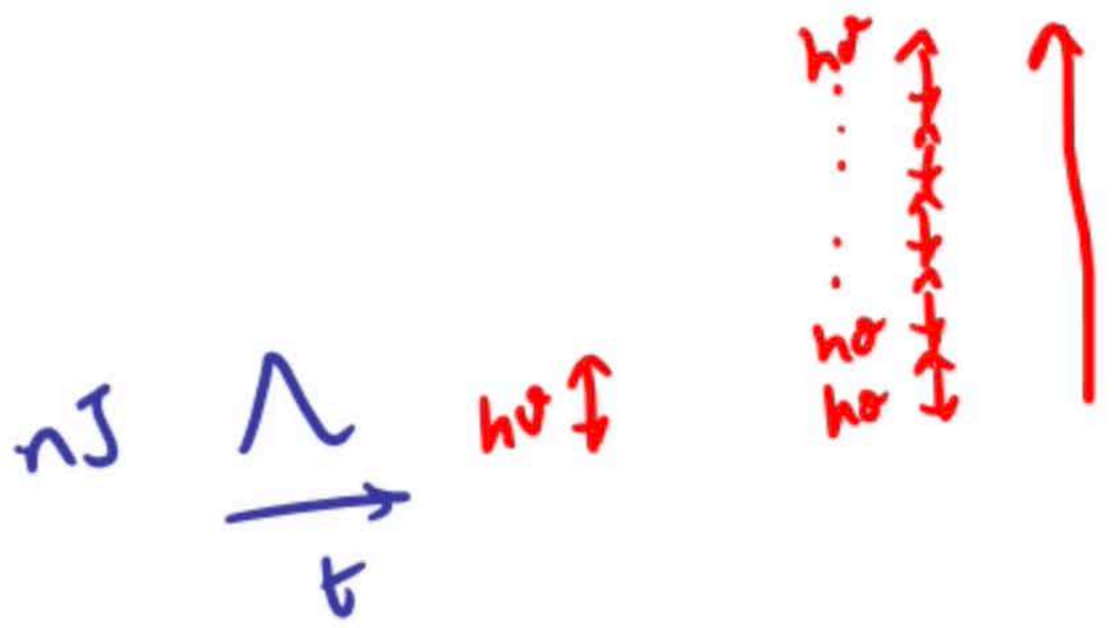
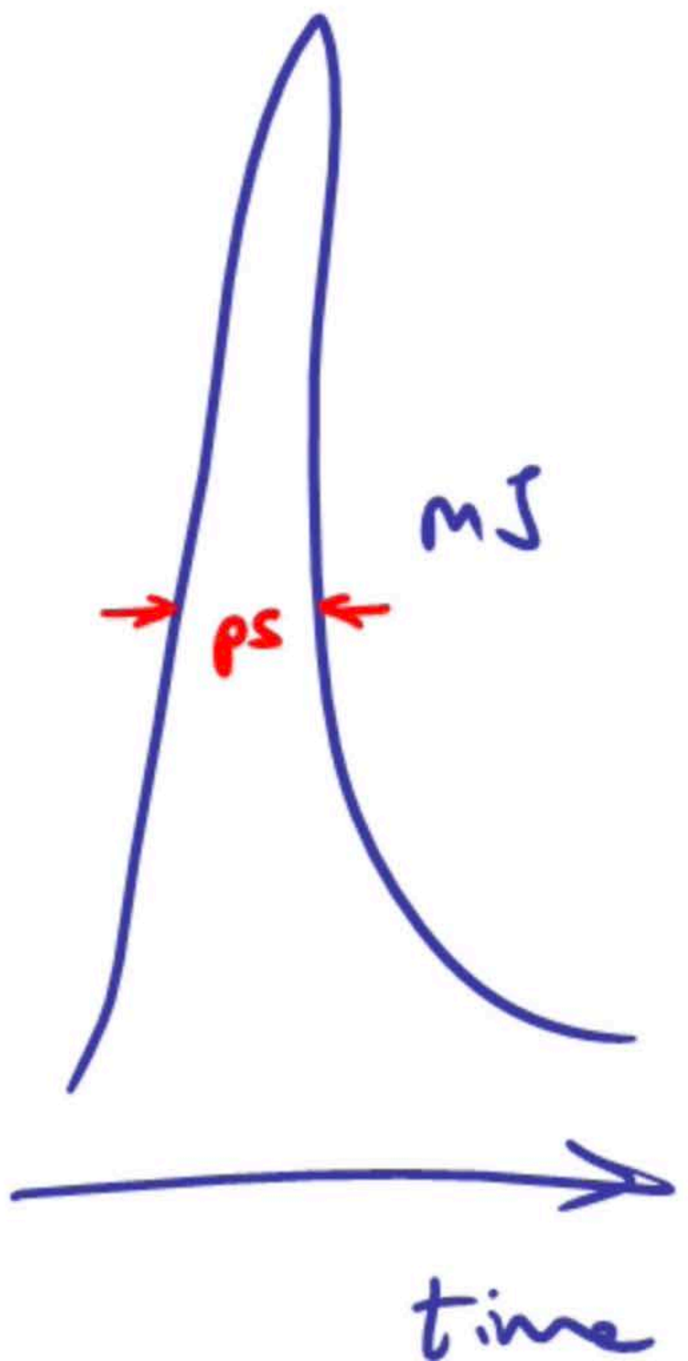
Chirped Pulse Amplification

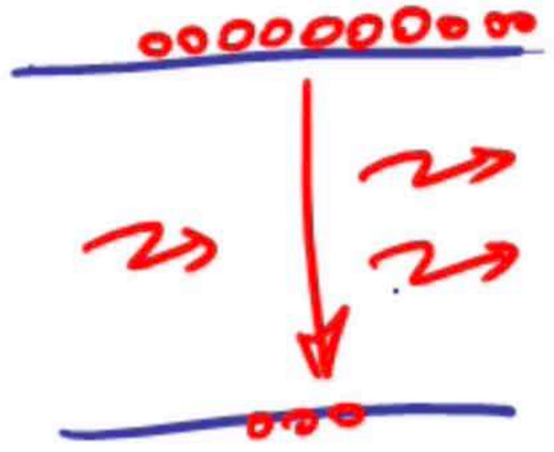
– Gerard Morou / Donna Strickland





$\frac{E_p}{h\nu} \rightarrow$ # of photons

$$N W_i = R - \frac{1}{2\tau_{21}}(N + N_a) \quad \Rightarrow \quad N = \frac{2\tau_{21} R - N_a}{2\tau_{21} W_i + 1}$$

