

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) $r_1 \rightarrow \infty$ 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

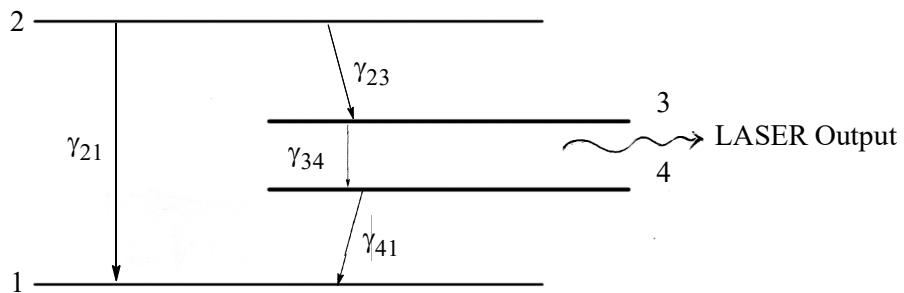
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5. What is Q-switching in Laser? Mention the method of Q-switching. 5
6. Show that the frequency spread ($\Delta\nu$) of a spectral line is of the order of the inverse of the coherence time (τ_c). 5

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

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

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

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 $n_2^2 < \frac{\beta^2}{k_0^2} < n_1^2$.

- (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 (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

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

- (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