Ministry of Higher Education and Scientific Research
Al-Mustaqbal University
College of Medical and Health Technologies
Aesthetic and Laser techniques Department

Laser Physics

Introduction to LASER

First stage

Lecture2

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What is LASER?

Light Amplification by Stimulated Emission of Radiation.

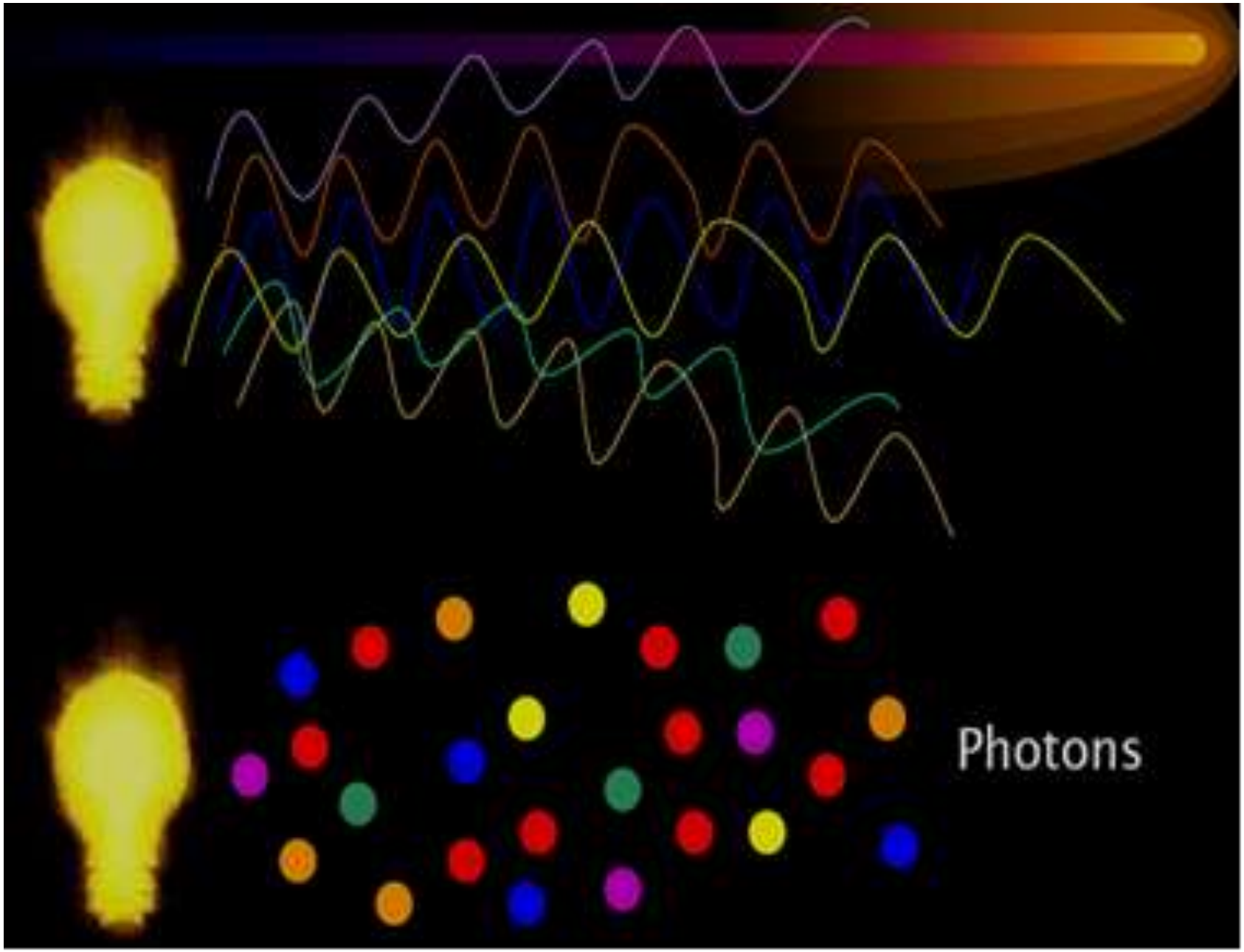
***Light*: All light is a form of electromagnetic radiation that is visible to the human eye.**

***Amplification*: This is simply the *process* of making something **bigger** or more **powerful**. When you turn up the volume on a radio, you are **amplifying** the sound; but with lasers, amplification makes the light brighter.**

***Stimulated*: To stimulate means to stir to action. Laser light is created when a burst of light (**electricity**) **excites the atoms in the laser to emit photons.** These photons then stimulate the creation of additional identical photons to produce the bright laser light.**

***Emission*: The word "**emission**" **refers** to something that is sent out or given off. Stimulated laser emission consists of **large numbers of photons** that create the intense laser light.**

Radiation:* The **laser light** is a form of **energy** that radiates, or moves out, from the **laser source*


