

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4270 - APPLIED OPTICS II

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) Define optical tooling and briefly explain why the He-Ne laser is usually preferred for this application. [3]
- (ii) It is required to align an object to an accuracy of 1 mm at a distance of 12 m using a He-Ne laser operating at 632.8 nm. Calculate the corresponding beam divergence angle and degree of expansion required, and comment on the accuracy of laser alignment? [5]
- (b) (i) Consider a cooperative target with a cube corner reflector with diameter 3 cm and the following measurement conditions; $P_t = 10$ kW, $\theta_t = 10^{-2}$ radians, $R = 10^3$ m, $d_{ta} = 10$ cm, $d_{ra} = 10$ cm, $T = 0,8$ and $\lambda = 1,06 \times 10^{-4}$ m (Nd - YAG laser). Calculate the received power P_r . [2]
- (ii) What will be the received power P_r if a non-cooperative target with $d_{tar} = 0.2$ m and reflectivity of 0.5 is subjected to the same conditions as in (i) above. Comment on the difference in your answers. [4]
- (c) Briefly explain how three components of velocity of a fluid can be determined at a point using Laser Doppler Velocimetry (LDV). [4]
- (d) Spectroscopy is an analytical technique arising from the interaction of species with electromagnetic radiation. The electromagnetic radiation absorbed, emitted or scattered by the molecule is analysed to give a spectrum.
 - (i) Explain how a vibrational absorption spectrum can be obtained when a beam of radiation from a source such as a laser is passed through a sample. [4]
 - (ii) Describe molecular beam spectroscopy and explain why it is an indispensable tool in analytical chemistry. [4]
- (e) Explain the following processes/terms naming the industries that use the lasers for the purposes:
 - (i) Laser uranium enrichment [3]

- (ii) Angular rotation [3]
- (f) List four lasers used in material processing and give your preference in selecting lasers for metal cutting. [4]
- (g) State the minimum requirements for lasers used for military purposes. What are the major laser military applications? [4]

SECTION B

- 2. (a) (i) Draw and label a sketch of basic design elements of a Twyman-Green interferometer . [2]
- (ii) Explain how the Twyman-Green interferometer operates. Include the following items in your explanation;
 - a.* Interference between emerging beams to form a fringe pattern when viewed with the eye.
 - b.* Effect on fringe pattern when an imperfect optical component, such as the mirror that reflects one of the beams, is used.
 - c.* Principal differences and similarities between the Twyman-Green interferometer and the Michelson interferometer [8]
- (b) What do you understand by the terms;
 - (i) Case depth
 - (ii) Transition zone?
 How would you increase these parameters? [5]
- (c) A CO₂ laser of spot size $A = 0.01\text{mm}^2$ impinges on a tissue. The penetration depth is $\alpha = 1000\text{ cm}^{-1}$. If the beam is fully absorbed in a volume $V = 4 \times 10^{-5}\text{ cm}^3$, calculate the ablation threshold density. Take $L = 4/\alpha$. [5]
- 3. (a) Starting from the expression of the polarisability α and the electric dipole moment μ , obtain the expression for the induced dipole moment and comment on three terms in the obtained equation. [6]
- (b) State and describe any two applications of holography you know. [8]
- (c) Explain with the aid of a diagram Atomic Absorption Spectroscopy [4]
- (d) In laser remote sensing, what are the physical properties that are usually measured? [2]
- 4. (a) Explain how a Police Laser gun (LIDAR) works? How can you avoid a speeding ticket? [5]
- (b) Distinguish the following using a clear example:
 - (i) Circuit switched and,
 - (ii) Packet switched networks. [2]

- (c) It is required to drill a 0,5mm diameter hole in a nickel sheet 1mm thick using a Nd - YAG laser with a 5kW peak power. Estimate the pulse length required. [4]
- (d) Describe the method used to treat
 (i) Malignant tumours,
 (ii) Blockage of arteries by atherosclerotic plague, and
 (iii) Urinary stones. [9]
5. (a) What is Lawson's criterion for sustaining a fusion reaction? Calculate the value of $n\tau$, given the following parameters:
 The ignition energy = 44 keV, Energy yield per reaction = 17,6 MeV and the product of the cross-section and velocity of the particle = $10^{-25} \text{m}^3 \text{s}^{-1}$. Derive the formular you will use. [8]
- (b) (i) What are the advantages of Wave Division Multiplexing (WDM) over Time Division Multiplexing (TDM) in high-speed data transmission networks. [3]
- (ii) In your own opinion what are the fundamental limitations in utilising the bandwidth offered by the optical fibre? Is the full bandwidth utilisation achievable? Explain [5]
- (c) A CO_2 laser beam operating at 10.6 μm has a beam diameter of 2.5 mm. A convex lens of focal length 150 mm focuses the beam. If 15 % variation in $w(z)$ can be tolerated, calculate the depth of focus. Explain the term depth of focus. [4]
6. (a) Explain the Raman effect. Starting from an expression for rotational term values show that;
- $$|\Delta\nu| = (4B_0 - 6D_0) (J + 3/2) - 8D_0 (J + 3/2)^3$$
- for rotational Raman transitions of a diatomic or linear polyatomic molecule. [6]
- (b) Describe the inertial confinement technique used to generate electrical power. Give necessary reactions. [6]
- (c) Describe differential Absorption Lidar used to monitor air pollution and briefly explain how a nitrogen gas laser can be used to track crude oil spillage in a river. [8]

- END OF EXAMINATION -

