ENGINEERING TRIPOS PART IIB

Tuesday 7 May 2013 9:30 to 11

Module 4B11

PHOTONIC SYSTEMS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1. (a) State the relationship between a computer generated hologram (CGH) and its associated replay field. Mathematically derive the replay field of the aperture with amplitude *A*, shown in Figure 1. State any assumptions made. [20%]

(b) Explain how the aperture in Figure 1 can be adapted to create a binary amplitude ($A \in [0,1]$) grating with periodicity $2a$. Using a simple graphical technique, derive the replay field structure of this grating and explain the significance of the result of part (a). [30%]

(c) Using the same graphical technique, show how the replay field for a binary amplitude grating can be used to derive the replay field for a binary phase ($A \in [-1, +1]$) grating. Comment on the diffraction efficiency into the first order of each type of grating. [30%]

(d) Explain what features of the binary phase grating in part (c) make it a suitable candidate for a routing hologram in an optical switch. What features make it less than ideal for use in the same application? [20%]

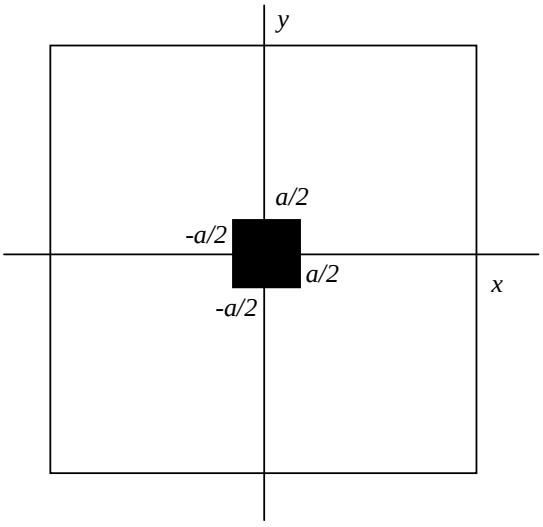

Figure 1. (The white area represents amplitude zero)

2 (a) Explain the basic function of an optically addressed spatial light modulator (OASLM). Give two different optical applications where an OASLM could have a useful function. How might liquid crystal technology be used to make such an OASLM, and what sort of modulation would be useful? [35%]

(b) A reflective liquid crystal based OASLM is used to display binary phase information within an optical system. Sketch the optical system used to read the OASLM and explain the role and orientation of the optical elements required. [25%]

(c) If the read light has a wavelength of 650nm and the liquid crystal has birefringence of 0.1, calculate the optimum thickness of the liquid crystal layer. [15%]

(d) A key element in making a reflective OASLM is the reflective layer within its structure. How might this reflective layer be constructed in reality and how will it affect the performance of the OASLM? [25%]

3 (a) Define the terms *loss* and *crosstalk* in the context of a fibre to fibre holographic beam steering optical switch. What is meant by the term fan-in loss for a holographic beam steering optical switch? [20%]

(b) Show that for a 1 by *n* port holographic beam steering optical switch, with a *N*x*N* pixel binary phase hologram, that a bounding value for the crosstalk can be derived as: [30%]

$$C = \frac{\eta}{1-2\eta} N^2$$

Define all of the variables in the equation and state any assumptions made.

(c) Explain with the aid of a sketch how a 1 by *n* holographic switch can be expanded into an *n* by *n* holographic switch. How does this expansion affect the crosstalk of the switch and what is the new bound on the crosstalk? [25%]

(d) Comment on the validity of the bounding crosstalk value derived in part (c) and explain why this form of *n* by *n* optical switch is not really practical. How could the design of the switch be changed to improve the crosstalk? What is the penalty for this change and how will it alter the bounding crosstalk value? [25%]

4 (a) Explain how the intensity of an image is related to the intensity of an object/aperture and define the point spread function (PSF). Assuming that there are no aberrations present in an optical system that consists of a circular aperture, sketch the PSF. What is meant by the term convolution? How is the PSF related to the aperture function? [25%]

(b) Sketch a typical layout of an adaptive optical system and describe the role of each component. With the aid of diagrams, give three examples of methods used to measure the aberrated wavefront and give some examples of the type of components used to compensate for the phase of the aberrated wavefront. [30%]

(c) Describe three sources of aberrations that can arise in an optical system and explain, using your answer to the first part of question (a), how aberrations affect image quality. What quantities are used to define the quality of an optical system? [25%]

(d) Describe how distortions in a wavefront are treated mathematically and give examples of some of the low order modes. [20%]

END OF PAPER