NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4280 – LASER TECHNOLOGY

BSC HONOURS PART IV : MAY 2002 DURATION : 3 HOURS

ANSWER ALL QUESTIONS IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS. DRAW NEAT DIAGRAMS WHEREVER NECESSARY.

Planck's Constant	h	$= 6.63 \times 10^{-34}$ Js
Boltzmann's Constant	k	$= 1.38 \times 10^{-23}$ JK^{-1}
Speed of light	c	$= 3.00 \times 10^{8}$ ms^{-1}
Charge on an electron	e	$= 1.6\,0x\,10^{-19}$ C
Mass of an electron	m_e	$= 9.10 \times 10^{-31}$ kg
Permittivity of free space	ε_o	$= 8.85 \times 10^{-12}$ Fm^{-1}
Permeability of free space	μ_o	$= 4\pi \times 10^{-7}$ Hm^{-1}

SECTION A

1. (a) The relation for the brightness of the source is

$$B = \frac{P}{S\cos\theta\sin\phi}$$

Is this source a Lambertian Source? Give reasons to support your answer. [3]

(b) The beam from an argon ion laser λ =514.5 nm is sent to the moon after passing through a telescope of diameter 1.5 m. If the beam is diffraction limited, calculate
(i) the beam divergence and
(ii) beam diameter at the surface of the moon situated at a distance 384×10^{6} m from the surface of earth. [5]

(c) Explain the causes for the spread of frequencies emitted by laser transition between two energy states. [4]

(d) Compare the resonators used at Microwave frequencies and at Optical frequencies. Give reasons for your choice. [6]

(e) An "ABCD" matrix for an optical element is given below:

$$\begin{bmatrix} 2.5 & 10 \\ 0.5 & 0.7 \end{bmatrix}$$

Calculate the lateral magnification, angular magnification, effective focal length and optical thickness. [4]

(f) Draw a neat diagram showing the geometrical significance of the parameters that characterize a monochromatic Gaussian beam. [6]

(g) A sodium vapour lamp emits light of wavelength 589.3 nm with a spread $\Delta\lambda = 0.6$ nm. Calculate the coherence length. Compare its value with a stabilized laser having $\Delta\nu = 10$ kHz. Give significance of the values so obtained. [6]

(h) Describe the construction of a Pockel's cell. Explain its operation as an electro-optic shutter for Q- switching. [6]

SECTION B

2. (a) Why is a nitrogen laser known as a super radiant laser? [4]

(b) Give necessary design consideration for the construction of a TEA nitrogen gas laser. Describe its operation. How will you measure its output power? [8]

(c) Draw an equivalent circuit for the nitrogen laser. Apply mesh theory to formulate the circuit equations. Give a flow chart for computer simulation to calculate the current in the external and laser circuit. [8]

3. (a) What do you understand by the terms:
(i) Stable
(ii) Unstable and
(iii) Conditionally stable resonators? [3]

(b) An optical cavity consists of two mirrors of radii curvatures R_1 and R_2 separated by a distance d.
(i) Construct an equivalent lens wave-guide.
(ii) Obtain a transformation matrix for the unit cell.
(iii) Derive the stability condition for such a system.
(iv) Sketch the stability diagram and indicate the regions of con-focal and plane mirror cavity.
[10]

(c) A laser operating at $\lambda = 0.6\ \mu m$ has a power gain of 2×10^{-2} per pass with a symmetric resonator consisting of two mirrors each of radius 10 m separated by a distance of 1m. Calculate appropriate mirror aperture to suppress TEM_{01} mode while allowing TEM_{00} mode. [7]

4. (a) For a TEM mode, the function which measures how beam deviates from a plane wave is given by

$$\varphi_0 = \exp\left[-j\left(P(z) + \frac{kr^2}{2q(z)}\right)\right]$$

where k is a wave vector and r is the distance. Evaluate the functions P(z) and q(z). Hence explain the meaning of the spot size and waist of the Gaussian beam. [10]

(b) Show that the beam divergence for the Gaussian beam is given by

$$\theta = \frac{2\lambda}{\pi w_0},$$

where the symbols have their usual meanings. [5]

(c) A laser resonator consists of two concave mirrors of radii of curvature 5 m each separated by a distance of 1m. Calculate the spot size for the TEM_{00} mode at the centre of the resonator and on the mirrors, when the cavity is oscillating at the wavelength 514.5 nm [5]

5. (a) Distinguish between the homo and hetero structure semiconductor lasers. [4]

(b) Obtain an expression for the threshold current density for a semiconductor laser and hence or otherwise calculate the quantum efficiency. [8]

(c) Describe in detail the double hetero-structure laser and enumerate its advantages over gas lasers. [8]

6. (a) Outline the main features of optical fiber communication system giving a block diagram. Explain the term *digital error probability*. Show that the total error probability is

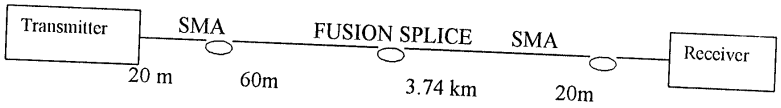
$$P_e = \frac{1}{2} erfc\left(\frac{Q}{\sqrt{2}}\right)$$

where the symbols have their usual meanings. [10]

(b) What are the essential factors to be considered in designing an optical fiber link?

[5]

(c) Calculate the minimum transmitter power necessary for the system shown below:



You may assume that the fiber has an average loss of 3.5 dB km^{-1}, fusion splice loss is 0.2 dB and minimum acceptable receiver power is –25 dB.

[5]

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