UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

B.Sc. *M.Sci.*

Physics 3C43: Lasers and Modern Optics

COURSE CODE	:	**PHYS3C43**
UNIT VALUE	:	**0.50**
DATE	:	**03-MAY-01**
TIME	:	**14.30**
TIME ALLOWED	:	**2 hours 30 minutes**

01-C1137-3-70

TURN OVER

Answer THREE questions.

The numbers in square brackets in the right-hand margin indicate the provisional allocation of maximum marks per sub-section of a question.

1. Explain the role of the **SYSTEM MATRIX** (M) in an optical system **[5]**

   What assumptions are implicit in the use of the **system matrix** in optics?

   Derive the system matrices for:

   (a) *Translation*
   (b) *Reflection*
   (c) *Refraction* **[9]**

   Consider a convex lens of thickness $t = 5$ cm in air with a radius of curvature of 10 cm. The refractive index of the lens is 1.5.

   (i) Determine the system matrix, M, for the optic

   (ii) Show that $\det(M) = 1$

   (iii) If an object is placed 10 cm to the left of the lens determine the location and linear magnification of the image. **[6]**

2. Explain the role of the Einstein A and B coefficients in the emission of light. **[2]**

   Explain, with an example in each case, how a population inversion is achieved by

   (a) *spatial separation*
   (b) *collisional transfer*
   (c) *selective pumping* **[9]**

   A four-level laser system is selectively pumped at a steady rate R. Solve the rate equations for the appropriate levels and show that the population inversion can be written as

   $$R[1 - A_{21}/A_{10}]\,[A_{21} + \rho B_{21}]^{-1},$$

   where ρ is the energy density of radiation at the wavelength of the laser transition between the lasing levels and A_{10}, A_{21} and B_{21} are the Einstein coefficients. The levels are denoted by 0, 1, 2, 3 in increasing energy with level 0 being the ground state. **[7]**

   What is the life-time requirement of the transitions involved to ensure a population inversion is achievable? **[2]**

3. (i) Derive an expression for the mode spacing in an inhomogeneously broadened laser and show how a single longitudinal mode in a cavity can be selected. **[4]**

(ii) Now derive the expression:

$$I(t) = E_0^2 \sin^2\left[\frac{N\phi}{2}\right] \Big/ \sin^2\left[\frac{\phi}{2}\right]$$

for the irradiance of a mode-locked laser where N is the number of modes, $\phi = \pi ct/L$, L is the cavity length and E_0 is the electric field amplitude of each mode. **[8]**

(iii) Show that I(t) for a mode-locked laser is N times that for the equivalent non-mode-locked laser. **[4]**

(iv) If L = 0.75m and the bandwidth of the laser gain curve is 2×10^{11} Hz determine the pulse width. **[4]**

4. Briefly describe how light can be modulated using

(a) The magneto-optic effect

(b) The acousto-optic effect **[8]**

Distinguish between the Kerr and Pockels effects. **[2]**

A beam of plane polarised light of wavelength λ and irradiance I, is incident on a Pockels crystal with the polarization vector inclined at 45° to the prefered axes. Show that the transmitted irradiance I is given by

$$I = I_0 \sin^2\left(\frac{\pi}{2}\frac{V}{V_0}\right)$$

where V is the applied voltage and $V_0 = \lambda/2rn_0^3$, n_0 is the refractive index when no field is applied and r is the linear electro-optic coefficient. **[10]**

5. A dielectric fibre optic of length L has a core refractive index n_1 and a cladding refractive index n_2, [6]

(a) Derive an expression for the maximum angular acceptance, α, of this fibre

(b) Derive an expression for the maximum time-dispersion $\Delta\tau$ of this fibre

(c) Given $n_1 = 1.55$, $n_2 = 1.50$ and $L = 2$ km, determine values for α and $\Delta\tau$.

What is meant by mode-dispersion? [2]

A semi-infinite planar dielectric wave-guide of thickness d and refractive index n_1 has a cladding of refractive index n_2. Show that the mode order m is given by

$$m \leq \frac{2dn_1}{\lambda}\left[1 - \left(\frac{n_2}{n_1}\right)^2\right]^{1/2} - \frac{\phi}{\pi}$$

where ϕ is the phase change on reflection and λ is the wavelength of the incident radiation. [10]

If $\lambda = 1\mu$m and $d = 50\mu$m estimate the number of modes that can propagate. [2]

END OF PAPER