5.5:

Find the poles of the denominator of Eq. 5.59:

$$\omega_R^2 - \omega^2 + j\omega\gamma = 0$$

$$(j\omega)^2 + (j\omega)\gamma + \omega_R^2 = 0$$

$$j\omega = \frac{-\gamma \pm \sqrt{\gamma^2 - 4\omega_R^2}}{2}$$

Thus, we see the poles occur for

$$0 = j\omega + \frac{\gamma}{2} \pm j\omega_R\sqrt{1 - \left(\frac{\gamma}{2\omega_R}\right)^2}$$

or

$$0 = j\omega + s_{1,2}$$

where $s_{1,2}$ are defined by Eq. 5.60.

5.7

Given in Problem

$L = 300um$
$w = 3um$
$t = 3 \times 80A$
$dI = (.10)(2*I_{th}) = 0.2I_{th}$
$\lambda_o = 0.98um$
$<\alpha_i> = 5cm^{-1}$

From table 5.1 we get:
group velocity: v_g
gain parameters: N_{tr}, N_s, g_o, and ε
recombination parameters: A,B, and C
resonance parameters: γ_{NN}, γ_{PP}, and ω_R

Find threshold gain, carrier concentration, and current at steady state:

Threshold gain:

$$g_{th} = \frac{\langle\alpha_i\rangle - \frac{1}{L}\ln\frac{1}{R}}{\Gamma} = \frac{5cm^{-1} + \frac{1}{0.03cm}\ln\frac{1}{0.32}}{0.06} = 718cm^{-1}$$

Threshold carrier concentration:

From table 5.1 the gain parameters for the laser let us write

$$g = \frac{g_o}{1+\varepsilon N_P}\ln\left(\frac{N+N_s}{N_{tr}+N_s}\right)$$

Neglecting gain compression ($\varepsilon N_P << 1$) can calculate the carrier concentration N_{th} as

$$N_{th} = 2.48 \times 10^{18}\ cm^{-3}$$

Threshold current:

$$A = 0$$

$$B = 0.8e-10cm^3/s$$

$$C = 3.5e-30cm^6/s$$

$$I_{th} = \frac{qV}{\eta_i}(AN_{th} + BN_{th}^2 + CN_{th}^3)$$

$$= \frac{(1.6e-19)(300e-4)(3e-4)(80e-8)(3)}{0.8}\left[(0.8e-10)(2.48e18)^2 + (3.5e-30)(2.48e-18)^3\right]$$

$$= 2.356mA$$

Find the steady state value for N_P for $I = 2.0I_{th}$

$$N_P = \frac{\eta_i (I - I_{th})}{q g_{th} v_g V} = 1.067x10^{14} cm^{-3}$$

The difference between N_P for $I = 2.0I_{th}$ and $I = 2.2I_{th}$ is

$$\Delta N_P = \frac{\eta_i (\Delta I)}{q g_{th} v_g V} = 2.13x10^{13} cm^{-3}$$

$$dN_P(t) = dN_P(t = \infty)\left[1 - e^{-\gamma t/2}\cos(\omega_{osc} t)\right]$$
$$\omega_{osc} = \omega_R \sqrt{1 - (\gamma / 2\omega_R)^2}$$

Use values in table 5.1 to solve:

$$\gamma = \gamma_{NN} + \gamma_{PP} = (1.56 + 1.32)x10^9 = 2.88x10^9 \text{ s}^{-1}$$

<u>(this γ has been calculated using the values in the table that are valid only for $P_o = 1mW$, it will be more accurate to recalculate these values using the correct N_P)</u>

