10.7 (a) The increases of $\ln J_{th}$ with inverse cavity length $1/L$ are because the decrease of the cavity length L will increase the threshold gain, $g_{th} = \alpha_i + \frac{1}{2L}\ln\frac{1}{R_1R_2}$.

The slope is determined by L_{opt} as shown in (10.3.39).

$$L_{opt} = \frac{1}{2}\frac{1}{n_W\Gamma_W g_0}\ln\left(\frac{1}{R_1R_2}\right)$$

(b) With a given number of quantum wells n_W, the optimal cavity length is L_{opt} which depends on n_W, Γ_W, g_0, R_1, and R_2.

(c) Assume: $J_0 = 200\ \text{A/cm}^2$ $\quad g_0 = 3000\ \text{cm}^{-1}$ $\quad \Gamma_W = 0.02$
$\alpha = 20\ \text{cm}^{-1}$ $\quad R_1 = R_2 = 0.3$ $\quad \eta = 0.8$ $\quad W = 2\ \mu\text{m}$

$$L_{opt} = \frac{1}{2}\frac{1}{n_W\Gamma_W g_0}\ln\left(\frac{1}{R_1R_2}\right) = \frac{200.7}{n_W}\ \mu\text{m}$$

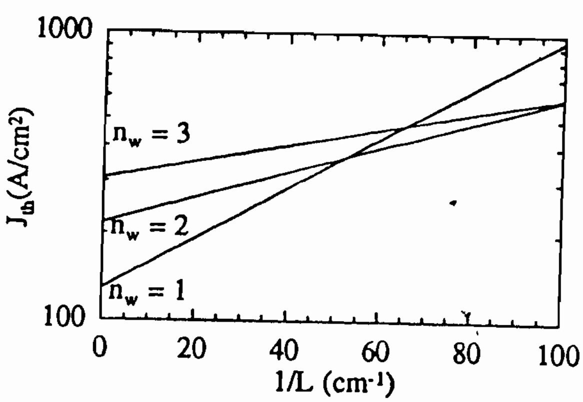
$$\ln J_{th} = \ln\left(\frac{n_W J_0}{\eta}\right) + \frac{\alpha}{n_W\Gamma_W g_0} + \frac{L_{opt}}{L} - 1$$

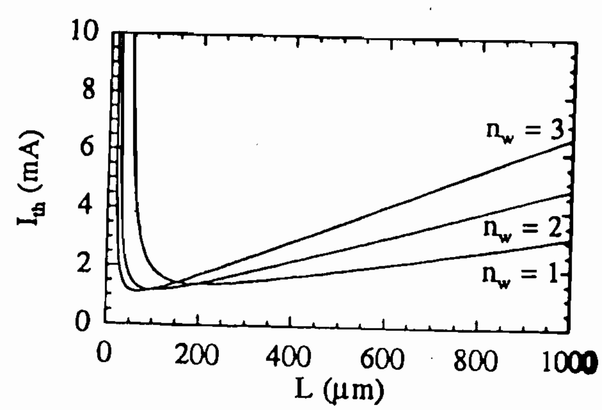
$$= \ln J_0 + \left(\ln n_W - \ln\eta + \frac{\alpha}{n_W\Gamma_W g_0} - 1\right) + \frac{L_{opt}}{L}$$

$$\ln\frac{J_{th}}{J_0} = \left(\ln n_W + \frac{1}{3n_W} - 0.777\right) + \frac{L_{opt}}{L}$$

$$\frac{I_{th}}{WLJ_0} = \frac{n_W}{\eta}\exp\left[\frac{1}{n_W\Gamma_W g_0}\left(\alpha + \frac{1}{2L}\ln\frac{1}{R_1R_2}\right) - 1\right]$$

The plots corresponding to Figs. 10.25(a) and (b) are shown below.





