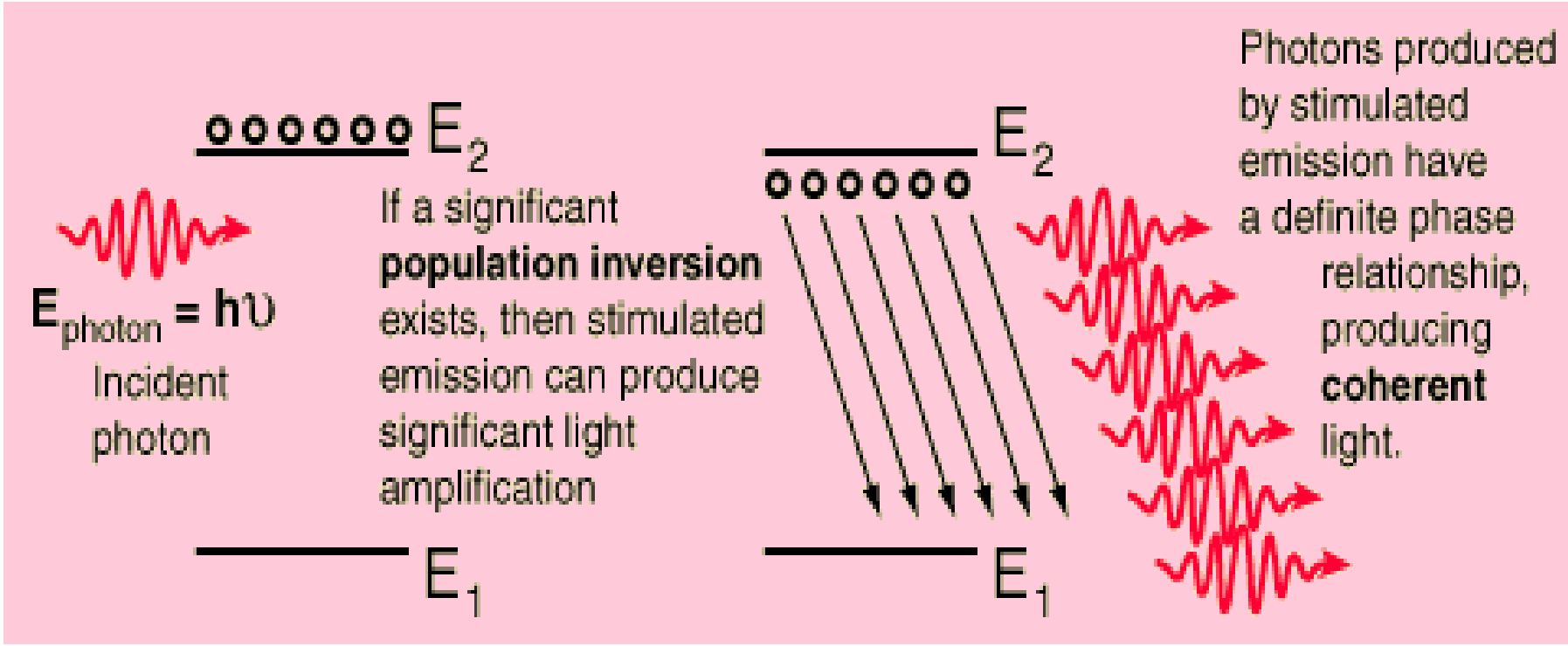
(a) Absorption (b) Spontaneous emission (c) Stimulated emission

Absorption, spontaneous (random photon) emission and stimulated emission.

