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M.Sc. in Biomedical Science

EP514 Lasers and Applications

Paper I : Optics and Lasers

Prof. J. Enderby  
Prof. T.J. Glynn

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 <sub>2</sub> laser           | (b) He-Ne laser <u>or</u> Argon ion laser |
| (c) Semiconductor diode laser       | (d) Nd-YAG <u>or</u> ruby laser.          |
| (e) Dye laser (CW <u>or</u> pulsed) | (f) Excimer laser                         |

Q2. Explain what is meant by the mode structure of a laser output beam. Sketch the intensity patterns for a few low-order transverse modes and describe in detail the TEM<sub>00</sub> mode. Write down expressions for the radius of curvature and beam waist radius of this mode as a function of distance from the point of minimum beam waist. In what circumstances might these formulae be used? Using a 10 cm focal length lens, to what diameter can a TEM<sub>00</sub> beam from an argon ion laser (at 514 nm), with a diameter at the minimum beam waist of 1 mm, be focussed in the diffraction limit.

Q3. Answer (a) **AND** (b)

- (a) A laser is specified as having an average power of 200 W in a beam of area  $0.2 \text{ cm}^2$ . Calculate the power density in the beam if the output is
- (i) continuous
  - (ii) pulsed at 150 Hz with a pulse width of 0.75 ms
  - (iii) Q-switched at 2 kHz with a pulse width of 250 ns
- (b) Explain how a light beam can be confined in circular fibres of suitable construction. Derive an expression for the acceptance angle of the fibre in terms of fibre parameters. Outline the various applications of such fibre waveguides.

Q4. Write on **two** of the following

- (a) Describe at least three different ways in which polarised light can be produced. Describe in detail one example of a practical application of polarised light.
- (b) Give an overview account of the different types of optical detector in general use.
- (c) Classify and describe briefly the different techniques in general use for the modulation of optical beams.
- (d) The effects of lens aberrations on the image quality obtainable with simple lenses. Indicate some approaches used to reduce these effects in various applications.
- (e) Give examples, with brief explanations, of the effects of interference, diffraction, and polarisation, in the operation and construction of lasers. (At least two examples for each effect)

Q5. 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 100 watt Nd:YAG laser (operating CW) is incident normally on a white matt surface and is diffusely reflected with a reflectance  $\rho = 80\%$ . If the Maximum Permissible Exposure for  $1.06 \mu\text{m}$  radiation is  $1.6 \text{ mW cm}^{-2}$ , calculate the Nominal Optical Hazard Distance for viewing the reflected beam at a reflected angle of  $20^\circ$  to the normal.