Photons

Properties of LASER

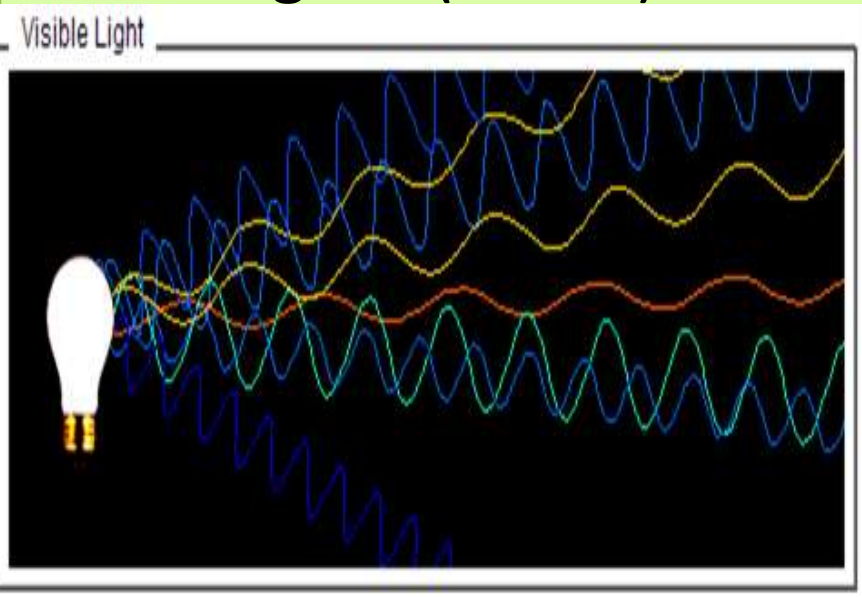
1. Monochromatic.

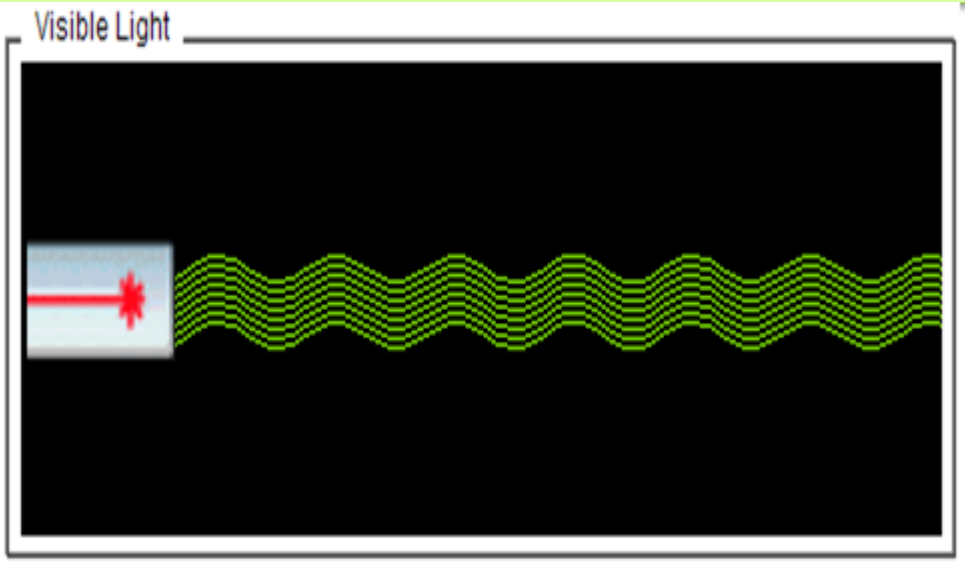
2. Directionality.

3. Coherence.

4. Brightness.

1- Monochromatic : The light emitted from a laser is monochromatic, it is of **one wavelength** (color). In contrast, ordinary white light is a combination of many different wavelengths (colors).





2- Directional :

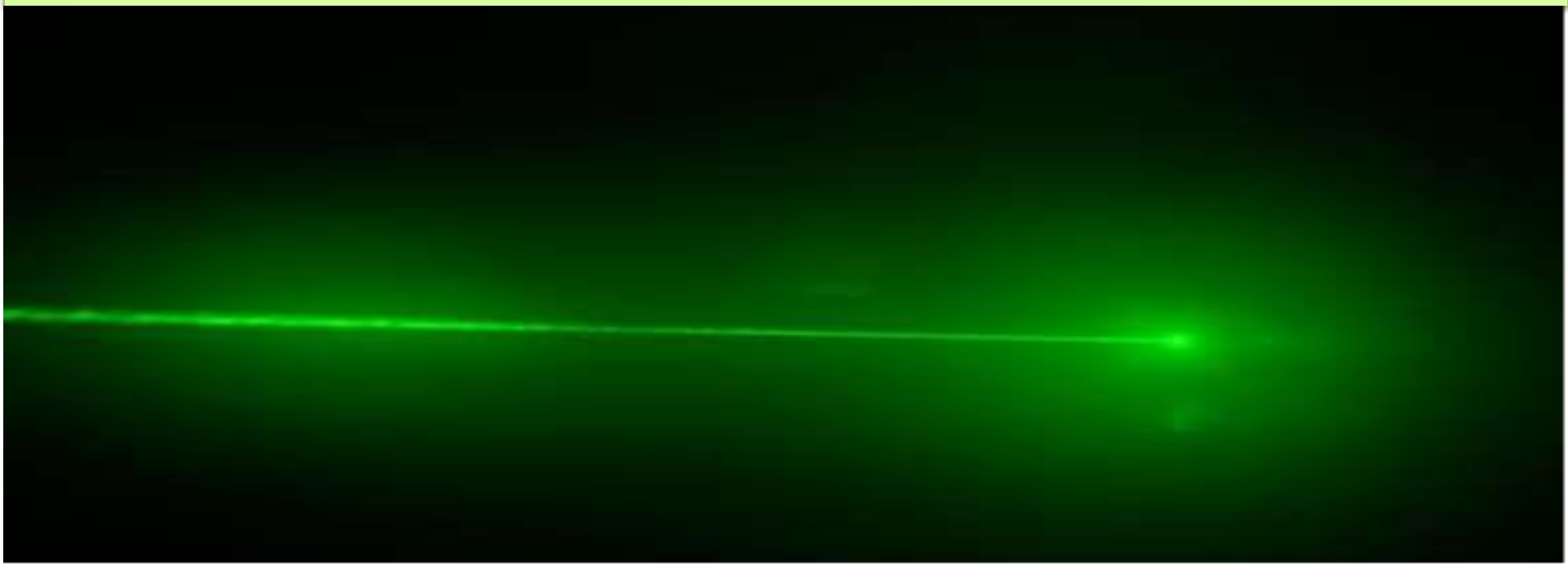
Lasers emit light that is highly directional. It is emitted as a narrow beam in a specific direction.

