UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2021

Module Number: EE7211 **Module Name: Optical Fiber Communication**

[Three Hours]

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

Q1 Answer any four parts of this question.

a) What are the elements of optical fiber communication system? Briefly explain the advantages of optical communication.

b) What is the difference between step index fiber and graded index fiber? How does the ray of light propagate in a graded index fiber?

c) A multimode step index fiber has a relative refractive index difference 1% and a core refractive index of 1.5. The number of modes propagating at a wavelength of 1.3 μm is 1100. Determine the diameter of the fiber.

d) An optical fiber has a numerical aperture of 0.344. What is the acceptance angle for meridional rays? Calculate the acceptance angle for skew rays which change the direction by 100^0 at each reflection.

e) A silica optical fiber with a core diameter large enough to be considered by the ray theory analysis, has a core refractive index of 1.50 and a cladding refractive index of 1.45. Determine,

i) the critical angle at the core-cladding interface.

ii) the numerical aperture of the fiber.

iii) the acceptance angle in air for the fiber.

[2.5 Marks × 4 = 10.0 Marks]

Q2 a) i) What are the main causes related to attenuation in an optical fiber?

ii) The mean power launched in a fiber link is 1.5 mW and the fiber has an attenuation of 0.5 dB/km. Determine the maximum possible link length when the mean optical power at the detector is 2 μW.

[2.0 Marks]

b) Suppose that the total pulse broadening of a light pulse (for meridional rays and totally ignoring the effect of skew rays) due to intermodal dispersion in a multimode step index fiber is given by

$$\delta T_s = \frac{L(NA)^2}{2n_1 C}$$

where L is the fiber length, NA is the numerical aperture, n_1 is the core refractive index and C is the velocity of light.

If the optical input to the fiber is a pulse $p_i(t)$ defined for $\frac{-\delta T_s}{2} \leq t \leq \frac{\delta T_s}{2}$ having a unit area, i.e., $\int_{-\infty}^{+\infty} p_i(t)\, dt = 1$, obtain an expression for the rms pulse broadening of the light pulse.

[3.0 Marks]

c) A multimode step index fiber has a core refractive index of 1.5 and a relative refractive index difference of 2%. The material dispersion parameter for the fiber is 250 $ps.nm^{-1}.km^{-1}$ and makes the material dispersion as the dominant component in terms of intramodal dispersion. Determine

i) the rms pulse broadening due to intermodal dispersion.

ii) the total rms pulse broadening per km when the fiber is used with an LED source having an rms spectral width of 50 nm.

iii) the corresponding bandwidth-length product of the fiber.

[5.0 Marks]

Q3 a) Illustrating the output characteristic curves (Optical power versus current) for an LED and a Laser diode, explain what is meant by the pumping threshold of a Laser diode.

[2.0 Marks]

b) Explain the emission pattern for a surface emitting LED and an edge emitting LED.

[2.0 Marks]

c) For a laser having a crystal length of 7 cm, refractive index of 1.5 and peak emission wavelength of 0.5 μm, determine

i) the number of longitudinal modes of the laser.

ii) the frequency separation among the modes.

[3.0 Marks]

d) i) List the two modulation methods used in optical fiber communication systems.

ii) Hence, discuss the implication of the modulation and demodulation process shown in Figure Q3.

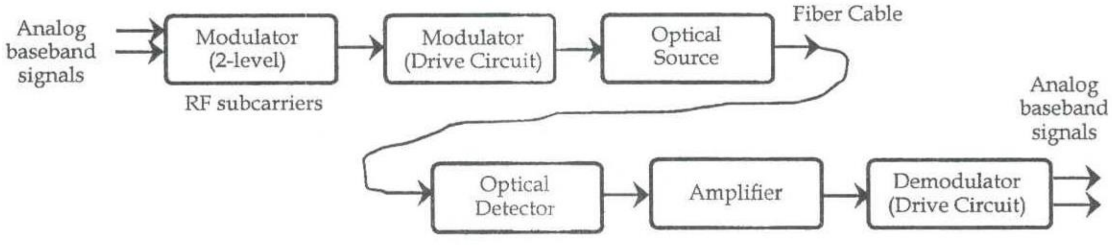

Figure Q3

[3.0 Marks]

Q4 a) Briefly explain the following parameters related to an optical detector.

i) Detector responsivity

ii) Quantum efficiency

iii) Capacitance

[3.0 Marks]

b) i) Explain the principle of optical detection process of a *p-n* photodiode.

ii) What is the significance of the intrinsic layer inserted between *p* and *n* layers in a *p-i-n* photodiode?

[3.0 Marks]

c) A *p-i-n* photodiode has a quantum efficiency of 50% at a wavelength of 0.9 μm. Determine

i) the responsivity of the photodiode at 0.9 μm.

ii) the received optical power, if the photocurrent is 10^{-6} A.

iii) the number of received photons at the 0.9 μm wavelength.

[4.0 Marks]

Q5 a) i) What are the main components of an optical receiver?

ii) Explain the necessity of a preamplifier in an optical receiver.

[2.0 Marks]

b) Briefly explain the following noise types associated with optical fiber communication systems.

i) Thermal noise

ii) Dark current noise

iii) Quantum shot noise

[3.0 Marks]

c) The internal gain mechanism used in an Avalanche Photodiode (APD) increases the current fed into the amplifier. If the photocurrent is increased by a factor M (Mean avalanche multiplication factor), then the shot noise is also increased by an excess noise factor M^x. Therefore, the SNR for APD can be determined by combining the noise contribution from the load resistor and the amplifier. The SNR for the APD is given by

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

A silicon APD (x = 0.3) has a capacitance of 5 pF, negligible dark current and is operated with a post detection bandwidth of 50 MHz. If the photocurrent before the gain is 10^{-7} A and the temperature is 18 ^{0}C, determine

i) SNR when $M = 1$

ii) SNR when $M = M_{OP}$. Assume all operating conditioned are maintained.

iii) SNR improvement from part i) and part ii).

[5.0 Marks]