SPONTANEOUS VS. STIMULATED EMISSION

Z LVL. SYS.

**ABSORPTION**

\[ E_2, n_2 \rightarrow E_1, n_1 \]

\[ h\omega = E_2 - E_1 \]

\[ E_n = -\frac{13.6 \text{eV}}{h^2} \]

**EMISSION**

\[ E_2, n_2 \rightarrow E_1, n_1 \]

THINK ABOUT MOLECULES IN A BLACKBODY CONTAINER (IN A RADIATION FIELD) AT THERMAL EQUILIBRIUM AT TEMP. T.

FOR A Z-LVL.-SYS., THE RELATIONSHIP BETWEEN \( n_2 \) AND \( n_1 \) IS

\[ \frac{n_2}{n_1} = \exp \left( \frac{-E_2 - E_1}{KT} \right) \]

\( K = 1.38 \times 10^{-23} \text{J/K} \)
Absorption:
\[-\frac{dn_1}{dt} = B_{12} n_1 u(v_i T)\]

\[\text{Planck's law} = \frac{8 \pi \hbar v^3}{c^3} \cdot \frac{1}{e^{\frac{\hbar v}{kT}} - 1}\]

Spontaneous Emission:
\[-\frac{dn_2}{dt} = A_{21} n_2\]

Also need:

Stimulated Emission:
\[-\frac{dn_2}{dt} = B_{21} n_2 u(v_i T)\]

\[\sum \frac{dn_1}{dt} = 0 \Rightarrow\]

\[B_{12} n_1 u(v_i T) = B_{21} n_2 u + A_{21} n_2\]

\[B_{12} = B_{21}\]

\[A_{21} = \frac{8 \pi \hbar v^3}{c^3} \cdot B_{12}\]

In a radiation field, stimulated emission exists.

\[\text{E.g. examine thermal radiation}\]

\[\text{Net rate} = \frac{\text{Stimulated}}{\text{Spontaneous}} = \frac{1}{e^{\frac{\hbar v}{kT}} - 1}\]

\[kT \approx 26 \text{meV @ 300K}\]

\[1 \mu \text{m} \rightarrow h\nu \approx 1.24 \text{eV}\]

\[\text{At RT stimulated emission is not very apparent}\]
\[ I = c u \quad (\text{4TH SPONTANEOUS}) \]

\[ dI = -h v B_{12} n_1 u dz + h v B_{21} n_2 u dz \]

\[ dI = -\alpha I dz \]

\[ \alpha = \frac{h v}{c} B_{12} \left( \frac{g_2}{g_1} n_1 - n_2 \right) \]

\[ q \equiv \text{DEGENERACY} \]

NOTE: AT EQUIL. \( n_1 > n_2 \)

\[ \therefore \alpha > 0 \]

\[ I = I(0) e^{-\alpha z} \]

IF \( \alpha \) IS NEGATIVE, i.e. \( n_2 > n_1 \) (population inversion)

\[-\alpha = \gamma \equiv \text{gain (AMPLIFICATION)}\]

* SOME PEOPLE CALL POP. UV. A (-)VE TEMP.

PROCESS BASED ON \( \frac{n_2}{n_1} > 1 \Rightarrow \exp\left(\frac{E_1 - E_2}{kT}\right) > 1 \)

WHICH IMPLIES (-)VE TEMP. BUT FOR POP. UV. THE PROCESS IS NON-EQUIL. AND \( n_2/n_1 = \exp\left(\frac{-E_2-E_1}{kT}\right) \)

DOES NOT APPLY.
\[ I(0) = \frac{R_1 R_2}{e^{2\delta L} - 2\delta L} e^{2\delta L} = I(0) \]

\[ Y = B - \frac{I}{ZL} \ln(R_1 R_2) \]

\[ n_2 = n_2(0) e^{-t/T_{\text{span}}} \quad \text{where} \quad T_{\text{span}} = \frac{1}{A_{z1}} \]

Pumping

Want \( n_2 > n_1 \)

... solving spontaneous emission eqn.
LASER BEAM CHARACTERISTICS

\[ \frac{\lambda}{2} \cdot n = L \]

LONGITUDINAL MODES

SPACING \[ \Delta \nu = \frac{C}{\lambda} = \frac{2nC}{L} \]  

\[ c - 10^8 \text{ m/s} \]

\[ v_0 \sim \omega \]
... could also have transverse waves.

A cavity with curved mirrors:

\[ 0 \leq \left( 1 - \frac{1}{r_1} \right) \left( 1 - \frac{1}{r_2} \right) \leq 1 \]

Gaussian beam optics:

\[ I(r,z) = I_0 e^{-2r^2/W(z)} \]

\[ W(z) = W_0 \left[ 1 + \left( \frac{z}{Z_0} \right)^2 \right]^{1/2} \]

\[ \alpha = \frac{\lambda}{\pi W_0} \]

\[ Z_0 = \frac{\pi W_0^2}{\lambda} \]

\[ W_0 = \left( \frac{\lambda L}{\pi} \right)^{1/2} \frac{1}{L} \left[ \frac{r_1 - r_2 - L}{L} \left( \frac{r_1 + r_2 - L}{L} \right)^2 \right]^{1/4} \]
Can use matrix method to compute relation of optical input and output.

**ABCD Law**: \[ \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} W_0 \\ W_0' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -1/f & 1 \end{pmatrix} \begin{pmatrix} W_i \\ W_i' \end{pmatrix} \]

Modes: \( \text{TEM}_{mn} \)

- \( \text{TEM}_{00} \)
- \( \text{TEM}_{01} \)
- \( \text{TEM}_{10} \)
- \( \text{TEM}_{11} \)

Types of lasers:

**Active Media**
- Gas
- Liquid
- Solid

**Pump Method**
- Optical
- Electrical

**Wavelength**
- Excimer visible
- Near infrared
- Middle I.R. (CO₂)
S.C. Lasers.