Population Inversion& Optical pumping

- **Population Inversion:** Population of atoms in the excited state is greater than the atoms in the ground state.
  No of atoms in energy level E2 › E1.
- **Conditions for population inversion:**
  1. A pair of energy levels E2 › E1with energy difference E=hγ
  2. A source to supply energy(incident photons) to the medium
  3. Atoms to be raised to E2 continuously.
- **Optical pumping:** The method of raising the particles from the lower energy state to the higher energy states. Methods for Pumping action:
  Optical pumping(excitation by photons)
  Electrical discharge method(Excitation by electrons)
  Direct conversion &
  Inelastic collision between atoms

Population Inversion

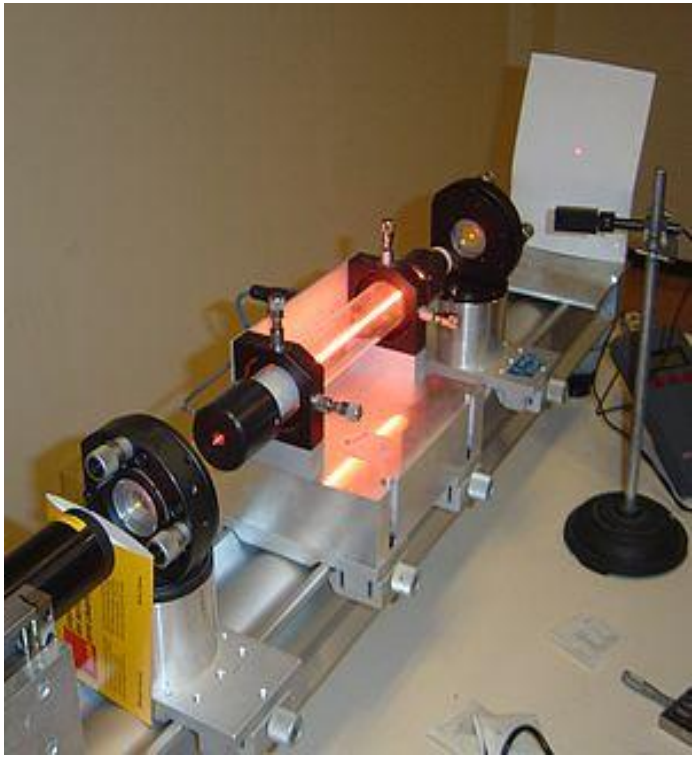


Types of Laser:

- Solid State laser–Ruby laser, Nd YAG laser
- Gas Laser– He–Ne ,CO_2, Argon ion
- Liquid laser– $SeOCl_2$, Europium chelate
- Dye laser–Rhodamine 6G, Coumarine
- Semi conductor laser– Ga As,GaAsP

Basic components of laser:

- Gain medium/Active material–solid/liquid/gas
- Pumping system/population inversion
- Optical resonator/High reflector
- Output coupler/ laser beam output



He Ne Gas laser

Defence application Laser

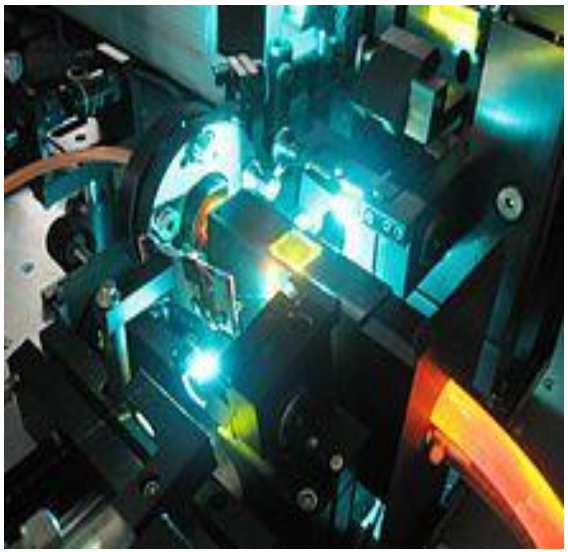
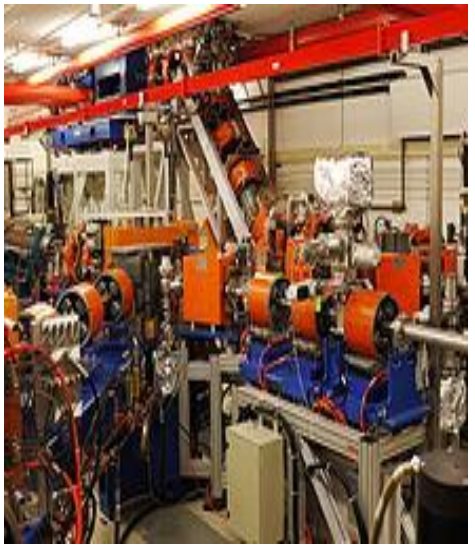


Table-top dye laser based on Rhodamine 6G.

