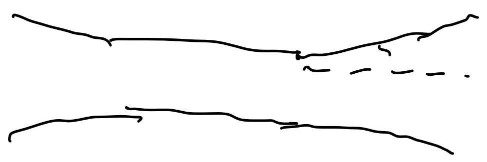
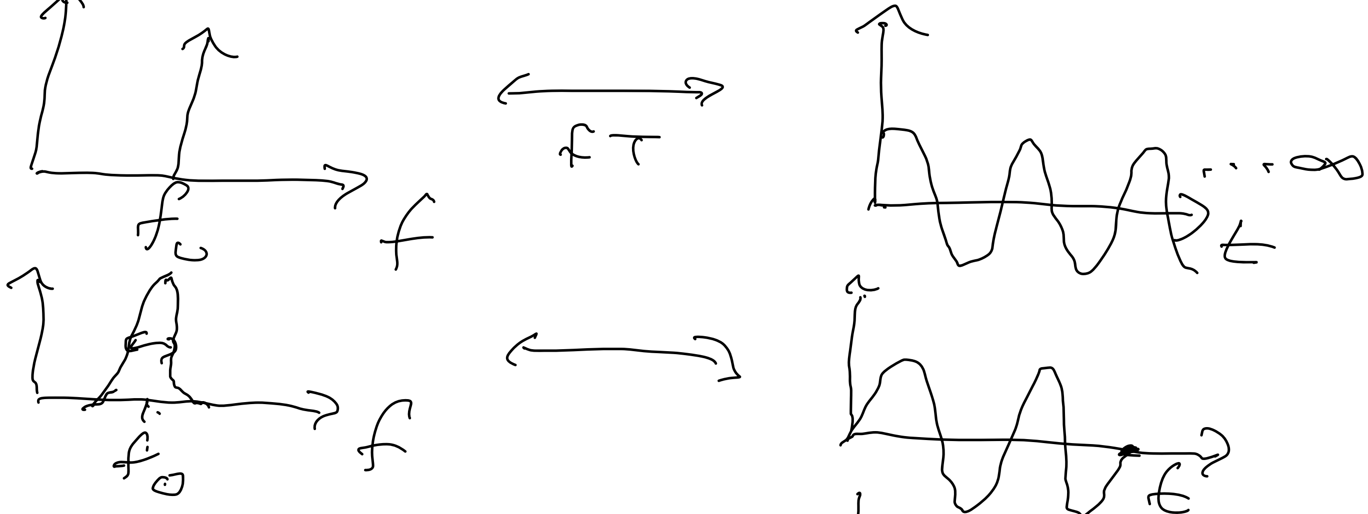
Lasers

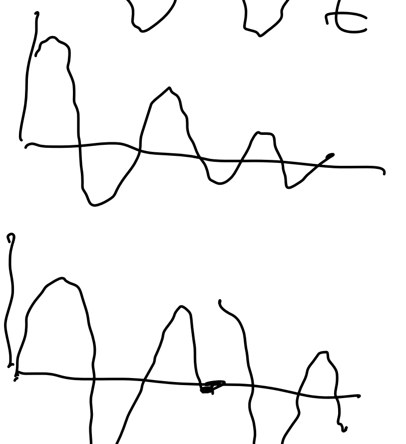
coherent
monochromatic
collimated -
directional