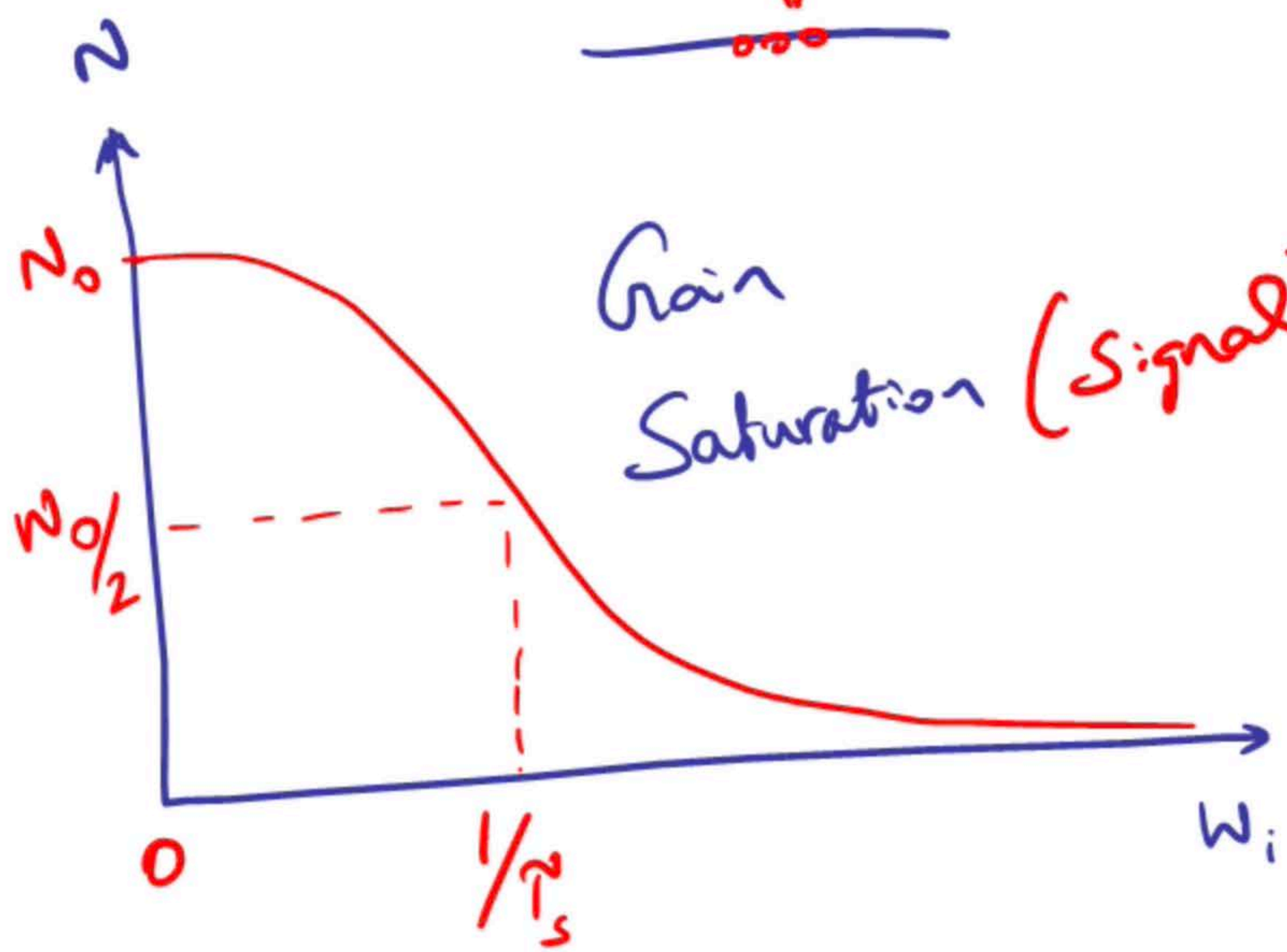


$$\boxed{N = \frac{N_0}{1 + \tau_s W_i}}$$

where $\tau_s = 2 t_{sp}$

$N_0 = 2 R t_{sp} - N_a$

Gain Saturation (Signal)



