NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4202 - LASERS AND MODERN OPTICS

EXAMINATION

BSc HONOURS PART IV: July 2005 DURATION: 3 HOURS

ANSWER **ALL** PARTS OF QUESTION 1 IN SECTION A AND ANY **THREE** QUESTIONS IN SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

SECTION A

1. (a) Given a laser cavity with spherical mirrors of radii of curvature of R_1 and R_2 and mirror separation L. Set the condition for the resonator stability in terms of R_1, R_2 and L [4]

(b) (i) How would you achieve population inversion in an atomic system? [3]

(ii) Give one example of a technique for achieving population inversion in each of the three different laser systems, namely: solid state, gas and semi-conductor lasers. [6]

(c) A laser beam, $\lambda = 514nm$, whose beam waist is 5 mm is sent to a target 10 km away. What will be its diameter at the target? [6]

(d) Given that the lifetimes of two stationary states of an atomic system are 1ns and 10ns respectively

(i) Draw a energy level diagram showing which of the two energy levels is likely to be the upper level in laser light emission. [5]

(ii) Estimate the energy spread of the levels and hence the linewidth of the laser. [5]

(e) Distinguish between Homogeneous and Inhomogeneous broadening, explaining the differences in the line shapes. [5]

(f) Derive an expression for the photon lifetime in a cavity consisting of two parallel mirrors of reflectivity R_1 and R_2 respectively. [6]

SECTION B

2. (a) In connection with laser resonators what do you understand by the terms.

(i) Stable
(ii) Unstable [4]

(b) (i) An optional cavity consists of two mirrors of radii of curvature R_1 and R_2 separated by a distance d. Express the beam waist w_o and the spot sizes w_1 and w_2 in terms of the stability parameters g_1 and g_2 [8]

(ii) Derive the stability condition in terms of g_1 and g_2 showing how one can justify this condition on the basis of the expressions for the spot sizes and beam waist as expressed above. Sketch the stability diagram and indicate the regions of con-focal and plane mirror cavity. [8]

3. Describe the construction of any two of the following types of lasers using appropriate diagrams:

(a) (i) Solid State [7]

(ii) Gas [7]

(iii) semiconductor [7]

(b) For each of the two types name at least two applications stating why these applications are suitable for this type of laser. [6]

4. (a) Using a labelled diagram compare 4-level and 3-level lasers pointing out the advantages and disadvantages of each. [8]

(b) (i) Deduce for each type the expression for the population inversion. [8]

(ii) Give expressions for the band width [4]

5. (a) For a TEM mode, the function which measures the beam deviation from a plane wave is given by

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

where k is a wave vector and r is the position vector. Evaluate the functions p(z) and q(z) from the equation of Gaussian beams. Hence explain how the beam waist w_o and the parameter Z_o are determined. [10]

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

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

where the symbols have their usual meanings. [4]

(c) A laser resonator consists of two concave mirrors of radii of curvature 5m each separated by a distance of 1m. Calculate the spot size for the TEM_{00} mode at the center of the resonator and on the mirrors, when the cavity is oscillating at the wavelength 514.5nm [6]

6. (a) Derive the relation between Einstein's A and B coefficients. [6]

(b) Obtain an expression for the threshold of population inversion for laser action. You may assume that the line shape function is Lorentzian. [6]

(c) For He-Ne laser, the typical parameters are: λ_o = 632.8 nm, the distance between the cavity mirrors is d = 20cm and probability of spontaneous transition is $10^7\ s^{-1}$ the line width $\Delta\nu = 10^9$ Hz and the reflectivity of the mirrors are $R_1 = R_2 = 0.98$. Calculate the threshold of population inversion for a laser action. Assume Lorentzian line shape function. [8]

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