BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS

I SEMESTER 2011 – 12 **COMPREHENSIVE EXAMINATION** **2 Jan 2012**

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

INSTRUCTIONS: This paper contains **ELEVEN (11)** 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: A Corning single mode step index cylindrical fiber has the following characteristics. The fiber has been designed to provide maximum possible core diameter at a wavelength of 1.55 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	Not available	10.4

(a) Determine the core diameter, if the numerical aperture of the fiber is 0.15.
(b) Based on suitable approximations, determine the mode field diameter if the fiber is operated at 1.31 μm.
(c) Does the fiber have single mode characteristics at 1.31μm? Explain.

[10 marks]

Q2. In a step index rectangular waveguide shown in Figure 1, the refractive index of the cladding is 1.48 while that of the core is unknown. The maximum value of the angle θ_{in} for light to be guided through the core is found to be twice the corresponding θ_1. Using the ray propagation model, determine the numerical aperture (NA) for the guide and the refractive index n_1 of the core. Also determine the maximum possible value of the angles θ_{in}, θ_1 and θ.

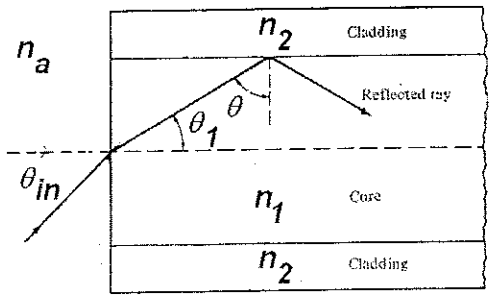

Figure 1

[8 marks]

Q3. A typical fiber-optic communication link is shown in Figure 2. 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	25 km	30 km	40 km

All fibers require splicing after every 20 km of length. The splice loss at each splice is 0.2 dB. In addition, the fibers are spliced at stations B and C. There is no splice loss at B and C. The link has two couplers (one each at stations *A* and *D*), each giving a loss of 0.5 dB. A safety margin of 8 dB is desired. Fresnel reflection losses may be assumed negligible.

(a) Calculate the minimum optical power that must be launched by the transmitters on the two sides for a duplex link (i.e., for two-way communication) if the receivers on either side require a minimum of 0.7 μW for signal recovery.

(b) Assume that the receivers and transmitters have rise times of 10 ns and 12 ns. The multipath time dispersion in all the fibers is almost negligible. The sources used in the transmitters have a spectral half-width of 20 nm. The material dispersion parameter for all fibers is 80 ps km^{-1} nm^{-1}. Calculate the maximum bit rate at which the system can be operated using NRZ format.

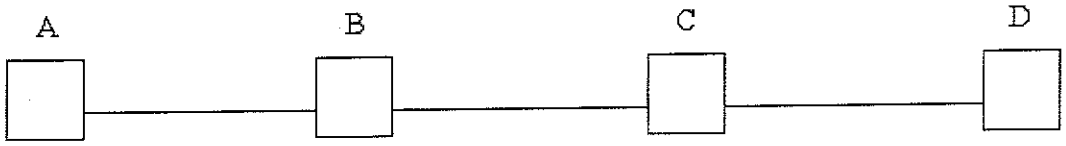

Figure 2 **[12 marks]**

Q4. A graded index optical fiber (Fiber A) with core dia 75 μm, cladding dia 125 μm and profile parameter of 2.1 is joined with another GI fiber (Fiber B) with core dia 70 μm, cladding dia 125 μm and unknown profile parameter α_2. The NA of the fibers A and B are 0.26 and 0.21 respectively.. The fiber axes are perfectly aligned and there is no air gap. If the total insertion loss for transmission in the forward direction (A to B) is 3 dB, calculate the profile parameter α_2. What is the insertion loss in the backward direction?

[8 marks]

Q5: A single mode rectangular guide has $n_1 = 1.48$, $n_2 = 1.46$ and is designed to guide a light source at 1.55 μm such that ua = 2wa.

Determine the frequency parameter, V .What is the thickness of the guide?

[6 marks]

Q6. Draw the electric field distribution in both the core and cladding layers for a mode represented by m = 5 in a planar waveguide.

[6 marks]

Q7. An impulse is launched into an optical fiber. The power, P(t), in the received pulse varies with time, t, according to the following relation:

$$P(t) = P_0 \exp(-t/\tau_e); \qquad 0 < t < \infty$$

Calculate : (a) The total energy in the pulse
(b) Mean pulse arrival time
(c) Rms pulse width.

[8 marks]

Q8. A p-n photodiode has on an average, generates three electron-hole pairs per five incident photons at a cut off wavelength of 1550 nm. Calculate the diode responsivity and the input optical power required to achieve a photocurrent of 5 μA.

