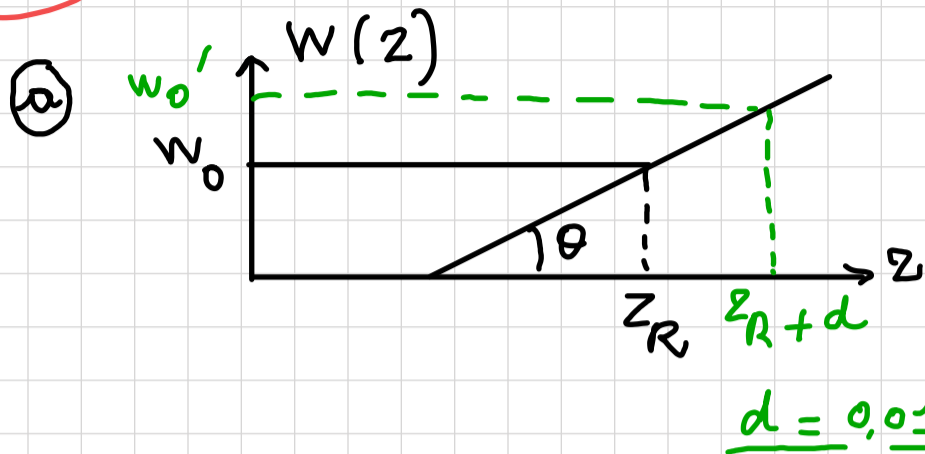


# TD Laser

Ex 1 a)  $\lambda = 632,8 \text{ nm}$ ,  $w_0 = 0,60 \text{ mm}$



$$\theta = \frac{\lambda}{\pi w_0}$$

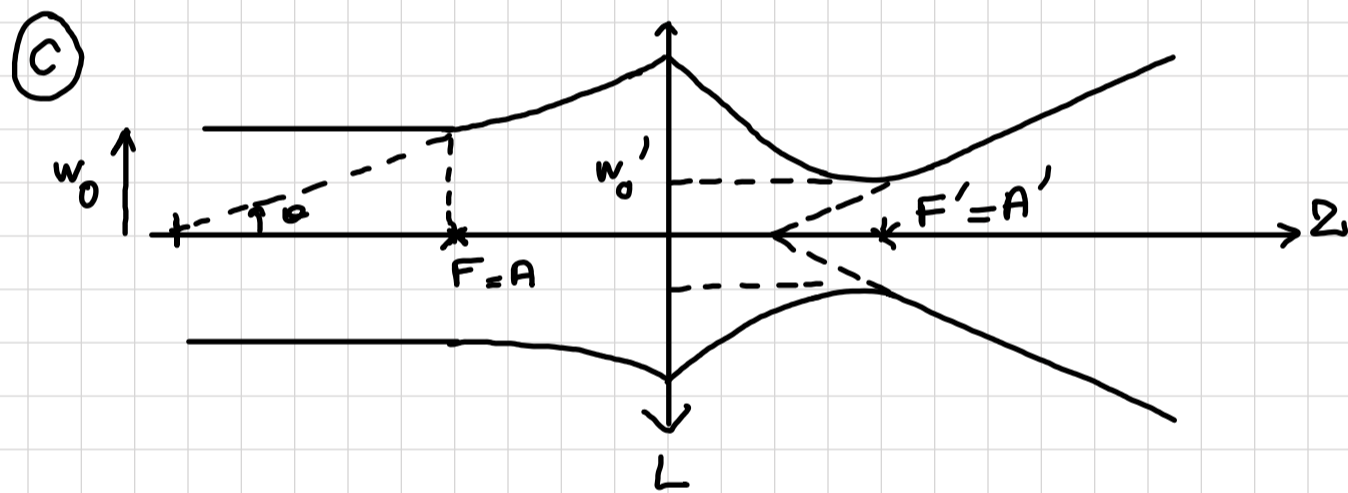
AN:  $\theta = 0,34 \text{ mrad}$

$$z_R = \frac{w_0}{\theta} = 1,79 \text{ m}$$

b)

$$\theta = \frac{w_0}{z_R} = \frac{w_0'}{z_R+d}$$

$$\Rightarrow w_0' = w_0 \left( \frac{z_R+d}{z_R} \right) = w_0 \left( 1 + \frac{d}{z_R} \right) \approx w_0 \ll 1$$