A 5.6 mm 'closed can' commercial laser diode



Free electron laser at Plasma Physics Lab

Characteristics of Laser

- Laser is
  - **a powerful,**
  - **monochromatic,**
  - **well collimated,**
  - **coherent,**
  - **highly directional**
  - **intense**

  beam of light.
- Laser beam travels with the velocity c.
  - $C=\gamma\lambda$ where λ =Wavelength & γ =Frequency of laser beam

Characteristics of Laser

- Power: Power output of laser beam varies from 1mW to 100 KW (pointer to Solid State Laser).
- Mono chromaticity: Normal light spread λ is 100 nm & for laser it is 1 nm.
- Collimation: the beam is well collimated that the minimum spread is always there.
- Coherence: Spatial & temporal coherence is there.
  - Normal light source emits light of random λ & no common phase relationship
  - Laser light is always in phase & of same frequency
  - Coherence length for He-Ne laser: 600km
    Na vapor lamp: 3cm
  - Coherence Time for He-Ne laser : 2ms
    Na vapor lamp: 10^{-10} s
- Intensity: Laser beam is the brightest, intense beam

Characteristics of Laser

- Directionality: Ordinary light source radiates in all possible directions. Laser source emits light in only one direction.

  Directionality is expressed in terms of full angle beam divergence. For laser beam the beam divergence is ‹ 0.01 milli radians(for one meter spread the beam diverges by just 0.01 milli radians only).

  Out put of laser beam is many million times › the best torch light.(earth-moon distance:3,84,400 Km,spread is few Km only)

Safety –laser warning labels/Symbols

- Low-power lasers with only a few milli watts of output power can be hazardous to human eyesight when the beam hits the eye directly or after reflection from a shiny surface.

- At wavelengths which the cornea and the lens can focus well, the coherence and low divergence of laser light means that it can be focused by the eye into an extremely small spot on the retina, resulting in localized burning and permanent damage in seconds or even less time.

- Lasers are usually labeled with a safety class number, which identifies how dangerous the laser is:
  - Class 1 : inherently safe, light is contained in an enclosure–CD players.
  - Class 2:safe during normal use, up to 1 mW power–laser pointers.
  - Class 3R :involve a small risk of eye damage, up to 5mW
  - Class 3B :cause immediate eye damage–scientific lasers
  - Class 4 :can burn skin– Industrial lasers

Applications of Lasers

- Lasers range in size from microscopic diode lasers with numerous applications, to football field sized neodymium glass lasers used for inertial confinement fusion, nuclear weapons research and other high energy density physics experiments.
- 1974–supermarket barcode scanner
  (first commercial use)
- 1978–laser disc player
  (first successful consumer product)
- 1982– compact disc player
  (first common laser–equipped device)
- Laser printers ….

Applications of Lasers

- Medicine: Bloodless surgery, laser healing, surgical treatment, kidney stone treatment, eye treatment, dentistry
- Industry: Cutting, welding, material heat treatment, marking parts, non-contact measurement of parts
- Military: Marking targets, guiding munitions, missile tracking, electro-optical counter measures (EOCM), alternative to radar, blinding troops.
- Law enforcement: used for latent fingerprint detection in the forensic identification field
- Research: Spectroscopy, laser ablation, laser annealing, laser scattering, laser interferometry, LIDAR, fluorescence microscopy
- Product development/commercial: laser printers, optical discs barcode scanners, thermometers, laser pointers, holograms, Laser light shows.
- Cosmetic treatments: acne treatment, skin care and hair removal.

Thank You