$W_i \rightarrow \phi_s \sigma$

flux density of incoming signal photons

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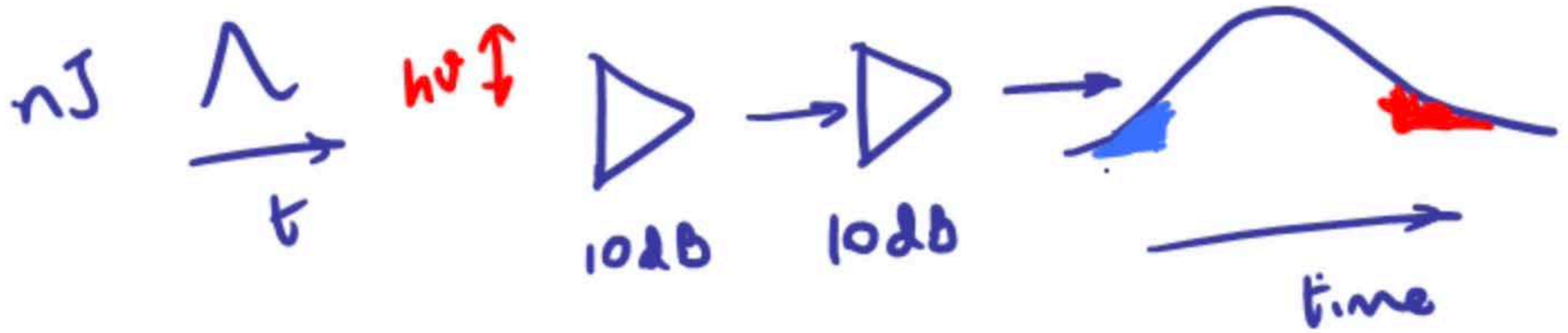
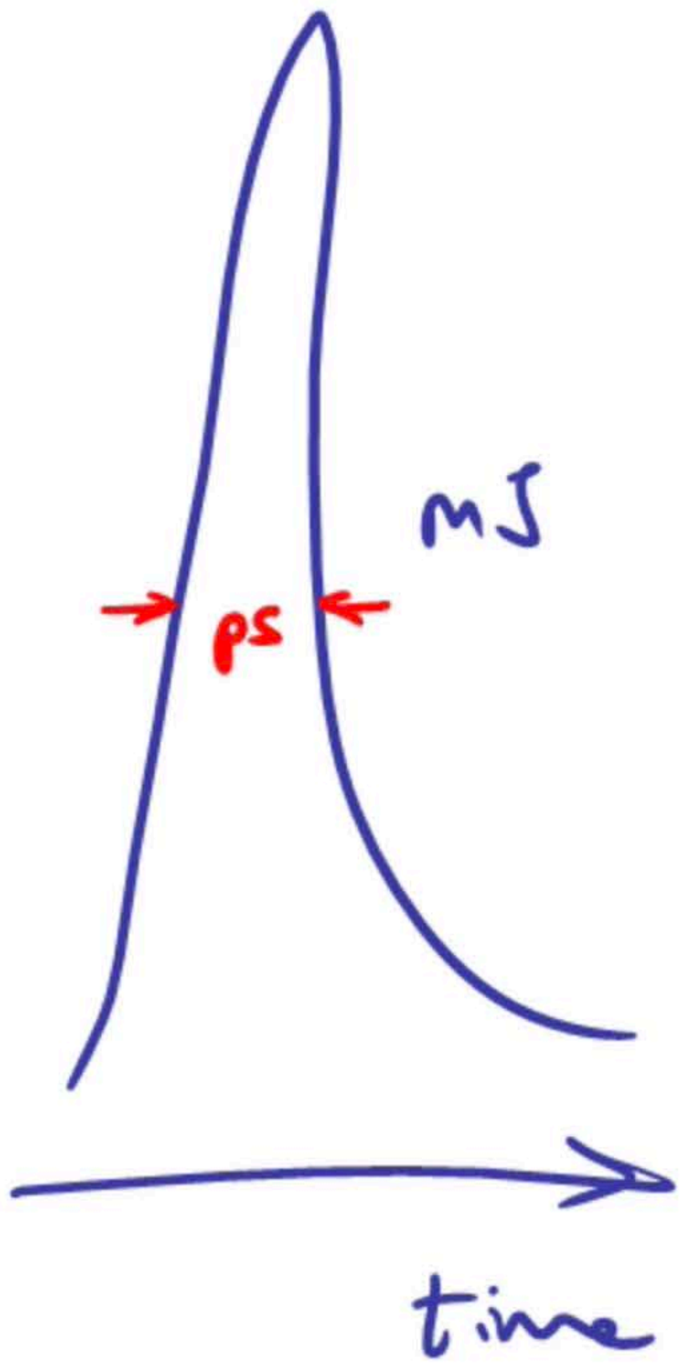




$$\frac{E_p}{h\nu} \rightarrow \# \text{ of photons}$$

Tutorial Session on Ray Optics & Wave Optics:

Example 1: Dispersion in a prism (thin)

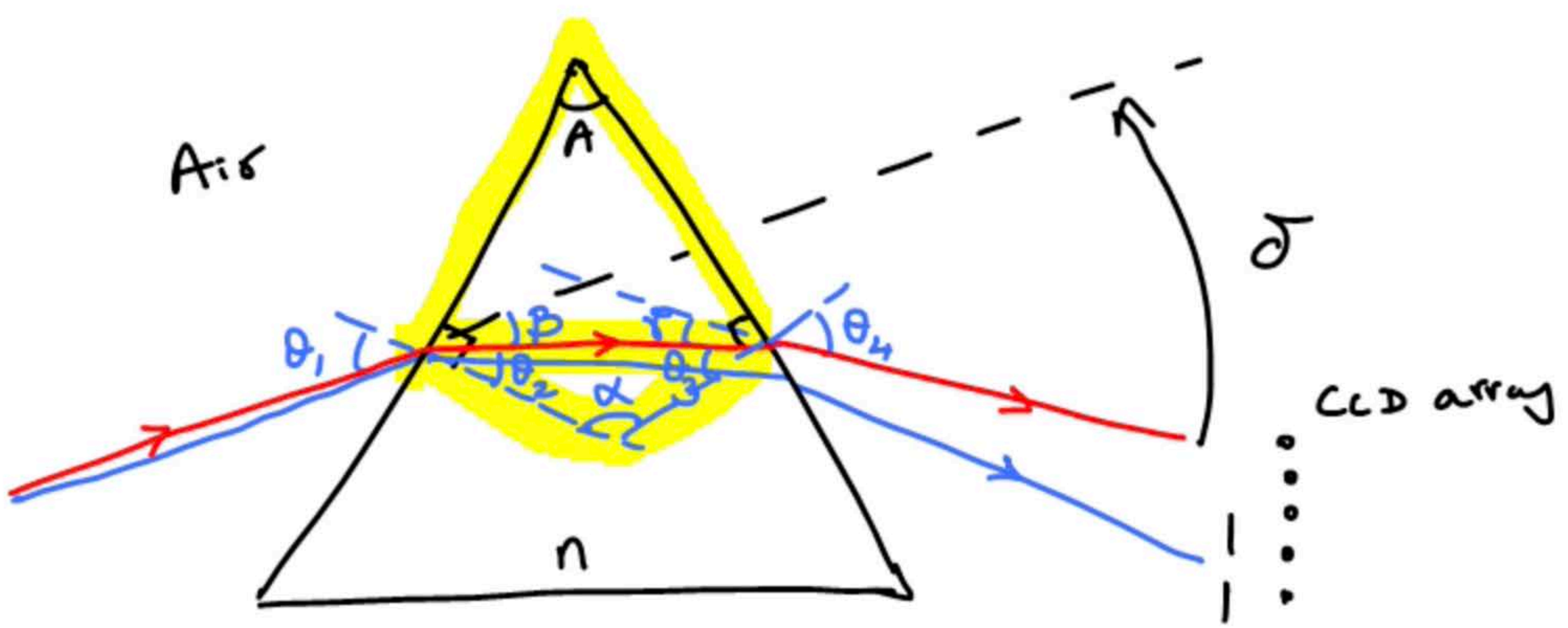
$\frac{c}{n(\lambda)}$ → velocity of light within a medium

