UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: August 2018

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

[Three Hours]

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

Notes:

- **Clearly mention any assumption you make.**
- **Use the following standard values for your calculations.**

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

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

Q1 a) State five advantages of using optical fibers in communication networks.

[1.5 Marks]

b) Briefly explain the concept of refractive index of the fiber and its dependent parameters.

[1 Mark]

c) A long-distance optical fiber link consists of three segments with two optical amplifiers (OA). At the end of each segment a dispersion shifted fibre (DSF) is spliced to compensate the pulse broadening due to dispersion. The parameters of the link are given in the following table.

Table Q1

Parameter	1st Segment (Tx-OA1)	2nd Segment (OA1-OA2)	3rd Segment (OA2-Rx)
Core refractive index (n_c)	1.48	1.51	1.51
Cladding refractive index (n_{cl})	1.46	1.48	1.45
Refractive index of outer gel (n_g)	1.525	1.53	1.515
Attenuation (dB/km)	0.25	0.3	0.22
Length (km)	100	80	120
Connector loss (dB)	0.5	0.35	0.4
Number of connectors	2	2	2
Splice loss (dB)	0.2	0.1	0.25
Number of splices	4	4	5
Dispersion parameter (D_{SM}) (ps/nm.km)	16	18	17
Transmit power (dBm)	2	-	-
Spectral width (nm)	1	-	-
Receiver sensitivity (dBm)	-	-	-38
OA1 gain (dB)	-	15	-
OA2 gain (dB)	-	20	-
DSF lengths (m)	420	250	650

i) Determine the numerical aperture of each segment of the fibre link.

[0.5 Marks]

ii) Calculate the acceptance angle of each segment of the fibre link.

[0.5 Marks]

iii) What is the total attenuation of the fiber link (neglecting DSF)?

[2 Marks]

iv) Determine the dispersion of each segment and the total dispersion of the link.

[2 Marks]

v) Calculate the dispersion parameter (D_{DSF}) of each dispersion fiber segment employed.

[3 Marks]

vi) Is the receiver capable of receiving the signal correctly? Briefly explain your answer.

[2 Marks]

Q2 a) State the two conditions that need to fulfill the stimulated emission?

[2 Marks]

b) Consider a material alloy $In_{(1-x)}\ Ga_x\ As_y\ P_{(1-y)}$ in general formula. The bandgap energy is given by,
$E_g = 1.35 - 0.72\ y + 0.12\ y^2$.
If x and y are 26% and 57% respectively, determine the

i) proportion of each element in the compound alloy.

[1 Mark]

ii) bandgap energy.

[1 Mark]

iii) peak emission wavelength.

[1.5 Marks]

c) A Fabry-Perot laser cavity has the following parameters. The refractive index of the cavity is 3.8. The facet power reflective coefficients are 90% and 40% respectively. The total cavity length is 250 μm and the field attenuation coefficient is 5 per cm. The laser is designed to emit 1550 nm peak wavelength.

i) Write down the general expression for the gain of the laser cavity and the free spectral range (FSR) of the laser.

[2 Marks]

ii) Calculate the gain required for the laser to exceed the threshold condition.

[2.5 Marks]

iii) Calculate the FSR of the laser.

[2.5 Marks]

Q3 a) What is meant by 3R-Regeneration in optical communication systems?

[1.5 Marks]

b) Mention four different types of optical amplifiers.

[1 Mark]

c) An erbium doped fiber amplifier is used to amplify a signal with following internal parameters. The gain of the amplifier is 10 dB. The peak wavelength of operation is 1550 nm and the inversion factor (n_{sp}) is 2. The considered optical bandwidth is 12.5 GHz in the link.

i) Calculate the power spectral density of the amplified spontaneous noise (ASE-PSD).

[3 Marks]

ii) Calculate the ASE power emitted by the amplifier.

[2 Marks]

d) An ultrahigh dense wavelength division multiplexed (UDWDM) long distance optical link is operated with multiple optical amplifiers (The optical amplifiers are placed equally spaced for separating fiber length segments of 120 km each with an attenuation co-efficient of 0.2 dB/km). There are two connectors at each fiber ends and 12 splices. The connector and splice losses are 0.5 dB and 0.15 dB respectively. The system is operated with 80 wavelengths and the noise figure of each amplifier is 5 dB. The output power of the link is 20 dBm.

i) If the required OSNR of the receiver is 15 dB, calculate the maximum number of amplifiers that can be employed in the link.

[2.5 Marks]

ii) What happens if there is no connector and splice losses in the link? Justify your answer with valid reasons.

[2.5 Marks]

ASE Noise Power;

$P_n = 2n_{sp}(G-1)hfB_{opt}$

OSNR of chain amplifier link;

OSNR (dB) $= P_{out} + 58 - 10\log(n) - 10\log(N+1) - L_{sp}$

Q4 a) Compare the direct and shared fiber architectures using illustrations.

[4 Marks]

b) Briefly explain the FTTx architectures using appropriate diagrams.

[4 Marks]

c) Draw a complete four wavelength add-drop multiplexer using circulators and fibre bragg gratings. Indicate the signal propagation directions in each component appropriately to illustrate the add and drop functions. Indicate all the important parameters.

[4.5 Marks]