BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS

I SEMESTER 2010 – 11 **COMPREHENSIVE EXAMINATION** **27 Dec 2010**

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

INSTRUCTIONS This paper contains **TEN (10)** questions and comprises **TWO (2)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

Q1 A symmetric step index planar waveguide is formed by sandwiching a 8 μm thick core layer of refractive index 1.49 between two cladding layers of refractive index 1.46. Incident wavelength is 1.33 μm. Determine the normalized frequency parameter, V. How many TE modes can this guide support? What should be the maximum thickness of the guide layer so that it can support only the fundamental TE mode. Without changing the thickness of the guide layer, is it possible to restrict the propagation to only the fundamental mode? If so how?

[10 marks]

Q2: Two compatible multimode step index fibers are joined together with a connector. At the joint, there is a lateral offset of 2 μm and an angular misalignment of core axes of 1°. The joint also has a certain end separation with an air gap in between. The total insertion loss was found to be 1 dB. Considering all the possible losses, determine the thickness of the air gap at the joint. The core of each fiber has a refractive index of 1.5, a diameter of 100 μm and a relative refractive index difference of 2%.

(8 marks)

Q3. Define injection efficiency of a p-n junction diode. For a GaAs p-n diode, $N_a = 5 \times 10^{16}$ cm^{-3}, $N_d = 5 \times 10^{15}$ cm^{-3} and is at room temperature. The injection efficiency is found to be 0.8. Assume that the minority carrier diffusion length for electrons is twice that for holes. How are the mobilities of electrons and holes related to each other? If the mobilities are independent of temperature, is the injection efficiency affected by temperature? How should the above parameters be adjusted so as to make the efficiency maximum?

(8 marks)

Q4. In an optical fiber, the received power, P(t) is a symmetrical triangular pulse with a peak value of P_0 corresponding to $t = 0$ and a full width half maximum of τ. Express P(t) as a function of t for all values of t from $-\infty$ to $+\infty$. Hence derive expressions for the total energy in the pulse and the rms pulse width. Determine the total energy in the pulse if the rms pulse width is 0.5 μs and P_0 is 1 μW.

(8 marks)

Q5. Differentiate between a p-n photo diode and a p-i-n photo diode. What is the purpose of the intrinsic layer in the p-i-n structure. A p-n photo diode requires 4 μW of input optical power to achieve a photocurrent of 3μA. If the quantum efficiency of the photodiode is 75%, determine the photon energy and the corresponding wavelength at which the diode is operating.

(8 marks)

Q6: An APD has a quantum efficiency of 60% at 1.33 μm. When illuminated with optical power of 0.3 μW at this wavelength, it produces an output photocurrent of 10 μA, after avalanche gain. Calculate the multiplication factor of the diode.

(4 marks)

Q7. A graded index optical fiber (A) with core diameter 70 μm, cladding diameter 125 μm and profile parameter of 1.9 is joined with another GI fiber (B) with unknown core diameter and profile parameter α_2. The NA of the fibers A and B are 0.25 and 0.21 respectively. The fiber axes are perfectly aligned and there is no air gap. The total insertion loss for transmission in the forward (A to B) and reverse (B to A) directions are 2.16 dB and 0.1 dB respectively. Calculate the core diameter and profile parameter α_2 of fiber B. Assume $\alpha_2 > 1.9$.

(8 marks)

Q8: Calculate the change in the refractive index due to longitudinal electro-optic effect for a 5 mm long crystal of lithium niobate for an applied voltage of 40 V. If the wavelength of light propagating through the crystal is 550 nm, calculate the net phase shift between the two polarization components after they emerge from the crystal. For lithium niobate, $n_o = 2.29$, $n_e = 2.20$ and the relevant electro-optic coefficient, $r = 3.08\times10^{-11}$ m/V. Also calculate V_π.