diffraction
$\theta \approx \frac{\lambda}{D}$

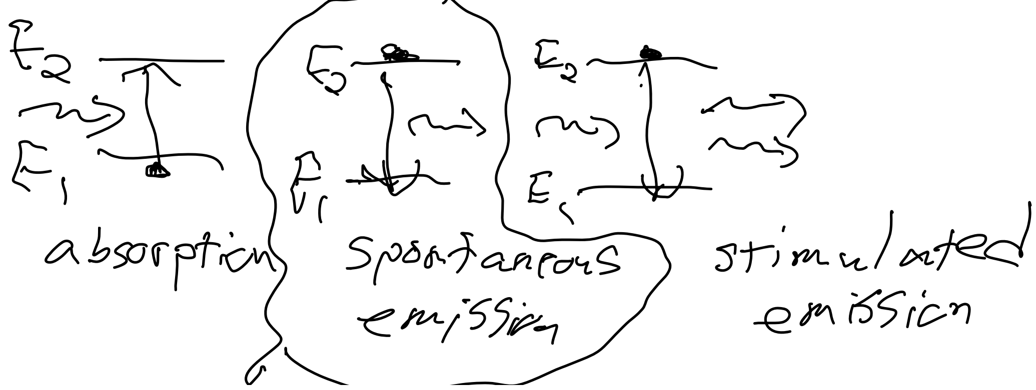
$c = f\lambda$

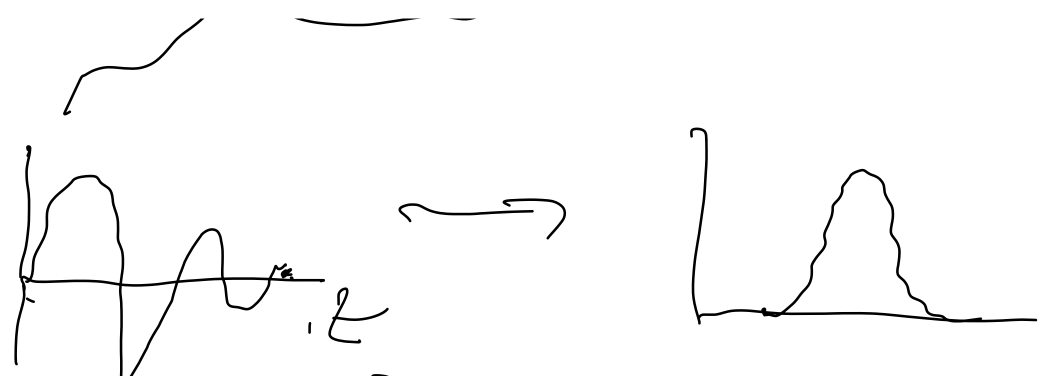




$\Delta\omega \Delta t \geq 1/2$

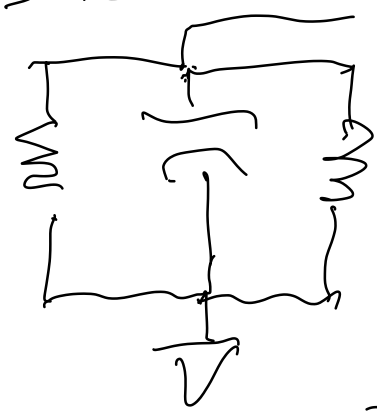
$\omega = 2\pi f$





__Need__ 1) Atoms emitting in phase
2) sustained emission

- Resonator



$$v_L = L\frac{di}{dt}$$

$$i_C = C\frac{dv}{dt}$$

$$\frac{v}{R} + C\frac{dv}{dt} + \int \frac{v_L}{L}\,dt - i = 0$$

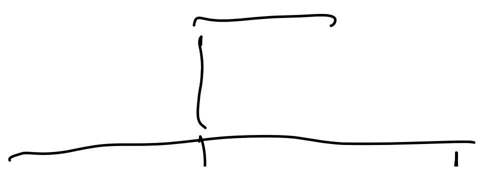
$$v = A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

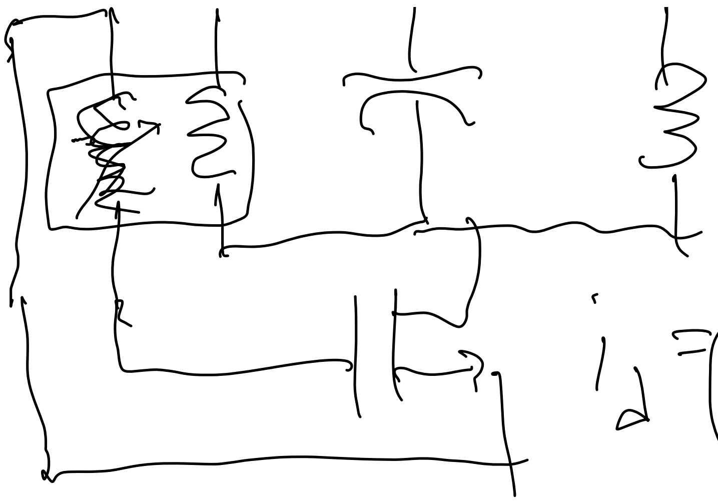
$$s_{1,2} = -\alpha \pm j\sqrt{\alpha^2 - \omega_0^2}$$

$$\alpha = \frac{1}{2RC}$$

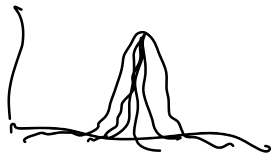
$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}}$$