Ordinary light (sun, light bulb, a candle), is emitted in many directions away from the source.

Beam divergence: $\theta_d = \beta \lambda / D$.....(1)

Divergence angle (**θd**) , **β ~ 1** = (type of light amplitude distribution, definition of beam diameter)

λ = wavelength , D = beam diameter



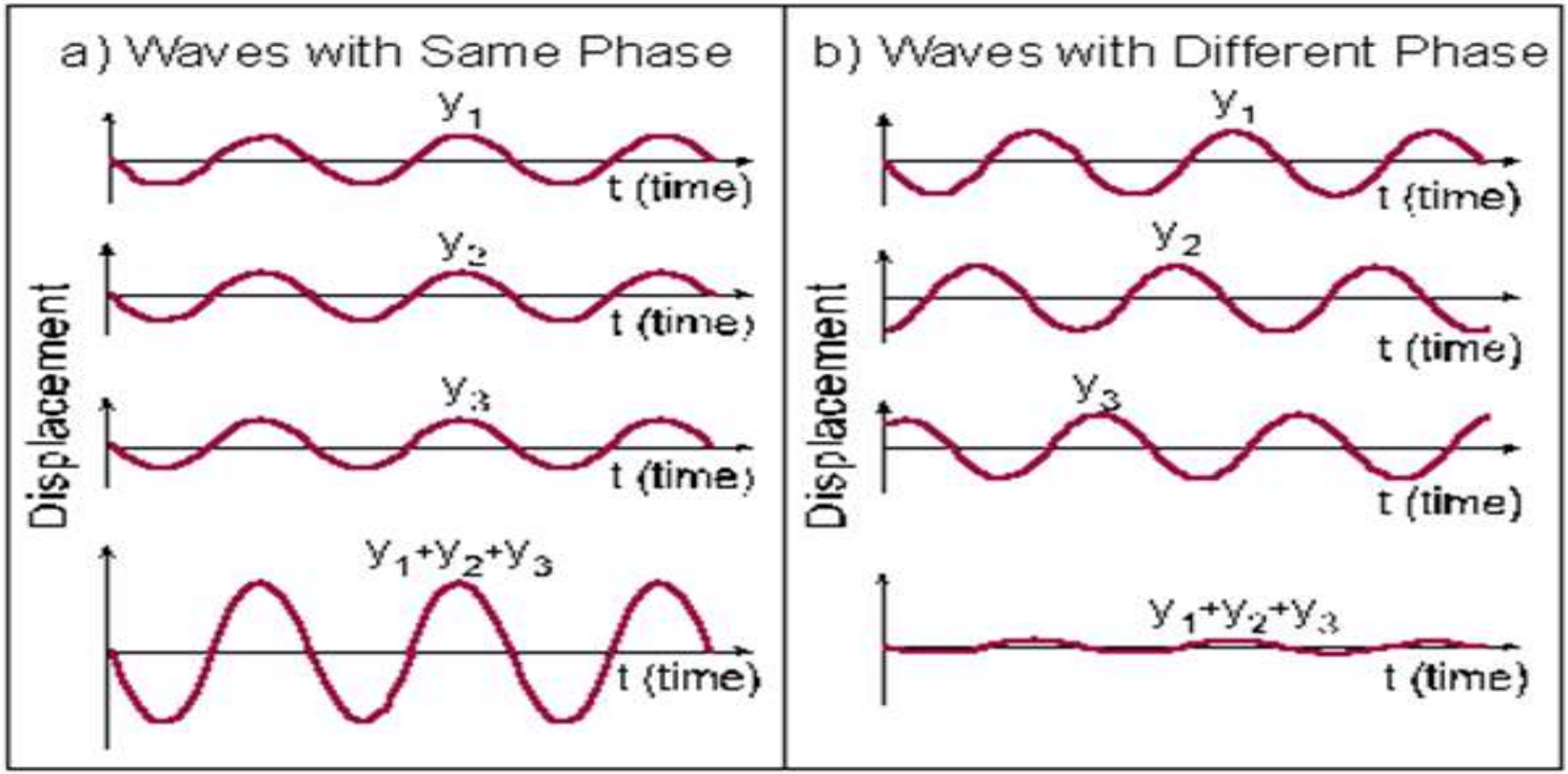
3- Coherence

$y = A \cos(\omega t + f)$

A = Amplitude . , **w = Angular Frequency** .

f = Initial **Phase** of the wave (Describe the starting point in time of the oscillation). , **(wt+ f)** = **Phase of the wave**.

