LASER FUNDAMENTALS

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LASERS

- Invented in 1958 by Charles Townes and Arthur Schawlow of Bell Laboratories

- Nobel prize in Physics 1964

- Laser is based on Einstein's idea of the "particle wave duality" of light

- Originally called MASER
  (m = "microwave")

What is Laser?

Light Amplification by Stimulated

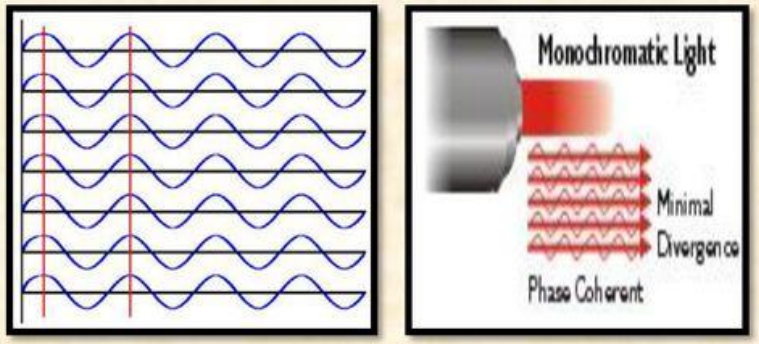
Emission of Radiation

- A device produces a coherent beam of optical radiation by stimulating electronic, ionic, or molecular transitions to higher energy levels

- When they return to lower energy levels by stimulated emission, they emit energy

DIFFERENCE

LASER LIGHT



1. **Coherent :** in phase (in harmony)

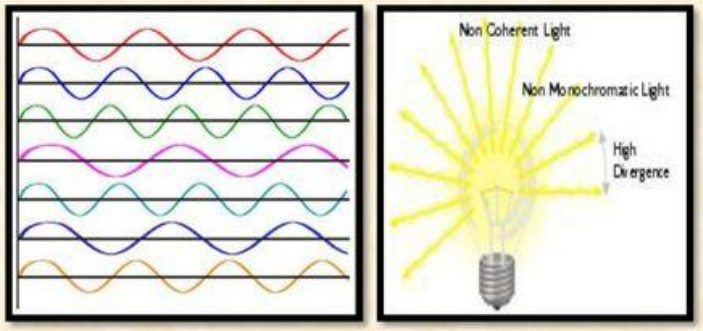
2. **Collimated:** parallel
   very narrow beam
   no divergence

3. **Monochromatic:** single wavelength
   single color

4. **Directional:** unidirectional

5. **Brightness :** extremely very high power density

ORDINARY LIGHT



1. Incoherent : random phase
2. Not collimated: unparallel
   very wide beam
   high divergence
3. Many wavelength
   Many color
4. Multi directional
5. Brightness : very low power density

Properties of Laser

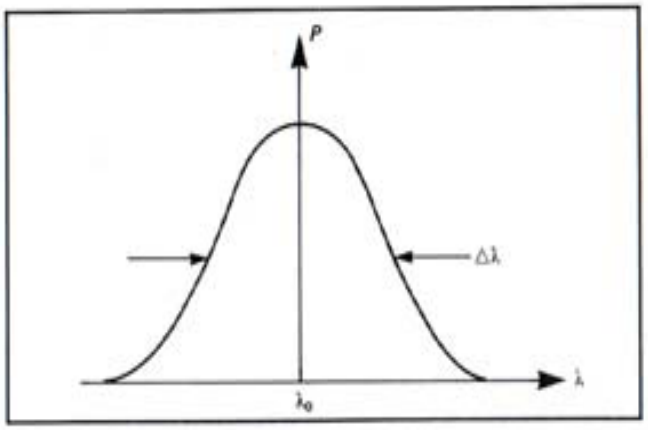
- The light emitted from a laser is highly **monochromatic**, that is, it is of one color/wavelength. In contrast, ordinary white light is a combination of many colors (or wavelengths) of light.

- Lasers emit light that is highly **directional**, that is, laser light is emitted as a relatively narrow beam in a specific direction. Ordinary light, such as from a light bulb, is emitted in many directions away from the source.