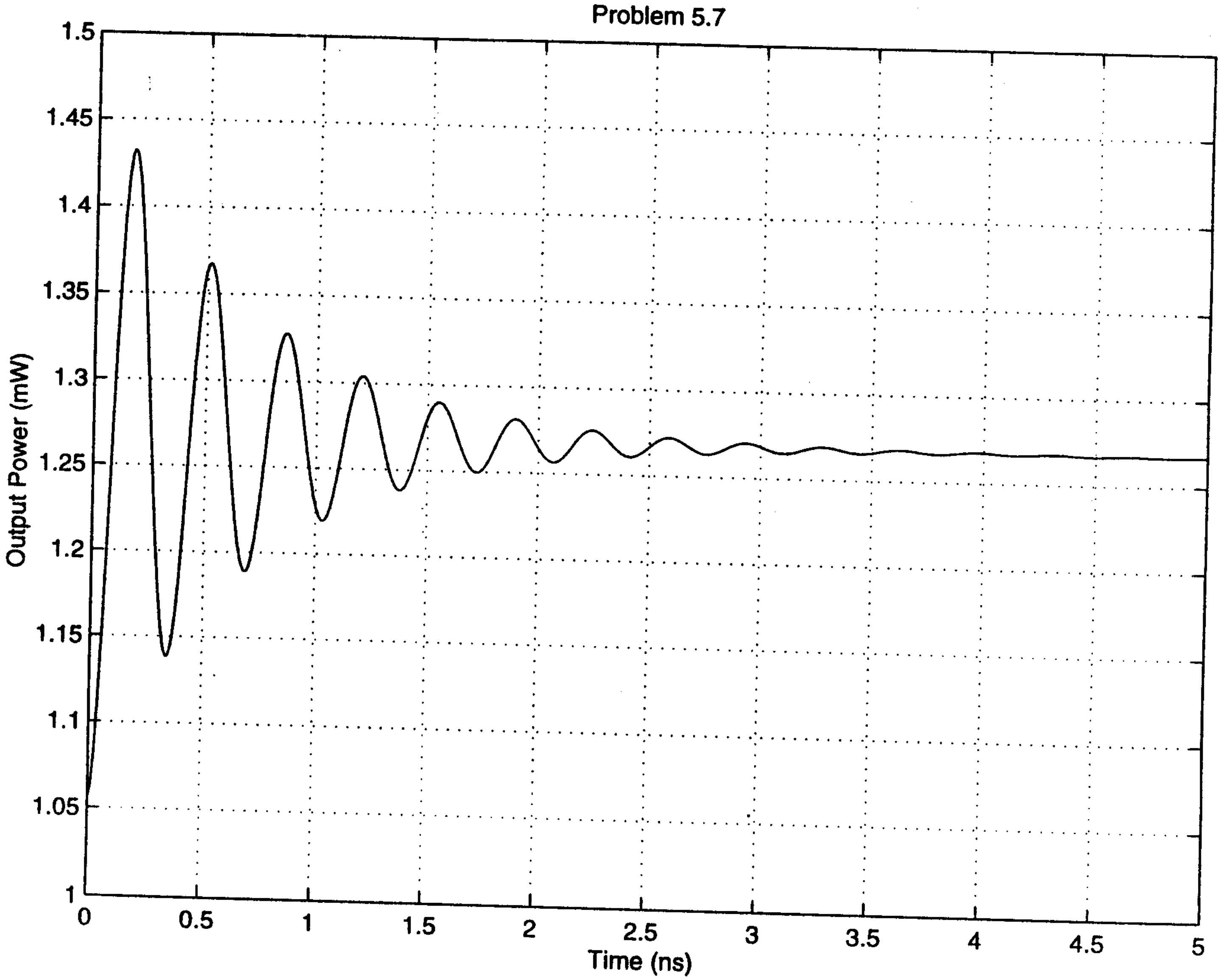
$\omega_{osc} = 1.819 \text{ x } 10^{10}$ rad/s

$dN_P(t) = (2.13 \text{ x } 10^{13} \text{ cm}^{-3})[1 - e^{-(2.88e9)t/2} \cos((1.819x10^{10} \text{ rad/s})t)]$