(8 marks)

Q9. Differentiate between longitudinal and transverse electro optic modulators and highlight any advantages or disadvantages in each. Briefly describe the function of a Pockel's longitudinal electro optic modulator. Express the normalized transmitted intensity (I/I_o) as a function of the applied voltage V. What drawbacks would the response of this modulator have, and how such drawbacks can be overcome? Show that the transmittance response with applied voltage can be made linear, for $V << V_\pi$, where V_π is the voltage that produces maximum transmittance.

(10 marks)

Q10. Consider the design of a fiber optic link of length 25 km that has splices after every 5 km length of fiber. The fiber cable has the following specifications: cable loss $\alpha_f = 1.6$ dB/km, $(\Delta T)_{intramodal} = 4$ ns/km, $(\Delta T)_{intermodal} = 1.5$ ns/km. The loss at each splicing is 0.4 dB. In addition there are losses of 1.5 dB each at each of the two connectors, one at the transmitting end and another at the receiving end. The transmitter and the receiver systems have rise times of 15 ns and 13 ns respectively. The photodetector can detect a minimum optical power of 25 nW. (a) If the optical source couples an average of 1.8 mW of power at the transmitting end, what safety margin has been maintained in the link that can overcome any unforeseen additional losses? (b) What is the maximum data transmission rate possible, using the RZ code?

(8 marks)

End of Paper

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

Sem1, 2010 - 2011 | OPEN BOOK | Time Allowed: 50 mins
Total Marks : 40 | Weightage: 20%

INSTRUCTIONS

1. This paper contains **SIX (6)** questions. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings. Make appropriate assumptions wherever applicable

Q1. Draw the electron energy (E) vs momentum (k) diagram for GaAs and Si. State the advantages and disadvantages of both materials in respect of being used as an optoelectronic device. Give reasons for your statement using the E-k diagram. **(5 marks)**

Q2 The bandgap of AlAs is 2.16 eV and that of GaAs is 1.43 eV. A ternary compound semiconductor $Al_xGa_{1-x}As$ is formed by alloying *A* grams of AlAs with *B* grams of GaAs It is required to fabricate a red LED operating at 700 nm using the ternary alloy. Determine the exact composition of the $Al_xGa_{1-x}As$ material needed and suggest any possible values for A and B. If the LED was fabricated using GaAs as the substrate and $Al_xGa_{1-x}As$ as the active layer, will there be any lattice imperfections at the junction interface? Give reasons. Given: Atomic weights of Ga, Al and As are 70, 27 and 75 grams / mole respectively. Lattice constant of GaAs = 5.65 Å and that of AlAs = 5.66 Å **(8 marks)**

Q3. A step index single mode fiber has a core index of 1.49 and relative refractive index difference of 0.1% and a core radius of 4.7 μm. Estimate the waveguide dispersion for the fiber at λ = 1.55 μm. What should be the zero dispersion wavelength λ_{ZD} for the core material so that the total dispersion is zero corresponding to λ = 1.55 μm? **(8 marks)**

Q4. A 60/120 μm graded index fiber with a numerical aperture of 0.23 and a profile parameter of 1.7 is joined to a 55/120 μm graded index fiber with a numerical aperture of 0.2 and a profile parameter of 2.3. At the joint, there is a lateral offset of 10% of the average core diameter. There are no other misalignments. Calculate the overall insertion loss at the joint in both the forward and backward directions. **(8 marks)**

Q5 A certain photodiode provides an output photocurrent of 1.5 μA for an input optical power of 4 μW at a wavelength of 1.33 μm. If 4×10^{10} photons at a wavelength of 1.33 μm are incident on the photodiode per second, at what rate are the electrons collected at the detector terminals? **(4 marks)**

Q6. A double heterostructure laser diode has a cavity length of 0.6 mm and an effective loss coefficient of 2.0 mm^{-1} and an optical confinement factor of 0.75. Determine the threshold gain coefficient for the laser if the reflectivities of the end facets are 0.55 each. By how much would the threshold gain coefficient increase or decrease if the facets are provided with mirror coatings that increase the reflectivities by 50%. What must be done to increase the optical confinement factor? What practical difficulties one would face in this regard?

