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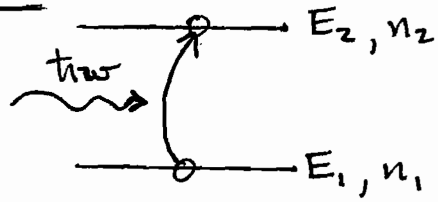
SPONTANEOUS VS. STIMULATED EMISSION

- 2 LVL. SYS.

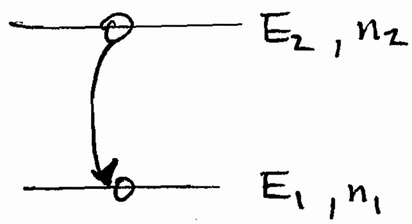
ABSORPTION



$$E_n = -\frac{13.6\,eV}{n^2}$$

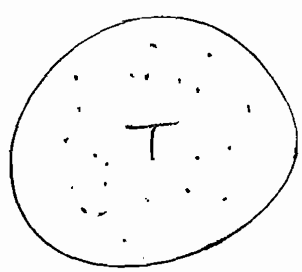
$$\hbar\omega = E_2 - E_1$$

EMISSION



SPONTANEOUS EMISSION

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



FOR A 2-LVL.-SYS., THE RELATIONSHIP BETWEEN n_2 & n_1 IS

$$\frac{n_2}{n_1} = \exp\left(-\frac{E_2 - E_1}{kT}\right)$$

(k ← $1.38 \times 10^{-23}\ J/K$)

ABSORPTION —

$$-\frac{dn_1}{dt} = B_{12} n_1 u(\nu, T)$$

↑ PLANCK'S LAW $= \frac{8\pi h \nu^3}{c^3} \cdot \frac{1}{e^{h\nu/kT} - 1}$

CANNOT EQUATE ALONE

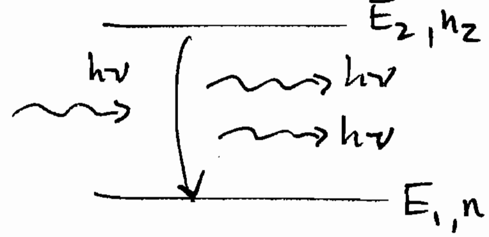
SPONTANEOUS EMISSION —

$$-\frac{dn_2}{dt} = A_{21} n_2$$

∴ ALSO NEED,

STIMULATED EMISSION —

$$-\frac{dn_2}{dt} = B_{21} n_2 u(\nu, T)$$



STIMULATED EMISSION

$$\sum \frac{dn_1}{dt} = 0 \implies$$

$$B_{12} n_1 u(\nu, T) = B_{21} n_2 u + A_{21} n_2$$

$$B_{12} = B_{21}$$

$$A_{21} = \frac{8\pi h \nu^3}{c^3} B_{12}$$

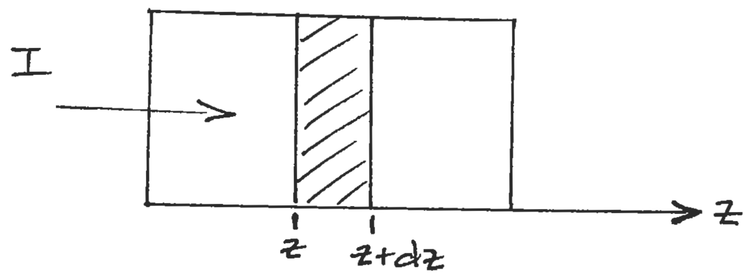
IN A RADIATION FIELD, STIMULATED EMISSION EXISTS

eg., EXAMINE THERMAL RADIATION

LET $m = \frac{\text{STIMULATED}}{\text{SPONTANEOUS}} = \frac{1}{e^{h\nu/kT} - 1}$ $kT \approx 26\,\text{meV}$ @ 300K

$1\,\mu m \rightarrow h\nu \approx 1.24\,\text{eV}$

∴ AT RT STIMULATED EMISSION IS NOT VERY APPARENT



$I = cu$ (4π SPONTANEOUS)

$dI = -h\nu B_{12} n_1 u\, dz + h\nu B_{21} u\, dz$

$dI = -\alpha I\, dz$

POP. INV.