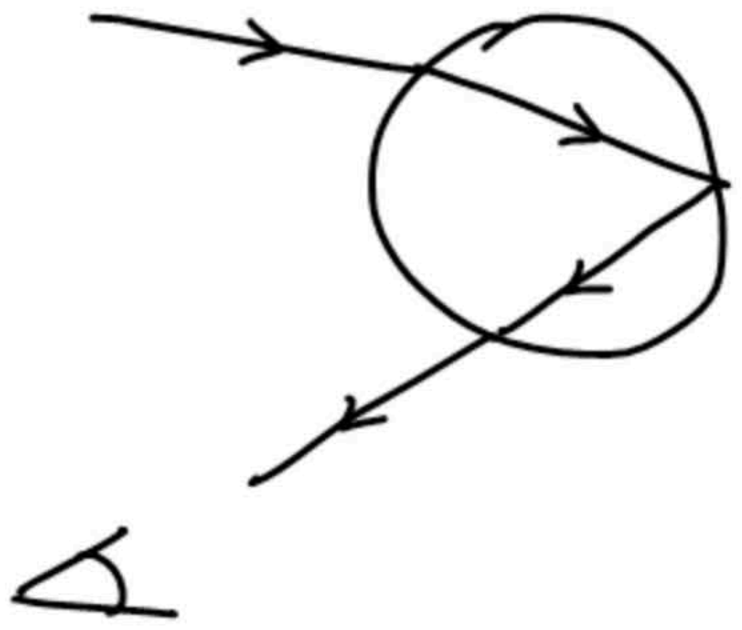
$n_{blue} = 1.34$

$n_{red} = 1.33$

Paraxial approximation

$n_1 \theta_1 = n_2 \theta_2$





$$\boxed{\delta = (n-1)\,A}$$

$A = 10^\circ$

$\delta_{red} = (1.33 - 1)\,10^\circ = 3.3^\circ$

$\delta_{blue} = (1.34 - 1)\,10^\circ = 3.4^\circ$

$\Rightarrow$ 0.1 deg

$$\left.\begin{aligned} \alpha + A &= 180^\circ \\ \theta_2 + \theta_3 + \alpha &= 180^\circ \end{aligned}\right\} \Rightarrow A = \theta_2 + \theta_3$$

$$\delta = \beta + \gamma = \theta_1 - \theta_2 + \theta_4 - \theta_3 = \theta_1 + \theta_4 - A$$
$$= n\theta_2 + n\theta_3 - A = (n-1)\,A$$

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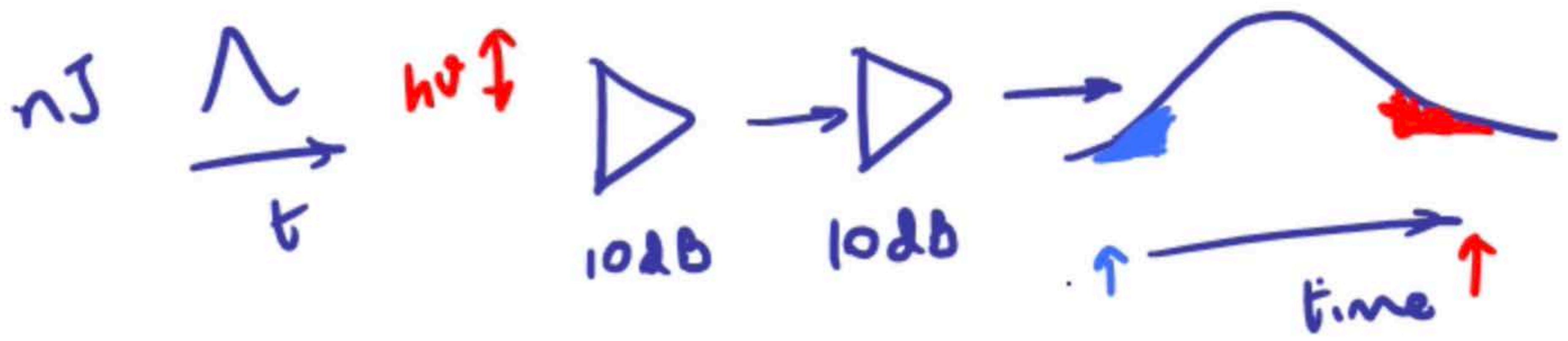
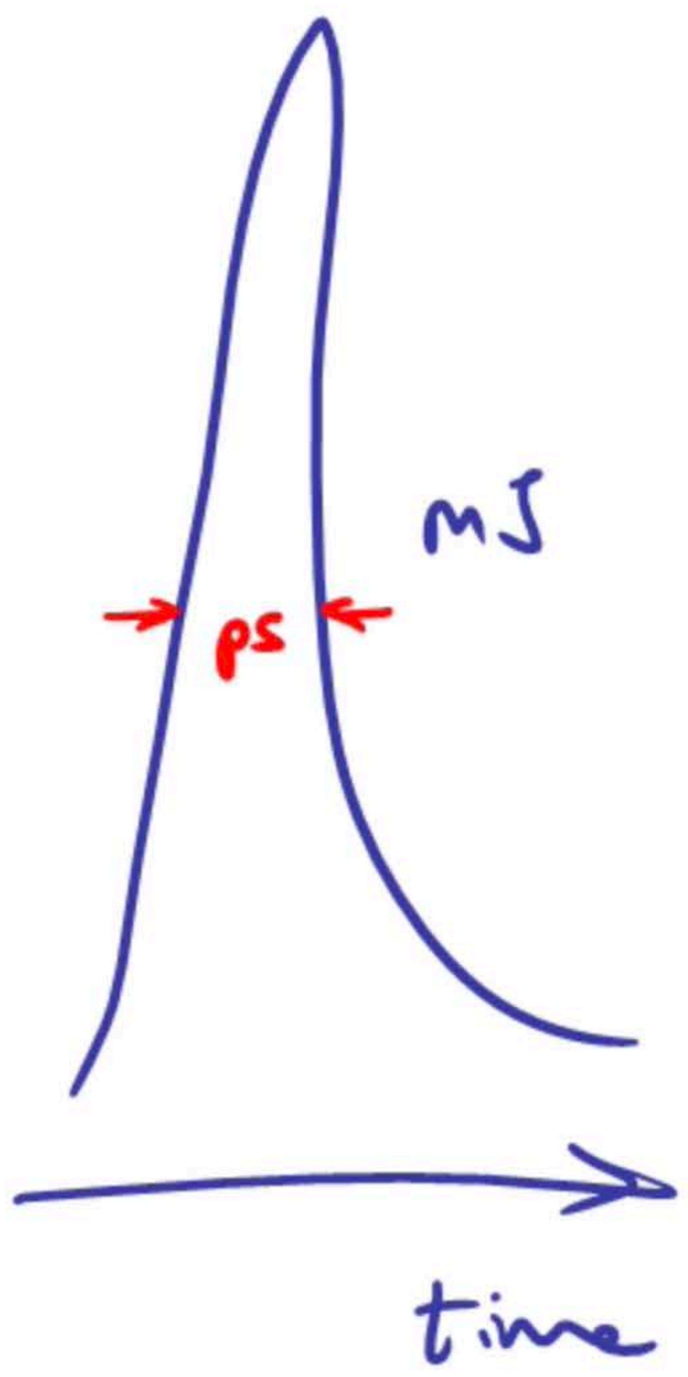