(7 marks)

End of Paper

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

Sem1 2010 - 2011 CLOSED BOOK Time Allowed: 50 mins
Total Marks : 50 Weightage: 25%

INSTRUCTIONS

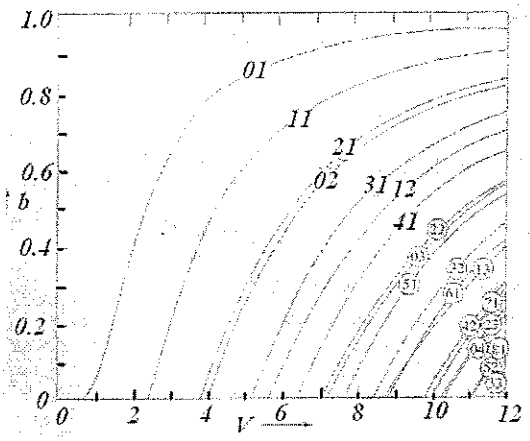
1. This paper contains **SIX (6)** questions and comprises **TWO (2)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

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) @1.55μm	Refractive index	
					core	cladding
SMF-xx	Standard Single Mode Fiber	Not provided	125	0.28	1.5	1.49

(a) If the fiber is operated at 1.31 μm, what modes are supported? Determine the normalized propagation constant b for all the modes that are supported by the fiber.

(b) Assuming that air is the medium through which light source is incident on the fiber, determine (i) the multipath time dispersion and (ii) the maximum number of reflections per unit length of the fiber for rays guided by it. Derive any necessary equations.



(12 marks)

Q2. The power p(t) of a light source as a function of time t, is found to be Gaussian, centered around t = 0 with a peak value of p_o. The FWHM of the pulse is $2\sqrt{\ln 2}$.

(a) Write down the expressions for p(t) in the range $-\infty < t \leq \infty$
(b) Calculate that the energy associated with the pulse.
(c) The abovementioned source is coupled to a switch that allowed light to pass through it only during the time interval $0 \leq t < 0.5$. Calculate the total energy contained in such a pulse. Given: erf (0.5) = 0.52

(8 marks)

Q3 Differentiate between phase velocity and group velocity. Show that the material dispersion parameter D_m of optical fibers can be expressed as

$$|D_m| = \frac{\lambda}{c}\left|\frac{d^2 n}{d\lambda^2}\right|$$

(8 marks)

Q4. Draw the electric field distributions in the core and cladding regions of a rectangular waveguide for mode numbers corresponding to m = 3 and 4. Label all axes.

(4 marks)

Q5. Design a planar rectangular optical waveguide so as to have a maximum guide thickness to allow three modes of propagation at wavelength $\lambda = 1.55$ μm. The critical angle for the guide – cladding interface is 80.3°. The guide refractive index is 1.49. Determine the normalized propagation constant b for the three modes. For what wavelength of the incident source does the waveguide allow single mode of propagation?

(10 marks)

