HIGHER PHYSICS

UNIT 3 - RADIATION and MATTER

OPTO-ELECTRONICS

4) LASERS

You must be able to:

- State that an incoming photon (with energy equal to the difference in energy between levels E_1 and E_0 of an atom) stimulates an "excited" electron to jump from energy level E_1 to E_0 (ground level) of the atom, causing another identical photon to be emitted.

- State that both photons are in phase and now travel in the same direction.

- State that the term LASER stands for Light Amplification by the Stimulated Emission of Radiation.

- Explain the function of the two mirrors in a laser.

- State that laser light is monochromatic, coherent, parallel and has a very high irradiance.

- Compare laser light to light from a filament lamp.

- Explain why a beam of laser light with a power of 0.1 mW can cause eye damage.

SPONTANEOUS and STIMULATED EMISSION

The transition of an electron in an atom from a higher energy level to a lower energy level with the emission of a photon can be either:

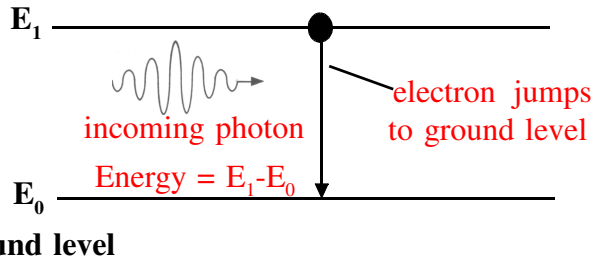
(a) Spontaneous

This is what happens during the production of the **line emission spectra** you have just studied. The process is **random** - We cannot predict when an electron will jump to a lower energy level, causing a photon to be emitted.

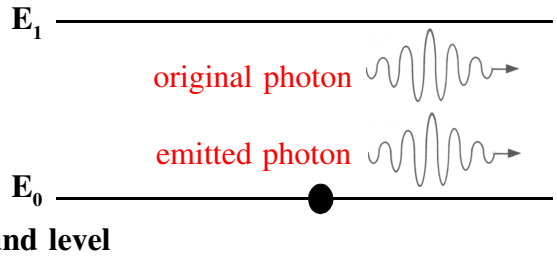
(b) Stimulated

This happens in a **laser**.

An incoming photon (with energy equal to the difference in energy between levels E_1 and E_0 of an atom) stimulates an "excited" electron to jump from energy level E_1 to E_0 (ground level) of the atom.

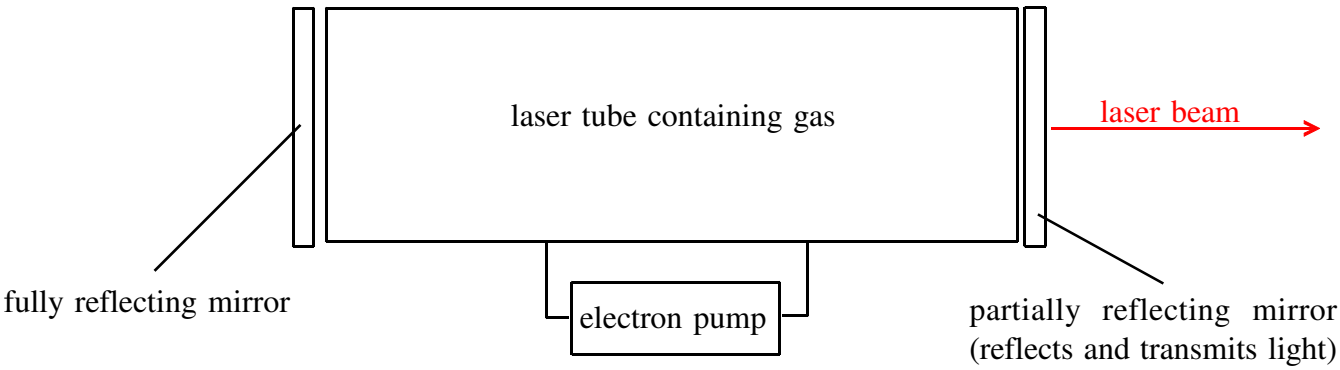


Another identical photon (same frequency and energy) is emitted as a result. Both photons are in phase and travel in the same direction.



LASERS

The term **laser** stands for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation.



In a **laser**, a gas is contained in a tube with a **fully-reflecting silver mirror** at one end and a **partially-reflecting silver mirror** at the other end.

Photons produced by **stimulated emission** travel through the gas, **reflecting between the two mirrors**. The photons **stimulate more electrons** to **jump from from excited energy level E_1 to the ground level E_0 of the gas atoms, producing more identical photons**.

Some of the **photons** created **escape through the partially reflecting mirror into the air**, creating a **laser beam**.

The **electron pump** provides energy to the atoms in the gas, to raise their electrons back to energy level E_1 , so the stimulated emission process can carry on.

Comparing Laser Light and Light from a Filament Lamp

Filament lamp (light bulb)	Laser
Emits photons of **all frequencies** in the visible spectrum.	Laser light is **monochromatic** - all the photons have the **same frequency**.
Light is **not coherent** (the emitted photons are **not in phase**).	Laser light is **coherent** - all the photons are **in phase**.
Light spreads out in all directions - so has a **low irradiance**.	Laser light does not spread out - It is **parallel**. It has a **very high irradiance** - all the photons are concentrated in a very small area. THE LASER BEAM HAS A **CIRCULAR CROSS-SECTION**.

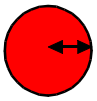
Laser Light and Eye Damage

Because a **laser beam** is **parallel** and has a **high irradiance**, it can cause serious damage to the human eye. For example:

Calculate the irradiance of a laser beam with typical power 0.1 mW (0.0001 W) which has a radius 0.5 mm (0.0005 m).

$$\text{Irradiance (I)} = \frac{\text{Power (P)}}{\text{Area (A)}} = \frac{0.0001 \text{ W}}{\pi \times \text{radius}^2} = \frac{0.0001}{3.14 \times 0.0005^2}$$

$$= 127 \text{ W m}^{-2}$$



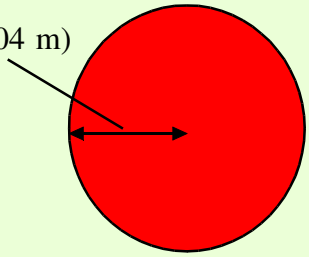
Cross-section of laser beam.
Radius = 0.0005 m.

An irradiance of 127 W m^{-2} is sufficiently high to cause severe eye damage.
It is far higher than the irradiance of light produced by a filament lamp (light bulb).

1)(a) Calculate the irradiance of this laser beam:

power = 0.1 mW (0.0001 W)

radius = 0.4 mm (0.0004 m)



(b) Explain whether the laser beam will be capable of causing eye damage:

2) With the aid of a labelled diagram, describe stimulated emission:

3) What does the term LASER stand for?

4) Describe laser light:

5) Describe the purpose of the 2 mirrors in a laser: