CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION (ONLINE) SEMESTER II SESSION 2020/2021

COURSE NAME	: OPTICAL COMMUNICATION
COURSE CODE	: BEB 41603
PROGRAMME CODE	: BEJ
EXAMINATION DATE	: JULY 2021
DURATION	: 3 HOURS
INSTRUCTION	: ANSWER **ALL** THE QUESTIONS **OPEN BOOK EXAMINATION**

TERBUKA

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

CONFIDENTIAL

Q1 (a) Distinguish between the technology aspect in first generation and fourth generation fiber optic communication system.

(4 marks)

(b) A typical single-mode fiber has a zero-dispersion wavelength of 1.31 μm with a dispersion slope of 0.09 ps/ nm^2 km. Calculate the total first-order dispersion for the fiber at the wavelengths of 1.28 μm and 1.55 μm. When the material dispersion at the latter wavelength are 13.9 ps/ nm km, determine the waveguide dispersion at this wavelength.

(5 marks)

(c) Compare 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, core refractive index of 1.48 and cladding refractive index of 1.46.

(7 marks)

(d) The typical optical fiber has high loss when operate at wavelength of 1390 nm. Briefly explain the reason for this phenomena.

(4 marks)

Q2 (a) The external power efficiency of a planar GaAs LED is 1.5% when the forward current is 50 mA and the potential difference across its terminals is 2 V. The transmission factor at the coated GaAs–air interface is 0.8. The refractive index of GaAs is 3.6. Estimate

(i) the optical power generated within the device

(3 marks)

(ii) the internal quantum efficiency if operating wavelength is 900 nm.

(2 marks)

(b) Justify why the Double-Heterojunction (DH) structure is adopted in LED fabrication.

(6 marks)

(c) Estimate the electrical modulation bandwidth for an LED with a carrier recombination lifetime of 8 ns. The frequency response of the device may be assumed to be Gaussian.

(4 marks)

(d) The behavior of the semiconductor laser can be described by rate equations for electron and photon density in the active layer of the device. Derive an expression of threshold current density from the rate equations.

(5 marks)

CONFIDENTIAL

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 digital optical fiber link employing ideal binary signaling at a rate of 50 Mbit/s operates at a wavelength of 1.3 μm. The detector is a germanium photodiode which has a quantum efficiency of 45% at this wavelength. An alarm is activated at the receiver when the bit-error-rate drops below 10^{-5}.

(i) Estimate the theoretical minimum optical power required at the photodiode in order to keep the alarm inactivated.

(3 marks)

(ii) State the reasons why in practice the minimum incident optical power would need to be significantly greater than this value.

(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.

(3 marks)

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

(4 marks)

(b) Draw Raman amplifier designs that incorporate laser pump. Describe why the laser pump is essential for the 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) Suggest 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

By using these components, the engineer wishes to construct a 5 km link operating at 20 Mb/s. If the sensitivities of the P-I-N 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