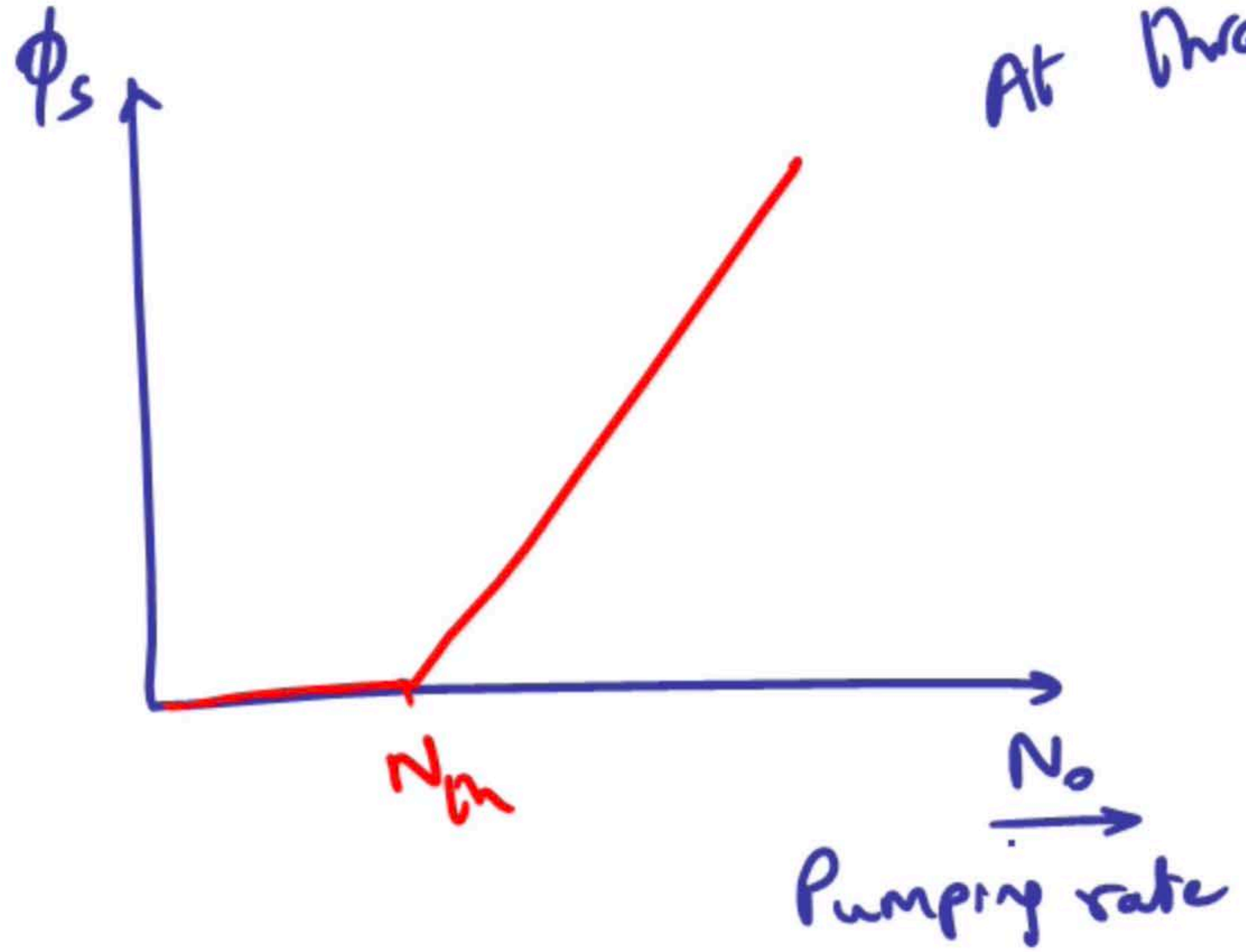
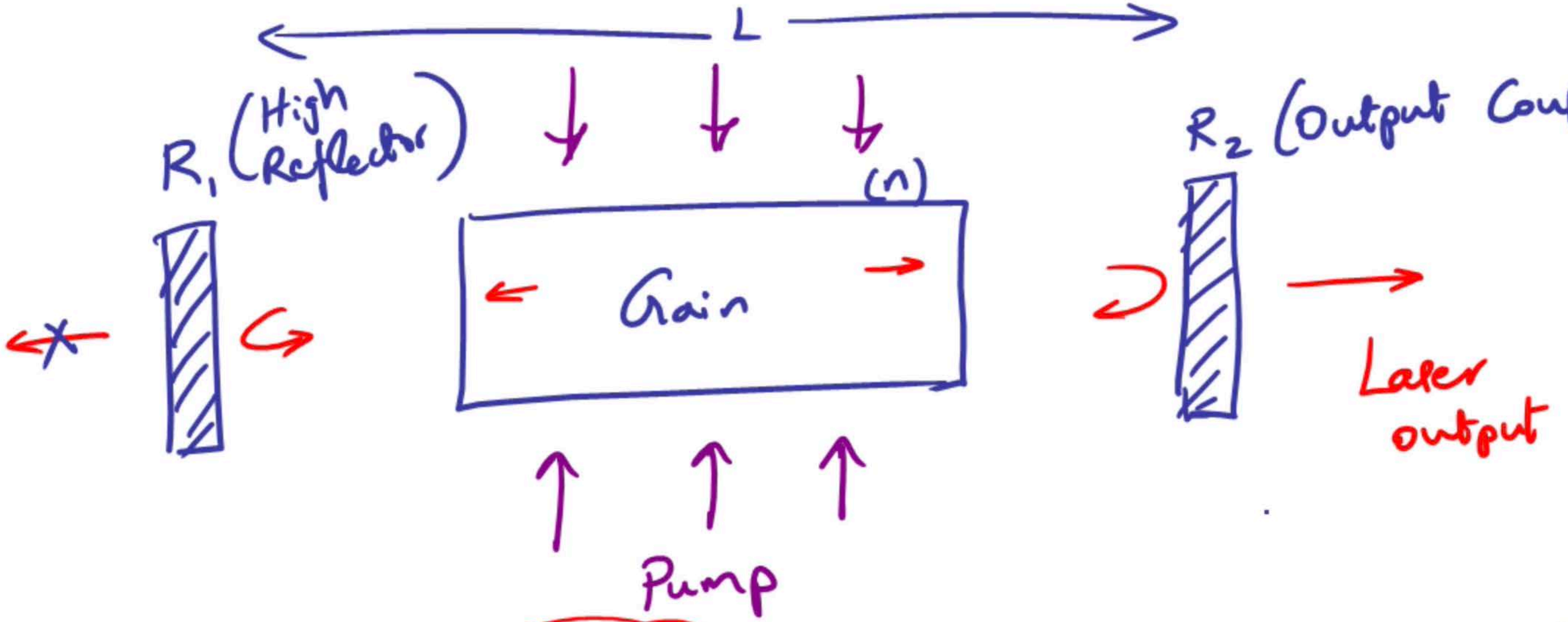
$$\frac{\gamma_0(\nu)}{1 + \phi_s(\nu)/\phi_{sat}} = \alpha_r \implies \phi_s(\nu) = \begin{cases} \phi_{sat} \cdot \left[\dfrac{\gamma_0(\nu)}{\alpha_r} - 1 \right] & \gamma_0(\nu) > \alpha_r \\ 0 & \gamma_0(\nu) \le \alpha_r \end{cases}$$