$$\frac{E_p}{h\nu} \rightarrow \text{\# of photons}$$



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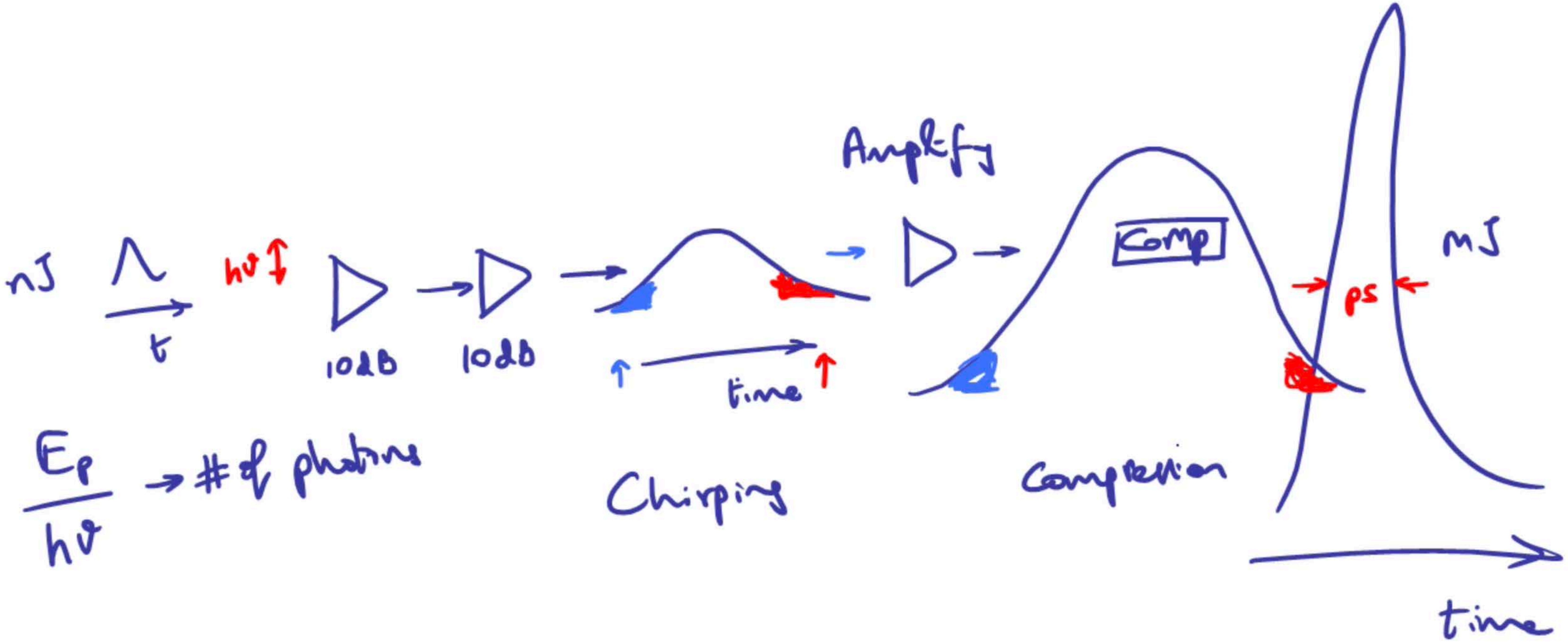
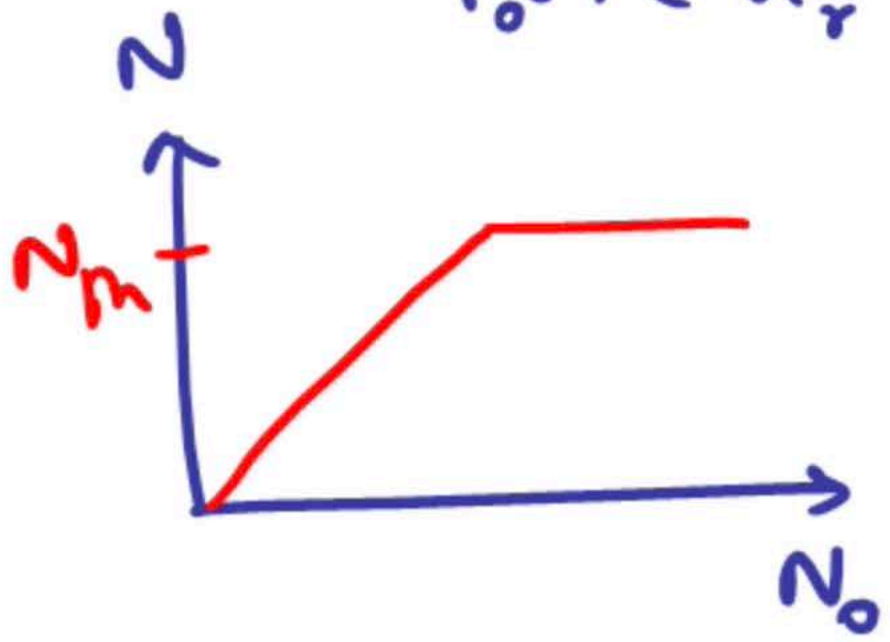
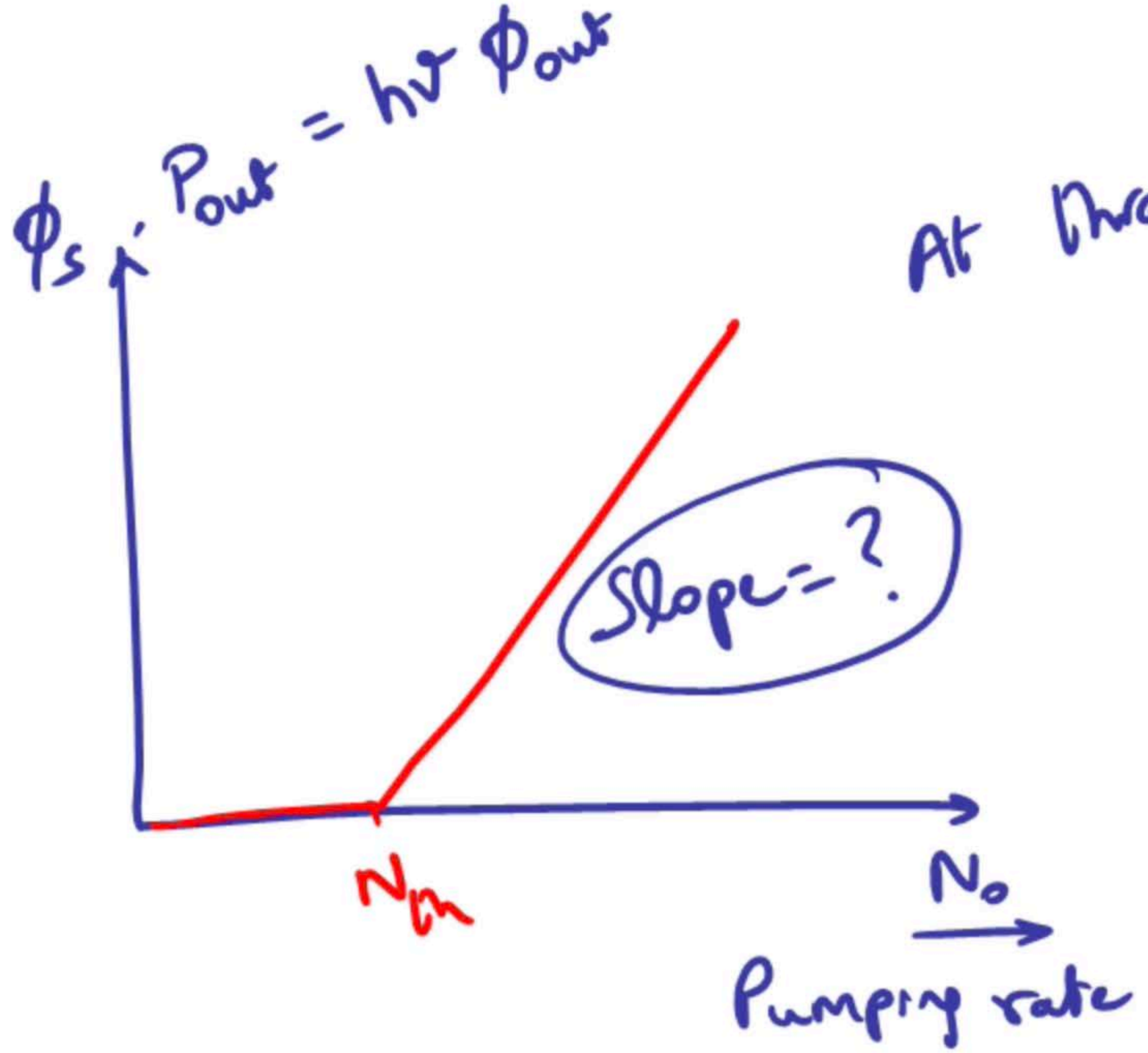


