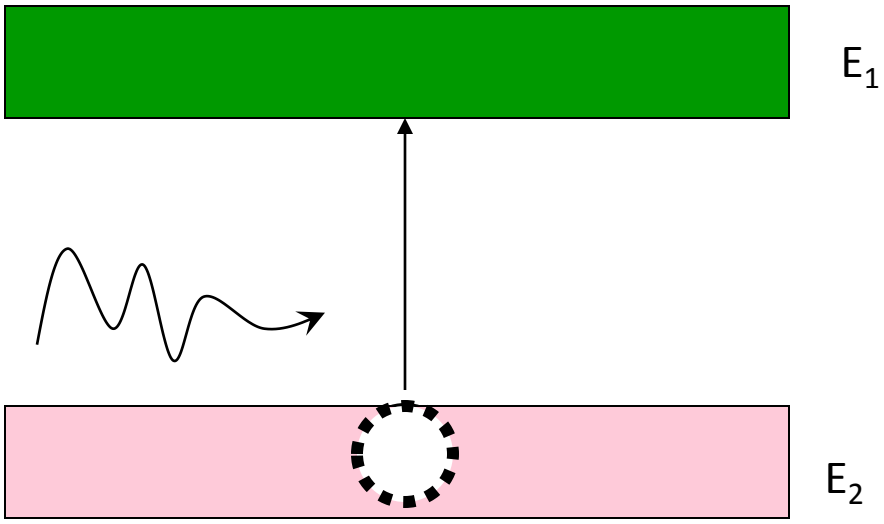
Absorption, Spontaneous Emission and Stimulated Emission

Absorption

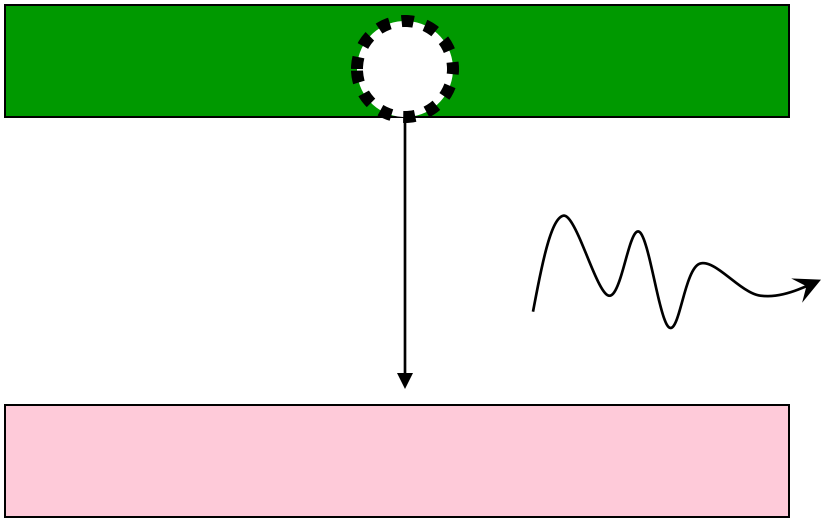
- Absorption: An atom in a lower level absorbs a photon of frequency hν and moves to an upper level.



Spontaneous Emission

An atom in an upper level can decay spontaneously to the lower level and emit a photon of frequency hν if the transition between E2 and E1 is radiative. This photon has a random direction and phase.

