UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2022

Module Number: EE7211 **Module Name: Optical Fiber Communication (N/C)**

[Three Hours]

[Answer **all questions,** each question carries 10 marks]

- **All the notations have their usual meaning.**
- **Use the following parameters, if required.**

Planck's Constant = 6.626×10^{-34} J. s **Charge of an Electron** = 1.602×10^{-19} C

Boltzmann Constant = 1.38×10^{-23} m^2. kg. s^{-2}. K^{-1}

Q1 a) Distinguish between meridional rays and skew rays used in optical wave propagation.

[2.0 Marks]

b) The refractive index profile of the graded index fiber is given by

$$n(r) = \begin{cases} n_1\left[1-2\Delta\right]^{1/2} \simeq n_1\ (1-\Delta) = n_2 & \text{for } r \geq a \\ n_1\left[1-2\Delta\left(\dfrac{r}{a}\right)^{\alpha}\right]^{1/2} & \text{for } 0 \leq r \leq a \end{cases}$$

where r is the radial distance from the fiber axis, a is the core radius, n_1 is the refractive index at the core axis, n_2 is the refractive index of the cladding and the dimensionless parameter α defines the shape of the index profile. Moreover, the relative refractive index difference Δ for the graded index fiber is

$$\Delta \simeq \frac{n_1 - n_2}{n_1}.$$

i) Draw the refractive profile for graded index fiber.

ii) Obtain an expression for numerical aperture of the step index fiber by approximating the expressions stated above.

[3.0 Marks]

c) i) Calculate the number of modes at 820 nm and 1.3 μm in a graded index fiber having a parabolic index profile $(\alpha = 2)$, a 25 μm core radius, $n_1 = 1.48$ and $n_2 = 1.46$.

ii) How do you compare the value obtained in part i) to a step index fiber?

[5.0 Marks]

Q2 a) Briefly explain the following.

i) Dispersion and pulse broadening

ii) Intramodal dispersion and Intermodal dispersion

iii) Rayleigh scattering and Mie scattering

[4.5 Marks]

b) Consider a standard non-dispersion shifted single mode optical fiber that has a zero-dispersion wavelength at 1310 nm with a dispersion slope of $S_0 = 0.090$ ps/(nm^2. km). Plot the dispersion in the wavelength range $(1270 \leq \lambda \leq 1340)$ nm.

[1.5 Marks]

c) A typical dispersion shifted single mode optical fiber has a zero-dispersion wavelength at 1550 nm with a dispersion slope $S_0 = 0.070$ ps/(nm^2. km).

i) Plot the dispersion in the wavelength range $(1500 \leq \lambda \leq 1600)$ nm.

ii) Compare the dispersion at 1500 nm with the dispersion value for the non-dispersion shifted fiber described in part b).

iii) Sketch the refractive index profiles of the dispersion shifted single mode optical fiber and the non-dispersion shifted fiber.

iv) Explain how it is possible to shift the zero-dispersion wavelength of dispersion shifted fiber to a higher wavelength.

[4.0 Marks]

Q3 a) With the help of illustrations, explain the difference of construction and working principles of surface emitting and edge emitting LEDs.

[2.0 Marks]

b) The radiative and non-radiative recombination lifetimes of the minority carriers in the active region of a double-heterojunction LED are 60 ns and 100 ns respectively.

i) Determine the total carrier recombination lifetime.

ii) What is the power generated within the device when the peak emission wavelength is 0.87 μm at a drive current of 40 mA?

[5.0 Marks]

c) i) What are the main responsibilities of a transmitter in an optical fiber communication system?

ii) Briefly explain two source-to-fiber coupling mechanisms used in optical transmitters?

[3.0 Marks]

Q4 a) What is meant by detector response time? Explain the factors that affect to the response time of a detector.

[2.0 Marks]

b) Briefly explain the optical detection principle of a *p-i-n* photodiode.

[3.0 Marks]

c) A silicon avalanche photodiode has a quantum efficiency of 65% at a wavelength of 900 nm.

i) Determine the responsivity of the photodiode.

ii) Assuming 0.5 μW of optical power to the photodiode produces a multiplied photocurrent of 10 μA, find the multiplication factor of the photodiode.

[5.0 Marks]

Q5 a) A schematic diagram of a typical receiver is shown in Figure Q5. Identify the basic stages of the receiver and briefly explain the functions of each stage.

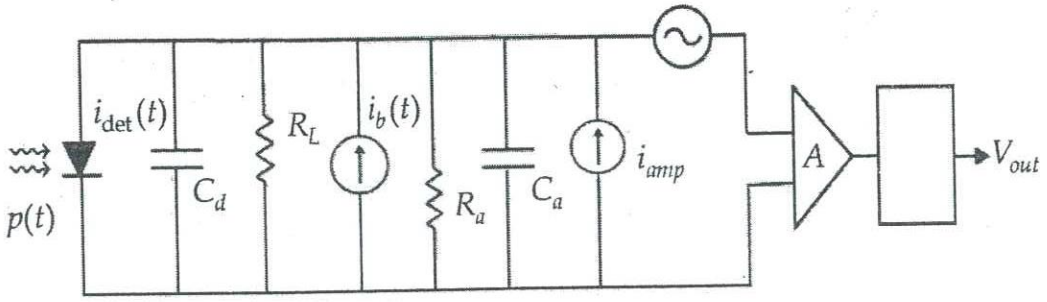

Figure Q5

Note:

You should redraw the diagram on the answer script and show the stages clearly.

[3.0 Marks]

b) A silicon *p-i-n* photodiode integrated into an optical receiver has a quantum efficiency of 60% when operating at a wavelength of 900 nm. The dark current in the device at this operating point is 3 nA and the total capacitance is 4 kΩ. The incident optical power to the photodiode is 200 nW and the post detection bandwidth of the receiver is 5 MHz at a temperature of 20^{0}C. Determine the

i) total shot noise

ii) thermal noise and

iii) SNR at the output of the receiver assuming the receiver has a noise figure of 3 dB.

Hint:

$$\frac{S}{N} = \frac{I_p^2}{2eB\left(I_p + I_d\right) + \frac{4KTBF_n}{R_L}}$$

[7.0 Marks]