Now calculate the power from a snigle facet:

$$P_o(t) = \frac{F_1 v_g \alpha_m (N_P + dN_P(t)) h\nu V}{\Gamma}$$
$$= 1.056mW + (9.91x10^{-15} x dN_P(t))\, mW$$

See attached matlab plot



Problem 5.7
Output Power (mW)
Time (ns)
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

5.8:

Evaluate the chirp using values from Fig. 5.6 and Table 5.1.

$$\Delta\nu = \frac{\alpha v_g \Gamma a \Delta N}{4\pi} \tag{5.75}$$

From Table 5.1, we find most of the parameters we need:

$v_g = \frac{c}{\bar{n}_g} = (3/4.2) \times 10^{10}$ cm/s

$\Gamma = \Gamma_{xy}\Gamma_z = 0.032 \times 1 = 0.032$

$a = 5.34 \times 10^{-16}$ cm^2

$\alpha = 5$ (given in problem statement)

ΔN can be approximated using values extracted from Fig. 5.6(a). To do this, first find ω_R and γ_R using the peaks of the carrier density in Fig 5.6(a).

$$\Delta N = \Delta N(t) = \Delta N_0 \; e^{-\gamma t} \sin(\omega_R t) \tag{5.63}$$

$$\omega_R \approx \frac{2\pi}{t_2 - t_1} = \frac{2\pi}{(0.55 - 0.1)ns} = 1.40 \times 10^{10} \; s^{-1}$$

where t_2 and t_1 are the peaks of the first two oscillations in the carrier density shown in Fig. 5.6(a).

Since at the peaks, $cos(\omega_R t) \approx 1$, we have

$$\Delta N(t_1) = \Delta N_0 \; e^{-\gamma t_1} \approx (3.784 - 3.774) \times 10^{18} \text{ cm}^{-3} = 10. \times 10^{15} \text{ cm}^{-3}$$

$$\Delta N(t_2) = \Delta N_0 \; e^{-\gamma t_2} \approx (3.781 - 3.774) \times 10^{18} \text{ cm}^{-3} = 7. \times 10^{15} \text{ cm}^{-3}$$

Solving for γ and N_0,

$$\gamma \approx 7.93 \times 10^{8} \; s^{-1}$$

$$\Delta N_0 \approx 7.58 \times 10^{15} \text{ cm}^{-3}$$

Use the analytic expression for ΔN in the equation for chirp:

$$\Delta N(t) = \Delta N_0 \; e^{-\gamma t} sin(\omega_R t) = (7.58 \times 10^{15} \text{ cm}^{-3}) \; e^{(-7.93\times10^{8} \; s^{-1})t} sin((1.40 \times 10^{10} \; s^{-1})t)$$

Use these values for parameters in Eq. 5.75 (see above) to find an analytical expression for $\Delta\nu$:

$$\Delta\nu = (3.68 \times 10^{8} \; s^{-1}) \; e^{(-7.93\times10^{8} \; s^{-1})t} \sin((1.40 \times 10^{10} \; s^{-1})t)$$

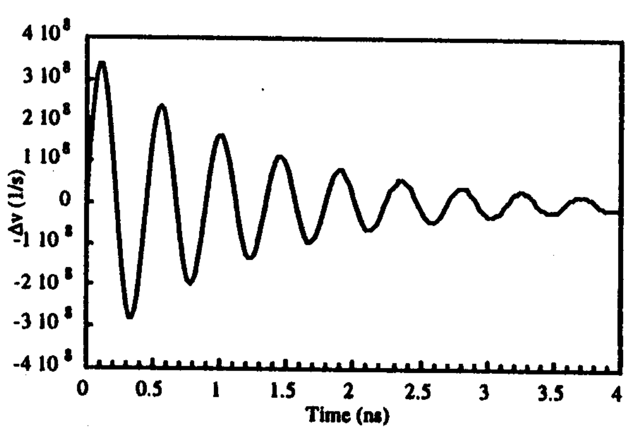


Figure 5.8. Chirp response of laser of Fig 5.6(a).