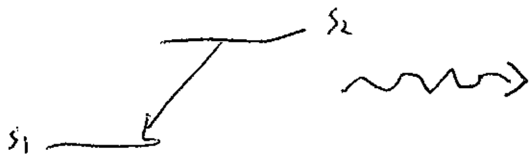
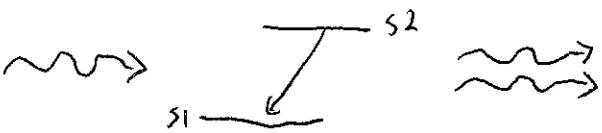
Lasers

L ight
A mplification
S timulated
E mission
R adiation

Spontaneous emission

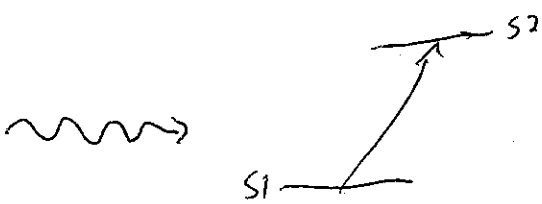


Stimulated emission



← coherent light

absorbtion



Stimulated Emission

Consider atoms in equilibrium with radiation

$$W_{1\to 2} = W_{spon\ 2\to 1} + W_{stim\ 2\to 1}$$

$$W_{spon,\ 2\to 1} = A\ N_2$$ ← Number of atoms in State 2

↑ Einstein A coefficient

S1 has energy E_1
S2 has energy E_2

$$E_2 - E_1 = \frac{hc}{\lambda}$$

$$W_{1\to 2} = B_{12}\ N_1\ \frac{du}{d\lambda}$$

↑ Einstein B coefficient

$$\frac{du}{d\lambda} = \frac{\pi h c^3}{2\lambda^5}\ \frac{1}{e^{hc/\lambda kT} - 1}$$

$$W_{stim,\ 2\to 1} = B_{21}\ N_2\ \frac{du}{d\lambda}$$

Combining

$$B_{12}\ N_1\ \frac{du}{d\lambda} = A\ N_2 + B_{21}\ N_2\ \frac{du}{d\lambda}$$

$$\frac{du}{d\lambda} = \frac{A}{B_{12}\frac{N_1}{N_2} - B_{21}} = \frac{A}{B_{12}\, e^{(E_2-E_1)/kT} - B_{21}}$$

$$\uparrow \quad = e^{(E_2-E_1)/kT}$$

$$\frac{\left(\frac{A}{B_{21}}\right)}{\frac{B_{12}}{B_{21}}\, e^{(E_2-E_1)/kT} - 1} = \frac{\pi h c^3}{2\lambda^5}\ \frac{1}{e^{hc/\lambda kT} - 1}$$

$$\frac{A}{B} = \frac{\pi h c^3}{2\lambda^5}$$

$$B \equiv B_{12} = B_{21}$$

$$\frac{W_{stim\ 2\to 1}}{W_{spon\ 2\to 1}} = \frac{B N_2 \frac{du}{d\lambda}}{A N_2} = \frac{1}{e^{(E_2-E_1)/kT} - 1} = \left(\frac{\pi h c^3}{2\lambda^5}\right)^{-1} \frac{du}{d\lambda}$$

↑ for thermal background radiation

↑ in general

Since $B_{12} = B_{21}$ the absorption cross section is the same as for stimulated emission

To generate and maintain coherent light

$N_2 > N_1$

This is population inversion

$N_2 > N_1$ must be maintained by supplying energy to the system

Amplification requires population inversion — long lived N_2 state; energy source

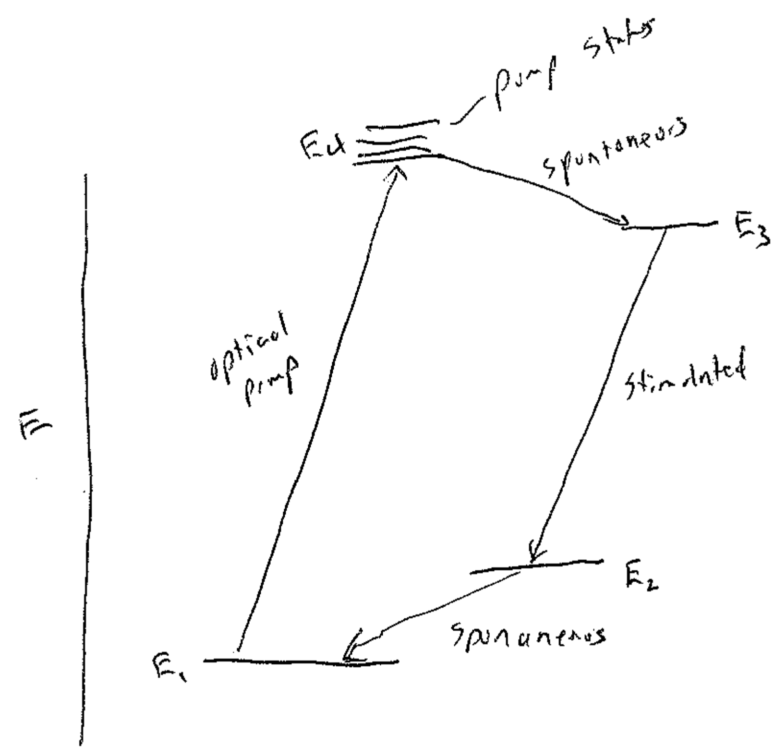
containment

Nd: YAG

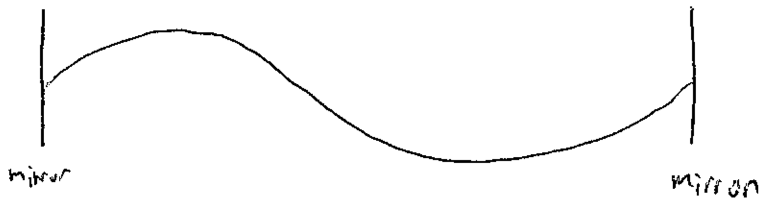
Nd - neodymium

YAG : yttrium - aluminum - garnet

$\lambda = 1.06$ um



Fabry - Perot cavity



Only standing waves are allowed

for He - Ne laser $\Delta\lambda = 2 \times 10^{-3}$ nm

Laser output at $\lambda = 633\,nm$

about how many modes are allowed in a 10 cm cavity?

$L = q \frac{\lambda}{2}$ q is integer called mode order

each mode has unique q

$$q = \frac{2L}{\lambda}$$

$$q_{min} - q_{max} = \frac{2L}{\lambda + \Delta\lambda} - \frac{2L}{\lambda - \Delta\lambda} \sim 6$$

~ 6 modes supported by HeNe Bandwidth