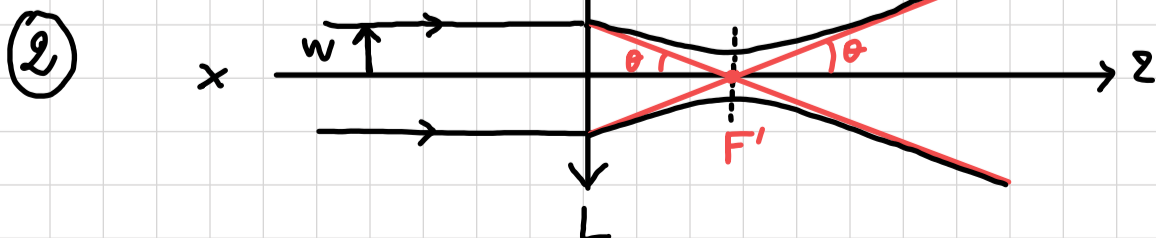


$$\sigma = \overline{FA} = 0 \Rightarrow \sigma' = \overline{F'A'} = 0$$

$$w_0' = \frac{w_0 f'}{\sqrt{\sigma^2 + z_R^2}} = \frac{w_0 f'}{z_R} \quad \text{avec } \begin{cases} w_0 = 0,60 \text{ mm} & \text{et } f' = 10 \text{ mm} \\ z_R = 1,79 \text{ m} \end{cases}$$

AN:  $w_0' = 33,6 \mu\text{m}$

$$\theta' = \frac{\lambda}{\pi w_0'} = 6,00 \text{ mrad}$$



x faisceau  $\approx$  cylindrique en entrée  
 $\Rightarrow \sigma = \overline{FA} \gg z_R \gg f'$

$$\Rightarrow \sigma' = \frac{f' \sigma}{\sigma^2 + z_R^2} = 0 \Rightarrow \boxed{F' = A'}$$

$$\times \theta = \frac{w}{f'} \text{ et } \begin{cases} \theta = \frac{\lambda}{\pi w_0'} \\ \theta = \frac{w_0'}{z_R'} \end{cases} \Rightarrow \theta^2 = \frac{\lambda}{\pi z_R'} = \frac{w^2}{f'^2}$$

$$\Rightarrow \boxed{f'^2 = \frac{\pi w^2 z_R'}{\lambda}}$$

$$\text{AN: } f' = 14,9 \text{ cm}$$

$$\textcircled{3} \text{ a) } f = n \left( \frac{c}{2d} \right) \Rightarrow \boxed{\Delta f = \frac{c}{2d}} \quad \text{AN: } \Delta f = 7,5 \times 10^8 \text{ Hz} = 750 \text{ MHz}$$

$$\text{b) } \Delta f = \frac{c}{2d} > \Delta f_{\text{filtre}}$$

$$\text{Avec } \boxed{\Delta f_{\text{filtre}} = \frac{c}{\lambda_0^2} \Delta \lambda_{\text{filtre}}}$$

$$\Rightarrow \boxed{d < \frac{\lambda_0^2}{2 \Delta \lambda_{\text{filtre}}}} \quad \text{AN: } d < 200 \mu\text{m}.$$

$\textcircled{4}$  a) • Intensité d'un rayon Gaussien :

$$I(r, z) = A_0 \frac{w_0^2}{w(z)^2} \exp\left(-\frac{2r^2}{w(z)^2}\right)$$

$$\Rightarrow P_{\text{tot}} = \int_0^{2\pi} \int_0^{\infty} I r dr d\theta = A_0 \frac{w_0^2}{w(z)^2} \times 2\pi \int_0^{\infty} r e^{-\frac{2r^2}{w^2}} dr$$

$$= 2\pi A_0 \frac{w_0^2}{w^2} \left[ -w^2 e^{-\frac{2r^2}{w^2}} \right]_0^{\infty}$$

$$\boxed{P_{\text{tot}} = 2\pi A_0 w_0^2}$$

$$\bullet P_e = \int_0^{2\pi} \int_0^{\infty} I e r dr d\theta = A_0 \frac{w_0^2}{w(z)^2} \times 2\pi \int_0^{\infty} r e^{-\frac{2r^2}{w^2}} dr$$

$$P_e = 2\pi A_0 \frac{w_0^2}{w^2} \left[ -w^2 e^{-2\pi^2/w^2} \right]_0^e$$

$$P_e = 2\pi A_0 w^2 \left[ 1 - e^{-2e^2/w^2} \right]$$

D'au :