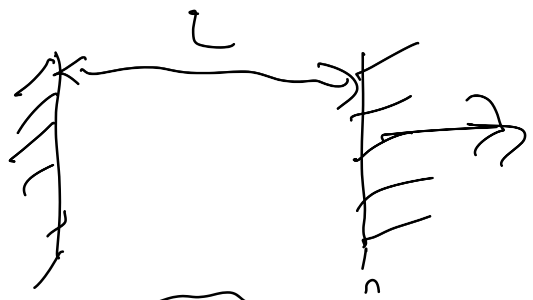
$$s = j\omega_0$$

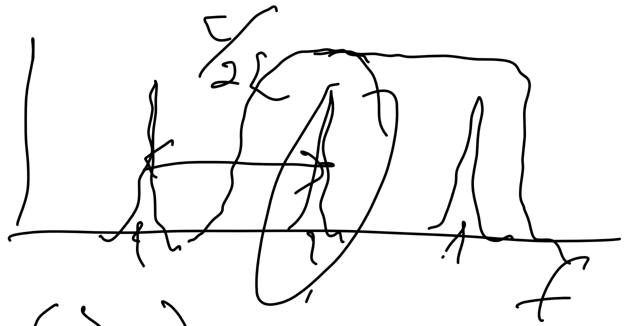


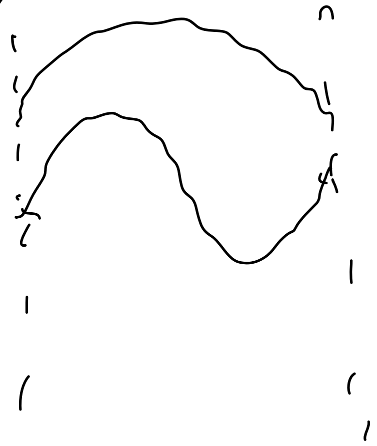


$$i_d = g_m V_{gs}$$





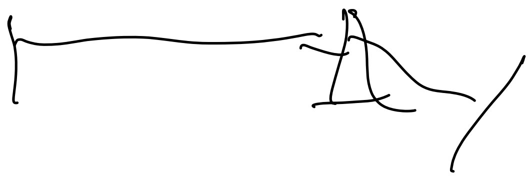




$$n\left(\frac{\lambda_n}{2}\right) = L$$

$$c = f\lambda$$

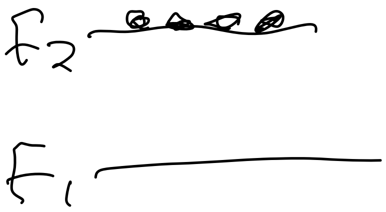
$$f_n = n\frac{c}{2L}$$

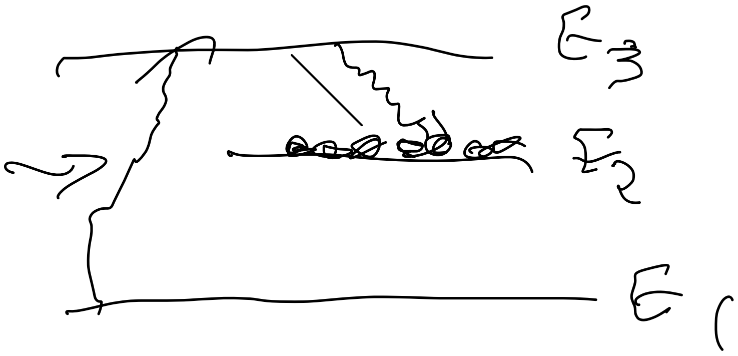


Einstein coefficient

$B_{12} = B_{21}$

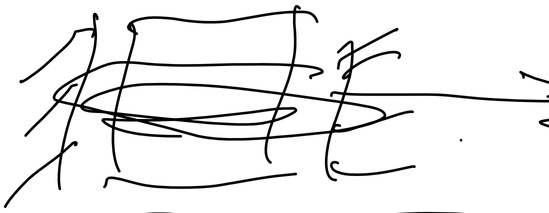
absorption   spont. emission





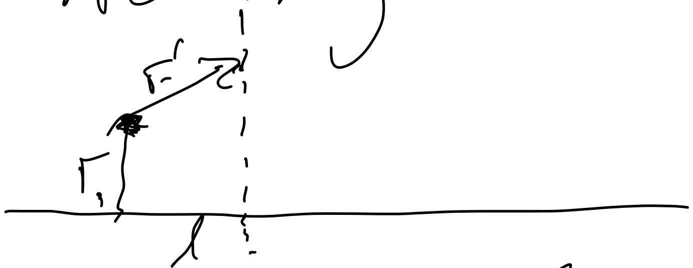
population inversion

≥ 3 levels



Lasing

Ray tracing



$$\begin{bmatrix} r_1 \\ r_1' \end{bmatrix} \longrightarrow \begin{bmatrix} r_1 + \ell r_1 \\ r_1' \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

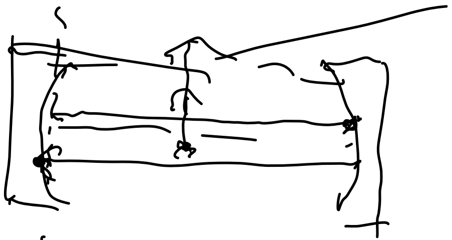
$$\begin{bmatrix} 1 & \ell \end{bmatrix}$$