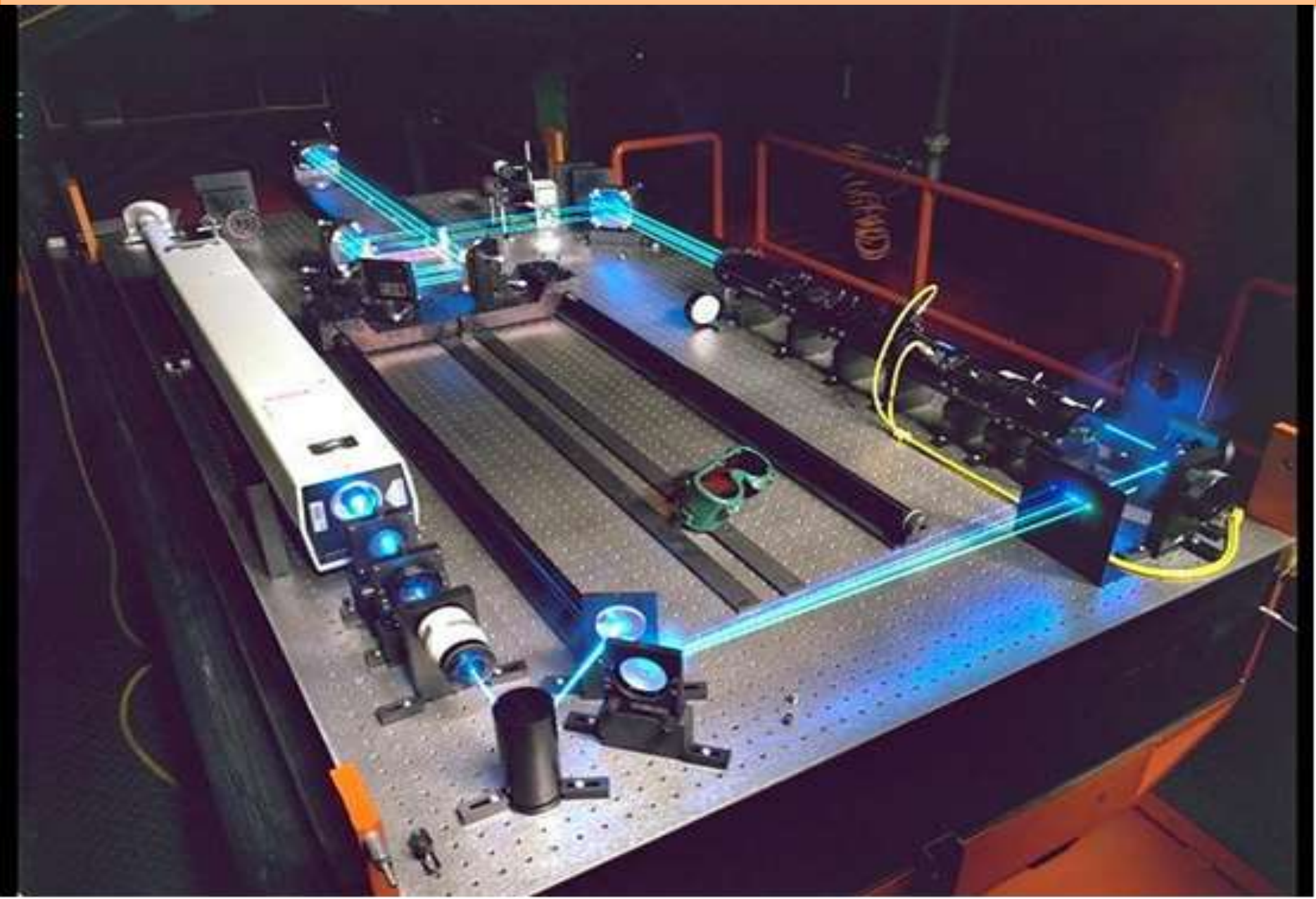
Coherent waves are waves that maintain the relative phase between them .



4. Brightness :

The other characteristic that cannot be ignored is high radiation
(Brightness) . It is defined as the amount of energy emitted per unit surface area per unit of solid angle.

How does a laser work?



The main components of the laser device :

In order for most laser to operate, three basic conditions must be satisfied

(1) The active medium: Collections of atoms, molecules or ions in the form of solid or liquid or gas.

