

**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  $1.059 \times 10^{-30}$ . 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)  $r_1 \rightarrow \infty$  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? 2+3
- If the output power is half of the input power, then find out the attenuation of the optical beam. 2+3

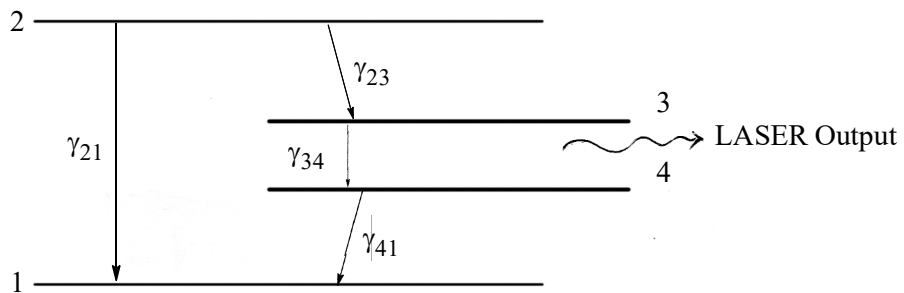
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5. What is Q-switching in Laser? Mention the method of Q-switching. 5
6. Show that the frequency spread ( $\Delta\nu$ ) of a spectral line is of the order of the inverse of the coherence time ( $\tau_c$ ). 5

**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

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

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

where  $n(r)$  is refractive index,

$k_0$  = free space wave number

$\beta$  = the wave propagation constant and

$a$  = radius of the core.

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

- (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  $n_1=1.49$  and  $n_2 = 1.465$  has a core radius  $a = 5.90 \mu\text{m}$ .  
Calculate the operational wavelength ( $\lambda_0$ ) 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

$$\Delta x = 4\lambda \text{ (Choose } \theta = 15^\circ \text{ )}.$$

- (b) Suppose the field incident on a nonlinear dielectric medium is given by  $E = E_0 \cos \omega t$ .
- (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  $v = \sqrt{\frac{8KT}{M\pi}}$ , 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