[4 marks]

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

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

Draw a schematic of the modified Pockel's electro optic modulator such that the transmittance response with applied voltage can be made linear, for $V << V_\pi$

[8 marks]

Q10. What advantages do heterostructure p-n junction LED devices have over normal homojunction p-n structures? Draw the band diagram of a double heterostructure LED under forward bias.

[5 marks]

Q11. It is desired to use a ternary compound semiconductor In_{1-x} Ga_x As as a material for an LED source, where x is the mole fraction. It is given that the bandgap of InAs is 0.36 eV and that of GaAs is 1.43 eV. The LED source is expected to operate at 1.55 μm. Determine the mole fraction x needed for the ternary compound. To obtain the compound, how many grams of GaAs is required to be mixed with 100 grams of InAs?

[5 marks]

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

End of Paper

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

Sem1, 2011 2012 | OPEN BOOK | Time Allowed: 50 mins
Total Marks : 40 | Weightage: 20%

INSTRUCTIONS: Answer **ALL** questions. All symbols have their usual meanings.

Q1. A cylindrical fiber has a cladding refractive index n_C. The core refractive index is linearly graded with a maximum value n_o at the center of the core. The radius of the core is a.

(a) Write down the expression for the numerical aperture $NA(r)$ of the fiber as a function of the radial distance r.

(b) Using a thin annular strip of radius r and width dr inside the core, determine the area dA of the strip and hence show that the rms value of the numerical aperture $NA(r)$ of the fiber averaged over the core area is given by

$$NA_{rms} = \sqrt{\frac{n_o^2 - n_c^2}{3}}$$

(c) If the core diameter is 50 μm, $n_o = 1.47$, $n_c = 1.45$ and the operating source wavelength is 1.55 μm, use the expression for the rms value of the numerical aperture as given above to calculate the total number of propagating modes in the fiber.

(10 marks)

Q2. A step index single mode fiber has a core diameter of 7.1 μm, core refractive index of 1.45 and a relative refractive index difference of 0.5 %. Use the Marcuse empirical approximation to evaluate the waveguide dispersion parameter D_w at two operating wavelengths (i) $\lambda = 1.33$ μm and (ii) $\lambda = 1.55$ μm. the fiber is designed to have a zero total dispersion at $\lambda = 1.55$ μm. Determine the wavelength at which the material dispersion parameter D_m is zero.

(10 marks)

Q3. A fusion splice is made between two identical multimode fibers having core refractive index n_1 and cladding refractive index n_2. After splicing, an extremely small air gap remained between the core ends. The coupling efficiency X due to the splicing was found to be 0.92. Determine the refractive index of the core. Show that if the core refractive index decreases by a very small amount, say, y%, the coupling efficiency increases by 0.4y%. Hence determine the core refractive index needed to achieve a coupling efficiency of 0.95.

(10 marks)

Q4. The bandgap of InAs is 0.36 eV and that of GaAs is 1.43 eV. A ternary compound semiconductor $In_xGa_{1-x}As$ is formed by mixing x part of InAs with (1-x) part of GaAs where x has a value between 0 and 1. Assume that the band gap of $In_xGa_{1-x}As$ can be obtained by a linear interpolation between the limits x = 0 and x = 1. Determine the exact composition of the $In_xGa_{1-x}As$ material that would enable it to be used as an optoelectronic source emitting light at 1300 nm. To obtain the ternary compound, how many grams of InAs is needed to be mixed with 100 grams of GaAs? Given: At. wts. of Ga = 69.72, As = 74.92, In = 114.82. Plank's constant h = 6.624 x 10^{-34} J.s, speed of light c = 3 x 10^8 m/s

(10 marks)

BITS PILANI, DUBAI CAMPUS

FIRST SEMESTER 2011 – 2012

TEST – 1 CLOSED BOOK YEAR IV ELECTIVE

Course Code: EA C422
Course Title: Fiber Optics and Optoelectronics
Duration : 50 minutes

Date: 25.09.11
Max Marks: 50
Weightage: 25%

Instructions: (if any): Answer ALL Questions.

1) (i) The speed of light in vacuum and in the core of a SI fiber is given by $3x10^8$ m/s and $2x10^8$ m/s respectively. The critical angle at the core cladding interface is 78°. Calculate the pulse broadening per unit length, D_1 due to multipath time dispersion of the fiber. Derive any necessary equation for D_1. [10 marks]

(ii) A graded index fiber of length 100 km has an LED source at its input end. The LED emits at 850 nm with a spectral spread of 30 nm. The material dispersion parameter D_m of the fiber at the source emission wavelength is 100 $ps.nm^{-1}km^{-1}$. Calculate the total pulse broadening due to material dispersion. [6 marks]

2) A light pulse has a power distribution p(t) as a function of time t, as shown in Figure 1. The FWHM of the pulse is τ.

