UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: July 2016

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

[3 Hours]

[Answer all questions, each question carries 12.5 marks]

Notes:

- Clearly mention any assumption you make
- 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) Name three different fiber types according to their refractive index profile.

[1.5 Marks]

b) Explain the difference between meridional and skew ray paths in step index fibers using diagrams.

[2.0 Marks]

c) A step index fiber has a core radius of 62.5 μm and a cladding radius of 125 μm. The core and cladding refractive indices are 1.51 and 1.49 respectively. Determine the number of modes that it supports at 1550 nm wavelength.

[3.0 Marks]

d) A perfect cylindrical rod of glass has a refractive index n_c . It is immersed in a liquid with refractive index of n_w . Show that all the light incident on the rod facet is guided through the rod when $n_c^2 > 2n_w^2$

[3.0 Marks]

e) An optical fiber has a numerical aperture of 0.20 in air and a cladding refractive index of 1.59. Determine the followings.

i) The acceptance angle for the fiber in water which has a refractive index of 1.33

ii) The critical angle at the core-cladding interface

[3.0 Marks]

Q2 Figure Q2 shows a Fabry-Perot laser cavity and a propagation path of the photons. Suppose R_1, R_2 are the power reflection coefficients of the two mirrors/facets

a) Starting from the initial electrical field E_0, derive an expression to determine the roundtrip amplitude and phase for a laser photon field.

[5.0 Marks]

b) Using the equation in a), find the relations for the followings.

i) Modal Gain

ii) Longitudinal Mode Separation

[5.0 Marks]

c) A semiconductor laser is made with reflecting mirrors 200 μm apart. One mirror is perfectly reflecting, while the other one transmits 20% of the light falling on it. If the refractive index of the semiconductor is 3.0 and the laser wavelength is 500 nm, determine the separation of the Fabry-Perot resonances (longitudinal modes) in nm and eV.

[2.5 Marks]

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

[2.0 Marks]

b) i) Mention three types of optical amplifiers

ii) Briefly explain the operation of most widely used optical amplifier type in optical networks

[3.5 Marks]

c) An optical amplifier has a gain of 16 dB and a noise figure of 4 dB. Calculate 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 70 GHz.

[3.0 Marks]

d) A transmitter launches a power of 0 dBm into an optical amplifier of gain 20 dB and noise figure 5.5 dB. This is then followed by a total fiber loss of 40 dB and finally a receiver with an optical filter. Determine the followings.

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

ii) OSNR at the receiver

[4.0 Marks]

Q4 a) Illustrate the following concepts using appropriate diagrams.

i) Optical Absorption

ii) Spontaneous Emission

iii) Stimulated Emission

[4.5 Marks]

b) Consider a 0.8 μm receiver with a silicon PIN photodiode. Assume 20 MHz bandwidth, 65% quantum efficiency, 1 nA dark current, 8 pF junction capacitance and 3 dB amplifier noise figure. The receiver is illuminated with 5 μW of optical power. Determine the followings.

i) The RMS noise current due to shot noise for photo current

ii) The RMS noise current due to shot noise for dark current

iii) The RMS noise current due to thermal noise (assume 27 ^{0} C temperature)

iv) Signal to Noise Ratio (SNR) of the system

[8.0 Marks]

Thermal noise variance for a Photo diode receiver $\sigma_{Th}^2 = \frac{4k_B T F_n B_e}{R_L}$

Shot noise variance for a PIN diode $\sigma_{sh}^2 = 2qiB_e$

Signal to Noise Ratio (SNR) $SNR = \frac{\left(i_p^2\right)}{\sum \sigma_x^2}$

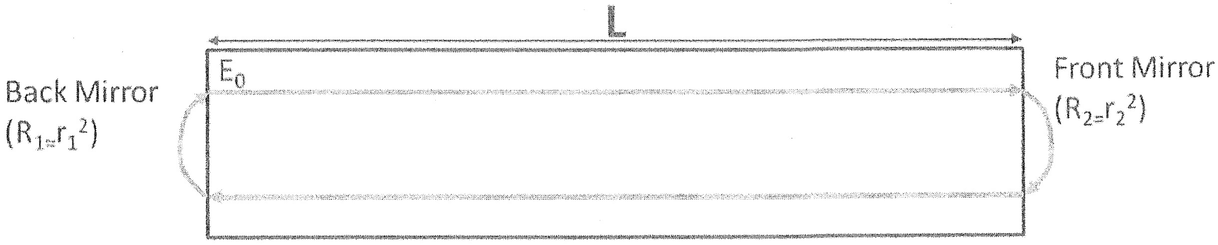

Figure Q2: Fabry-Perot laser cavity