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53 (IE 703) FOLI

2021

(Held in 2022)

**FIBRE OPTICS AND LASER  
INSTRUMENTS**

Paper : IE 703

Full Marks : 100

Time : Three hours

***The figures in the margin indicate  
full marks for the questions.***

*Answer any five questions.*

1. (a) State the advantages of an Optical fibre system. 5
- (b) Define the terms — acceptance angle and numerical aperture. 3
- (c) A silica optical fibre with a core diameter large enough to be considered by ray theory analysis, has a core refractive index of 1.5 and a cladding refractive index of 1.47. Determine —
  - (i) the critical angle at the core-cladding interface

*Contd.*



- (ii) the NA for the fibre
- (iii) the acceptance angle in air for the fibre. 6

(d) A typical relative refractive index difference for an optical fibre designed for long distance transmission is 1%. Estimate the NA and the solid acceptance angle in air for the fibre when the core index is 1.46. Further calculate the critical at the core-cladding interface within the fibre. 6

2. (a) What are step index and graded index fibres? Draw their refractive index profiles. 2+4=6

(b) State the advantages of multimode fibre over single-mode fibre. 3

(c) A multimode step index fibre with a core diameter of  $80 \mu m$  and a relative refractive index difference of 1.5% is operating at a wavelength of  $0.85 \mu m$ . If the core refractive index is 1.48, estimate —

- (i) the normalized frequency for the fibre

(ii) the number of guided modes.

4

(d) When the mean optical power launched into an 8km length of fibre is  $120 \mu\text{W}$ , the mean optical power at the fibre output is  $3 \mu\text{W}$ .

Determine —

(i) the overall signal attenuation or loss in decibels through the fibre assuming there are no connectors or splices

(ii) the signal attenuation per *km* for the fibre

(iii) the overall signal attenuation for a 10 *km* optical link using the same fibre with splices at 1 *km* intervals, each giving an attenuation of 1dB

(iv) the numerical input/output power ratios in (iii).

7





3. (a) Silica has an estimated fictive temperature of  $1400\text{K}$  with an isothermal compressibility of  $7 \times 10^{-11} \text{m}^2 \text{N}^{-1}$ . The refractive index and the photoelastic coefficient for silica are  $1.46$  and  $0.286$  respectively. Determine the theoretical attenuation in decibels per  $\text{km}$  due to the fundamental Rayleigh scattering in silica at optical wavelengths of  $0.63$ ,  $1.00$  and  $1.30 \mu\text{m}$ . Boltzmann's constant is  $1.381 \times 10^{23} \text{JK}^{-1}$ . 8

(b) A long single-mode optical fibre has an attenuation of  $1.3 \mu\text{m}$ . The fibre core diameter is  $6 \mu\text{m}$  and the laser source bandwidth is  $600 \text{MHz}$ . Compare the threshold optical powers for stimulated Brillouin and Raman scattering within the fibre at wavelength specified. 4

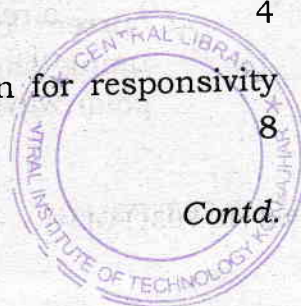
(c) Two-step indexed fiber has the following characteristics :

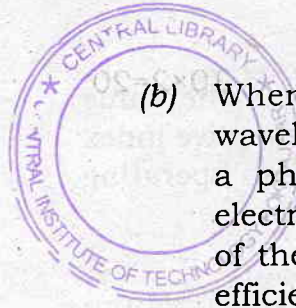
(i) A core refractive index of  $1.5$  with a relative refractive index difference of  $0.2\%$  and an operating wavelength of  $1.55 \mu\text{m}$ .

- (ii) A core refractive index the same as (i), but a relative refractive index difference of 3% and an operating wavelength of  $0.82\mu\text{m}$ .

Estimate the critical radius of curvature for both. 4+4=8

4. (a) Derive the Einstein's relation for stimulated emission rate and spontaneous emission rate. 10
- (b) State the advantages of LED as source for optical fibre system. 6
- (c) The radiative and non-radiative recombination lifetimes of the minority carriers in the active region of a double heterojunction LED are  $60\text{ns}$  and  $100\text{ns}$  respectively. Determine the total carrier recombination lifetime and the power internally generated within the device when the peak emission wavelength is  $0.87\mu\text{m}$  at a drive current of  $40\text{mA}$ . 4
5. (a) Derive the expression for responsivity of a photodiode. 8





- (b) When  $3 \times 10^{11}$  photons each with a wavelength of  $0.85 \mu\text{m}$  are incident on a photodiode, an average  $1.2 \times 10^{11}$  electrons are collected at the terminals of the device. Determine the quantum efficiency and the responsivity of the photodiode at  $0.85 \mu\text{m}$ . 6
- (c) A photodiode has a quantum efficiency of 65% when photons of energy  $1.5 \times 10^{-19} \text{J}$  are incident upon it.
- (i) At what wavelength is the photodiode operating ?
- (ii) Calculate the incident optical power required to obtain a photocurrent of  $2.5 \mu\text{A}$  when the photodiode is operating as described above. 6
6. (a) Explain the measurement technique for water level and displacement using optical fibres. 10
- (b) What are polarization sensor ? How can current be measured by optical fibre using the technique modulation of polarization ? 10

7. Write short notes on :  $10 \times 2 = 20$

(a) Holography

(b) Fibre splices.