(2) population inversion

(3) *Optical feed back*

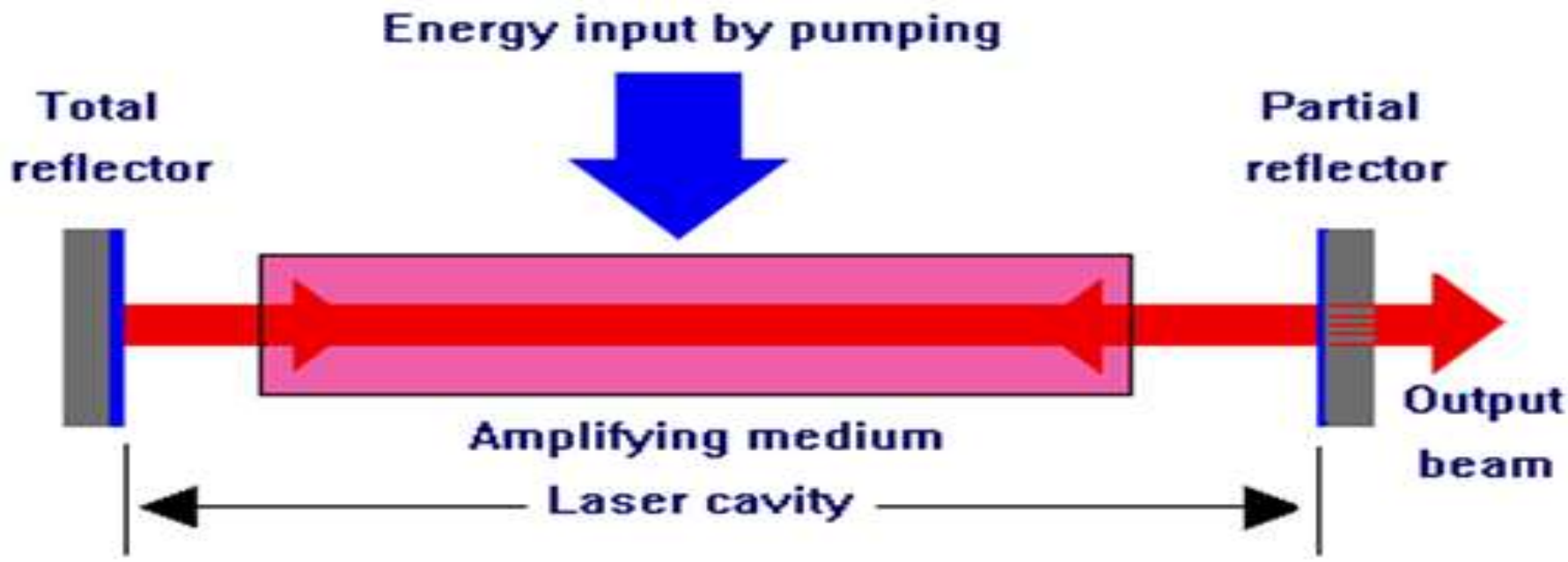


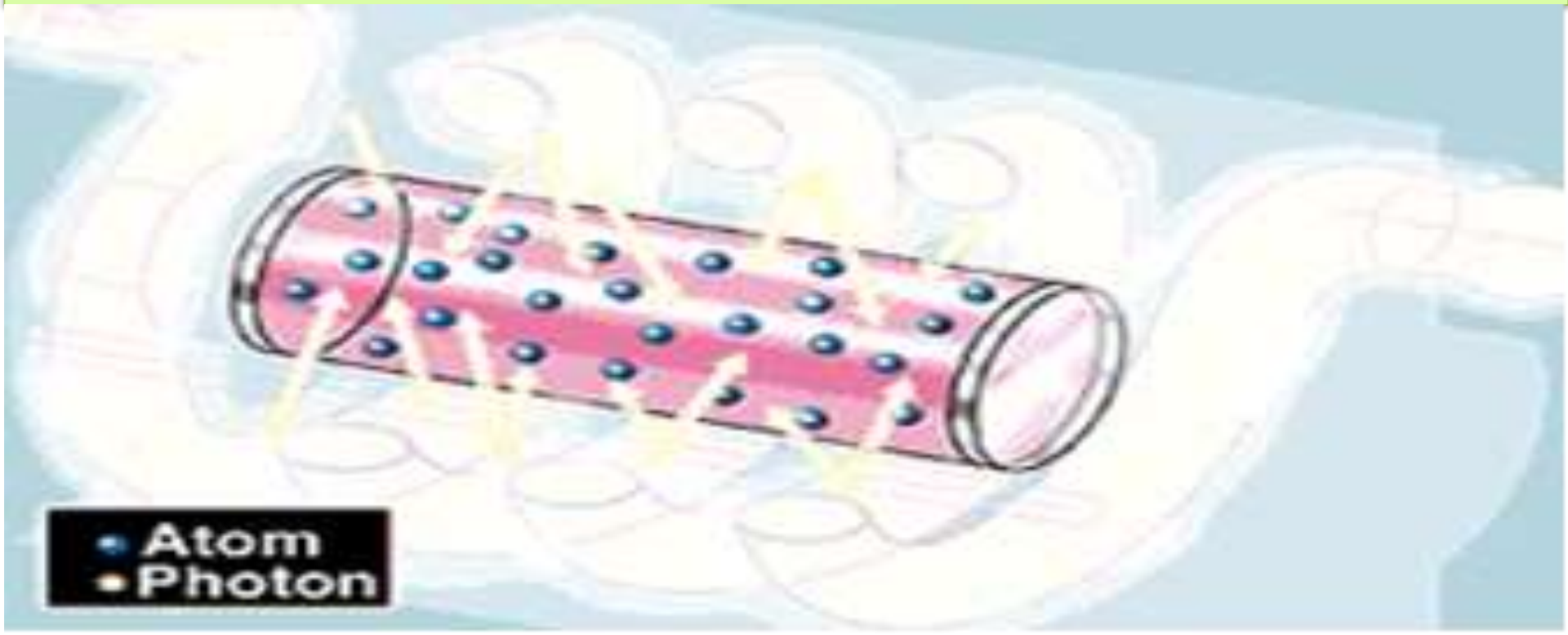
Figure : The main components of the laser device :

Stages of laser production :

It is divided into four stages:

1- The first stage: Excitation

High-voltage electricity causes the **quartz flash tube** to emit an intense burst of light, **exciting** some of the **atoms** in the **ruby crystal** to **higher energy levels**.