$\frac{E_p}{h\nu} \rightarrow$ # of photons

$$\frac{\gamma_0(\nu)}{1+\phi_s(\nu)/\phi_{sat}} = \alpha_r \implies \phi_s(\nu) = \begin{cases} \phi_{sat}\cdot\left[\dfrac{\gamma_0(\nu)}{\alpha_r}-1\right] & \gamma_0(\nu)>\alpha_r \\ 0 & \gamma_0(\nu)\le\alpha_r \end{cases}$$





At threshold, $N_m \cdot \sigma(\nu) = \alpha_r$

Photon flux

$$\phi_s(\nu) = \begin{cases} \phi_{sat}\left(\dfrac{N_o}{N_m}-1\right) & N_o > N_m \\ 0 & N_o \le N_m \end{cases}$$

Optimization of Output Coupling.

Assume $R_1 = R_2$.

$$\phi_{out} = \frac{\phi_s}{2} \cdot T_2$$

$$= \frac{\phi_{sat} T_2}{2} \left(\frac{\gamma_0}{\alpha_r} - 1 \right)$$

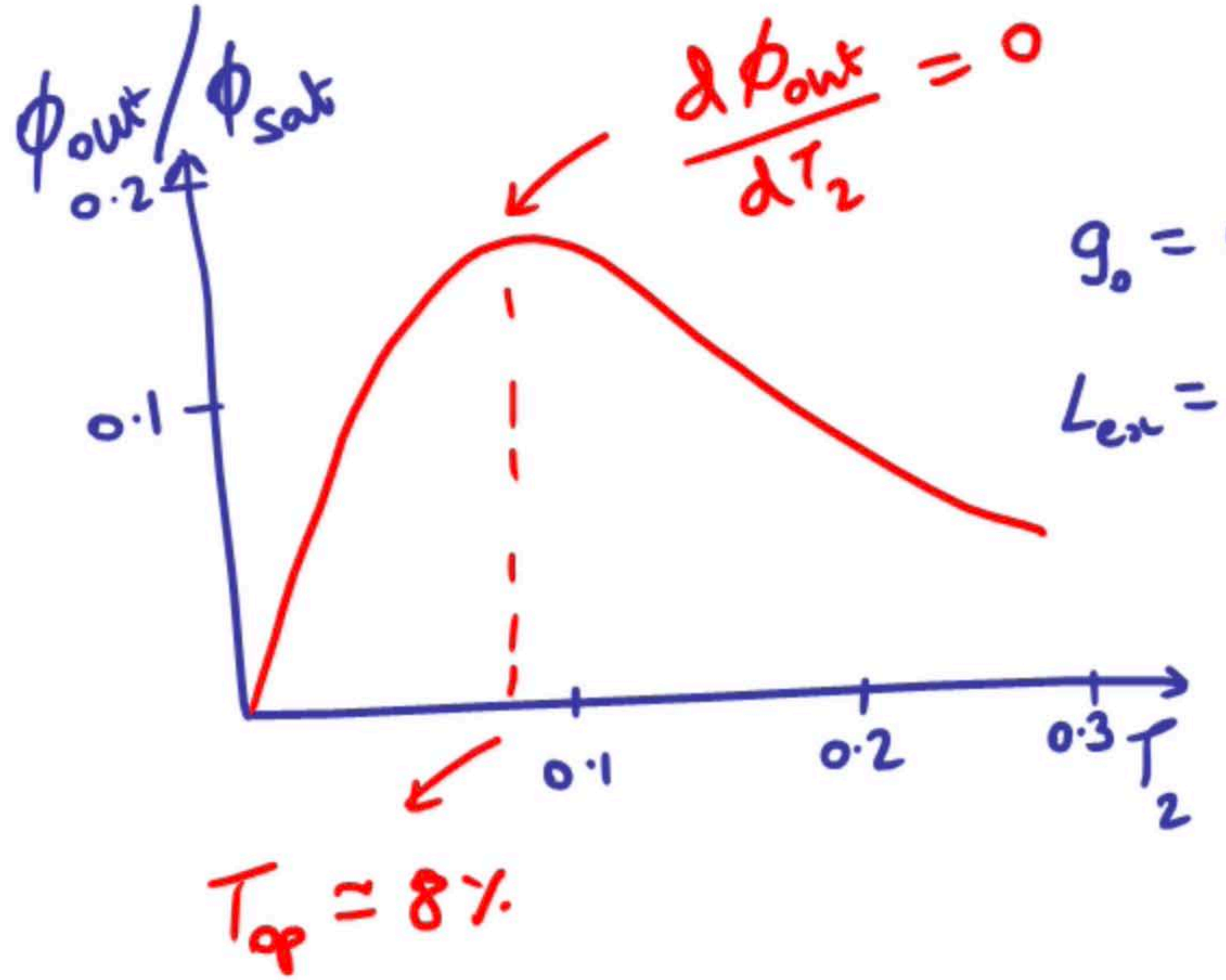
$$= \frac{\phi_{sat} T_2}{2} \left[\frac{\gamma_0 . 2L}{L_{ex} - \ln(1-T_2)} - 1 \right]$$

