# EPL 442: FIBER AND INTEGRATED OPTICS

(IInd Semester, 2006-2007)

## MJAOR TEST

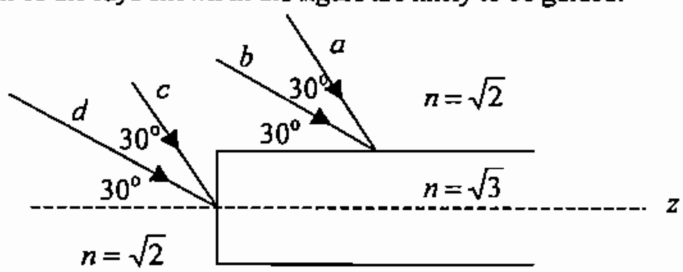
**Duration: 2 hours** **Max. Marks: 46**

**Question No. 1 is compulsory.**

**Attempt ANY FIVE of the remaining questions.**

1. **[Compulsory] Attempt all parts:**

(a) Which of the rays shown in the figure are likely to be guided: 2



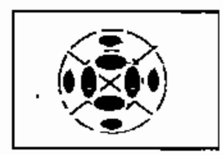

(b)The electric field of a uniform plane wave propagating in a medium is given by 2

$$E = \hat{x}\,2\cos\left(10^{14}t - \frac{10^6 z}{\sqrt{3}}\right) - \hat{y}\sin\left(10^{14}t - \frac{10^6 z}{\sqrt{3}}\right) \ \text{V/m}$$

What are the polarization of the wave and the refractive index of the medium?

(c) Two pulses, one at 1300 nm and the other at 1500 nm, are launehed simultaneously in a fiber with silica core. Which one would first reach the other end of the fiber? Give brief explanation. 2

(d) The intensity pattern of an LP mode is given in the adjoining figure. Indicate the electric field directions in each lobe by short arrows for the two orthogonal polarized cases. 2



(e) The peak power of a soliton propagating in a fiber is doubled. Does the temporal width of the soliton remain the same or does it change? If it changes, then by what factor? 2

(f) Calculate the distance over which the optical power falls by a factor of 10 in a fiber with a loss of 0.2 dB/km. 1

2. Calculate the maximum loss-limited and dispersion-limited distances of a link operating at 850 nm at 100 Mb/s using the NRZ scheme. Following components are used: 7

i. Source: A GaAlAs laser diode with 0 dBm power out of the fiber pigtail, $\Delta\lambda = 2$ nm and rise time=1 ns.

ii. Detector: Si PIN with a margin of –30 dBm and rise time = 2 ns.

iii. Fiber: a multimode silica parabolic-index fiber with $\Delta = 0.01$, $n_1 = 1.46$ and a loss of 3.5 dB/km (all at 850 nm). Material dispersion of silica at 850nm is about 852 ps/km-nm.

iv. Splice every 2 km with a loss of 0.1 dB at each splice.

What is the repeater spacing that would be necessary?

3. (a) A pulse propagating in a medium is described as 5+2

$$f(z,T) = f_0(T)e^{-i\Phi(z,T)}$$

where $T = t - z/v_g$. Is the medium only dispersive, only nonlinear, or both? Justify your answer. What changes would be necessary to make in the above equation if it has to represent a soliton and why?

(b) What is dispersion compensation and where is it needed?

4. (a) What are different types of fiber optic sensors? Discuss briefly giving the relative merits and demerits of each type. 4+3
(b) Describe the principle of ***any one*** of the following sensors giving a diagram: (i) Interferometric sensor, (ii) acoustie sensor, or (iii) mierobend sensor.

5. (a) What are different types of defects that can oecur when two fibers are spliced? 3+2+2
(b) Assuming that the field of the single mode fiber can be approximated by a Gaussian field, the transmitted fractional power in presence for a transverse misalignment $\xi$ between the axes of identical fibers is given by

$$T = \exp(-\xi^2/w^2)$$

where $w$ is the Gaussian spot-size of the fiber. Obtain an expression for loss in dB for the loss. How can this expression be improved for better estimation of splice loss for small offset?
(c) It is not possible to design a fiber, which is optimized for tilt loss as well as transverse offset loss. Justify this statement.

6. Explain the working principle of a directional coupler switch based on the electro-optic effect in $LiNbO_3$ giving necessary diagrams. 7

7. (a) The TE modes of a planar waveguide are the solutions of the wave equation 3+2+2

$$\frac{d^2E_y}{dx^2} + \left[k_0^2 n^2(x) - \beta^2\right]E_y(x) = 0$$

where all symbols have their usual meanings. Considering a step-index waveguide, give simple arguments to show that $n_2 < \beta/k_0 < n_1$.
(b) Draw the electric field variation of the $TE_1$ mode for $V = 2.0$ and $V = 5.0$ on the same diagram.
(c) Draw the transverse electric and magnetic field variation of the $TM_1$ mode on the same diagram.

**Formulae:**

(A) Directional Coupler: The variation of the field amplitudes $a(z)$ and $b(z)$ in the two arms of a directional coupler is given by

$$|a(z)|^2 = 1 - \frac{\kappa^2}{\frac{1}{4}\Delta\beta^2 + \kappa^2}\sin^2\left[z\sqrt{\tfrac{1}{4}\Delta\beta^2 + \kappa^2}\right] \qquad \text{and} \qquad |b(z)|^2 = 1 - |a(z)|^2$$

where all symbols have their usual meanings.

(B) Group delay in power-law profiles:

$$\tau(\tilde{\beta}) = \left(\frac{2\tilde{\beta}}{2+q} + \frac{qn_1^2}{2+q}\frac{1}{\tilde{\beta}}\right)\frac{L}{c}$$