BITS PILANI DUBAI CAMPUS
EA C422 – FIBER OPTICS AND OPTOELECTRONICS
I SEMESTER 2012 – 13 **COMPREHENSIVE EXAMINATION** **31 DEC 2012**

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

INSTRUCTIONS

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

Q1: A step index fiber has a core refractive index n_1 and a cladding refractive index of n_2. The diameter of the core extends from y = -50 μm to y = +50 μm. The axial length of the fiber is along the x-axis. A ray of light is incident on one end of the fiber at y = 0 making an angle α with respect to the normal to the surface at y = 0. Assuming that the fiber is kept in water, the maximum allowable value of α is found to be 11°. The critical angle for the core – cladding interface is 80°. Refractive index of water is 1.33. Calculate the following:

a) Numerical aperture of the fiber.
b) Minimum and maximum angles of incidence that the ray of light will make at the core – cladding interface so that it can propagate through the fiber.
c) Refractive indices, n_1 and n_2.
d) Multipath time dispersion of the fiber.
e) The minimum and maximum number of reflections per meter for rays guided by it along the core.

(10 marks)

Q2. Two identical fibers having a core diameter of 10 μm and a numerical aperture of 0.2 are spliced almost perfectly, except for a small air gap of thickness 1μm that is formed at the joint. When tested, there was an overall loss of 0.5 dB at the joint. Determine the refractive indices of the core and cladding layers

(8 marks)

Q3. Draw the electric field distribution in both the core and cladding layers for a mode represented by m = 4 in a planar waveguide.

(6 marks)

Q4. Compare, with appropriate diagrams, the structure of a $p - n$ photodiode with that of an *RAPD*. Draw their electric field distribution characteristics and highlight the principal uses of these detectors.

(8 marks)

Q5. A p-n photodiode is used as an optical detector. What factors are needed to be considered in order to improve the response of the detector to any incident radiation? What are the limitations of the p-n detector and how they are overcome in an avalanche photodiode?

A p-n diode generates four electron-hole pair out of every 5 incident photons corresponding to a wavelength of 1.3 μm. The response of a photodiode is in the form of a photocurrent I_p for an incident optical power P_{in}. Calculate the maximum possible bandgap energy (in eV) of the semiconductor assuming the incident wavelength to be the long wavelength cut off. Also calculate the optical power required to achieve a photocurrent of 1μA

(10 marks)

Q6. 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 x moles of AlAs with $(1-x)$ moles of GaAs. It is required to fabricate an LED operating at 800 nm using the ternary alloy. Determine the exact composition of the $Al_xGa_{1-x}As$ material needed Given: Atomic weights of Ga, Al and As are 70, 27 and 75 grams / mole respectively.

(3 marks)

Q7. Answer the following questions:

(a) A semiconductor is doped with both donors (N_d) and acceptors (N_a) at comparable doping levels. The free electron concentration at thermal equilibrium is given by (i) N_d (ii) n_i^2 / N_a (iii) $(N_d - N_a)$ if $N_d > N_a$ (iv) $n_i^2 / (N_a - N_d)$ if $N_a > N_d$ (iv) none of the above

(b) Given that Si has a bandgap of 1.12 eV, what range of wavelengths will be absorbed by it?

(3 marks)

Q8. An impulse is launched into an optical fiber. The power, p(t), in the received pulse varies with time, t, according to Figure 1. (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) Calculate the total energy in the pulse and (c) Determine the rms pulse width.

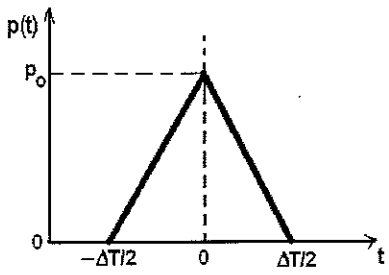


Figure 1

(8 marks)

Q9. Explain the principle of operation 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 (FSR) and the required order of the arrayed waveguides.

(6 marks)