10.8 Assume single subband pair, $n = C_1$, $m = hh_1$

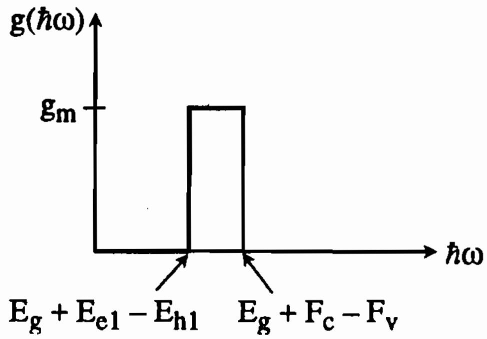
$$g(\hbar\omega) = \begin{cases} g_m [f_c - f_v] & \hbar\omega > E_{e1} - E_{h1} + E_g \\ 0 & \hbar\omega < E_{e1} - E_{h1} + E_g \end{cases}$$

$$g_m = C_0 \, |\hat{e}\cdot M|^2 \rho_r^{2D} = \frac{\pi e^2}{n_r c \varepsilon_0 m_0^2 \omega} \underset{\uparrow \text{ TE polarization}}{\left(\frac{3}{2}M_b^2\right)} \frac{m_r}{\pi\hbar^2 L_z} = 6254\ \text{cm}^{-1} \ \text{(Assume: } \hbar\omega \approx E_g\text{)}$$

$$f_c = \frac{1}{1+\exp\left[\dfrac{E_{e1}+(\hbar\omega - E_{e1}+E_{h1}-E_g)\frac{m_r}{m_c^*} - F_c}{k_B T}\right]}$$

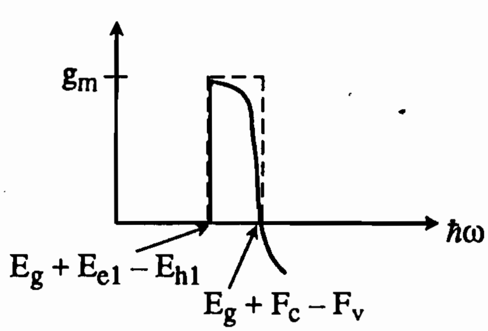
$$f_v = \frac{1}{1+\exp\left[\dfrac{E_{h1}+(\hbar\omega - E_{e1}+E_{h1}-E_g)\frac{m_r}{m_h^*} - F_v}{k_B T}\right]}$$

If assume $T = 0$ K $\Rightarrow$ $f_c = \begin{cases} 1 & \hbar\omega < F_c - F_v + E_g \\ 0 & \hbar\omega > F_c - F_v + E_g \end{cases}$ $\quad f_v = \begin{cases} 0 & \hbar\omega < F_c - F_v + E_g \\ 1 & \hbar\omega > F_c - F_v + E_g \end{cases}$



[Note: F_c and F_v are determined from injection carrier concentrations $n = p$.]

If $T \neq 0$



10.9 (a) single subband (C1 and HH1), T = 300 K, L_z = 100 Å

$$n_c = \frac{m_e^* k_B T}{\pi \hbar^2 L_z} = 7.18 \times 10^{17}\ \text{cm}^{-3} \quad (m_e^* = 0.0665\ m_0)$$

$$n_v = \frac{m_h^* k_B T}{\pi \hbar^2 L_z} = 3.67 \times 10^{18}\ \text{cm}^{-3} \quad (m_h^* = m_{hh}^* = 0.034\ m_0)$$

(b) $f_c = f_v \quad \Rightarrow \quad 1 - \exp\left(-\frac{n_{tr}}{n_c}\right) = \exp\left(-\frac{n_{tr}}{n_v}\right)$

$\Rightarrow \quad n_{tr} = 10.18 \times 10^{17}\ \text{cm}^{-3} = 1.02 \times 10^{18}\ \text{cm}^{-3}$

10.10 The number of quantum wells can be chosen by drawing a horizontal line that corresponds to the desired threshold gain on Fig. 10.24(b), and then by selecting the number of quantum wells that will give a minimized current density of the crossing point of the gain curve and the horizontal line.

For example, as shown in the left plot, the optimum number is 1 for $g_{th} = g_1$, and is 2 for $g_{th} = g_2$.

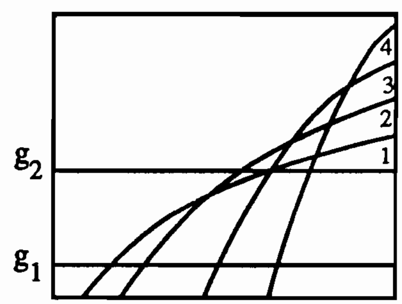


Fig. 10.24(b)