BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS

II SEMESTER 2011 – 12 **COMPREHENSIVE EXAMINATION** **3 June 2012**

Total Marks : 80 Weightage: 40% Time Allowed: 3 hours

INSTRUCTIONS: This paper contains **NINE (9)** questions and comprises **THREE (3)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings. Assume suitable value for any constant not mentioned.

Q1. Light of wavelength λ passes through a symmetric SI planar waveguide of guide thickness 2a and whose core and cladding refractive indices are given by n_1 = 1.495 and n_2 = 1.48 respectively. For symmetric modes of propagation, the electric field is expressed by

$$E_y(x) = A\cos(ux), \ |x| < a$$
$$= C.\exp(-w|x|), \ |x| > a$$

(a) Derive an expression for the normalized frequency parameter V in terms of 2a, λ and NA, where NA is the numerical aperture. Show that for a symmetric mode to propagate with a specific value of u and w, the frequency parameter V is also given by V = (ua).sec(ua)

(b) What is the maximum thickness of the guide that will support only the first three modes at λ = 1.31 μm? If the wavelength is increased by 18.3 %, by how much percentage should the cladding refractive index be increased or decreased under limiting conditions so that only the fundamental mode is just supported.

(c) If the rectangular planar waveguide is replaced by a cylindrical fibre, what will be the maximum diameter of the core needed to support only the modes LP_{01} and LP_{11} at λ = 1.31 μm?

(d) The core of the cylindrical fibre as described in (c) above has a refractive index n(r) that is increasing linearly from n_2 at the edge of the core to n_1 at the central axis. If the fibre is to support only the fundamental mode, what should be the diameter of the core?

(20 marks)

Q2: A Corning step index cylindrical fiber has the following characteristics. The fiber has been designed with maximum possible core diameter for single mode characteristics at a wavelength of 1.31 μm.

Corning Fiber	Fiber Type	Core Diameter (μm)	Cladding Diameter (μm)	Attenuation (dB/km)		Mode Field Diameter (MFD) (μm)	
				@1.31μm	@1.55μm	@1.31μm	@1.55μm
SMF-xxx	Standard Single Mode Fiber	Not available	125	0.35	0.20	10.4	Not available

(a) Determine the core diameter and the numerical aperture of the fiber.
(b) If the fiber is operated at 1.55 μm, determine the mode field diameter.
(c) Does the fiber have single mode characteristics at 1.55μm? Explain.

(8 marks)

Q3. A light source at 1.33 μm is guided through a rectangular guide having $n_1 = 1.49$, $n_2 = 1.45$ with a propagation that supports only a single mode such that ua = 2wa.

(a) What is the thickness of the guide?

(b) Determine the power confinement factor G for the mode. How will you increase G? Explain.

(c) When the above designed guide is operated at a lower wavelength λ_l, it is found to guide 3 modes. Determine λ_l.

(10 marks)

Q4. The bandgap of InAs is 0.36 eV and that of GaAs is 1.43 eV. A ternary compound semiconductor $In_{1-x} Ga_x As$ is used as the active layer for an LED source, where x is the mole fraction. It is observed that the LED source operates at 1.5 μm. To prepare for the active layer, how many grams of InAs is required to be mixed with 100 grams of GaAs?

(5 marks)

Q5. Draw the electric field distribution in both the core and cladding layers for a mode represented by m = 6 in a planar waveguide.

(5 marks)

Q6. A typical fiber-optic communication link is shown in Figure 1. The fibers between stations *A* & *B*, *B* & *C* and *C* & *D* have the following characteristics:

	Fiber between A&B	Fiber between B&C	Fiber between C&D
Numerical aperture	0.19	0.17	0.19
Fiber type/ value of α	Graded Index / 2.0	Graded Index / 1.9	Graded Index / 2.0
Total attenuation	0.1 dB / km	0.12 dB / km	0.1 dB / km
Length	35 km	30 km	40 km

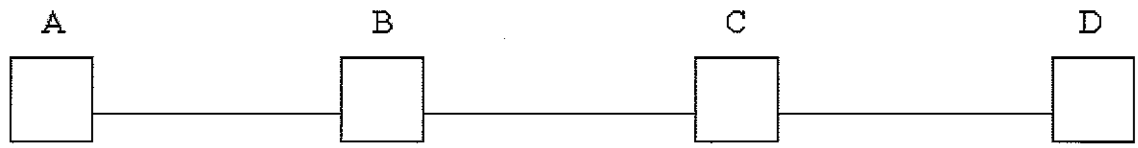

Figure 1

All fibers require splicing after every 25 km of length. The splice loss at each splice is 0.2 dB. In addition, the fibers are spliced at stations B and C. The splice losses at B and C are 0.1 dB each. The link has two couplers (one each at stations *A* and *D*), each giving a loss of 0.5 dB. A safety margin of 5 dB is desired. Fresnel reflection losses may be assumed negligible.

