UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2017/2018

COURSE NAME	:	OPTICAL COMMUNICATIONS
COURSE CODE	:	BEB41603
PROGRAMME	:	BEJ
EXAMINATION DATE	:	DECEMBER 2017 / JANUARY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** THE QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) List **THREE (3)** advantages of optical communications.

(3 marks)

(b) When the mean optical power launched into an 8 km length of fiber is 120 μW, the mean optical power at the fiber output is 3 μW. Estimate:

(i) the overall signal attenuation or loss in decibels through the fiber assuming there are no connectors or splices,

(2 marks)

(ii) the signal attenuation per kilometer for the fiber,

(2 marks)

(iii) the overall signal attenuation for a 10 km optical link using the same fiber with splices at 1 km intervals where each giving an attenuation of 1 dB.

(2 marks)

(c) Justify how the utilization of graded-index fibers can reduce modal dispersion in optical fibers. Describe your answer with ray-optics diagram.

(4 marks)

(d) A glass fiber exhibits material dispersion given by $\left|\lambda^2\left(d^2 n_1 / d\lambda^2\right)\right|$ of 0.025. Estimate:

(i) the material dispersion parameter at a wavelength of 0.85 μm,

(2 marks)

(ii) the rms pulse broadening per kilometer for a good LED source with an rms spectral width of 20 nm at this wavelength,

(2 marks)

(iii) the rms pulse broadening when the optical source used is an injection laser with a relative spectral width σ_λ / λ of 0.0012 at a wavelength of 0.85 μm.

(3 marks)

Q2 (a) Make comparison between spontaneous and stimulated emission in optical fibers. Illustrate your answer with the aid of energy level diagram.

(4 marks)

(b) Justify the need to forward-bias the P-N junction for light emission of LEDs and lasers.

(4 marks)

(c) Compare the electrical and optical bandwidths for an optical fiber communication system and develop a relationship between them.

(6 marks)

(d) The minority carrier recombination lifetime for an LED is 5 ns. When a constant DC drive current is applied to the device, the optical output power is 300 μW.

(i) Determine the optical output power when the LED is modulated with an rms drive current that has frequency of 100 MHz.

(2 marks)

(ii) Estimate the 3-dB optical bandwidth of the LED.

(2 marks)

(iii) Estimate the 3-dB electrical bandwidth of the LED.

(2 marks)

Q3 (a) Justify the need to reverse-bias the P-N junction for light detection of photodiodes.

(4 marks)

(b) GaAs has a bandgap energy of 1.43 eV at 300 K. Determine the wavelength above which an intrinsic photodetector fabricated from this material will cease to operate.

(2 marks)

(c) A silicon p-i-n photodiode has an intrinsic region with a width of 20 μm and a diameter of 500 μm in which the drift velocity of electrons is 10^5 ms^{-1}. When the permittivity of the device material is 10.5 x 10^{-13} Fcm^{-1}, estimate

(i) the drift time of the carriers across the depletion region,

(2 marks)

(ii) the junction capacitance of the photodiode.

(2 marks)

(d) A silicon p-i-n photodiode incorporated into an optical receiver has a quantum efficiency of 60% when operating at a wavelength of 0.9 μm. The dark current in the device at this operating point is 3 nA and the load resistance is 4 kΩ. The incident optical power at this wavelength is 200 nW and the post detection bandwidth of the receiver is 5 MHz. The receiver has an amplifier with a noise figure of 3dB.

(i) Compare the short noise generated in the photodiode with the thermal noise in the load resistor at a temperature of 20^0C.

(6 marks)

(ii) Determine the signal-to-noise ratio (SNR) at the output of the receiver.

(4 marks)

Q4 (a) An erbium-doped fiber amplifier (EDFA) requires optical components of a laser diode, a multiplexer and an erbium-doped fiber. Outline the function for each of those optical components for the operation of the EDFA. Describe with the aid of suitable diagrams.

(4 marks)

(b) Outline Raman amplifier designs that incorporate laser pump. Describe why a laser pump is essential for Raman amplification.

(5 marks)

(c) Explain the term amplified spontaneous emission (ASE) noise and describe its impact on the optical output signal.

(4 marks)

(d) Propose a method that can introduce gain clamping in semiconductor optical amplifiers (SOAs).

(3 marks)

(e) An SOA operating at a signal wavelength of 1.55 μm produces a gain of 30 dB with an optical bandwidth of 1 THz. The device has a spontaneous emission factor of 4 and the mode number is equal to 2.2 when the net gain coefficient over the length of amplifier is 200. Estimate:

(i) the length of the device,

(2 marks)

(ii) the ASE noise signal power at the output of the amplifier.