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

$$\phi_s(\nu) = \begin{cases} \phi_{sat} \left(\dfrac{N_0}{N_m} - 1 \right) & N_0 > N_m \\ 0 & N_0 \le N_m \end{cases}$$

Lo : Identify the fundamental principles of laser & quantify their characteristics



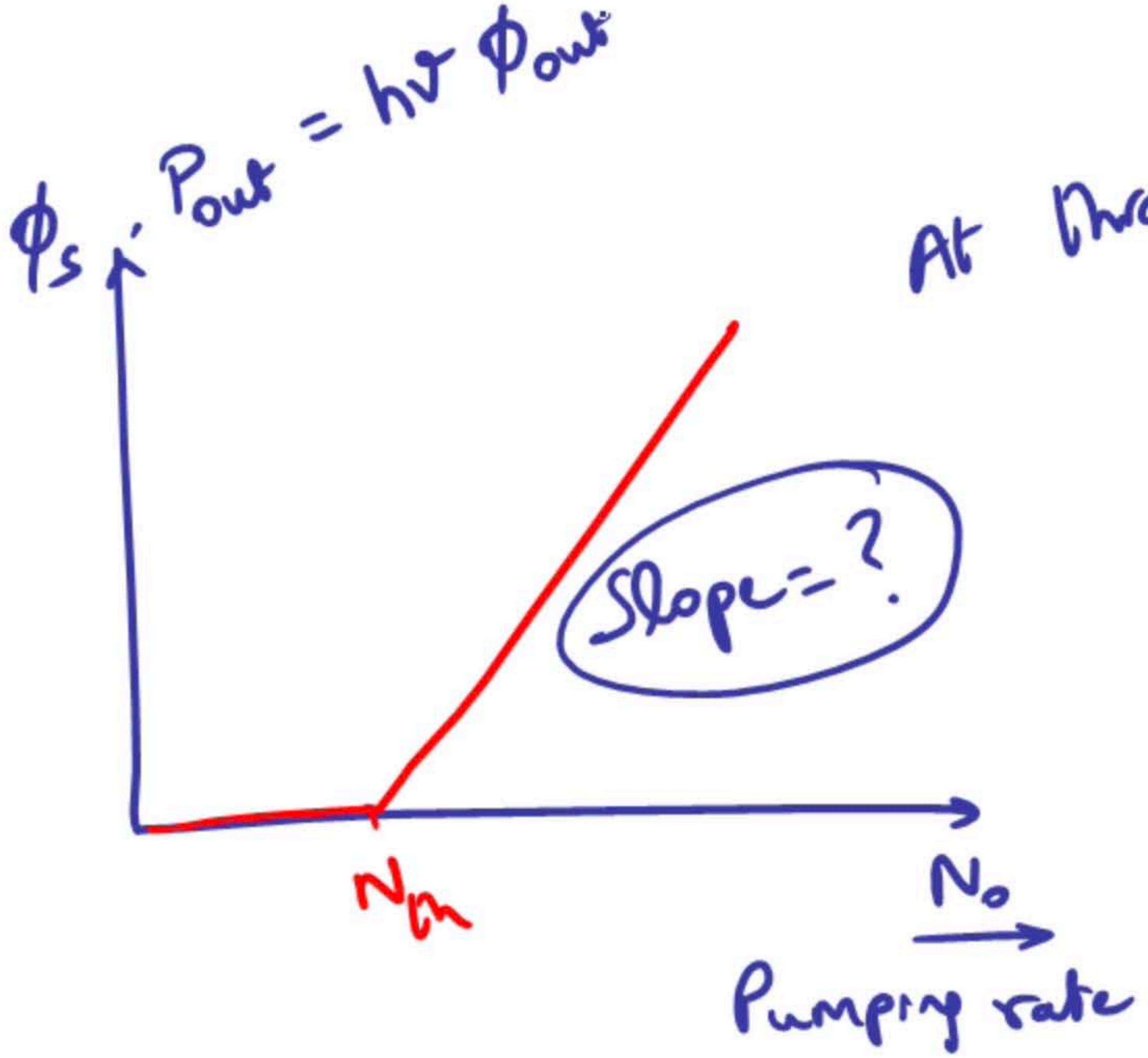
Laser oscillation condition

$$E_0 \, e^{+\gamma/2 \cdot 2L} \, e^{-\alpha_{int}/2 \cdot 2L} \sqrt{R_1 R_2} \cdot e^{-j k_0 n \cdot 2L} = E_0$$