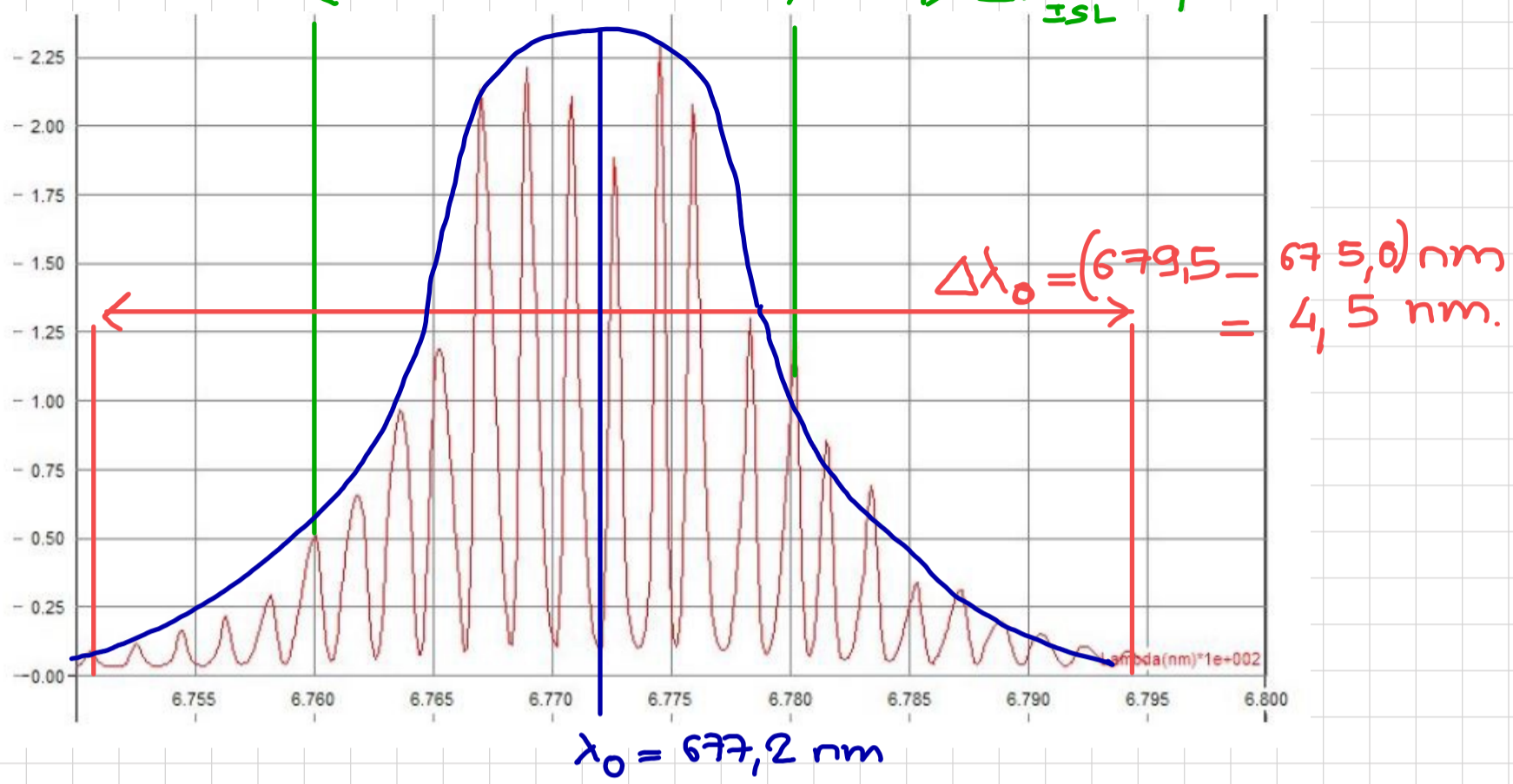
$$\frac{P_e}{P_{tot}} = 1 - e^{-2e^2/w^2}$$

