NATIONAL UNIVERSITY OF SINGAPORE

PC3247 Modern Optics

(Semester I: AY 2012-13, November/December 2012)

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **SIX (6) short** questions in **Part I** and **THREE (3) long** questions in **Part II**. It comprises **NINE (9)** printed pages.
2. Answer **ALL** the questions in **Part I** and **TWO** questions in **Part II**.
3. Answers to the questions in **Part I** are to be written in this book.
4. Answers to the questions in **Part II** are to be written in the answer books.
5. This is an **OPEN BOOK** examination.
6. The mark for each short question is **7** and the mark for each long question is **29**. The total mark for **Part I** is **42** and the total mark for **Part II** is **58**.

IMPORTANT

Matriculation No.	Marks

Part I Short Questions

1. A vertically, linearly-polarized light beam with light intensity, I_0, passes consecutively through (1) a linear polarizer with transmission axis at 0° clockwise from the vertical, (2) a half-wave plate with fast axis at θ clockwise from the vertical, and (3) a linear polarizer with transmission axis at 90° clockwise from the vertical. Use the matrix method to find the light intensity as a function of θ after passing through the two polarizers and the wave plate.

2. A glass slab has a thickness $d = 0.1$ μm with interior index $n_m = 1.5$, and each surface has silver coating with a reflectance $R = 0.8$. A white light beam is normal incident on the glass slab. Find both minimum transmittance and visible wavelengths for minimum transmittance.

3. Refer to a Michelson interferometer in which the degree of coherence function for the light source is measured to be $|\gamma(\tau)| = \exp(-a\tau^2)$, where $a = 5 \times 10^{20}$ $/sec.^2$. Estimate the range that the moving mirror can move with observable pattern of interference.

4. Given an optical imaging system with focal length $f = 5$ cm and aperture diameter $D = 5$ cm, there is a minimum size that is resolvable by the system due to diffraction limitation. Estimate the minimum size if the light wavelength used is $\lambda = 500$ nm.

5. An optical imaging system consists of two lenses that are separated by 5 cm. The matrix of the first lens is given by $\begin{bmatrix} 1 & 0 \\ -\dfrac{1}{2.5cm} & 1 \end{bmatrix}$, and the matrix of the second lens is given by $\begin{bmatrix} 1 & 0 \\ -\dfrac{1}{5cm} & 1 \end{bmatrix}$. Find the effective focal length of the optical system.

6. Light from a laboratory sodium lamp has two strong yellow components at 589.5923 nm and 588.9953 nm. It is shone on to a grating having 10,000 lines per cm and the diffraction pattern is measured on a screen that is 2.0 m away from the grating. What is the total number of lines that the grating must have in order just to separate the sodium doublet in the second order?

Part II Long Questions

1. The amplitude of an optical wave propagating along the z-axis is given by

$$E(x, y) = E_0 \exp[-(x^2+y^2)/b^2] + E_n \cos(2\pi x/a),$$

where E_0, E_n, a and b are positive constants; $a << b$; and x or y is one of the Cartesian coordinates.

(a) Find the Fourier transform of $E(x, y)$.

(b) With a sketch, design an optical setup for the observation of light intensity of the above Fourier transform. Indicate all the optical components involved in the setup.

(c) Indicate what kinds of extra optical components are needed in order to filter out the second term in the optical wave, $E(x, y)$. Sketch the new setup and explain how the term is filtered out.

2. Apply the Fresnel-Kirchhoff diffraction formula (Eqn. 7.1 in the lecture notes) to a monochromatic plane wave with intensity I_0, which goes through a circular block of diameter ℓ.

(a) Find the electric field of the light on axis (i.e. $x, y = 0$).

(b) Find the intensity of the light on axis (i.e. $x, y = 0$).

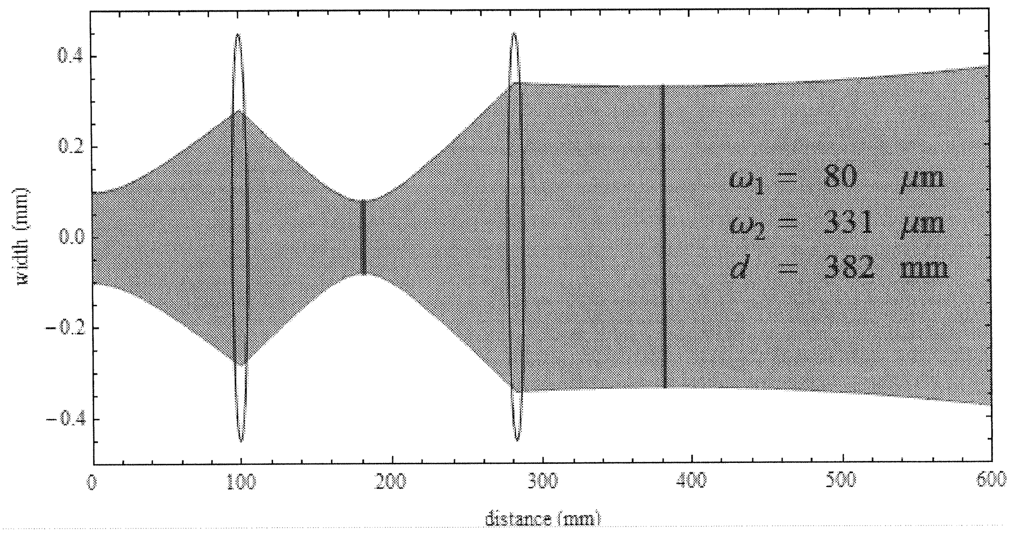
(c) Compared to the intensity of the light on axis (i.e. $x, y = 0$) under the far-field (or Fraunhofer) approximation, what conclusion do you draw?

3. A laser emits a Gaussian beam: the beam waist is $\omega_0 = 100$ μm and locates at $z = 0$, as shown in Figure below; and the laser wavelength is 514 nm.

   (a) After the first thin lens which is located at $z = 100$ mm, the beam waist becomes $\omega_1 = 80$ μm and locates near to the position $z = 180$ mm. Find the focal length of the first thin lens.

   (b) The second thin lens is positioned at $z = 282$ mm. After the second thin lens, the beam waist becomes $\omega_2 = 331$ μm and locates at $z = 382$ mm. Find the focal length of the second thin lens.

   (c) Find the radius of curved wave front at $z = 600$ mm.



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