- The light from a laser is said to be **coherent**, which means that the wavelengths of the laser light are in phase in space and time. Ordinary light can be a mixture of many wavelengths.

These three properties of laser light are what can make it more hazardous than ordinary light. Laser light can deposit a lot of energy within a small area.

Monochromacity



Nearly monochromatic light

Example:

He-Ne Laser: $\lambda_0 = 632.5$ nm

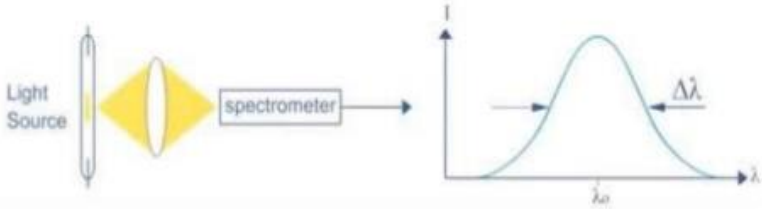
$\Delta\lambda = 0.2$ nm

Diode Laser: $\lambda_0 = 900$ nm

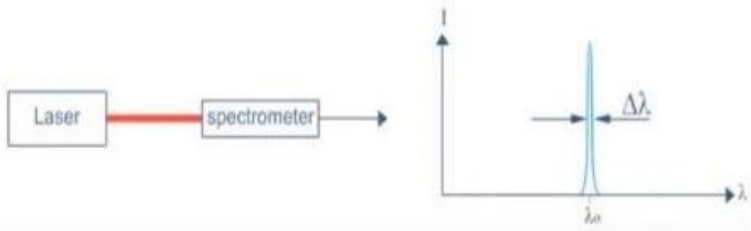
$\Delta\lambda = 10$ nm

HIGH MONOCHROMATICITY (NARROW SPECTRAL WIDTH)

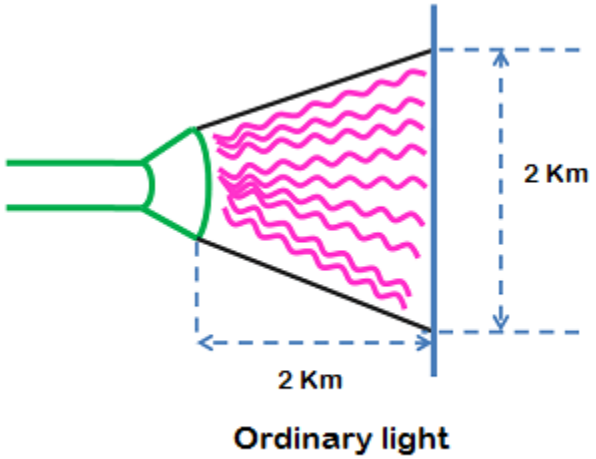
- In Light Source ---
  A plot of intensity versus wavelength and it has a certain width ($\Delta\boldsymbol{\lambda}$)

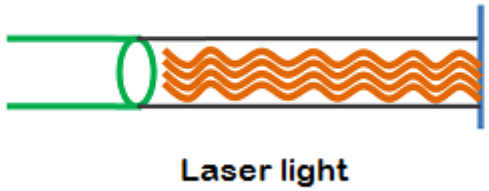


- In Laser Device --- the width is extremely narrow and this means a radiation of a monochromatic wave [2]