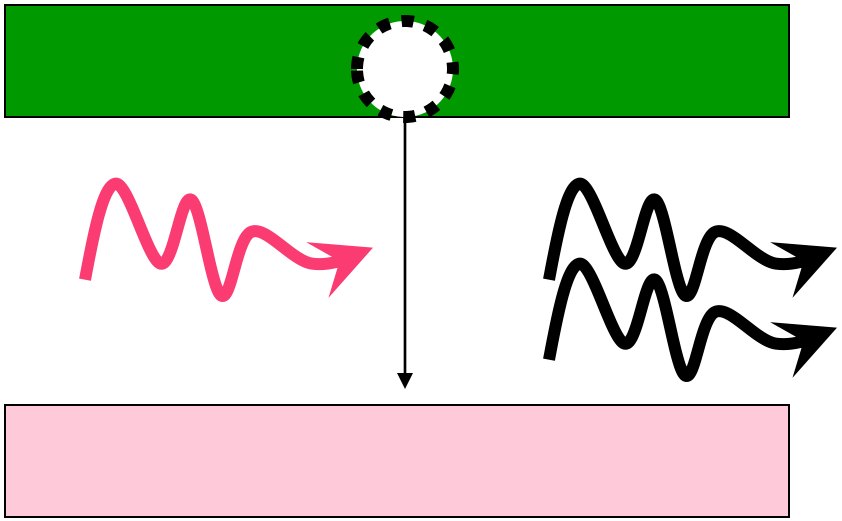
Spontaneous Emission

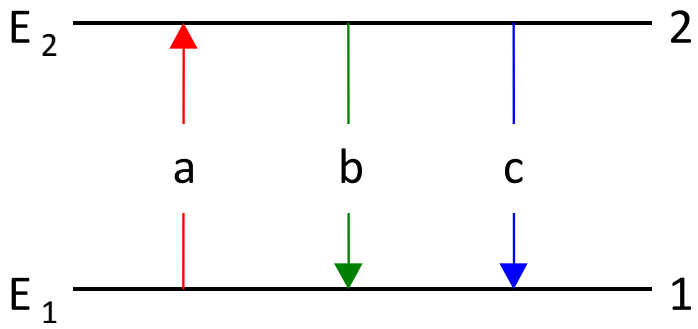


Stimulated Emission

An incident photon causes an upper level atom to decay, emitting a “stimulated” photon whose properties are identical to those of the incident photon. The term “stimulated” underlines the fact that this kind of radiation only occurs if an incident photon is present. The amplification arises due to the similarities between the incident and emitted photons.

Stimulated Emission





a absorption

b spontaneous emission

c stimulated emission

Absorption

Molecule absorbs a quantum of radiation (a photon) and is excited from 1 to 2.

$$M + h\upsilon \rightarrow M^*$$

(state 1) (state 2)

Spontaneous emission

M* (in state 2) spontaneously emits a photon of radiation.

$$M^* \rightarrow M + h\upsilon$$

Stimulated emission

A quantum of radiation is required to stimulate M* to go from 2 to 1.

$$M^* + h\upsilon \rightarrow M + 2h\upsilon$$

- Rates are determined by the Einstein coefficients for each process

$$\frac{dN_1}{dt} = N_1 B_{12} \rho(\upsilon)$$ Absorption

$$\frac{dN_2}{dt} = N_2 B_{21} \rho(\upsilon)$$ Stimulated emission

$$\frac{dN_2}{dt} = N_2 A_{21}$$ Spontaneous emission

$\rho(\upsilon)$ is the energy density of the incident radiation and N_1 and N_2 are the populations of states 1 and 2 respectively.

Under thermal conditions the population of two states 1 and 2, is determined by the Boltzman distribution.

$$\frac{N_2}{N_1} = \exp\left(\frac{-\Delta E}{kT}\right)$$

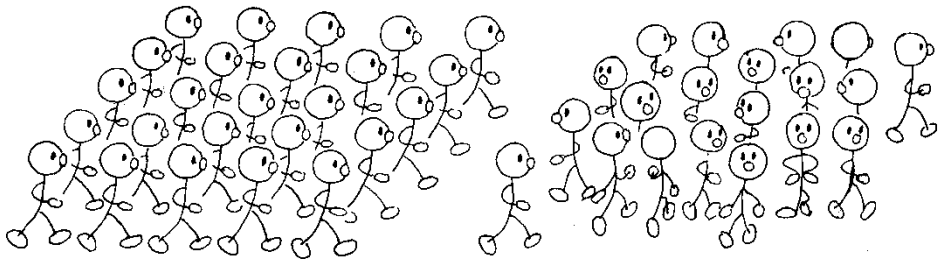
Where ΔE is the energy difference between the two states, T is the temperature and k is Boltzmans constant.

Spontaneous emission

- Photons emitted in all directions and on a random time scale.
- The emitted photons are INCOHERENT

Stimulated emission

- Emitted and stimulating photons have the same :
  - Frequency
  - Direction
  - Phase
- The emitted and incident photons are COHERENT



First condition for laser action

If $N_1 > N_2$

- If most molecules in state 1, then incoming radiation is mainly absorbed.
- Incident radiation is attenuated (reduced).

If $N_2 > N_1$

- If most molecules are in state 2, absorption of incoming radiation is hindered.
- The result is stimulated emission.
- Incident radiation is amplified.

Thus for laser action require a population inversion, $N_2 > N_1$