(a) Calculate the minimum optical power that must be detected by the receivers for signal recovery on the two sides for a duplex link (i.e., for two-way communication) if the transmitters on either have a power of 0.15 mW.

(b) Assume that the receivers and transmitters along with their associated circuits have rise times of 10 ns and 12 ns respectively. The intermodal dispersion in all the fibers is almost negligible. The sources used in the transmitters have a spectral half-width of 20 nm centered around a peak at 850 nm. The material dispersion parameter for all fibers is 0.6 ps km^{-1} nm^{-1}. Calculate the maximum bit rate at which the system can be operated using NRZ format.

(12 marks)

Q7. The power, P(t), in a pulse received at the end of a fiber optic cable, is triangular, centered around t = 0 with a FWHM of τ and a peak power of P_o at t=0. Calculate: (a) the total energy in the pulse, (b) mean pulse arrival time, and (c) the rms pulse width

(10 marks)

Q8. Explain the principle of operation of a PHASAR based demultiplexer. It is required to design a demultiplexer for 32 channels spaced at 50 GHz with a central wavelength of 1.55μm. Calculate the spectral range.

(5 marks)

Q9. For a Pockel's longitudinal electro optic modulator, the normalized transmitted intensity is expressed as

$$\frac{I}{I_0} = \sin^2\left(\frac{\pi}{2}\frac{V}{V_\pi}\right)$$

Show mathematically, that by adding a quarter wave plate, the normalized transmitted intensity becomes a linear function of V for $V << V_\pi$

(5 marks)

PHYSICAL CONSTANTS

Use the following data wherever applicable:
Plank's constant, h = 6.624 x 10^{-34} J.s
Speed of light, c = 3 x 10^8 m/s
Atomic wt. of (i) Ga = 69.72 (ii) As = 74.92 (iii) In = 114.82

End of Paper

BITS, PILANI – DUBAI CAMPUS
SECOND SEMESTER 2011 – 2012 YEAR IV ELECTIVE
TEST – 2 OPEN BOOK

Course Code: EA C422 Date: 18.04.12
Course Title: Fiber Optics and Optoelectronics Max Marks: 40
Duration : 50 minutes Weightage: 20%

INSTRUCTIONS: Answer ALL questions. All symbols have their usual significance

1. For a p^+-n GaAs diode the electron mobility is 8500 $cm^2.V^{-1}s^{-1}$ and the hole mobility is 400 $cm^2.V^{-1}s^{-1}$. The diffusion lengths of electrons and holes are assumed equal. The thermal equilibrium electron concentration in the p^+ side at 300 K is 9.7×10^{-4} cm^{-3}. The intrinsic carrier concentration in GaAs at 300K is 2.2×10^{6} cm^{-3}.

   (i) The injection efficiency is found to be 80%. Determine the donor concentration for the diode.

   (ii) For GaAs, the effective mass of electrons and holes are given by $0.07*m_0$ and $0.56*m_0$ respectively where m_0 is the free electron mass = 9.11×10^{-31} kg. How would you estimate the bandgap of GaAs from the above given data ?

   (iii) If the acceptor concentration is doubled, by how much % will the injection efficiency change, compared to (i) above.

(12 marks)

2. What are direct bandgap and indirect band gap semiconductors? Give two examples of each. An LED is to be used as an optoelectronic source. Compare the advantages of using a ternary layer as the active layer for the DH LED. What advantage does the quaternary layer provide over the ternary material?

(8 marks)

3. A step index fiber operates at a wavelength of 1.55 μm. The core refractive index is 1.46 and the relative refractive index difference is 1%. The diameter of the core needed to make the total dispersion zero is found to be 10 μm. Determine the amount of material dispersion contributed by the fiber at the operating wavelength. Assume suitable empirical approximation for the contribution due to waveguide dispersion.

(8 marks)

4. Describe the modified CVD method for the fabrication of silica fibers. What is the main limitation of this method and how it can be overcome?

(4 marks)

5. Two identical step index fibers with core and cladding refractive indices of 1.5 and 1.48 respectively and a core diameter of 10 μm when joined together are perfectly aligned except for a small gap between the ends. The total loss efficiency at the joint (expressed as a ratio) with the joint placed in air is 99.97% of the total loss efficiency when the joint is placed in water. Determine the amount of gap between the joined ends and the overall loss efficiency with the joint placed in water.

(8 marks)

END OF PAPER

BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS

II SEMESTER 2011 – 12 **TEST 1** **29 Feb 2012**

Total Marks : 25 Weightage: 25% Time Allowed: 50 mins

INSTRUCTIONS: Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings. Assume suitable value for any constant not mentioned.