Directionality



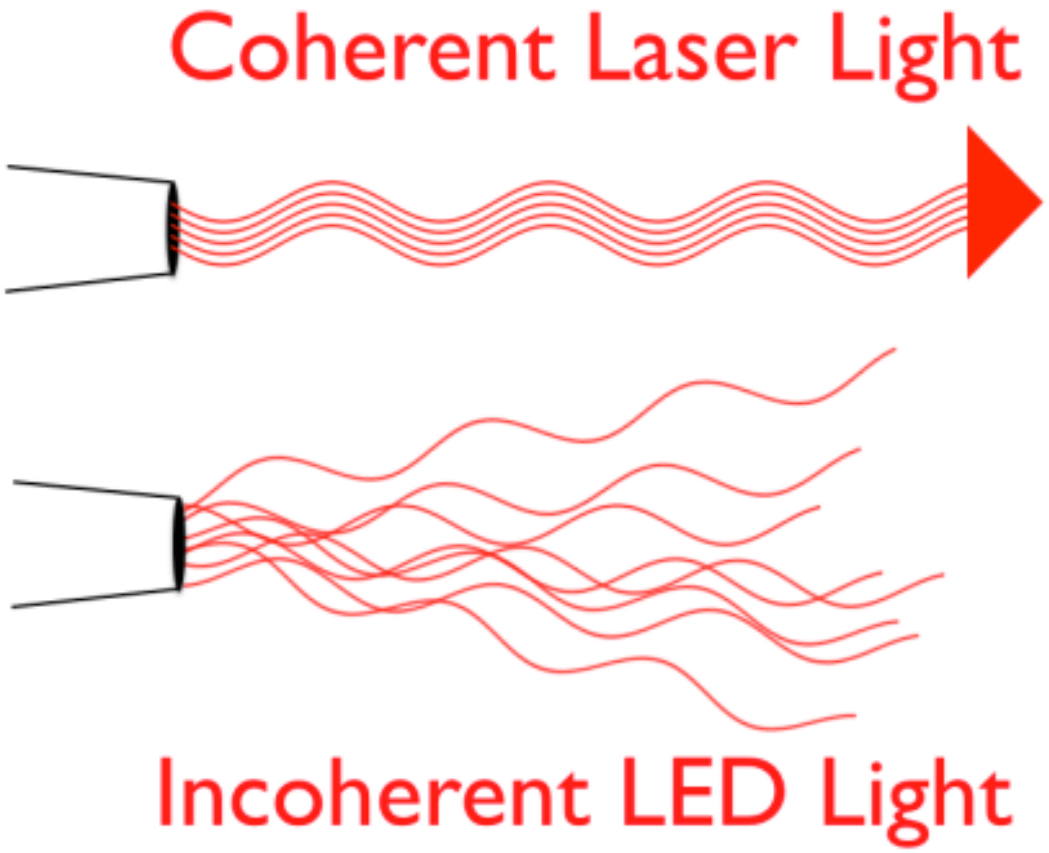


Conventional light source

Beam divergence: $\theta_d = \beta \lambda / D$

β ~ 1 = f (type of light amplitude distribution, definition of beam diameter)
λ = wavelength
D = beam diameter