$$\alpha_r = \alpha_{int} + \alpha_{m1} + \alpha_{m2}$$

$$= \alpha_L + \frac{1}{2L} \ln\left(\frac{1}{R_2}\right)$$

$$= \alpha_L - \frac{1}{2L} \ln(1 - T_2)$$

$$= \frac{1}{2L} \left[L_{ex} - \ln(1 - T_2) \right]$$



$g_0 = 0.5$

$L_{ex} = 0.02$

$\frac{d\phi_{out}}{dT_2} = 0$ & when $T_2 << 1$

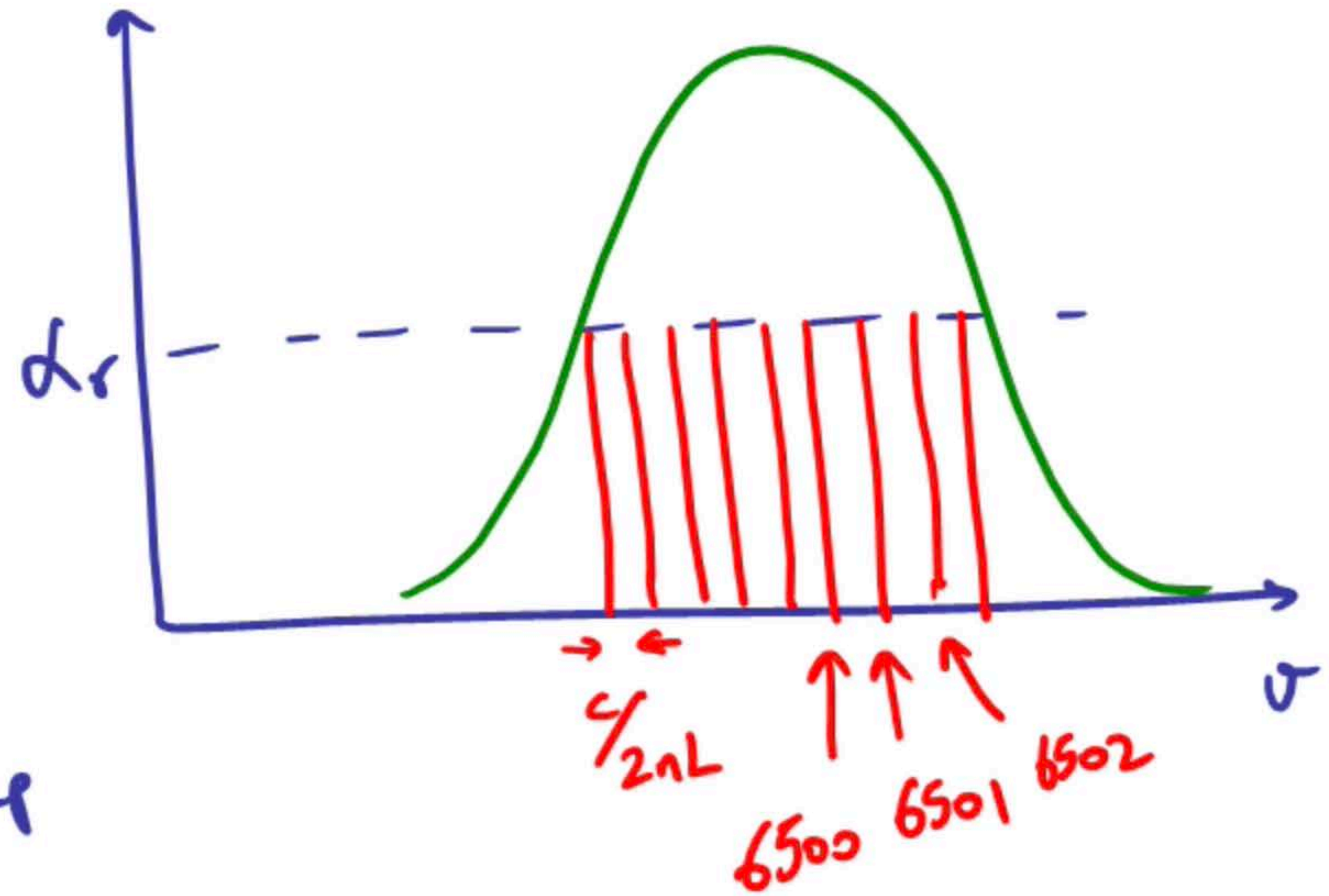
$$\ln(1 - T_2) \simeq -T_2$$