$\frac{g_2}{g_1} n_1 - n_2 < 0$

$$\alpha = \frac{h\nu}{c} B_{12} \left(\frac{g_2}{g_1} n_1 - n_2 \right)$$

$g \equiv$ DEGENERACY

NOTE: AT EQUIL. $n_1 > n_2$

$\therefore \alpha > 0$

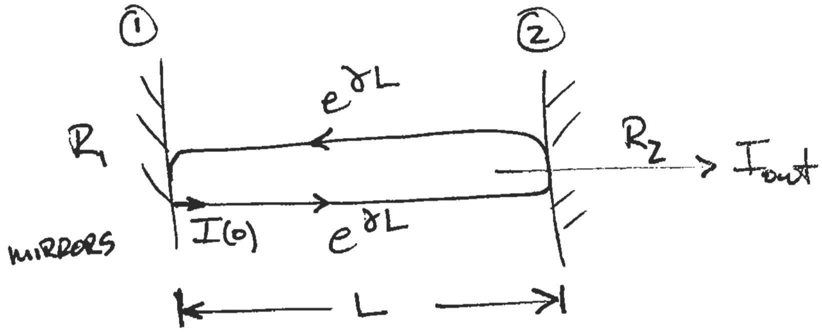
$$I = I(0)\, e^{-\alpha z}$$

IF α IS NEGATIVE, i.e. $n_2 > n$ (population inversion)

$$-\alpha = \gamma \equiv \text{gain} \quad \text{(AMPLIFICATION)}$$

* SOME PEOPLE CALL POP. INV. 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. INV. THE PROCESS IS NON-EQUIL. AND $n_2/n_1 = \exp\left(-\frac{E_2 - E_1}{kT}\right)$ DOES NOT APPLY

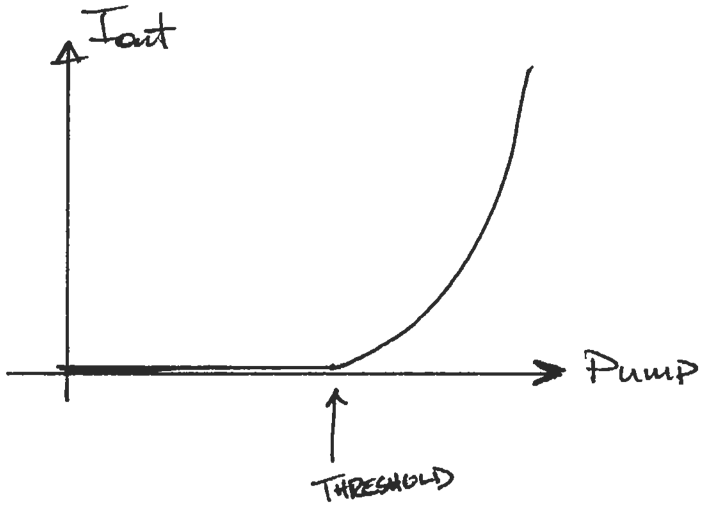
MIRROR CAVITY



$$\cancel{I(0)}\, R_1 R_2\, e^{2\gamma L}\, e^{-2\beta L} = \cancel{I(0)}$$

$$\gamma = \beta - \frac{1}{2L}\ln(R_1 R_2)$$

TYPICAL CURVE



PUMPING

WANT $n_2 > n_1$

... SOLVING SPONTANEOUS EMISSION EQN.

$$n_2 = n_2(0)\, e^{-t/\tau_{spon}} \quad ; \quad \tau_{spon} = \frac{1}{A_{21}}$$

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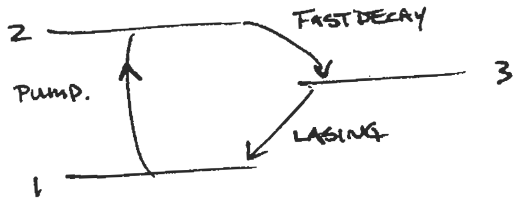
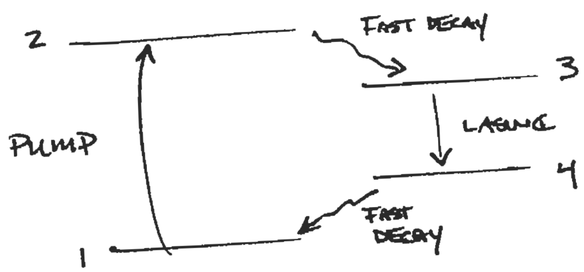
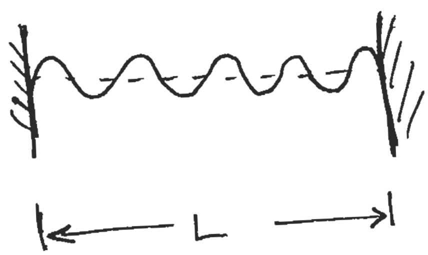
3-LVL.-SYS.



4-LVL-SYS.