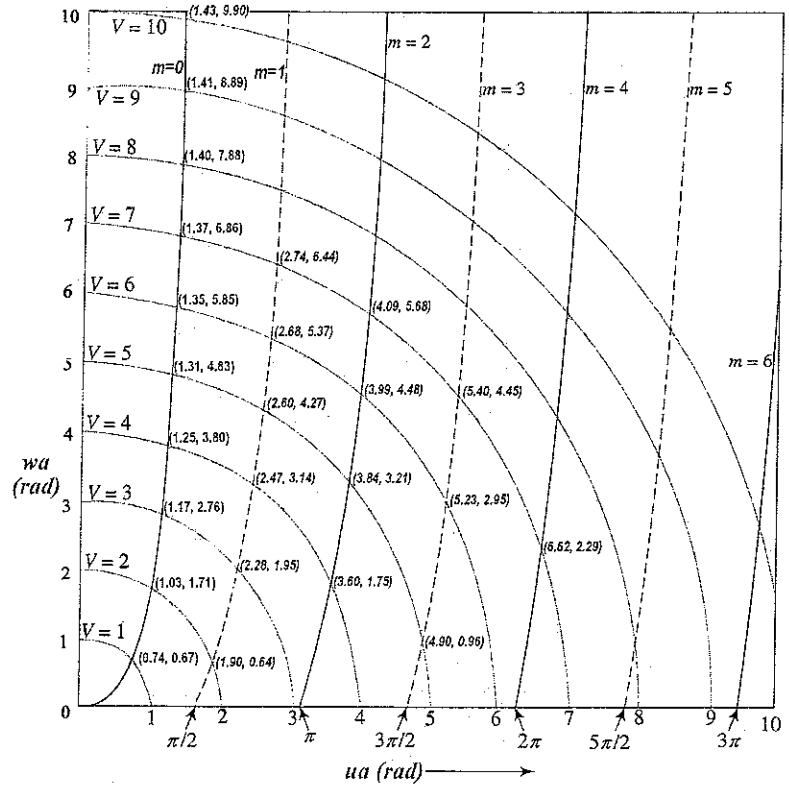


Figure 2

Q6 A linearly graded index cylindrical fiber supports the propagation of 500 guided modes at 1.31 μm wavelength. If the wavelength is increased to 1.55 μm, how many modes will be supported? By what factor should be the core diameter be changed such that only the fundamental mode is supported at this wavelength (1.55 μm)? What are the limitations of multimode fibers?

(8 marks)

End of Paper

NAME:
ID NO.

SET A

5BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS - Quiz 2

Sem1, 2010 2011 | CLOSED BOOK | Time Allowed: 20 mins
Total Marks : 14 | Weightage: 7%

INSTRUCTIONS: Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

A1. Distinguish between Pockel Effect and Kerr Effect.

A2. 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.

A3. 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 $(I = I_o)$.

A4.Based on the answer to question A3, show that the intensity I varies as the square of the applied voltage V, for all values of $V << V_\pi$.

A5. Explain the term birefringence

A6. Why it is more convenient to introduce a quarter wave plate before the electro optic crystal in a longitudinal electro optic modulator?

A7. Draw the energy level diagram of an erbium ion (Er^{3+}) and show possible transitions

A8. How are the limitations in a Semiconductor Optical Amplifier overcome in a Erbium Doped Fiber Amplifier?

NAME: SET B
ID NO.

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

Sem1, 2010 2011 CLOSED BOOK Time Allowed: 20 mins
Total Marks : 16 Weightage: 8%

INSTRUCTIONS: This paper contains **FIVE (5)** questions and comprises **TWO (2)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

B1. A linearly graded cylindrical fiber with a core diameter of 100 μm supports 700 guided modes at 1.3 μm wavelength. If the cladding refractive index is 1.48 determine the refractive index of the core at a distance of 10 μm from the core centre. [4M]

B2. The cut off value of the normalized frequency parameter (V_c) to support single mode in a step index cylindrical fiber is given by [3M]
(a) $\pi/2$ (b) 2.405 (c) 3.832 (d) 4.165 (e) 5.136 (f) π
Show the steps

NAME:
ID NO.

SET B

B3. What is Peterman – 2spot size? Express in terms of the normalized frequency parameter V.[3M]

B4. A step index single mode cylindrical fiber has a core refractive index of 1.48, a relative refractive index difference of 0.3%. The waveguide dispersion parameter for the fiber at 1.5 μm is -5.5 ps. km^{-1} .nm^{-1}. Determine the diameter of the core. [3M]

B5. Two identical multimode fibers are joined with a small air gap of 1 μm. There is no other offset of any kind in the joint. The core refractive index is 1.5. Determine the loss due to Fresnel reflection. The overall loss efficiency at the joint is 0.83176. Find the coupling efficiency due to longitudinal misalignment. [3M]