Q1.(a) A step index rectangular waveguide is shown in Figure 1. The critical angle at the core cladding interface is found to be 8.4 times the maximum value of the angle θ_{in} for light to be guided through the core. The numerical aperture for the waveguide is 0.1723. Using the ray propagation model, determine the refractive indices n_1 and n_2 of the core and cladding layers

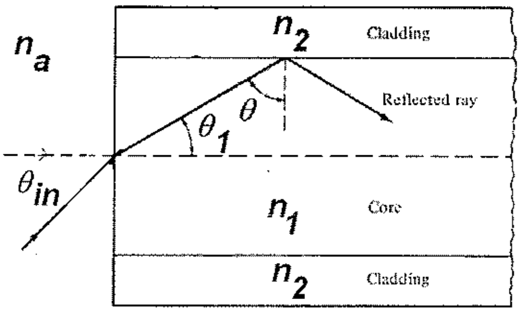

Figure 1 [4 marks]

(b) The rectangular guide described in Question Q1(a) is designed to guide a single mode light source at 1.33 μm such that ua = 2wa. Determine the frequency parameter, V .What is the thickness of the guide?

[4 marks]

(c) Determine the power confinement factor for the mode. How would you increase the power confinement in the core?

(3 marks)

(d) The designed guide is capable of accepting light with propagation constants ranging from a maximum β_1 to a minimum β_2.
Determine the normalized propagation constant $b = [\beta^2 - \beta_2^2] / [\beta_1^2 - \beta_2^2]$ corresponding to the mode that is propagating.

(3 marks)

Q2. Draw the electric field distribution in both the core and cladding layers for a TE mode represented by m = 5 in a planar waveguide. Label all relevant axes and explain the nature of distribution in different regions

[5 marks]

Q3. In an optical fiber, the received power, P(t) is a symmetrical Gaussian given by

$$P(t) = P_o \exp[-t^2/\tau]$$

Draw the Power distribution for all values of t from $-\infty$ to $+\infty$. Determine the full width half maximum ΔT for the above distribution. Hence derive expressions for the total energy in the pulse..

[6 marks]

End of Paper

NAME: ID NO.: SET B

BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS - Quiz 2

Sem2, 2011 2012 CLOSED BOOK Time Allowed: 20 mins
Total Marks : 14 Weightage: 7%

INSTRUCTIONS

1. This paper contains **THREE (3)** questions and comprises **TWO (2)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

Q1 A p-n diode generates two electron-hole pairs out of every 3 incident photons corresponding to a wavelength of 0.9 μm. The response of a photodiode is in the form of a photocurrent I_p for an incident optical power P_{in}. Define Responsivity of the diode . For an input optical power of 10 μW, what is the generated photocurrent?

[5 marks]

Q2. What is meant by quarter wave plate? A thin slab of electro optic crystal of thickness 2 mm is used as a quarter wave plate for a plane polarized beam of wavelength 590 nm. If the refractive index for the ordinary ray is 1.545 determine the refractive index for the extraordinary ray.

(4 marks)

Q3. Draw a schematic of a longitudinal electro optic amplitude modulator. Write down the equation that describes the relative intensity (I/I_o) in terms of the relative applied voltage (V/V_π), where V_π is the voltage required for maximum transmission ($I = I_o$). show that the intensity I varies as the square of the applied voltage V, for all values of $V << V_\pi$.

(5 marks)

The End

NAME: ID NO.

BITS PILANI DUBAI CAMPUS

EA C422 – FIBER OPTICS AND OPTOELECTRONICS – QUIZ1

Sem1, 2011 - 2012 CLOSED BOOK Time Allowed: 20 mins

Total Marks : 16 Weightage: 8%

INSTRUCTIONS: This paper contains **Three** questions. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings. Make appropriate assumptions wherever applicable

Q1. A typical step index fiber has a mode field radius of 4.7 μm and a normalized frequency parameter of 2.00 for a wavelength of propagation 1.3 μm. Determine the Peterman radius. If the relative refractive index difference is 0.5% determine the refractive index of the core and cladding. [6M]

Q2. An under-sea fiber developed a split at some point along the length of the fiber. It was tested on site for the Fresnel loss at the split and the loss efficiency was found to be 0.47 dB. The same damaged fiber was tested in a laboratory and the Fresnel loss efficiency was found to be 0.09 dB. Determine the refractive index of the sea water where the cable was originally laid.

(4 marks)

NAME: ID NO.

Q3. A step index single mode fiber has a core index of 1.5, relative refractive index difference of 0.5%, core diameter of 8 μm. At what wavelength of propagation is the waveguide dispersion parameter D_w smallest in magnitude? Determine this value of D_w. If the wavelength is changed to 1.55 μm, determine the waveguide dispersion at this wavelength. If the total dispersion is zero at this wavelength, determine the zero material dispersion wavelength.

(6 marks)