

HW #6

Due Nov. 21 (Tuesday) in class

- 1) In LaserMOD, build a 1550 nm Fabry-Perot laser (in 1-D) using these parameters:

Parameter	Sym.	Value	Unit
Cavity length	L	500	μm
Cavity width	w	2	μm
Quantum well thickness	d	80	\AA
Number of quantum wells	N	1	-
Material loss	α_i	5	cm^{-1}
Mirror reflectivity	R	0.286	-

Layers

Metal
1 μm n-type InP bulk. doping = $5 \cdot 10^{17} \text{ cm}^{-3}$
80 nm SCH $\text{Ga}_{0.29}\text{In}_{0.71}\text{As}_{0.61}\text{P}_{0.39}$
80 \AA quantum well $\text{Ga}_{0.24}\text{In}_{0.76}\text{As}_{0.79}\text{P}_{0.21}$
80 nm SCH $\text{Ga}_{0.29}\text{In}_{0.71}\text{As}_{0.61}\text{P}_{0.39}$
1 μm p-type InP bulk. doping = $1 \cdot 10^{18} \text{ cm}^{-3}$
Metal

- 2) Simulate the gain spectrum for different carrier concentrations (try $8 \cdot 10^{11}$ to $1.5 \cdot 10^{12} \text{ cm}^{-2}$). Simulate the peak gain vs. carrier concentrations. Turn in a copy of this graph. From the graph, derive and label the differential gain coefficient (a_0) and transparency carrier density (N_{tr}). The differential gain coefficient is the slope of the gain curve in units of cm^2 . Remember to divide the sheet carrier density with the total thickness of the quantum wells.
- 3) In the “Simulate laser” dialog box, turn off all physical models by unchecking all checkboxes in the left column. Simulate the laser from 0 to 10 mA. Turn in a copy of the L-I-V graph. From the graph, derive and label the threshold current (I_{th}) and differential quantum efficiency (η_d) (in W/A). η_d should be the slope of the L-I curve above lasing.
- 4) Calculate the distributed mirror loss (α_m) using $\alpha_m = \frac{1}{L} \ln\left(\frac{1}{R}\right)$.
- 5) Plot Current vs. Confinement factor. Using the graph, extract the confinement factor (Γ) from the graph. The value should be relatively constant over the entire current range.
- 6) Calculate the threshold carrier density (N_{th}) using $\Gamma g_{th} = \alpha_i + \alpha_m$ and $g_{th} \equiv g(N_{th}) = a_0(N_{th} - N_{tr})$.

- 7) Calculate the carrier lifetime (τ_n) from the threshold current, assuming $\eta_i=1$:

$$I_{th} = \frac{qV}{\eta_i} \left(\frac{N_{th}}{\tau_n} \right).$$

- 8) Calculate the differential quantum efficiency and compare it with the one extracted from the L-I graph. Make sure they are close (within 5%).

- 9) Using the parameters you have, plot an L-I graph from 0 to 10 mA using

$$P_0 = \eta_i \left(\frac{\alpha_m}{\alpha_m + \alpha_i} \right) \frac{h\nu}{q} (I - I_{th}).$$

- 10) Simulate a time-dependent step function in the bias (similar to the one in the tutorial). Plot the frequency response for bias points of 2, 5, and 10 mA. Using the plots, extract the resonance frequency for each.

- 11) Plot the optical spectrum at 10 mA and confirm that the wavelength is close to 1550 nm.

Design

- 1) In laser fabrication, we can easily change the laser length by cleaving the laser bar to our desired length. We can also utilize thin-film coatings on the facets to change the reflectivity from 100% to close to 0%. (a) Determine the laser length that uses the least amount of current to obtain a 2 mW output power, given a reflectivity of $R=0.286$. (b) Determine the reflectivity that uses the least amount of current to obtain a 2 mW output power, given a laser length of 500 μm .

Some useful formulas:

First, find the value for α_m that minimizes the current for a given output power.

$$P_0 = \eta_i \left(\frac{\alpha_m}{\alpha_m + \alpha_i} \right) \frac{h\nu}{q} (I - I_{th})$$

Then, use the mirror loss formula to obtain the dependency of L and R.

$$\alpha_m = \frac{1}{L} \ln \left(\frac{1}{R} \right)$$