LO U

$$[\quad] = [\quad]_{\ell_1}[\quad]_{\ell_2}\begin{bmatrix} r' \\ r_1' \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix}$$ thin lens

$$\begin{bmatrix} 1 & 0 \\ -2/R & 1 \end{bmatrix}$$ mirror



$$\begin{bmatrix} 1 & 0 \\ -2/R_1 & 1 \end{bmatrix}\begin{bmatrix} 1 & \ell \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ -2/R_2 & 1 \end{bmatrix}\begin{bmatrix} 1 & \ell \\ 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{RT}$$

$$r_{s+1} = A r_s + B r_s'$$

$$r'_{s+1} = C r_s + D r_s'$$

$$\Gamma_{s+2} = (A+D)\Gamma_{s+1} - \Gamma_s$$

$$\Gamma_{s+2} - (A+D)\Gamma_{s+1} + \Gamma_s = 0$$

$$\Gamma_s = \lambda^s$$

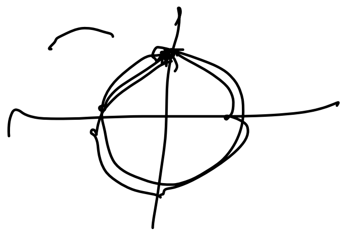
$$\lambda = \frac{A+D}{2} \pm \sqrt{\frac{(A+D)^2}{4} - 1}$$

$$m = \frac{A+D}{2}$$

$$\lambda = m \pm \sqrt{m^2 - 1}$$

$$m = 0 \qquad \lambda = j = e^{j\frac{\pi}{2}}$$

$$\Gamma_s = \lambda^s = \underbrace{e^{j\frac{\pi}{2}s}} \sim$$



$$m > 1$$

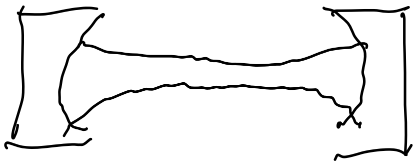
$$\Gamma_s = \lambda^{s\uparrow}$$

$$|m| < 1$$

$$\boxed{\left|\frac{A+D}{2}\right| < 1}$$

Stability Condition

real Gaussian beams



$$E(x,y,z) = E_0 \psi(x,y,z) e^{-jkz}$$

$$\nabla^2 E + k^2 E = 0$$

$$\nabla^2 \psi - j2k \frac{d\psi}{dz} = 0$$

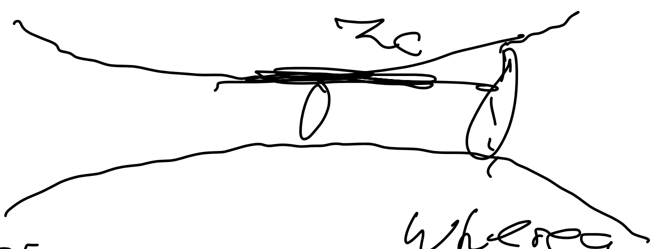
$$\psi = \exp\left(-jP(z)\right) \exp\left(-j\frac{kr^2}{2q(z)}\right)$$

$$q(z) = z + jz_0$$

$$e^{r^2}$$

$$z_0 = \frac{\pi w_0^2}{\lambda}$$

Rayleigh range
confocal parameter



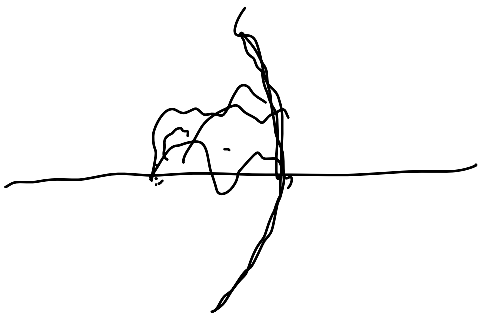
where area doubles

$$w_0^2 = \left[1+\left(\frac{z}{z_0}\right)^2\right]$$

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

$$\frac{1}{q(z)} = \underbrace{\frac{1}{R(z)}}_{} - j\underbrace{\frac{\lambda}{\pi w^2(z)}}_{}$$

$$E(r,t) = \frac{w_0}{w}\underbrace{e^{-r^2/w^2(z)}}_{\text{Gaussian shape}} \times$$



$$e^{-j\frac{kr^2}{2R(z)}}$$ curvature field

$$e^{-j\tan^{-1} z/z_0}$$ extra phase

1) derived q
2) ABCD

$$q_2 = \frac{A q_1 + B}{C q_1 + D}$$

$$\frac{1}{q_2} = \frac{C + D/q_1}{A + B/q_1}$$