2-The second stage Photon Emission

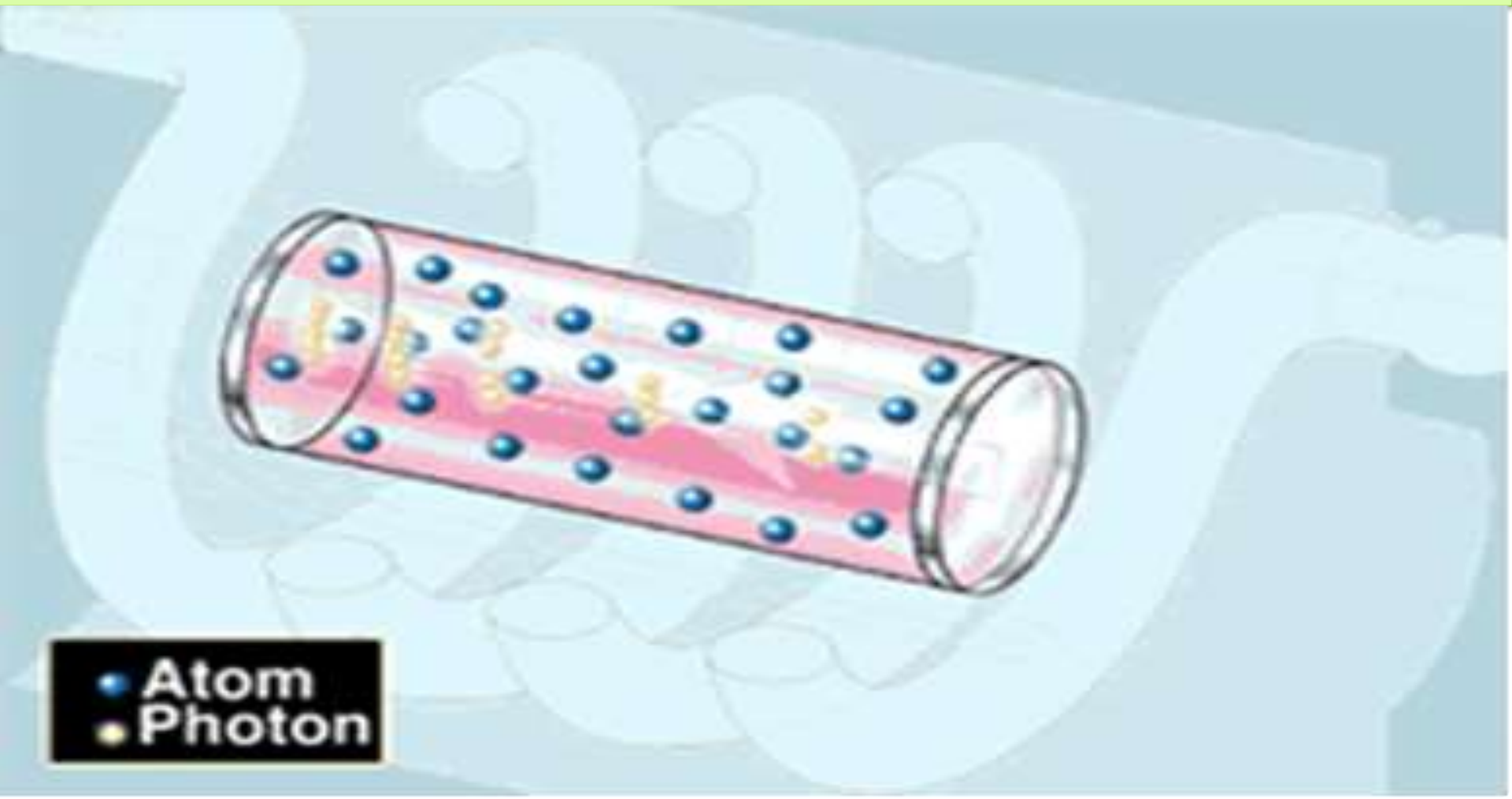
At a specific **energy level**, some **atoms emit photons**.

At first the photons are emitted in all directions.

Photons from **one atom stimulate emission of photons from other atoms and the light intensity is** rapidly amplified.

