UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: July 2017

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

[3 Hours]

[Answer **all questions**, each question carries 12.5 marks]

Notes:

- **Use following standard values for your calculations.**

Planck's constant (h) = 6.63 x 10^{-34} Js **Velocity of light in vacuum (c) = 3 x 10^{8} m/s**

Charge of an electron (e) = 1.602 x 10^{-19} C **Boltzmann constant (k_B) = 1.38 x 10^{-23} J/K**

Q1 a) Briefly explain the numerical aperture (NA) of an optical fiber.

[1.0 Marks]

b) Starting from the first principle, derive expressions for the numerical aperture (NA) and the acceptance angle (θ_A) of an optical fiber. Assume that the core and cladding refractive indices are n_1 and n_2 respectively and the fiber is surrounded by air (n_o).

[1.5 Marks]

c) The fractional index change Δ is defined as $\Delta = (n_1 - n_2)/n_1$ for the same optical fiber in part b). Derive the following.
Clearly mention the assumptions.

i) Numerical aperture of the fiber;

$$NA = n_1(2\Delta)^{1/2}$$

ii) Intermodal dispersion (Multipath dispersion or ISI);

$$\tau = \frac{Ln_1^2}{cn_2}\Delta$$

[7.0 Marks]

d) Consider a step index multimode fiber with core refractive index of 1.48 and index-difference of 2%. Determine the following.

i) Numerical aperture (NA)

ii) Intermodal dispersion (τ), if the regenerating interval is 100 km

[3.0 Marks]

Q2 a) Explain two types of light scattering mechanisms in optical fibers.

[2.0 Marks]

b) Assume an optical link with 1 Gb/s data rate and Non Return to Zero (NRZ) modulation. The dispersion at 1.55 μm is 17 ps/nm-km and the attenuation is 0.25 dB/km. At 1.3 μm, the attenuation is 0.5 dB/km. Determine the maximum link lengths for following cases and comment on the possible longest link length with proper justification. (Neglect all losses except the attenuation loss in the fiber)

i) A transmitter that operates at a wavelength of 1.55 µm, has a spectral width of 1 nm and an output power of 0.5 mW. Assume that the receiver requires −30 dBm of input power to achieve the desired bit error rate.

ii) A transmitter that operates at a wavelength of 1.3 µm, has a spectral width of 2 nm and an output power of 1 mW. Assume the same receiver as before.

[10.5 Marks]

Q3 a) Describe 3R-Regeneration in optical fiber communication systems.

[2.0 Marks]

b) i) State three types of optical amplifiers.

ii) Briefly explain the operation of Erbium doped fiber amplifier in optical networks.

[3.5 Marks]

c) An optical amplifier has a gain of 20 dB and a noise figure of 5 dB. Determine its Amplified Spontaneous Emission Power Spectral Density (ASE PSD) at 1550 nm and noise power passed through an optical band-pass filter of noise bandwidth of 0.4 nm.

Hint:

ASE-Power spectral density; $ASE-PSD = 2n_{sp}(G-1)hf$

ASE Noise Power; $P_n = 2n_{sp}(G-1)hfB_{opt}$

[3.0 Marks]

d) A transmitter launches a power of 2 dBm into an optical amplifier of gain 15 dB and noise figure 4 dB. This is then followed by a total fiber loss of 30 dB and finally a receiver with an optical filter with a bandwidth of 2 nm. Determine the following.

i) Optical Signal to Noise Ratio (OSNR) after the amplifier

ii) OSNR at the receiver input

[4.0 Marks]

Q4 a) State three loss mechanisms in optical fibers.

[1.5 Marks]

b) i) Sketch both attenuation (dB/km) and dispersion (ps/nm/km) characteristics of a silica fiber identifying the main wavelength regions.

ii) Explain the factors to choose 1550 nm window region for current Dense Wavelength Division Multiplexed (DWDM) systems.

[4.0 Marks]

c) Explain briefly, fiber dispersion and its impact on optical data transmission.

[3.0 Marks]

d) You are asked to design a 1550 nm laser for a 100 km DWDM fiber-optic link with a 50 GHz channel spacing and a data rate of 10 Gb/s per channel. If the fiber dispersion is 17 ps/(nm km), what is the maximum allowable spectral linewidth of your laser?

[4.0 Marks]