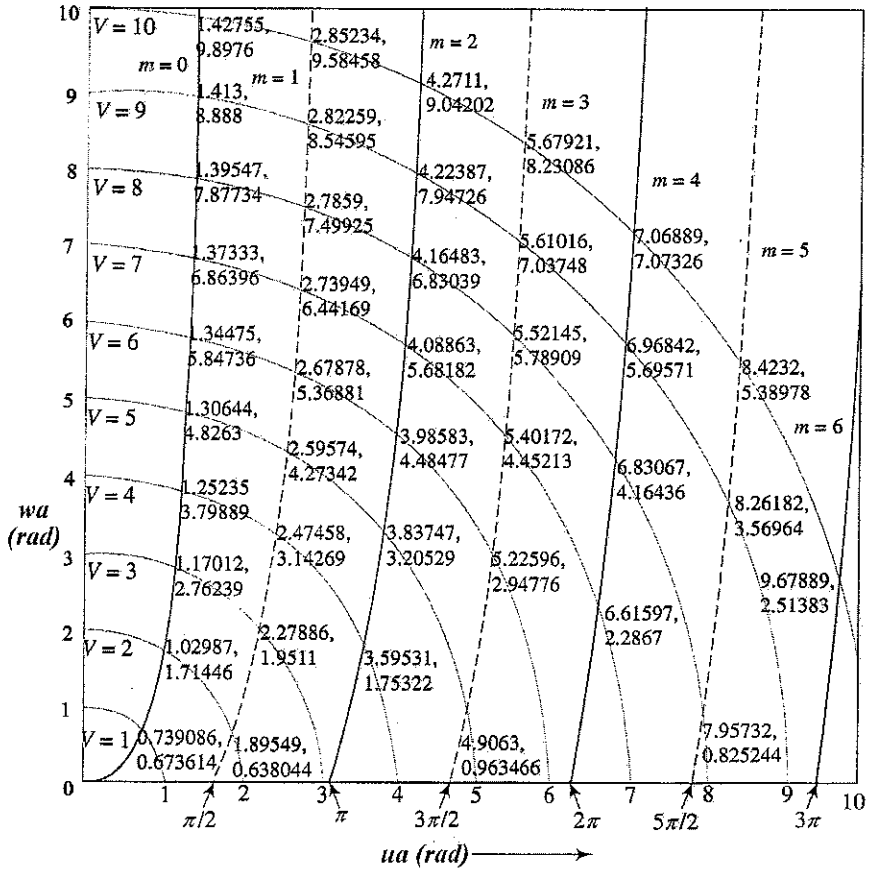
Q10. Design a planar rectangular optical waveguide so as to have a maximum guide thickness to allow two modes of propagation at wavelength $\lambda = 1.31$ μm. The critical angle for the guide – cladding interface is 80^o. The guide refractive index is 1.5. Which of the two modes will have maximum power confined within the guide? Why? If the wavelength is reduced to 0.9 μm, how many modes can the guide support now? Under what condition is the power confinement factor for any mode high?

Given that the power confinement factor G for symmetric modes is expressed by

$$\frac{G}{wa(1-G)} = \sec^2(ua) + \frac{\tan(ua)}{ua}$$

G for antisymmetric modes can be obtained by replacing any cos(ua) term by –sin(ua) and sin(ua) by cos(ua) in the above equation

(10 marks)



Q11. Consider the design of a fiber optic link of length 20 km that has splices after every 5 km length of fiber. The fiber cable has the following specifications: cable loss α_f = 1.6 dB/km, $(\Delta T)_{intramodal}$ = 4 ns/km, $(\Delta T)_{intermodal}$ = 1.5 ns/km. The loss at each splicing is 0.5 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

FIRST SEMESTER 2012 – 2013 YEAR IV ELECTIVE TEST – 2 OPEN BOOK

Course Code: EA C422 Date: 22.11.12
Course Title: Fiber Optics and Optoelectronics Max Marks: 40
Duration : 50 minutes Weightage: 20%

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

Q1. 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. With a donor concentration of 10^{16} cm^{-3}, the injection efficiency is found to be 80% when operated at 300 K.

(i) Determine the acceptor concentration for the diode.

(ii) If the temperature is increased to 500 K, what will be the injection efficiency of the diode?

(iii) With the temperature remaining at 300 K, if the acceptor concentration is doubled, by how much % will the injection efficiency increase compared to (i) above.

(9 marks)

Q2 A certain photodiode provides an output photocurrent of 1.5 μA for an input optical power of 4.5 μW at a wavelength of 1.33 μm. If 5 x 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? **(7 marks)**

Q3. A double heterostructure laser diode has a cavity length of 0.6 mm, an effective loss coefficient of 2.0 mm^{-1} and an optical confinement factor of 0.8. The threshold gain coefficient for the laser is 3.75 mm^{-1}. The reflectivity at one end facet is 0.6. Determine the reflectivity at the other end facet. 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)

Q4. What is an avalanche photo diode? Explain what is meant by dark current. Sketch the cross section of a double heterostructure p – i – n photodiode using a p^+ InP substrate. Why is a layer of InGaAs used as the intrinsic layer? An APD has a quantum efficiency of 50% at 1.55 μm. When illuminated with optical power of 0.5 μW at this wavelength, it produces an output photocurrent of 10 μA, after avalanche gain. Calculate the multiplication factor of the diode.

