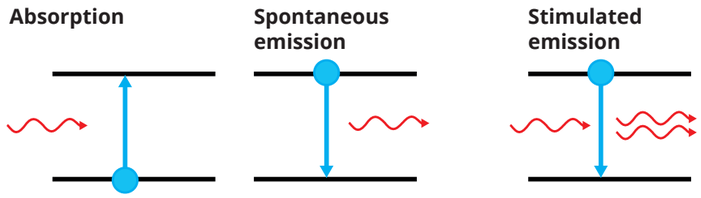
A level Physics Component 3.5 Lasers

Stimulated emission:

When photos of light interact with electrons in different energy levels, 3 processes can occur.

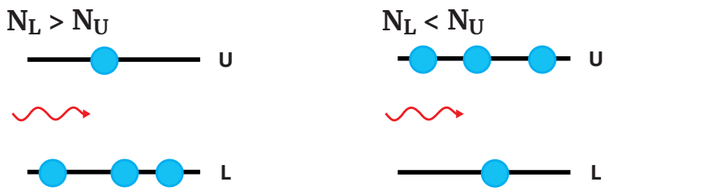


See Unit 2.7

Stimulated emission is essential for a laser. **One incident photon** causes an electron to drop an energy level and release a **second photon**. The second photon has the **same energy**, **polarisation**, **phase and direction** as the initial photon; it is coherent.

Population inversion:

When an incident photon interacts with an electron in these energy levels, it can cause absorption or stimulated emission. **For a laser to work**, **there must be a population inversion between the energy levels**.



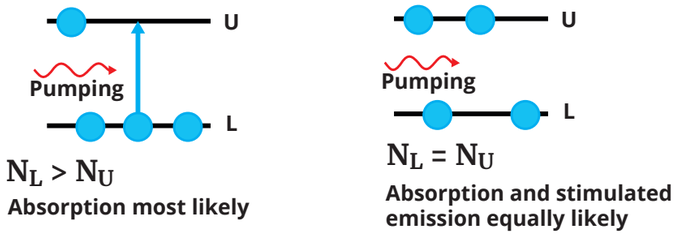
Absorption most likely

Stimulated emission most likely

Pumping:

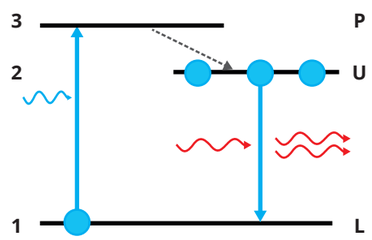
Under normal conditions, **most electrons in an atom will be in the lowest energy level**. To ensure that stimulated emission can occur, these electrons must be **promoted to a higher level through absorption** of photons. This is known as **pumping**.

2-level system:



In a 2-level energy system, **it is not possible to create a population inversion** because the best it can create is $N_L = N_u$. After this has been reached, the pumping photon is equally likely to cause absorption or stimulated emission.

3-level system:



Electrons are pumped to level 3, which is not stable, so the electrons quickly drop to level 2.

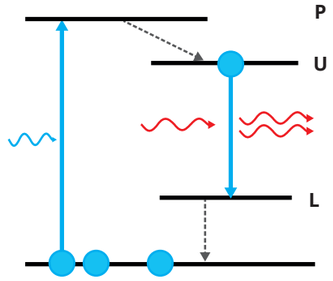
Level 2 is metastable so the electron will stay in this level long enough for a photon of the laser frequency to cause stimulated emission.

Population inversion is possible in a 3-level system because the pumping frequency and the laser frequency are different. However, at least half the electrons in the lower level must be promoted to ensure a higher number in level U, this takes a lot of energy.

Structure:

A typical laser has **an amplifying medium between 2 mirrors**, one of which reflects only 99% of the photons. The other 1% of the photons are transmitted, this is the laser light.

4-level system:



Electrons are pumped to level 4, which is not stable so the electrons quickly drop to level 3.

Level 3 is metastable so the electron will stay in this level long enough for a photon of the laser frequency to cause stimulated emission.

Level 2 is not stable so the electrons quickly drop to level 1, so level 2 is almost always empty.

Population inversion is easier to create in a 4-level system as stimulated emission occurs between level 3 and 2 and level 2 is almost always empty. Therefore, only a small number of electrons need to be pumped to a high level to ensure population inversion.

The frequency of the pumping light is still higher than the frequency of the laser so the laser will not be very efficient.

Semiconductor laser :

Conventional lasers are not very efficient, therefore **semiconductor lasers which are small**, **cheap and far more efficient** are now commonly used. These lasers use **electrical current to pump** the electrons to produce a high population inversion and the mirrors used in a semiconductor laser transmit up to 60% of the photons. This makes semiconductor lasers ideal for use in optical fibres, barcode scanners and in laser printers.

However, semiconductor lasers cannot produce the high power, focussed beams that conventional lasers do.