NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4202 – LASERS AND MODERN OPTICS

BSc HONOURS PART IV: *MAY 2006* *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF QUESTION **ONE** IN SECTION A AND ANY **THREE** QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

SECTION A

1. (a) (i) Distinguish between homogeneous and inhomogeneous broadening giving examples. [4]

(ii) How can you relate the broadening to the laser medium in both homogenous and inhomogeneous broadening. [4]

(b) Discuss how amplified spontaneous emission might limit the amount of energy that can be stored in the population inversion of an amplifier. The discussion should include the formulation of a differential equation, but a solution is not necessary. [10]

(c) Draw a labelled graph showing the distribution of light intensity along the axis of a Gaussian laser beam. [8]

(d) Using Boltzmann's statistics write down the expression for the ratio $\frac{N_2}{N_1}$ for a two level system. Define all the quantities that you use. [4]

(e) Consider a transition at 5 000Å with a width of 1Å and a cavity 2 cm^3 in volume.
(i) Convert this wavelength interval (1Å) to frequency units. [4]

(ii) How many electromagnetic modes exist in this frequency band for this cavity? [6]

SECTION

2. (a) Show that the power spectrum of a damped oscillator is given by a Lorentzian profile function. [6]

(b) (i) From the rate equations for a photon amplifier one obtains $\frac{\Delta I_v}{\Delta Z} = \gamma_o(v) I_v$

Define all these quantities. [4]

(ii) Show that $\gamma_o(\nu) = A_{21} \frac{\lambda^2}{8\pi} g(\nu)(N_2 - \frac{g_2}{g_1} N_1)$. Define all quantities [10]

3. Consider any two of the following laser systems: gas laser, solid state laser and semiconductor laser.

(i) Using labelled diagrams show by comparison of the two how the lasing energy levels of the medium are arranged compared to the non radiative levels. [10]

(ii) How is the population inversion realised in each case? [5]

(iii) What are the applications of each of these laser systems. [5]

4. Given a $1-W \quad TEM_{00}$ beam of $\lambda = 500nm$ from a laser with minimum spot size $w_0 = 2.20mm$ located at Z = 0

(a) How far will this beam propagate before the spot size is 1 cm? [6]

(b) What is the radius of curvature of the phase front at this distance? [7]

(c) What is the amplitude of the electric field, at this distance, for r = 0? [7]

5. (a) Given a resonator of two mirrors with radii of curvature R_1 and R_2 respectively, with L the distance between the mirrors. Define the stability parameters g_1 and g_2 and hence the stability condition of the resonator given in terms of these parameters. [6]

(b) Show that the $Z_0 = \frac{(1-g_1)g_2 L}{g_{1+} g_2 - 2g_1 g_2}$ [6]

(c) Find the spot sizes w_1 and w_2 at the mirror surfaces in terms of g_1 and g_2. [8]

6. An optical cavity has mirrors with radii of curvature $R_1 = \infty$ and $R_2 = \frac{4}{3}L$, where L is the distance between the mirrors. The reflectivities are $r_1^2 = 0.99$ and $r_2^2 = 0.97$.

(a) Find an expression for the resonant frequencies of the TM_{00} modes of the cavity. [10]

(b) If the radius of curvature $R_2 = 2m$ and the wavelength of interest is 500nm compute:

(i) the free spectral range in MHz and in Å units, [2]

(ii) the cavity Q, [2]

(iii) the photon lifetime, and [3]

(iv) the finesse [3]