2021

PHYSICS — HONOURS

Paper : DSE-A-1(b)

(Laser and Fibre Optics)

Full Marks : 65

The figures in the margin indicate full marks.

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

Answer **question nos. 1** and **2** and ***any four*** questions from the rest.

1. Answer ***any five*** questions: 2×5

(a) Distinguish between holography and photography.

(b) What is the physical significance of V-number of an optical fibre?

(c) What fraction of sodium atom to be in the first excited state in a sodium vapor lamp at a temperature of 523 K [λ = 590 nm]?

(d) What is the basic idea of laser cooling?

(e) The Coherence time for the red cadmium line (λ = 6438A°) is about 10^{-9}S. Estimate the monochromaticity of the line.

(f) Calculate the gap in frequency between two longitudinal modes in a laser cavity of length 300 mm.

(g) An optical fibre has an attenuation of 3.5 dB/km at 850 mm. If 0.5 mW of optical power is initially launched into the Fibre, then what is the power level in μW after 4 km.?

2. Answer ***any three*** questions.

(a) (i) How does stimulated emission occur in a semiconductor laser?

(ii) Deduce the relations between the frequency of incident photon and energy gap with the conduction band electron energy and valence band hole energy. 2+3

(b) (i) Draw a generic block diagram of a fibre optical communication system. What is the specialty of guided mode?

(ii) What are the advantages of using optical fibre sensors? (2+1)+2

(c) The electric field associated with a mode is given by $E(t) = E_0 e^{-\omega_0 t/2Q}\ e^{2\pi i \nu_0 t}$.

(i) Find out the frequency spectrum associated with this wave train. (which extends from $t = 0$ to $t = \infty$)

(ii) Draw the frequency dependence curve w.r.t. intensity and indicate full width half maxima. 2+2+1

(d) Draw the schematic diagram of a three level laser. Indicate the non-radiative transitions. Identify the metastable state. Write down the rate equations for different levels explaining each terms. 1+1+1+2

(e) Explain with suitable energy diagram how does population inversion take place in He-Ne Laser. Also discuss about the Lasing action in this Laser. 3+2

3. (a) For a step index fibre with core diameter d show that the distance between two successive reflections is given by $L = d\sqrt{\left(\frac{\mu_1}{\mu_0 sin\theta_i}\right)^2 - 1}$.

where μ_1 and μ_0 are the refractive indices of core and surrounding medium respectively and θ_i is the angle of incidence.

(b) A fibre has a diameter of 6 mm and refractive index of its core is 1.47 and that for cladding is 1.43. How many modes can propagate into the fibre if the wavelength of the source is 1.5 mm?

(c) What will be the shape of the path for a ray within a graded index fibre and why? 5+3+2

4. (a) What are the fundamental modes of vibration of a CO_2 molecule? Which mode/modes is/are responsible for lasing action?

(b) Draw a neat diagram to show the important Lasing transition. What are the corresponding wavelengths?

(c) Explain the role of N_2 in this lasing action clearly mentioning the forbidden transitions. (1+1)+(3+2)+3

5. (a) Consider a laser system with mirror M_1 and M_2 having reflectivity R_1 and R_2 respectively. Mirrors are separated by a distance L.

(i) Write down the beam intensity at M_2 if the intensity at M_1 is I_0 (given γ is the gain coefficient, α is the absorption coefficient of the laser medium).

(ii) Write down the beam intensity after reflection at M_2.

(iii) Write down the final intensity after completing one round trip.

(iv) Find out the amplification factor.

(v) Find out the condition for Lasing action and write down threshold gain.

(b) A injection laser has active cavity with losses of 30/cm and reflectivity of each mirror is 30%. Determine the laser gain coefficient (per cm unit) for the cavity when it has the length of 600 nm.

1+1+2+1+3+2

6. (a) Write down the one dimensional ray equation in $x - z$ plane in a medium for which $n = n(x)$

(b) In an inhomogeneous medium the refractive index is given by

$n^2(x) = 1 + \frac{x}{L}$ for $x > 0$

$= 1$ for $x < 0$

Write down the equation of a ray in the x–z plane, passing through the point (0, 0, 0) where its orientation w.r.t. x-axis is 45°.

(c) A glass clad Fibre is made with core glass of refractive index 1.5 and the cladding is doped to give a fractional index difference of 0.0005.

Find

(i) the cladding index

(ii) numerical aperture

(iii) the external critical acceptance angle 2+4+(1+1½+1½)

7. (a) Consider the formation of a hologram with a point object and a plane reference wave. The point source is situated at a distance 'd' from the photographic plate. Assume the reference wave falls normally on the plate. Calculate the intensity pattern $I(x, y)$ at a point $P(x, y, z = 0)$ on the photographic plate.

(b) Write down $I(x, y)$ when $d \gg (x, y)$.

(c) Suppose two coherent light wavetrains of unequal frequencies ω_1 and ω_2 are travelling in the non-linear dielectric material. The electric field in the material is given by $E = \left(E_1\, e^{i\omega_1 t} + E_2\, e^{i\omega_2 t}\right) + C.C.$

Find the 2nd order non-linear polarization and show that $P(\omega_1 + \omega_2) = 2\chi^{(2)}\ E_1 E_2$ —where symbols have usual meaning. 4+3+3

8. (a) Discuss the operation of Nd:YAG laser with energy level diagram.

(b) What is Pockels Effect? Give a brief description of Pockels Cell. 5+(2+3)

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