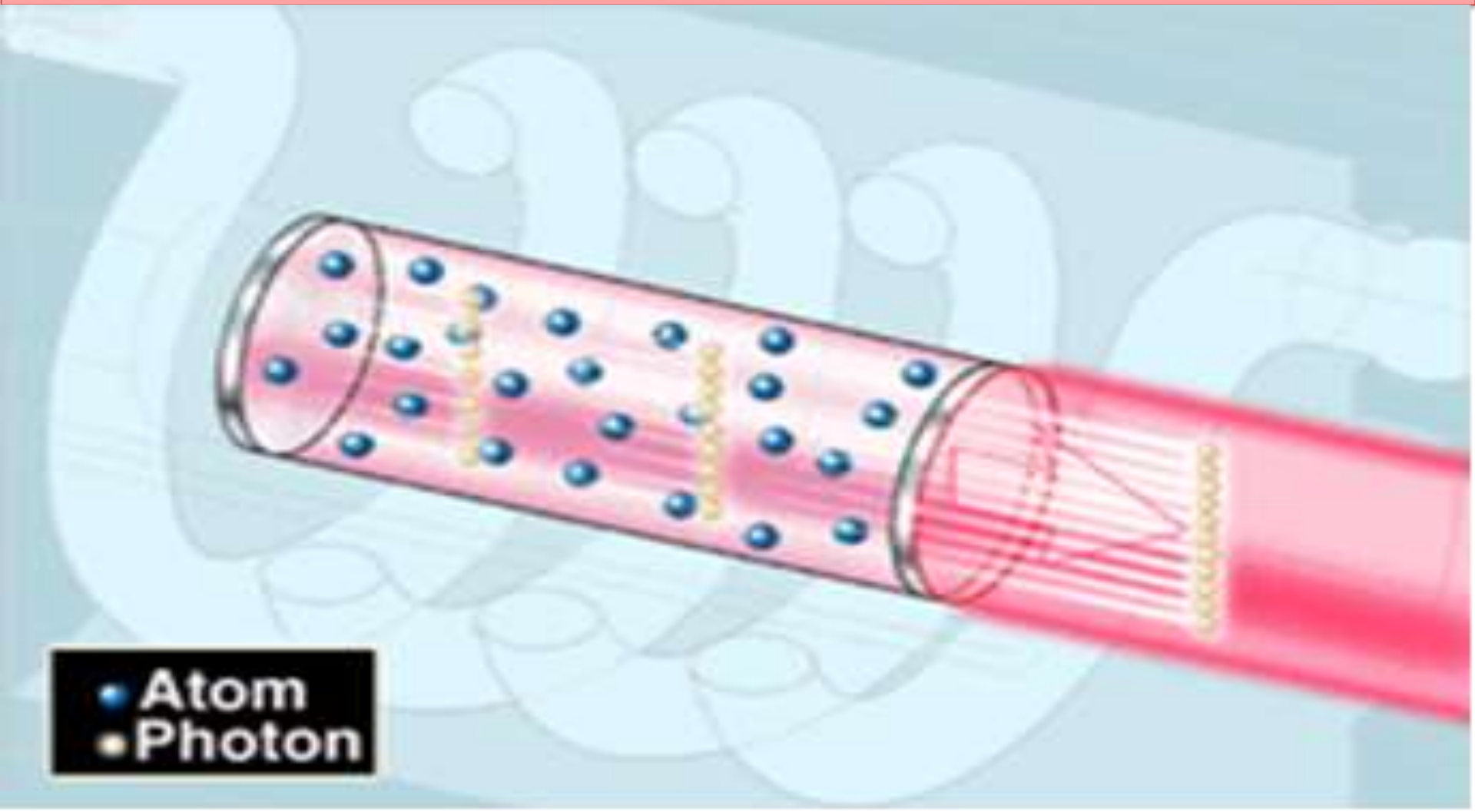
3- The third stage Amplification

Mirrors at **each end reflect the photons back** and forth, continuing this process of **stimulated emission and amplification**.



4-The fourth stage *Laser Beam*

The photons leave through the partially silvered mirror at one end. This is laser light.



The Interaction of Electromagnetic Radiation with Matter

Emission and Absorption of Radiation

The interactions between electromagnetic radiation and matter cause changes in the energy states of the electrons in matter.

Electrons can be transferred from one energy level to another , while absorbing or emitting a certain amount of energy. This amount of energy is equal to the ,energy difference between these two energy levels (E2-E1).

When this energy is absorbed or emitted in a form of electromagnetic radiation, the energy difference between these two energy levels (E2-E1) determines uniquely the frequency (υ) of the electromagnetic radiation:

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

Example

The visible spectrum wavelength range is: 0.4 - 0.7 [μm] (400-700 [nm]).

The **wavelength of the violet light is the shortest**, and **the wavelength of the red light is the longest**. Calculate:

a)What is the **frequency range of the visible spectrum**.

b) What is the amount of the photon's energy associated with the violet light, compared to the photon energy of the red light.

Solution:

The frequency of violet light:

$$\nu_1 = \frac{c}{\lambda_1} = \frac{3 \cdot 10^8 \cdot \frac{m}{sec}}{0.4 \cdot 10^{-6} \cdot m} = 7.5 \cdot 10^{14} \cdot \frac{1}{sec}$$

The frequency of red light:

$$\nu_2 = \frac{c}{\lambda_2} = \frac{3 \cdot 10^8 \cdot \frac{m}{sec}}{0.7 \cdot 10^{-6} \cdot m} = 4.3 \cdot 10^{14} \cdot \frac{1}{sec}$$

The difference in frequencies:

$$\Delta\nu = \nu_1 - \nu_2 = 7.5 \cdot 10^{14} - 4.3 \cdot 10^{14} = 3.2 \cdot 10^{14} \cdot \frac{1}{sec}$$

The **energy of a violet photon:**

$$E_1 = h \cdot \nu_1 = (6.626 \cdot 10^{-34} \cdot J \cdot sec) \cdot \left(7.5 \cdot 10^{14} \cdot \frac{1}{sec}\right)$$

$$E_1 = 5 \cdot 10^{-19} \cdot Joule$$

The **energy of a red photon:**

$$E_2 = h \cdot \nu_2 = (6.626 \cdot 10^{-34} \cdot J \cdot sec) \cdot \left(4.3 \cdot 10^{14} \cdot \frac{1}{sec}\right)$$

$$E_2 = 2.85 \cdot 10^{-19} \cdot Joule$$

The difference in energies between the violet photon and the red photon is:

$2.15*10^{-19}$ [J]

