M.TECH/ECE/VLSI/3RD SEM/ECEN 6125/2021

DESIGN AND TECHNOLOGY FOR PHOTONIC INTEGRATED CIRCUITS
(ECEN 6132)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The Lorentz oscillator model is applicable for
(a) Dielectric (b) Metals
(c) Semiconductors (d) All of the above.

(ii) The Drude model
(a) is applicable for metals
(b) is a special case of Lorentz oscillator model
(c) includes mean-free-time between two successive collisions
(d) is attributed to all of the above.

(iii) The imaginary part of the complex permittivity is
(a) responsible for polarization of charges
(b) responsible for power loss
(c) responsible for determining the speed of wave in a medium
(d) None of them.

(iv) If $\widetilde{\epsilon_r}$ is the complex permittivity having the real part ϵ_r, which one is the correct form of Ampere's law?
(a) $\nabla \times \vec{H} = j\omega\epsilon_0\, \widetilde{\epsilon_r}\, \vec{E}$ (b) $\nabla \times \vec{H} = \sigma\vec{E} + j\omega\epsilon_0\epsilon_r\, \vec{E}$
(c) both of the above (d) None of the above.

(v) For a slab waveguide the refractive indices of the substrate, core and cladding are n_s, n_1 and n_c, respectively. Which one is correct for the waveguide if the vertical propagation constants of the substrate, core and the cladding are ξ, κ and σ?
(a) $\kappa^2 = \beta^2 - k^2 n_1^2$ (b) $\xi = \sqrt{k^2 n_s^2 - \beta^2}$
(c) $\sigma = \sqrt{k^2 n_c^2 - \beta^2}$ (d) All of the above.

(vi) The effective index method is useful in analysing
(a) slab waveguide (b) rectangular waveguide
(c) ridge waveguide (d) only for (a) and (c).

(vii) The measurement of refractive index is done using
(a) A Febri-Perot interferometer (b) Mach-Zehnder interferometer
(c) Any interferometer (d) None of them.

(viii) The Bragg's law states that
(a) $d = (2n+1)\frac{\lambda}{2}$ (b) $d = n\lambda \sin\theta$
(c) $d = n\frac{\lambda}{4}\cos\theta$ (d) $d = n\frac{\lambda}{2}\sin\theta$

(ix) The M matrix for a composite medium composed of two dielectrics of refractive indices n_1 and n_2 , respectively, is expressed as
(a) $M = \frac{n_2}{n_1}\begin{bmatrix} n_2+n_1 & n_2-n_1 \\ n_2-n_1 & n_2+n_1 \end{bmatrix}$ (b) $M = \frac{1}{2n_2}\begin{bmatrix} n_2+n_1 & n_2-n_1 \\ n_2-n_1 & n_2+n_1 \end{bmatrix}$
(c) $M = \frac{1}{2n_1}\begin{bmatrix} n_1+n_2 & n_1-n_2 \\ n_1-n_2 & n_1+n_2 \end{bmatrix}$ (d) Both (b) and (c).

(x) For a quarter-wave anti-reflection coating which one is correct if the middle layer has a refractive index n_2?
(a) $n_2 = n_1 n_3$ (b) $n_1 = \sqrt{n_2 n_3}$
(c) $n_2 = \sqrt{n_1 n_3}$ (d) $n_3 = \sqrt{n_1 n_2}$

Group – B

2. (a) Recalling Lorentz-Oscillator model show that the electric susceptibility of the dielectric material can be expressed as $\chi_e(\omega) = \frac{\omega_p^2}{\omega_0^2 - \omega^2 - j\omega\Gamma}$, where ω_p is plasma frequency. Also find an expression of conductivity. [(CO1) (Remember/LOCQ)]
(b) Show that both the ordinary refractive index and extinction coefficient cannot be chosen arbitrarily. [(CO1) (Understand/LOCQ)]

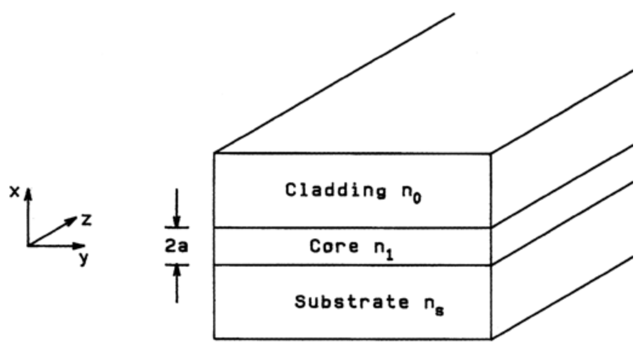
6 + 6 = 12

3. (a) The ordinary refractive index of a material is defined as $n_0 = 2\left(\frac{\omega}{\omega_1}\right)$ $for\ 1 \le \omega \le \omega_1$. Using the Kramers-Kroning relation evaluate the attenuation constant. [(CO1) (apply/IOCQ)]
(b) What is biaxial crystal? How do you differentiate from an isotropic crystal? [(CO1) (Apply/IOCQ)]

