2020

PHYSICS — HONOURS

Paper : DSE-A-2

(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.*

Group - A

1. Answer *any five* questions : 2×5

    (a) The ratio of population of two energy level is $1·059×10^{-30}$. Find the wavelength of the light emitted at 330 K.

    (b) What is metastable state? What is the importance of such state in achieving laser action?

    (c) Discuss the role of reflectors in an optical resonator.

    (d) Define the quality factor Q in a resonator cavity.

    (e) Distinguish between step index fibre and graded index fibre structure.

    (f) Is light amplification possible in the absence of stimulated emission?

    (g) What is meant by self-focusing?

Group - B

Answer *any three* questions.

2. Write down the rate equations in two level laser system. Show that population inversion cannot be achieved in this system. 2+3

3. Write down the equation for stability condition in an optical resonator and draw the stability diagram. Indicate the points in the stability diagram for the following configurations of optical resonators :

    (a) $r_1 = r_2 = {}^{L}/_2$ (b) $r_1 \to \infty$ and $r_2 = 2L$,

    where r_1 and r_2 are the radii of curvature of the two mirrors of the resonator and L is the length of the cavity. 1+2+2

4. What are the sources of attenuation in an optical fibre?

   If the output power is half of the input power, then find out the attenuation of the optical beam. 2+3

Please Turn Over

5. What is Q-switching in Laser? Mention the method of Q-switching. 5

6. Show that the frequency spread (Δv) of a spectral line is of the order of the inverse of the coherence time (τ_c). 5

Group - C

Answer *any four* questions.

7. Deduce the relation, with a suitable diagram, between Einstein's A and B coefficients. Hence, at thermal equilibrium, obtain the ratio of the number of spontaneous to stimulated emissions. 8+2

8. (a) Why is a four level laser more effective than a three level laser?

   (b) How are modes formed in a cavity of length L? What is mode locking?

   (c) What is the benefit of using spherical resonator? 3+(3+2)+2

9. The schematic diagram of a four level LASER with correspondig decay rates is given below :
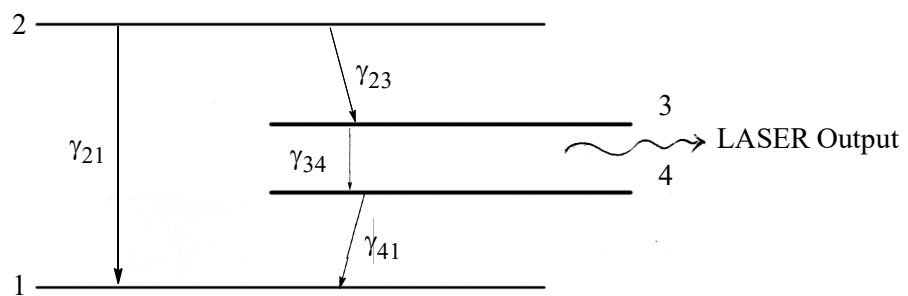
   (a) Indicate the metastable state.

   (b) Mention the levels between which non-radiative transitions take place.

   (c) Write down decay rates in descending order and explain.

   (d) Write down the rate equations for different levels in this system and explain each term. 1+2+3+4

10. (a) Let a step index single mode fibre is characterised by

$$n(r) = n_1 \text{ for } 0 < r \le a \text{ (core)}$$

$$= n_2 \text{ for } r > a \text{ (cladding)}$$

   where $n(r)$ is refractive index,

   k_0 = free space wave number

   β = the wave propagation constant and

   a = radius of the core.

   Show that the guided mode is possible when $n_2^2 < \dfrac{\beta^2}{k_0^2} < n_1^2$.

(b) In the case of multimode grade index fibre, using power law profile, show that a parabolic index fibre can accommodate nearly 25 modes.

(c) A step index fibre with $n_1 = 1 \cdot 49$ and $n_2 = 1 \cdot 465$ has a core radius $a = 5 \cdot 90$ μm.

Calculate the operational wavelength (λ_0) for which wave guide parameter, $V = 9$.　　　　6+2+2

11. (a) Suppose the reference wave in hologram is given by $E_r = E_0 e^{-i(\omega t - k_z - k_n \sin\theta)}$ and the spherical wave emanating from point source is given as

$$E_{sph} = E_1 e^{-i\left(\omega t - k_z - \frac{k_x^2}{2z_0}\right)}$$

Then find out the resultant intensity on the plate. Show that condition for maxima in the hologram is given by

$\Delta x = 4\lambda$ (Choose $\theta = 15°$).

(b) Suppose the field incident on a nonlinear dielectric medium is given by $E = E_o \cos \omega t$.

(i) Calculate the polarization P and identify the 2nd harmonic term.

(ii) Why can 2nd harmonic generation not occur in isotropic medium?　　　　5+(3+2)

12. (a) Due to movement of the radiating atom there is a change in frequency and the corresponding broadening of light is known as Doppler broadening. Considering an average velocity of atoms $v = \sqrt{\dfrac{8KT}{M\pi}}$, find an expression of Doppler width of spectral line.

(b) Explain TE and TM mode propagation for a guided wave with suitable diagram. Also write the expression of the fields of such wave if the fiber is along z-direction.　　　　6+4

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