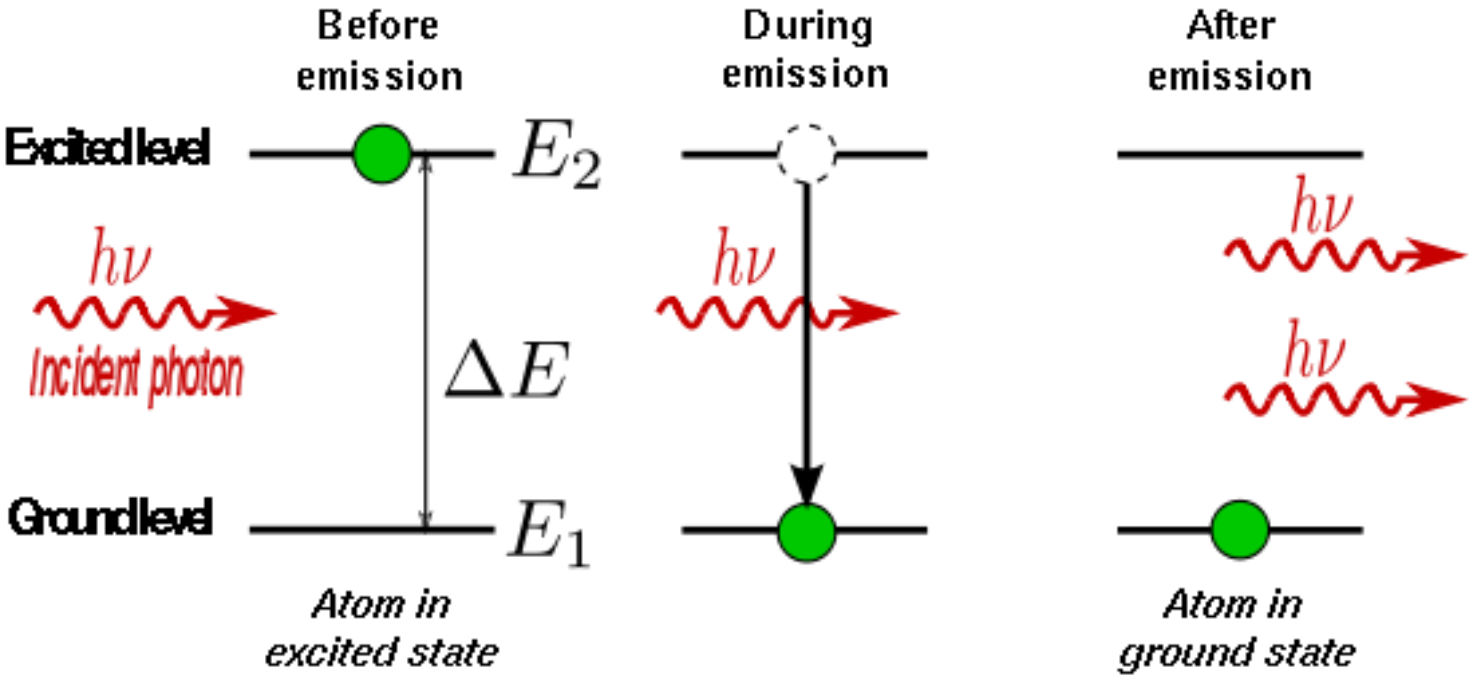
Coherence



Basic concepts for a laser

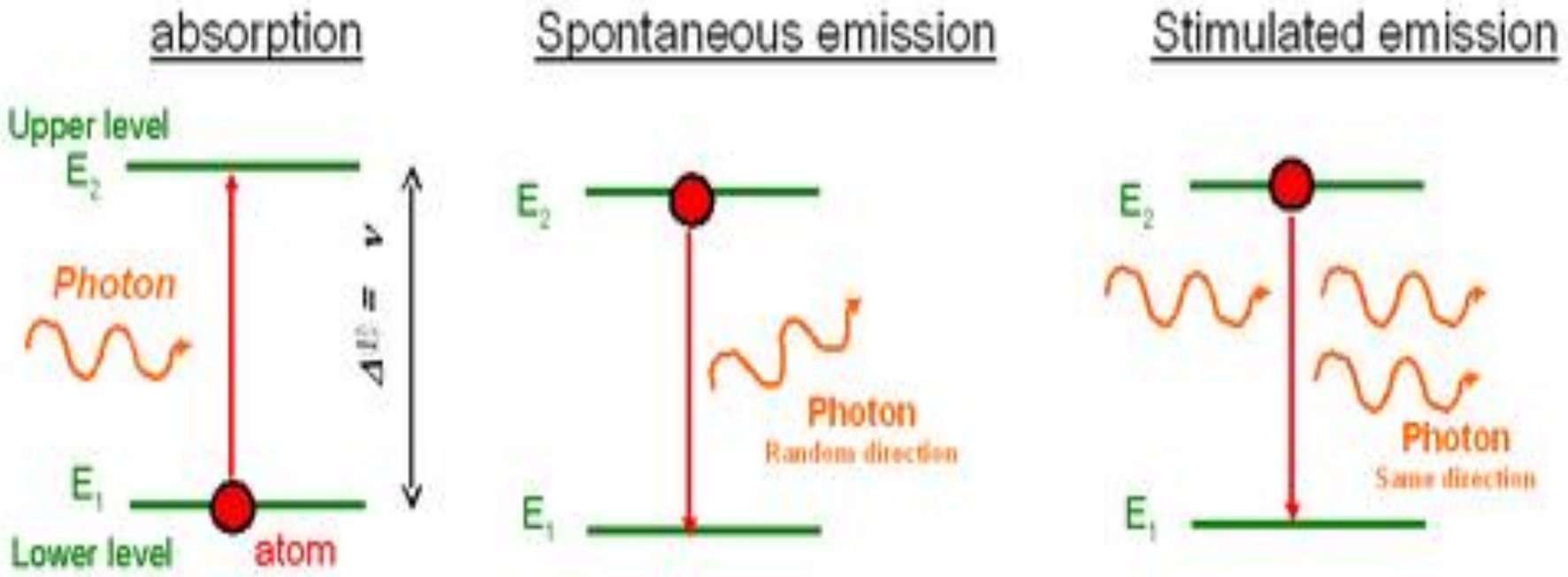
- Absorption
- Spontaneous Emission
- Stimulated Emission
- Population inversion