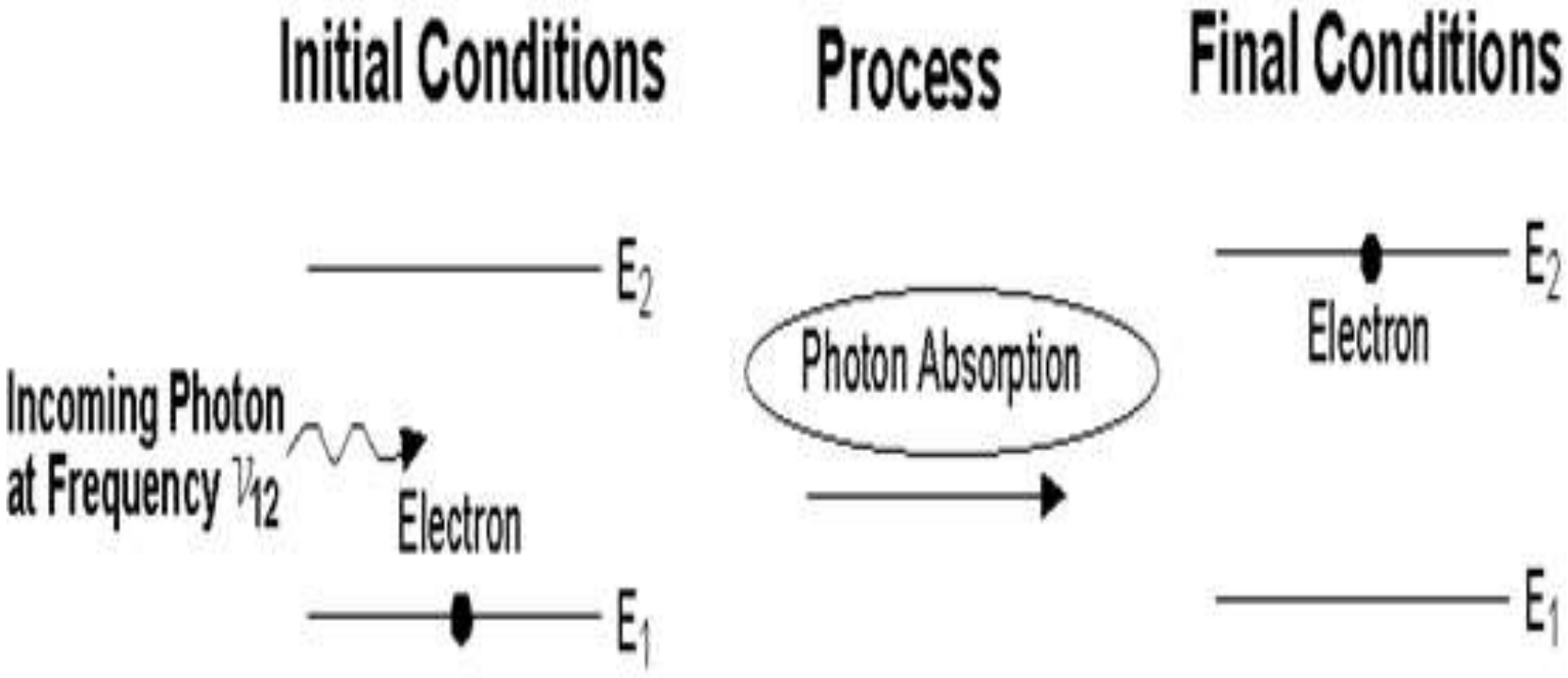
This example shows how **much more energy the violet photon have compared to the red photon**.

Three possible processes between photons and atoms

- Stimulated Absorption
- Spontaneous **Emission**
- Stimulated **Emission**

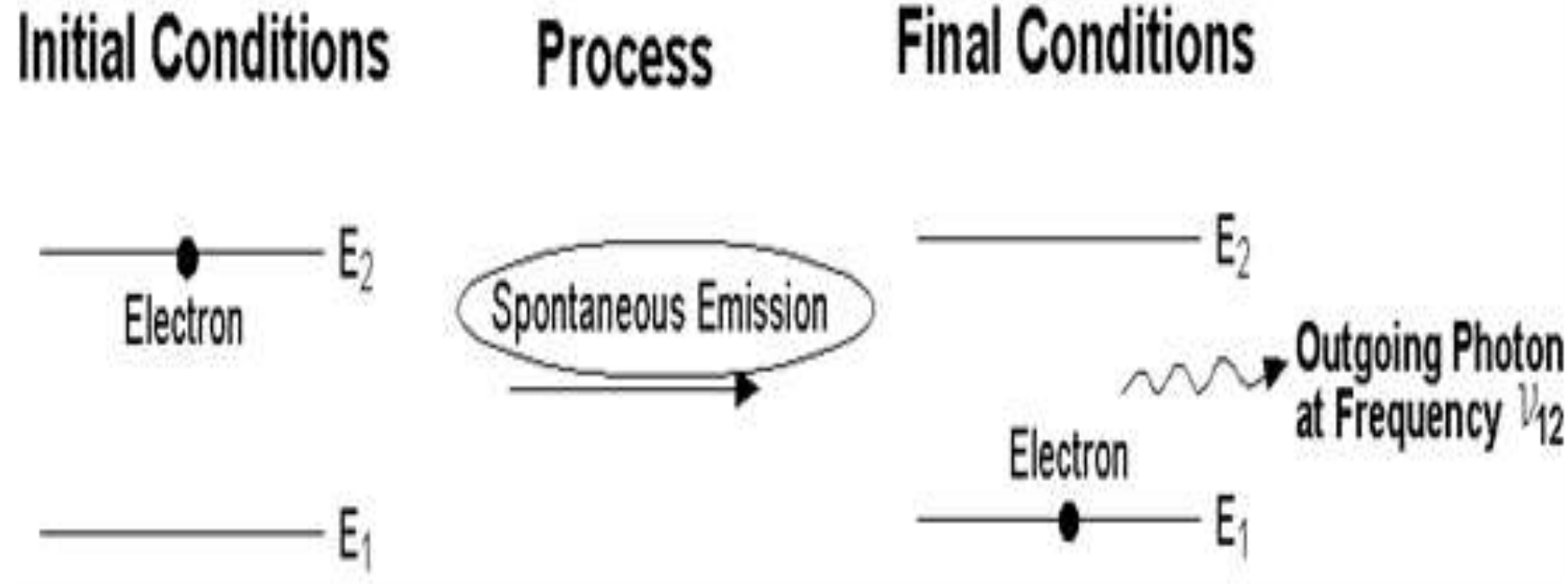
Absorption

Photon Absorption: A photon with frequency υ_{12} hits an atom at rest (left), and excites it to higher energy level (E2) while the photon is absorbed.



Spontaneous Emission

Spontaneous emission of a photon: An atom in an excited state (left) emits a photon with frequency υ_{12} and goes to a lower energy level (E1).



Stimulated Emission

Stimulated emission of a photon: A photon with frequency $\boldsymbol{\upsilon_{12}}$ hit an excited atom (left), and cause emission of two photons with frequency $\boldsymbol{\upsilon_{12}}$ while the atom goes to a lower energy level (E1).