$$L_{ex} = 2L(\alpha_{int} + \alpha_{m1})$$

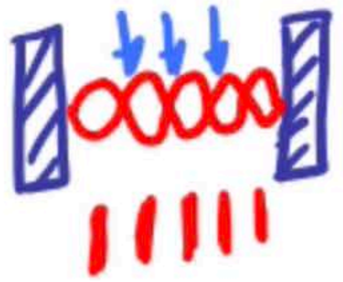
$$\boxed{T_{op} = (g_0 L_{ex})^{1/2} - L_{ex}}$$

$g_0 = \gamma_0 . 2L$

Gain factor

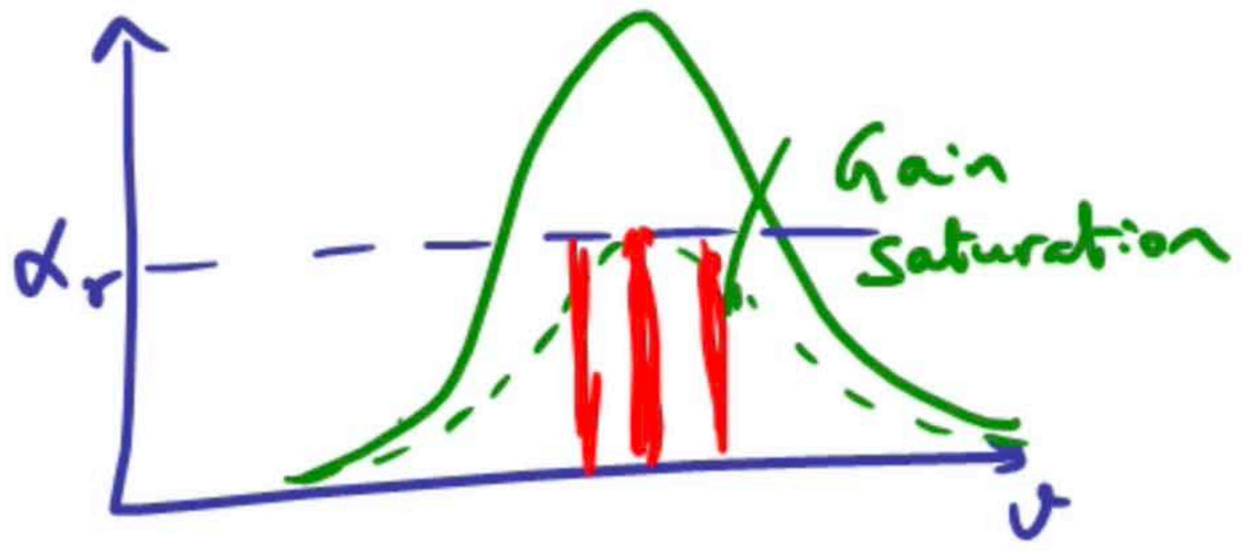


Spatial Hole Burning

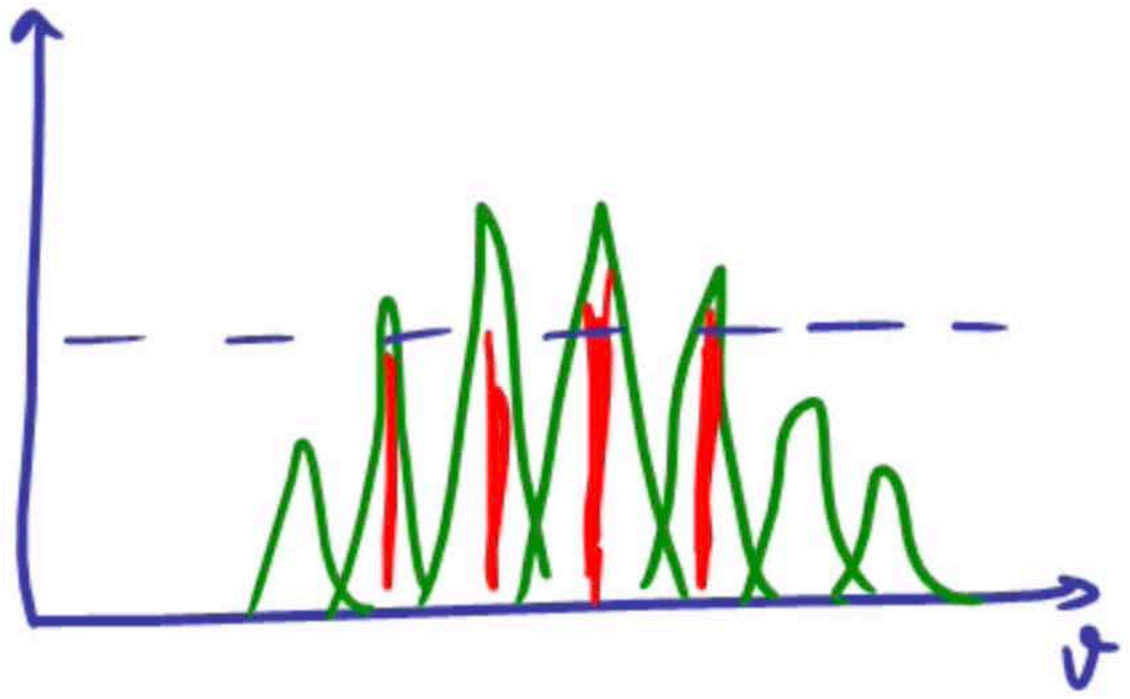


Homogeneous

Ex: Semiconductor



Inhomogeneous



Ex: Nd: glass