6 + 6 = 12

Group – C

4. (a) Find the electric and magnetic field of TE mode for the slab wave guide shown below. Derive and sketch for possible solutions of propagation constant. [(CO2)(Analyze/IOCQ)]



(b) A light wave of wavelength $\lambda_0 = 1.5\mu m$ is applied to a slab waveguide. The refractive index of core and substrate are 1.5 and 3.5, respectively. If the normalise frequency is 45 find width of the waveguide. [(CO2) (Analyze/IOCQ)]

6 + 6 = 12

5. (a) Design a rectangular waveguide and find the dispersion relation for E^x_{pq} mode of a rectangular waveguide and draw E^x_{12} and E^x_{21} modes. [(CO3) (Create/IOCQ)]

(b) Dimensions of a rectangular waveguide along the x and y directions are 2 μm and 4 μm, respectively. The refractive indices of the core and cladding are 2 and 4, respectively. If $\gamma_x = 4k_x$, $\gamma_y = \frac{\pi}{6} k_y$ determine the propagation constant β for wavelength $\lambda = 1.5\ \mu m$. [(CO3) (Apply/IOCQ)]

6 + 6 = 12

Group – D

6. (a) Two waveguides made of refractive indices n_1 and n_2 $(n_1 > n_2)$ are separated by d along the x direction while are placed along the z direction. Assuming that the field in the high indexed guide has a little perturbation in the low indexed guide and a zero butt coupling coefficient find an expression for the field coupling coefficient from the low indexed guide to the high indexed guide. [(CO3) (Remember/LOCQ)]

(b) The coupled modes of a coupler are given as $\frac{dA}{dz} = -j\kappa B e^{-j(\beta_1-\beta_2)z}$ and $\frac{dB}{dz} = j\kappa^* A e^{+j(\beta_1-\beta_2)z}$. Based on the statement judge what type of coupler it is. Find an expression of A for a coupler of length L. Assume $A(0) = A_0$ and $B(L) = 0$. [(CO3) Evaluate(/HOCQ)]

6 + 6 = 12

7. (a) What is an interferometer? Describe the operation of Fabry-Perot interferometer? [(CO1)(Remember/IOCQ)]

(b) Design an anti reflection coating by sandwiching a material of refractive index n_2 between two other materials of refractive index n_1 and n_3. [(CO3)(Evaluate/IOCQ)]

(c) Consider two partially transmitting mirrors, separated by a homogeneous medium of width d, are placed in front of a monochromatic light source. Find an expression of the transmitted amplitude from the second mirror. [(CO1)(Analyze/IOCQ)]

4 + 4 + 4 = 12

Group – E

8. (a) Find the expression for transmission from a periodic structure that satisfies the Bragg's condition. [(CO4)(Evaluate/IOCQ)]

(b) A periodic structure of dielectric materials is required to design in such a way that the reflected waves from each period will interfere constructively. What will be the relation between the wavelength and period to achieve it? Assume a monochromatic wavelength. [(CO3)(Evaluate /IOCQ)]

6 + 6 = 12

9. Explain the following phenomena for photonic crystals
   (i) Origin of photonic band-gap
   (ii) Left hand propagation
   (iii) Self collimation. [(CO4) (Remember/LOCQ)]

(4 + 4 + 4) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	35.42%	35.42%	29.16%

Course Outcome (CO):

After the completion of the course students will be able to

1. Students will be able to solve problems associated with wave propagation through anisotropic mediums.
2. Students will be able to design different components such as planar and rectangular waveguides, bends, Y- section, couplers, filters etc.
3. Students will be able to design coupled waveguides and resonators.
4. Students will be able to design photonic band-gap devices.
5. Students will understand the fabrication process for different optical devices.
6. Students will be able to characterize the basic photonic components using simple python coding.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission link:
ECE & VLSI	https://classroom.google.com/c/NDA0OTUzOTQ2NDkx/a/NDYzODQxNDY0NTI5/details