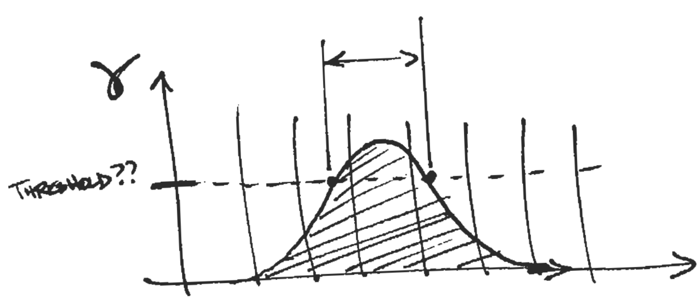


LASER BEAM CHARACTERISTICS



INTEGER

$$\frac{\lambda}{2} \cdot n = L$$



LONGITUDINAL MODES

SPACING $\Delta \nu = \frac{c}{\lambda} = \frac{2nc}{L}$

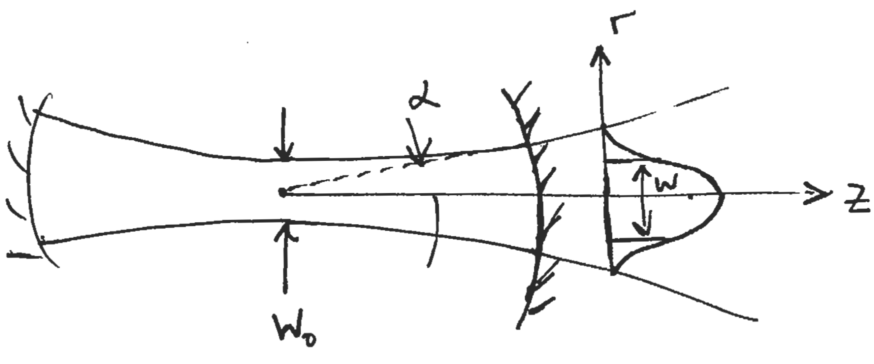
$c \sim 10^8$ m/s

$\nu_0 \sim 10^{14}$

... COULD ALSO HAVE TRANSVERSE MODES

A CAVITY W/ CURVED MIRRORS —

$$0 \leq \left(1-\frac{L}{r_1}\right)\left(1-\frac{L}{r_2}\right) \leq 1$$



GAUSSIAN BEAM OPTICS

$$I(r,z) = I_o\, e^{-2r^2/w^2(z)}$$

$$w(z) = w_o\left[1+\left(\frac{z}{z_0}\right)^2\right]^{1/2}$$

$$\alpha = \frac{\lambda}{\pi w_o}$$

$$z_o = \frac{\pi w_o^2}{\lambda} \qquad w_o = \left(\frac{\lambda L}{\pi}\right)^{1/2}\left[\frac{(r_1-L)(r_2-L)(r_1+r_2-L)}{L(r_1+r_2-2L)^2}\right]^{1/4}$$

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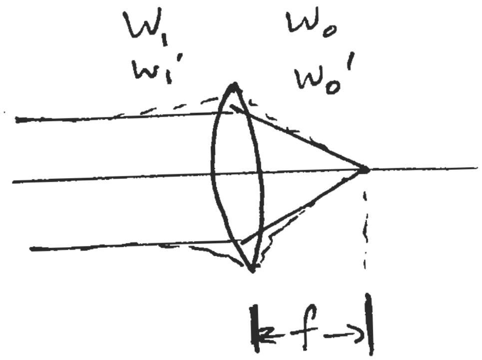


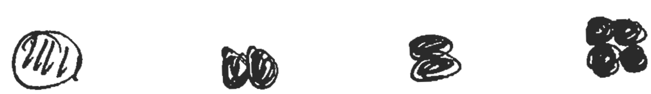
CAN USE MATRIX METHOD TO ~~COMPUTE~~ RELATE OPTICAL INPUT & OUTPUT

ABCD LAW (FROM $\left(\ \right) = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \left(\ \right)$)

$$\begin{pmatrix} W_o \\ W_o' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 0 \end{pmatrix} \begin{pmatrix} W_i \\ W_i' \end{pmatrix}$$

<u>MODES</u> TEM_{mnq}

TEM_{00} TEM_{01} TEM_{10} TEM_{11}



TYPES OF LASERS

ACTIVE MEDIA
- GAS
- LIQUID
- SOLID

WAVELENGTH
- EXCIMER
- VISIBLE
- NEAR INFRARED
- MIDDLE I.R. (CO_2)

PUMP METHOD
- OPTICAL
- ELECTRICAL

S.C. LASERS.