(8 marks)

Q5: Two compatible multimode step index fibers when joined with a connector, forms a lateral offset of 3 μm, an angular misalignment of core axes of 2° and 8 μm end separation with an air gap in between. If the core of each fiber has a refractive index of 1.49, a diameter of 100 μm and a relative refractive index difference of 2%, calculate the total insertion loss at the connector.

(9 marks)

END OF PAPER

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

Sem1, 2012 2013 | CLOSED BOOK | Time Allowed: 50 mins
Total Marks : 50 | Weightage: 25%

INSTRUCTIONS

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

Q1. 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:

$$P(t) = P_0 \text{ for } -\tau/2 \leq t \leq +\tau/2$$

$$= 0 \text{ otherwise.}$$

Calculate : (a) The total energy in the pulse and (b) rms pulse width. If the rms pulse width is 1 μs and energy is 10^{-12} J, determine the peak pulse power.

(12 marks)

Q2. For symmetric modes of propagation through a rectangular guide, the electric field is expressed by

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

Show that the normalized frequency parameter can be expressed by $V = (2\pi a/\lambda).NA$, where NA is the numerical aperture.

(8 marks)

Q3. A rectangular guide has $n_1 = 1.48$, $n_2 = 1.46$ and is designed to guide only the mode m = 0 for a light source at 1.55 μm such that ua = 2wa. Determine the frequency parameter V .What is the thickness of the guide?

(10 marks)

Q4. A step-index fiber has a guide thickness of 10 μm. It is observed that the maximum number of guided modes increases by 1 when the incident wavelength is decreased from 1.55 μm to 1.3 μm. Determine the numerical aperture of the fiber.

(10 marks)

Q5. A cylindrical graded index fiber has a core refractive index profile $n_1(r)$ which is linear 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.

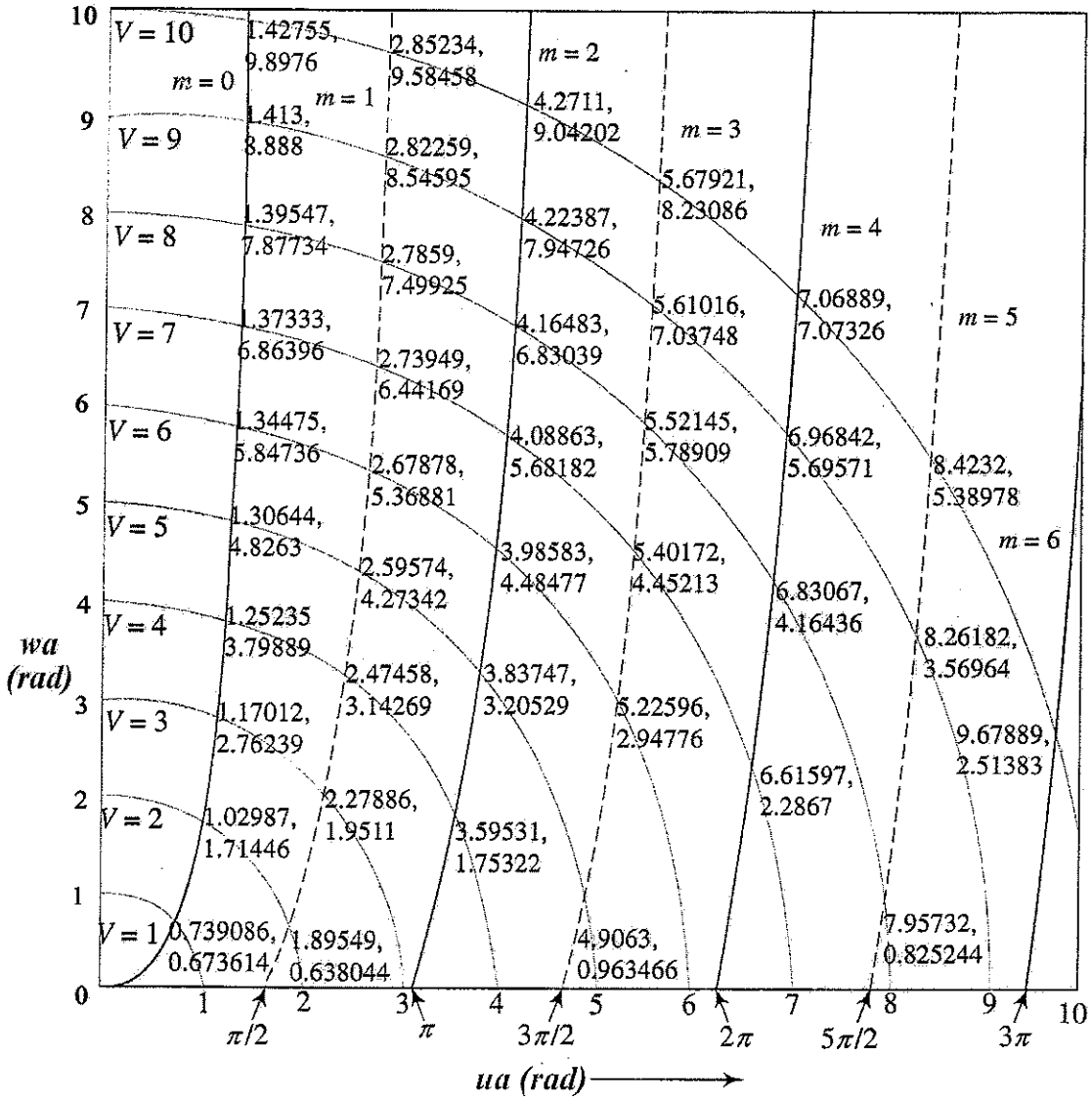
(ii) Express $n(r)$ as a function of r for all values of r from $-a$ to a.