(2 marks)

Q5 (a) An engineer has the following components available :

- GaAlAs laser diode operating at 850nm and capable of coupling 1mW (0dBm) into a fiber.
- Ten sections of cable each of which is 500m long, as a 4dB/km, attenuation, and has connectors on both ends.
- Connector loss of 2dB/connector
- A pin photodetector receiver
- An avalanche photodiode receiver

Using these components, the engineer wishes to construct a 5 km link operating at 20 Mb/s. If the sensitivities of the pin and APD receivers are -45 and -56 dBm, respectively, which receiver should be used if a 6 dB system operating margin is required?

(8 marks)

(b) A grating is an important element in WDM systems for combining and separating individual wavelengths. With the aid of diagrams, explain the concept of fiber grating filters in WDM system. Show its regular interval pattern, and discuss the outcome if the interval pattern is increased.

(5 marks)

(c) With the aid of diagrams, describe the two basic philosophies for implementing single-hop wavelength division multiplexing (WDM) architectures.

(7 marks)

- END OF QUESTION -

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FINAL EXAMINATION

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Constant

Velocity of light in vacuum, $c = 3 \times 10^8$ ms^{-1}
Plank constant, $h = 6.626 \times 10^{-34}$ Js
Boltzmann constant, $k = 1.381 \times 10^{-23}$ JK^{-1}
Absolute temperature, T = 17 $^{\circ}$C or 290 K

Formula

$$V = \frac{2\pi}{\lambda} a n_1 (2\Delta)^{\frac{1}{2}},\ \tau_g = \frac{1}{c}\left(n_1 - \frac{\lambda d n_1}{d\lambda}\right),\ \tau_m = \frac{L}{c}\left(n_1 - \frac{\lambda d n_1}{d\lambda}\right),\ \sigma_m = \frac{\sigma_\lambda L}{c}\left(\lambda \frac{d^2 n_1}{d\lambda^2}\right)$$

$$\tau_s = \frac{(NA)^2}{2cn_1},\ \tau_g = \frac{n_1 \Delta^2}{8c},\ \sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}c},\ \sigma_s = \frac{L(NA)^2}{4\sqrt{3}n_1 c},\ \sigma_T = (\sigma_m^2 + \sigma_s^2)^{\frac{1}{2}},\ \delta T_S = \frac{L n_1 \Delta}{c}$$

$$B_T = \frac{0.2}{\sigma} \text{ bits/sec},\ B_T = \frac{1}{2\tau} \text{ bits/sec},\ BW = B_T\,(RZ),\ BW = \frac{1}{2} B_T\,(NRZ)$$

$$\eta_{int} = \frac{1}{1 + \tau_r / \tau_{nr}} = \frac{\tau}{\tau_r},\ P_{int} = \eta_{int} \frac{h v I_p}{e} = \eta_{int} \frac{h c I_p}{e\lambda},\ \eta_{ep} = \frac{P_e}{P},\ P = IV,\ R = \frac{I_P}{P_0},\ R = \frac{\eta e \lambda}{hc}$$

$$n = \frac{P_0}{hf} = \frac{P_0 \lambda}{hc},\ P_e = \frac{P_{int} F n^2}{4 n_x^2},\ r_e = \frac{I_P}{e},\ r_p = \frac{P_o}{hf},\ L = \frac{\lambda}{2n} q,\ \Delta\lambda = \frac{\lambda^2}{2nL},\ \Delta f = \frac{c}{2nL}$$

$$\overline{i_{th}^2} = \frac{4kTB}{R}(A^2),\ \overline{i_{shot}^2} = 2eB(I_p + I_d)(A^2)$$

$$SNR = \frac{I_P^2}{\overline{i_{shot}^2} + \overline{i_{th}^2} + \overline{i_{amp}^2}},\ SNR = \frac{M^2 I_P^2}{\overline{i_{shot}^2} M^{2+x} + \overline{i_{th}^2} + \overline{i_{amp}^2}} \qquad SNR = \frac{I_P^2}{\overline{i_{TS}^2} + \overline{i_t^2} F_n}$$

$$P_e = \frac{1}{2} erfc\left(\frac{\sqrt{SNR}}{2\sqrt{2}}\right),\ P_e = \frac{1}{2} erfc\left(\frac{I_P}{2\sqrt{2}\sigma_s}\right),\ \sigma_s^2 = 2qI_p \Delta f \qquad A = 10\log_{10}\frac{P_i}{P_0}$$

$$G = \exp(gL), \qquad P_{ASE} = m n_{sp} (G_S - 1) hfB$$

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