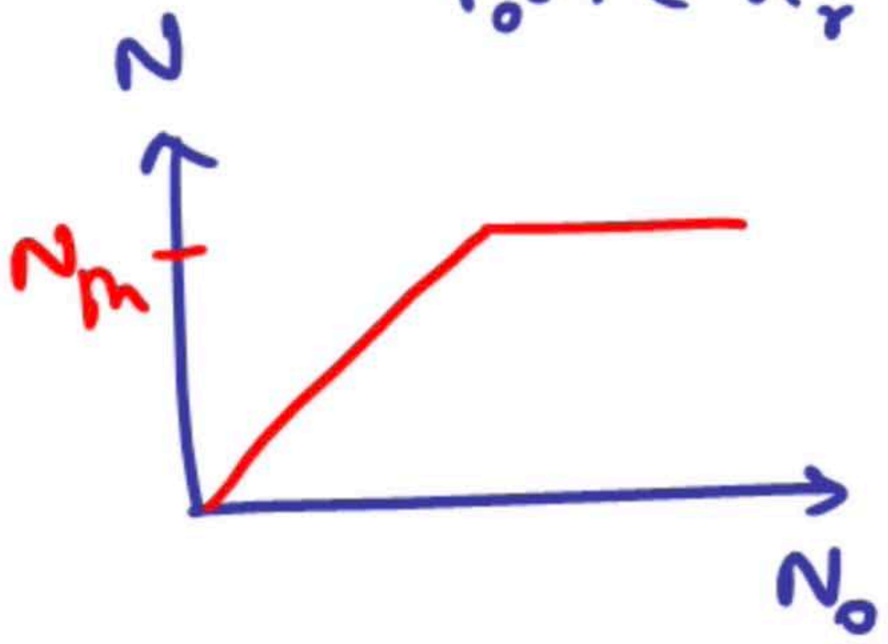
(1) $$e^{\gamma L} e^{-\alpha_{int} L} \sqrt{R_1 R_2} = 1$$

$$k_0 \cdot n \cdot 2L = 2\pi m \quad (2)$$

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



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



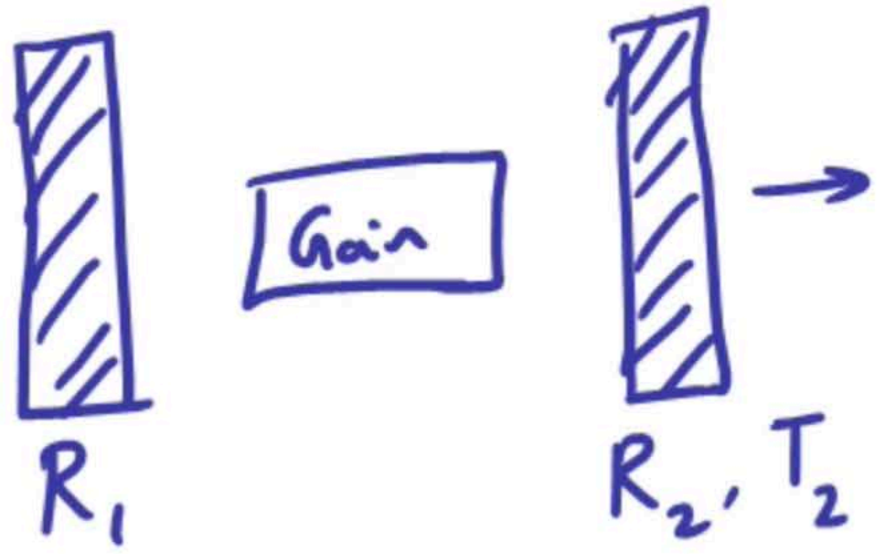
Photon flux

$$\phi_s(\nu) = \begin{cases} \phi_{sat} \left(\dfrac{N_0}{N_m} - 1 \right) & N_0 > N_m \\ 0 & N_0 \le N_m \end{cases}$$

Output power, $P_{out} = \eta_e (P - P_{th})$

↓

slope efficiency



$$\eta_e = \frac{\alpha_{m2}}{\alpha_r}$$

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

$$= \frac{1}{c\,\tau_{ph}}$$

$$\alpha_{m2} = \frac{1}{2L} \ln\left(\frac{1}{R_2}\right)$$

$$\boxed{\eta_e = \frac{c\,\tau_{ph}}{2L} \ln\left(\frac{1}{R_2}\right)}$$

If $T_2 = 1 - R_2 \ll 1$

$$\ln\left(\frac{1}{R_2}\right) \simeq T_2$$

$$\eta_e \simeq \frac{\tau_{ph}}{\tau_{rt}} T_2$$

Optimum?

Optimization of Output Coupling.

Assume $R_1 = R_2$.