Absorption



$$E_2 - E_1 = \Delta E = h\nu$$

Spontaneous Emission & Stimulated Emission



Stimulated Emission

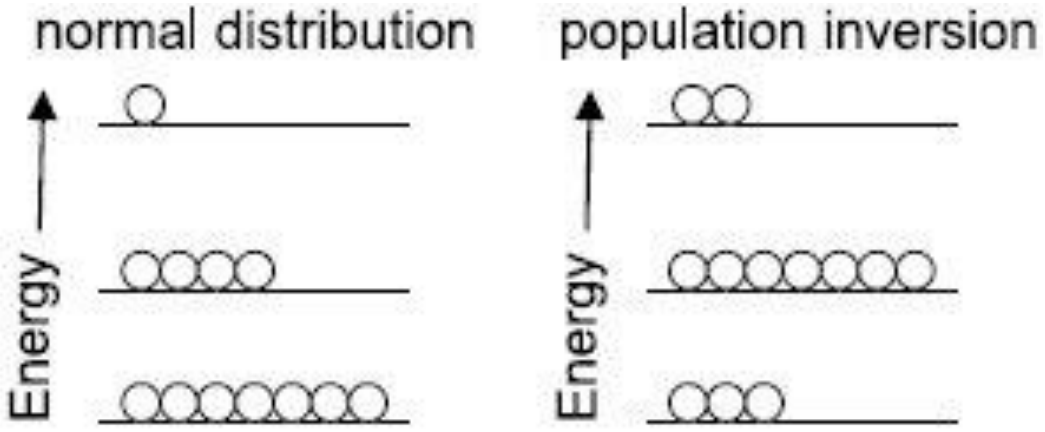
The stimulated photons have unique properties:

- In phase with the incident photon
- Same wavelength as the incident photon
- Travel in same direction as incident photon

Population Inversion

- At Normal state more number of atoms are in ground state than in excited state ($N_1 > N_2$)

- More atoms or molecules are in a higher excited state. ($N_2 > N_1$). This state is called as pumping



Pumping

The process of producing a population inversion is called pumping.

Types:

- Optical: flashlamps and high-energy light sources
- Electrical: application of a potential difference across the laser medium
- Semiconductor: movement of electrons in "junctions," between "holes"

Pumping Methods

The methods commonly used for pumping action are:

1. Optical pumping (Excitation by Photons)
2. Electrical discharge method(Excitation by electrons)
3. Direct conversion
4. In elastic atom – atom collision between atoms

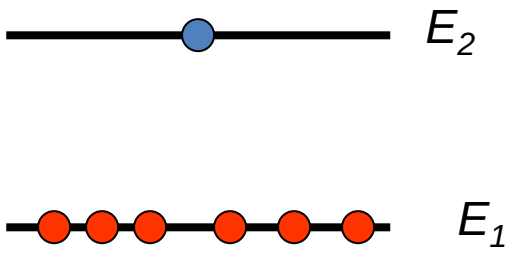
Types of Laser

Based on the type of active medium, Laser systems are broadly classified into the following categories.

S.No	TYPE OF LASER		EXAMPLES
1.	Solid State laser	:	Ruby Laser Nd:YAG laser
2.	Gas laser	:	He-Ne Laser, CO2 Laser
3.	Liquid Laser	:	Europium Chelate Laser
4.	Dye laser	:	Coumarin dye laser
5.	Semiconductor Laser	:	GaAs laser, GaAsP laser

Condition for the laser operation

If $n_1 > n_2$



- radiation is mostly absorbed absorbowane
- spontaneous radiation dominates.

