DUBLIN CITY UNIVERSITY

SEMESTER TWO SOLUTION ASSIGNMENT 2015

MODULE: EE506: Fundamentals of photonic devices

YEAR: Master of Engineering

e	$1.6 \times 10^{-19} C$
c	$3 \times 10^{8} m/s$
h	$6.62 \times 10^{-34} Js$
k	$1.38 \times 10^{-23} J/K$
cavity length	$250 \mu m$
active region width	$2 \mu m$
active region thickness	$200 nm$
N_o	1.2×10^{8}
A	$8 \times 10^{3} s^{-1}$
τ_p	$1.6 ps$
τ_e	$2.2 ns$

1 Question 1 [30 marks]

1.1 [5 marks]

1. **The set of equations given below are called rate equations:**

$$\begin{cases} \frac{dN}{dt} = \frac{I}{e} - A(N - No)P - \frac{N}{\tau_e} \\ \frac{dP}{dt} = A(N - No)P - \frac{P}{\tau_p} + \beta\frac{N}{\tau_e} \end{cases} \quad (1)$$

What does this set of equations describe? Identify and name all the symbols appearing in Eq. 1. This set of equations describes the time evolution of both the carrier number and the photon number.

1.2 [15 marks]

Use Eq. (1) to determine the expression for the current threshold and from the list of constants attached to this exam paper calculate the threshold current. What assumption do you use to facilitate this calculation?

1.3 [10 marks]

Determine the expression for the number of carriers as a function of the bias current set above threshold and below the threshold. Comment these results.

2 Question 2 [30 marks]

2.1 [10 marks]

If $\bar{N}$, $\bar{P}$ and $\bar{I}$ represent steady state quantities, carry out a small signal analysis for the rate equations (1) from Question 1, for the following perturbations δN, δP and

δI around these steady state points. Your solution must be presented as:

$$\begin{pmatrix} \frac{d\delta N}{dt} \\ \frac{d\delta P}{dt} \end{pmatrix} = M \begin{pmatrix} \delta N \\ \delta P \end{pmatrix} + \begin{pmatrix} \frac{\delta I}{e} \\ 0 \end{pmatrix} \tag{2}$$

where M is a 2×2 matrix.

2.2 [5 marks]

Identify all the elements of the matrix, M.

2.3 [15 marks]

If $\widetilde{\delta N}$, $\widetilde{\delta P}$ and $\widetilde{\delta I}$ are the expression of the first order perturbation of δN, δP and δI in the Fourier domain, derive the expressions for $\widetilde{\delta N}$ and $\widetilde{\delta P}$ as a function $\widetilde{\delta I}$.

Hint:

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}^{-1} = \frac{1}{(ad - cb)} \begin{pmatrix} d & -b \\ -c & a \end{pmatrix} \tag{3}$$

3 Question [30 marks]

Consider a photodiode with an efficiency $\eta = 0.85$ maximal at the wavelength of $1550nm$. This photodiode has a bandwidth of $20GHz$ with a load impedance of 50Ω. It works at a temperature of 300^0K and an optical power of $-3dBm$ launched at its input.

Hint:

$$\frac{S}{N} = \frac{(\frac{\eta e}{h\nu})^2 {P_s}^2}{(2e(\frac{\eta e}{h\nu})P_s + \frac{4kT}{R_c})\Delta f}$$

3.1 [10 marks]

What is the signal-to-noise ratio of this photodiode?

3.2 [10 marks]

What is the value of the signal- to-noise ratio if the temperature is set at 0^oC?

3.3 [5 marks]

If the temperature of a photodiode increases, what is the consequence on the signal-to-noise ratio? Justify your answer.

3.4 [5 marks]

If the bandwidth of a photodiode increases, what is the consequence on the signal-to-noise ratio? Justify your answer.

[End of Question 3]

4 Question [10 marks]

4.1 [10 marks]

What is the value of the internal and external quantum efficiency of the light emitting diode. The radiative and non-radiative carrier lifetimes are 50ns and 75ns. We assume that there is no default in the semiconductor material and the contacts are not light absorbing. The refractive index of the LED is 3.6 and its emission is maximal at a wavelength of 450nm and bias current of 300 mA.

[End of Question 4]