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M.Sc. in Biomedical Science

EP514 Lasers and Applications

Paper I : Optics and Lasers

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Time allowed : **TWO** hours.

Answer **THREE** questions.

Q1. In the case of **one** of the laser types given below, describe with as much quantitative detail as you can, (i) the energy level structure in the active medium, (ii) the method used to obtain population inversion, (iii) the spectral characteristics of the output, and (iv) the physical construction and typical output power. State whether the output can be Q-switched. Survey the principal applications of the laser you have chosen and describe one application in detail.

(a) CO_2 laser
(b) He-Ne laser or Argon ion laser
(c) Semiconductor diode laser
(d) Nd-YAG or ruby laser.
(e) Dye laser (CW or pulsed)
(f) Excimer laser

Q2. Answer (a) **AND** (b)

(a) A laser is specified as having an average power of 200 W in a beam of area 0.2 cm^2. Calculate the power density in the beam if the output is
(i) continuous
(ii) pulsed at 400 Hz with a pulse width of 0.5 ms
(iii) Q-switched at 1.5 kHz with a pulse width of 200 ns

If the beam divergence of this laser is 1.2 milliradians, estimate also the power density obtainable at the focal point of a 10 cm focal length lens.

(b) Explain briefly how a light beam can be confined in circular fibres of suitable construction. Outline some applications of such fibre waveguides.
A plane wave travelling in air impinges on the end of a slab guide with core index $n_1 = 1.5$ and cladding index $n_2 = 1.46$. What is the maximum angle of incidence of the incoming wave with respect to the axial plane of the guide for the wave to be guided?

p.t.o.

Q3. Give an account of the hazards associated with the use of high power lasers, emphasising the potential damage to the skin and eyes of operating personnel. Explain why the maximum permitted exposure levels depend on (i) the wavelength of operation, (ii) the pulse duration, and (iii) the viewing conditions i.e. whether intra-beam or diffuse reflection conditions are involved.

A 1 mW laser beam, with a beam divergence of 1 milliradian, is incident on the cornea of a standard eye (focal length 1.6 cm), so that it just fills the fully-dilated aperture of 7 mm. Calculate the power density on the cornea and, making reasonable assumptions, the power density on the retina. Hence calculate the optical gain of the eye.

Q4. Answer **TWO** of the following :

(a) Describe at least 3 different ways in which polarised light can be produced. A piece of quartz is to be made into a ¼ -wave plate for use at 600 nm. Describe how his could be made if the refractive indices for the ordinary ray (n_o) and extraordinary ray (n_e) for quartz are 1.544 and 1.553, respectively.

(b) Classify and describe briefly the different techniques in general use for the modulation of optical beams.

(c) An optical beam of power 2 mW (at 633 nm) is incident on a silicon phodiode. If all the photons in the beam are absorbed, and the current in the photodiode is 1 mA, what is the quantum efficiency of the photodiode ?

[Speed of light c $= 3\times10^{8}$ m s^{-1}
Planck's Constant h $= 6.63 \times 10^{-34}$ J s
Electronic charge e $= 1.6 \times 10^{-19}$ C]

(d) Give examples, with brief explanations, of the effects of interference, and diffraction, in the constr uction and operation of lasers. (At least two examples for each effect). A He-Ne laser ($\lambda = 633$ nm) illuminates a human hair and produces a diffraction pattern on a screen 3 m away. If the distance between the first minima of the diffraction pattern on the screen is 2.7 cm, calculate the diamèter of the hair.

(e) Give an account of the output mode structure (longitudinal and transverse) of lasers. Describe in detail the properties and propagation characteristics of the TEM_{00} mode.

Q5. Give a brief overview account of the different types of optical detector in general use. For such a detector, explain what is meant by the terms : noise equivalent power (NEP), detectivity, quantum efficiency, spectral response.