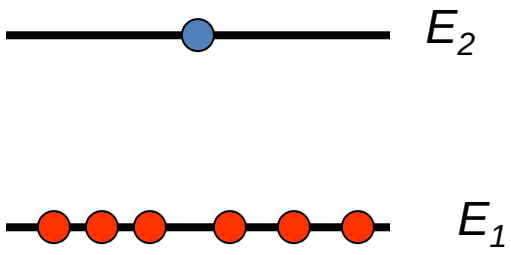
if $n_2 >> n_1$ - *population inversion*

- most atoms occupy level E2, weak absorption
- stimulated emission prevails
- light is amplified

Necessary condition:
population inversion

Boltzmann's equation

$$\frac{n_2}{n_1} = \exp\left(\frac{-(E_2 - E_1)}{kT}\right)$$



Example:

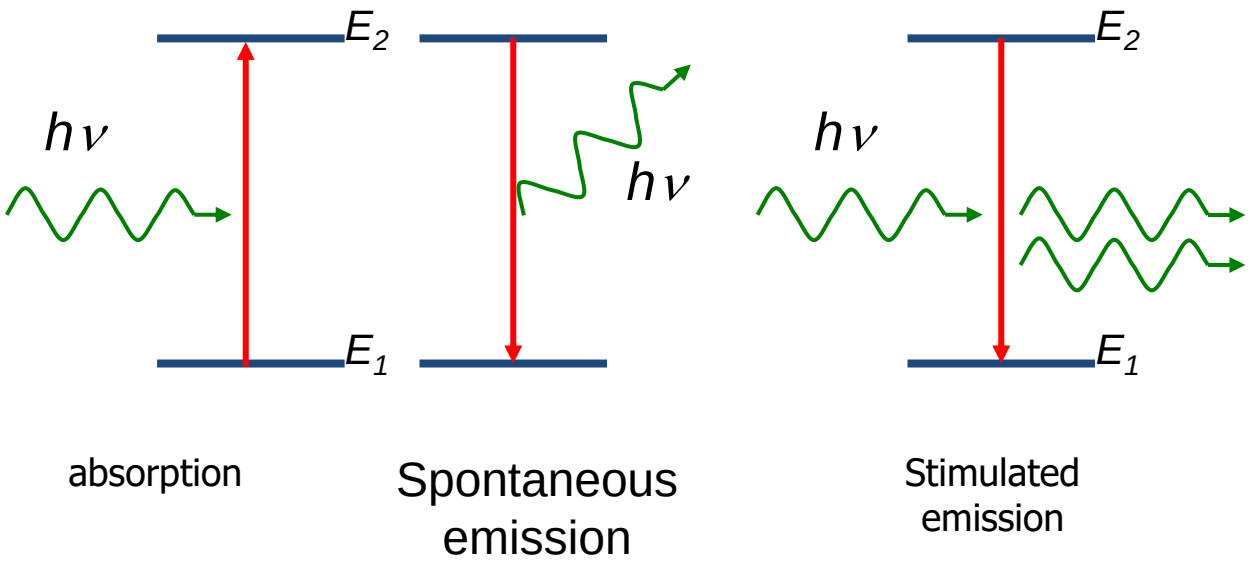
T=3000 K E_2-E_1=2.0 eV

- n_1 - the number of electrons of energy E_1
- n_2 - the number of electrons of energy E_2

$$\frac{n_2}{n_1} = 4.4 \times 10^{-4}$$

Two level system

$h\nu = E_2 - E_1$



Laser: everywhere in your life

Laser printer

Laser pointer

Generally one can state that a laser is more dangerous with:

(i) **Higher power**
Higher intensty means more power per time that can cause damage when the light is absorbed

(ii) **Less visibility of its wavelength**
Infrared and ultraviolet light will not cause the blinking reflex (aversion response)of the human eye, This means the retina will be exposed longer and the damagewill therefore be greater

(iii) **Higher intensity (stronger focus of the light)**
Stronger focus means more power per area which means that the damage may be more but at the same time worse.