(a) Write down the expressions for p(t) in the range $-\Delta T/2 < t \leq 0$ and $0 < t \leq \Delta T/2$.
(b) Show that the energy associated with the pulse is $p_o.\tau$.
(c) Determine the rms pulse width σ

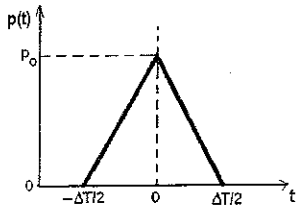

Figure 1

[15 marks]

3) A cylindrical graded index fiber has a core refractive index profile $n_1(r)$ which is parabolic with a maximum value of n_o along the core axis. The cladding layer has a uniform refractive index n_2. The radius of the core is 'a' and the thickness of the cladding layer is $(b-a)$.

(i) Sketch the refractive index of the fiber as a function of radial distance on either side of the core axis. Assume that there is no discontinuity of the index at the core – cladding interface.

(ii) Express $n(r)$ as a function of r for all values of r from $-a$ to a.

(iii) Hence determine the numerical aperture NA of the fiber in terms of n_o, r, a and the relative refractive index difference Δ. Show that NA is maximum along the core axis and zero at the core – cladding interface.

(10 marks)

4) A planar waveguide of thickness 10 μm and index n_1 is sandwiched between two cladding layers of refractive index $n_2 < n_1$. Two light sources are available for transmission through the waveguide: (i) Source A corresponding to 1.56 μm and (ii) Source B corresponding to 1.3 μm. It is observed that the maximum number of guided TE modes increases by 1 when the source is changed from A to B. Determine the numerical aperture of the fiber. What would be the maximum number of guided modes if a source of wavelength 0.975 μm is used?

(9 marks)

End of Paper

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

SET A

Sem1, 2011 2012 | CLOSED BOOK | Time Allowed: 20 mins
Total Marks : 14 | Weightage: 7%

INSTRUCTIONS: Answer **ALL** questions. All symbols have their usual meanings.

Q1. A p-n photodiode detector on the average generates two e-h pairs for every three incident photons at an operating wavelength of 1.0 μm. Determine the maximum possible bandgap of the semiconductor that can be used for this purpose. Determine the photocurrent produced in response to an incident optical power of 10 μW

(4 marks)

Q2. Draw a schematic of a Reach-through Avalanche Photo Diode (RAPD) detector circuit and indicate the electric field variation across various regions of the device.

(3 marks)

Q3. A calcite half plate of thickness 0.002 mm is used for a certain light source. The ordinary and extra-ordinary ray refractive indices for calcite are 1.658 and 1.486 respectively. Determine the wavelength of the source used.

(3 marks)

Q4. Briefly explain the principle of a PHASAR – based demultiplexer. A PHASAR-based demultiplexer with 32 channels spaced at 50 GHz and a central wavelength of 1.55 μm is to be designed. Calculate the Free Spectral range and the required order for the arrayed waveguide. If the group index is 1.45, determine the optical path difference ΔL of the adjacent arrayed waveguides

(4 marks)

BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS – Quiz 1

Sem1, 2011 2012 | CLOSED BOOK | Time Allowed: 20 mins
Total Marks : 16 | Weightage: 8%

INSTRUCTIONS: Answer **ALL** questions. All symbols have their usual meanings.

Q1. Draw the electric field distribution for a mode m = 4 of a rectangular SI planar waveguide, with a guide thickness of $2a$. Clearly label all axes and mark the points corresponding to a and $-a$. Determine the nature of distribution inside and outside the core layer. If the numerical aperture of the guide is $(1/\pi)$, what should be the minimum value of the guide thickness for a source wavelength of 1 μm?

(3 marks)

Q2. Two cylindrical fibers A & B of identical dimensions are given. In A, the core has a uniform index n_o while in B, it has a graded index with a maximum value n_o along the core axis.

For a given source wavelength λ, it is observed that the maximum number of guided modes in A is 6 more than in B.

If the source wavelength in A is unchanged but that in B is reduced to 0.5773 λ, the maximum number of guided modes become same in both fibers.

Determine the nature of the graded index in fiber B. If $2a$ = 50 μm, NA of the SI fiber = 0.25, calculate the wavelength λ of the source used.

(6 marks)

Q3. A parabolic graded index fiber supports 500 guided modes. The fiber has a relative refractive index difference of 2%, core dia of 50 μm. If the core refractive index is 1.48, determine the operating wavelength.

(3 marks)

Q4. Plot the normalized propagation constant b as a function of normalized frequency parameter V, in a SI cylindrical fiber for various modes LP_{lm} where l = 0,1,2,... and m = 1,2,3,...

Explain the significance of the plots.

(4 marks)

Q1