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

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

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

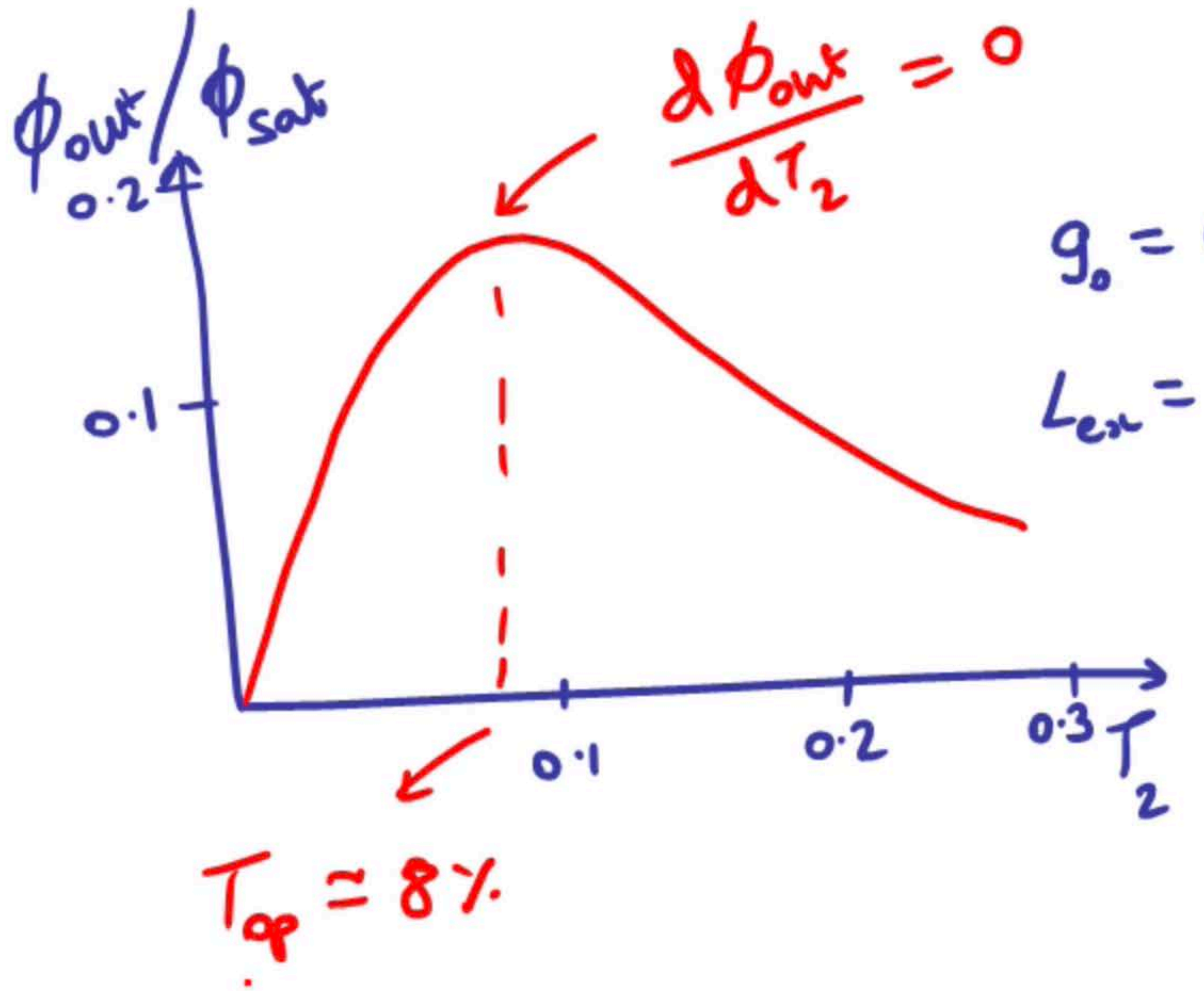
$$\alpha_r = \alpha_{int} + \alpha_{m1} + \alpha_{m2}$$

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

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

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

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



$g_0 = 0.5$

$L_{ex} = 0.02$

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

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

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

$g_0 = \gamma_0 \cdot 2L$

Gain factor