(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)

End of Paper.

NAME: _____ **ID NO.** _____


V = 10
V = 9
V = 8
V = 7
V = 6
V = 5
V = 4
V = 3
V = 2
V = 1
m = 0
m = 1
m = 2
m = 3
m = 4
m = 5
m = 6
1.42755, 9.8976
2.85234, 9.58458
4.2711, 9.04202
5.67921, 8.23086
7.06889, 7.07326
8.4232, 5.38978
1.413, 8.888
2.82259, 8.54595
4.22387, 7.94726
5.61016, 7.03748
6.96842, 5.69571
8.26182, 3.56964
9.67889, 2.51383
1.39547, 7.87734
2.7859, 7.49925
4.16483, 6.83039
5.52145, 5.78909
6.83067, 4.16436
7.95732, 0.825244
1.37333, 6.86396
2.73949, 6.44169
4.08863, 5.68182
5.40172, 4.45213
6.61597, 2.2867
1.34475, 5.84736
2.67878, 5.36881
3.98583, 4.48477
5.22596, 2.94776
1.30644, 4.8263
2.59574, 4.27342
3.83747, 3.20529
4.9063, 0.963466
1.25235 3.79889
2.47458, 3.14269
3.59531, 1.75322
1.17012, 2.76239
2.27886, 1.9511
1.02987, 1.71446
1.89549, 0.638044
0.739086, 0.673614
wa (rad)
ua (rad)
0
1
2
3
4
5
6
7
8
9
10
π/2
π
3π/2
2π
5π/2
3π

NAME:---------- ID NO: _____

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

Sem1, 2012 2013 CLOSED BOOK Time Allowed: 20 mins
Total Marks : 14 Weightage: 7%

INSTRUCTIONS

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

Q1 Calculate the change in refractive index due to longitudinal electro optic effect for a 5 mm wide KDP crystal with an applied voltage of 5 KV. If the wavelength of light propagated through the crystal is 550 nm, calculate the net phase shift between two polarization components after they emerge from the crystal. What is the half wave voltage for the crystal?

[6 marks]

Q2 For a longitudinal electro optic modulator, $(I/I_o) = \sin^2[(\pi V)/(2V_\pi)]$. Show that by adding a quarter wave plate, the response reduces to a linear relationship $(I/I_o) = (1/2)[1+(\pi V/V_\pi)]$.

{3 mark}

NAME:---------- ID NO: _____

Q3 Describe with a neat sketch, the working of an angular dispersion type demultiplexer based on (a) Littrow prism type, (b) reflection grating type, conventional lens, (c) reflection grating type, GRIN rod lens

(5 marks)

The End

NAME:---------- ID NO: _____

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

Sem1, 2012 2013 CLOSED BOOK Time Allowed: 20 mins
Total Marks : 8 Weightage: 8%

INSTRUCTIONS

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

Q1 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.

(a) What are the various contributions to the total insertion loss that can occur at the joint?
(b) If the total insertion loss for transmission in the forward direction (A to B) is 3 dB, calculate the profile parameter α_2.
(c) What is the insertion loss in the backward direction?

[5 marks]

NAME:---------- ID NO: _____

Q2 To minimize Fresnel's loss at a joint between two fibers, what steps should be taken?

{1 mark}

Q3 Explain the terms Intrinsic and Extrinsic absorption with reference to losses due to material absorption in fibers. If the attenuation in a fiber due to absorption is governed by Beer's Law, write down an expression for the absorption coefficient α. How does Rayleigh's scattering depend on the wavelength?

(2 marks)

The End