

## Optimum output coupling [Read Svelto 7.5]

$P_{th}$  also depends on  $\gamma_2$ , so to find the optimum, we need this.

First, we know  $R_{cp} = \frac{N_c}{\tau} = \frac{\gamma}{\alpha L \tau}$  critical pump power

We can write the effective pump power as

$$\boxed{\text{ }} \quad \boxed{\text{ }}$$

$h\nu_{31}$  is the quantum energy to reach the upper laser level. The actual pump power required to produce this effective pump power is generally higher. Define pump efficiency as

$$\eta_p = \frac{P_{eff}}{P_p} \quad | P_p - \text{actual pump power}$$

This takes into account spectral efficiency, electrical efficiency of the pump source, geometric efficiency, etc. So

$$R_p = \eta_p \frac{P_p}{A L h \nu_{31}} \quad ; \quad V = A L$$

To get the threshold pump power, set

$$\eta_p \frac{P_{th}}{A L h \nu_{31}} = \frac{\gamma}{\alpha L \tau}$$

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$$\boxed{\text{ }}$$

(96)

Now we need to examine  $\gamma$  in more detail. The three components in  $\gamma$  are  $\gamma_1$ ,  $\gamma_2$  and  $\gamma_i$ .

$$\gamma_1 = -\ln(1-T_1) \quad \text{the loss due to M}_1 \text{ transmission.}$$

$$\gamma_2 = -\ln(1-T_2) \quad " \quad " \quad " \quad " \quad M_2 \quad "$$

$$\gamma_i = a + L_i \quad a - \text{mirror absorption loss}$$

$$L_i - \text{internal loss in active medium}$$

$\gamma$  is single pass loss, so

$$\gamma = \gamma_i + \frac{\gamma_1 + \gamma_2}{2}$$

The minimum pump threshold is with  $\gamma_2 = 0$

$$P_{\text{mth}} = \frac{hV_3}{\eta_p c} \frac{A}{\sigma} \left[ \gamma_i + \frac{\gamma_1}{2} \right]$$

We can then write for  $\gamma_2 \neq 0$

Recall

$$P_{\text{out}} = (A_b I_s) \left( \frac{\gamma_2}{2} \right) \left[ \frac{P_p}{P_{\text{mth}}} - 1 \right]$$

$$= A_b I_s \left( \frac{\gamma_2}{2} \right) \left[ \frac{P_p}{P_{\text{mth}}} \frac{\left[ \gamma_i + (\gamma_1/2) \right]}{\left[ \gamma_i + \frac{\gamma_1}{2} + \frac{\gamma_2}{2} \right]} - 1 \right]$$

the total losses after the output coupling

$$P_{\text{out}} = A_b I_s \left( \frac{\gamma_2}{2} \right) \left[ \frac{P_p}{P_{\text{mth}}} \frac{\gamma_T}{\gamma_T + (\gamma_2/2)} - 1 \right]$$

let  $P_{\text{mth}} = C \gamma_T$

$$P_{\text{out}} = A_b I_s \frac{\gamma_2}{2} \left[ \frac{P_p}{C} \frac{1}{\gamma_T + (\gamma_2/2)} - 1 \right]$$

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To find the optimum value for  $\delta_2$ , take  $\frac{\partial P}{\partial \delta_2} = 0$

let  $\delta_2 = \frac{\gamma_2}{2}$ , find optimum for  $\delta_2$

- let  $P_p/C = Y$ .

$$P_{out} = A_b I_s \delta_2 \left[ \frac{Y}{\gamma_T + \delta_2} - 1 \right]$$

$$\begin{aligned} \frac{\partial P_{out}}{\partial \delta_2} &= A_b I_s \left[ Y \left\{ \left( \frac{1}{\gamma_T + \delta_2} \right) - \frac{\delta_2}{(\gamma_T + \delta_2)^2} \right\} - 1 \right] \\ &= A_b I_s \left[ \frac{Y \cdot \gamma_T}{(\gamma_T + \delta_2)^2} - 1 \right] \end{aligned}$$

$$\boxed{\quad}$$

$$\frac{Y \cdot \gamma_T}{(\gamma_T + \delta_2)^2} = 1$$

$$\gamma_T + \delta_2 = \sqrt{Y \gamma_T}$$

$$\boxed{\quad}$$