b) AN

$$\left\{ \begin{array}{l} e = 0,5w \Rightarrow \frac{P_e}{P_{tot}} = 1 - e^{-1/2} = \\ e = 0,75w \Rightarrow \frac{P_e}{P_{tot}} = 1 - e^{-2 \times \frac{9}{16}} \\ e = w \Rightarrow \frac{P_e}{P_{tot}} = 1 - e^{-2} \\ e = 2w \Rightarrow \frac{P_e}{P_{tot}} = 1 - e^{-8} \end{array} \right.$$

# Exercice 2

$m \times \Delta \lambda_{ISL} = (678,0 - 676,0) \text{ nm} = 2 \text{ nm}$   
 $\Rightarrow \Delta \lambda_{ISL} = 0,18 \text{ nm}$



\* ou  $\begin{cases} \Delta \lambda_{ISL} = \text{intervalle spectrale libre (modes longitudinaux)} \\ \Delta \nu_{ISL} = \frac{c}{2nd} = \frac{c}{\lambda_0^2} \Delta \lambda_{ISL} \Rightarrow \Delta \lambda_{ISL} = \frac{\lambda_0^2}{2nd} \end{cases}$

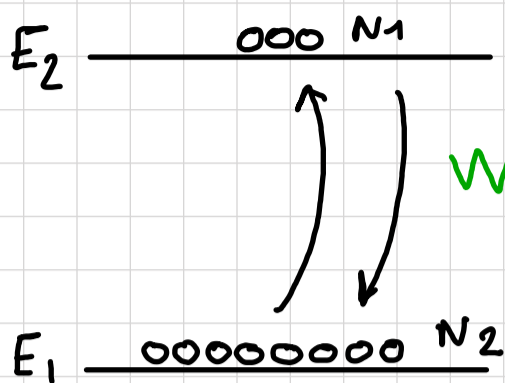
$\Rightarrow d = \frac{\lambda_0^2}{2n \Delta \lambda_{ISL}} \quad \underline{\underline{AN}} \quad d = 3,5 \text{ mm}$

et  $\Delta \nu_{ISL} = \frac{c}{\lambda_0^2} \Delta \lambda_{ISL} = \underline{\underline{118 \text{ GHz}}}$

\*  $\Delta \nu_0 = \frac{c}{\lambda_0^2} \Delta \lambda_0 = \underline{\underline{2,94 \text{ THz}}}$

\*  $\Delta \nu_0 \times \tau_c = 1 \Rightarrow \tau_c = 340 \text{ ps}$  et  $d_c l_c = c \tau_c = \underline{\underline{102 \mu\text{m}}}$

# Exercice 3



$$\textcircled{2} \begin{cases} \frac{dN_1}{dt} = AN_2 - BN_1 u g(\omega) + BN_2 u g(\omega) \\ \frac{dN_2}{dt} = -AN_2 + BN_1 u g(\omega) + BN_2 u g(\omega) \end{cases}$$

$$RB : \begin{cases} AN_{2eq} - BN_{1eq} u_{eq} g(\omega) + BN_{2eq} u_{eq} g(\omega) \\ N = N_{1eq} + N_{2eq} \end{cases}$$

$$\Rightarrow \begin{cases} N_{1eq} = N \left( \frac{A + B u_{eq} g(\omega)}{A + 2 B u_{eq} u_{eq} g(\omega)} \right) \\ N_{2eq} = N \left( \frac{B u_{eq} g(\omega)}{A + 2 B u_{eq} u_{eq} g(\omega)} \right) \end{cases}$$



on ne peut pas avoir  $N_2 > N_1$  (au mieux  $N_2 = N_1 = \frac{N}{2}$ )

$\textcircled{3}$  x Facteur de Boltzmann :

$$\frac{N_{1eq}}{N_{2eq}} = \exp\left(\frac{E_2 - E_1}{k_B T}\right) > 1$$

x  $B u g(\omega) \gg A \Rightarrow$  Le gaz est placé ds une densité com intense  $\Rightarrow$  bcp d'absorption et d'émission stimulée (pas d'émission spontanée)

$\textcircled{4}$  x Transition optique  $\Rightarrow E_2 - E_1 \gg k_B T$

$$\Rightarrow \frac{N_{1eq}}{N_{2eq}} = \exp\left(\frac{E_2 - E_1}{k_B T}\right) \gg 1$$

$$\underline{AN} \begin{cases} T = 300K \\ \lambda = 60nm \\ N_2 / N_1 = 2 \cdot 10^{-35} \ll 1 \end{cases}$$

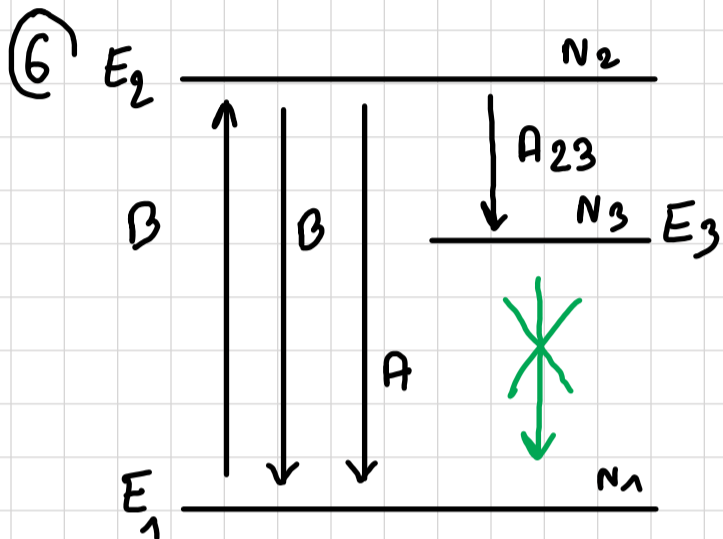
$$\text{x } \underline{\underline{OR}} : \frac{N_{1eq}}{N_{2eq}} = \frac{A + B u_{eq} g(\omega)}{B u_{eq} g(\omega)} \gg 1 \Rightarrow \frac{A}{B u_{eq} g(\omega)} \gg 1$$

$\Rightarrow$  Cavité "dilué" : c'est l'émission spontanée qui prédomine

⑤ Suite de la question 4 :  $A \gg B \mu g(0)$

$$\begin{cases} \frac{dN_1}{dt} = AN_2 = A(N - N_1) \\ \frac{dN_2}{dt} = -AN_2 \end{cases} \begin{cases} \frac{dN_1}{dt} + AN_1 = AN \\ \frac{dN_2}{dt} + AN_2 = 0 \end{cases}$$

$$\Rightarrow \tau_2 = \frac{1}{A} = \text{durée de vie radiative}$$



⑥ on ne tient compte que de l'émission spontanée :

$$\begin{cases} \frac{dN_1}{dt} = AN_2 \\ \frac{dN_2}{dt} = -AN_2 - A_{23}N_2 \\ = -(A + A_{23})N_2 \end{cases}$$

$$\begin{cases} \frac{dN_1}{dt} = AN_2 \\ \frac{dN_2}{dt} + \underbrace{(A + A_{23})}_{1/\tau_2} N_2 = 0 \end{cases}$$

⑦

$$\begin{cases} \frac{dN_1}{dt} = B \mu g(0) (N_2 - N_1) + AN_2 & (1) \\ \frac{dN_2}{dt} = -B \mu g(0) (N_2 - N_1) - (A + A_{23})N_2 & (2) \\ \frac{dN_3}{dt} = -A_{23}N_2 & (3) \end{cases}$$

Equilibre :  $\frac{dN_3}{dt} = 0 \stackrel{(3)}{\Rightarrow} N_2 = 0 \stackrel{(1)}{\Rightarrow} N_1 = 0$  et dc  $\boxed{N_3 = N}$

Inversion

Interprétation : on remplit le niveau 3 car les probabilités de transition st  $\neq 0$  sauf  $3 \rightarrow 1$



