UNIVERSITY OF CAMBRIDGE

ENGINEERING TRIPOS PART IIB

Thursday 28 April 2005 2:30 to 4:00pm

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

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

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1. (a) Define the relationship between a hologram and its replay field. State any assumptions made. Show, with the aid of sketched diagrams, that the pixellation of a computer generated hologram leads to an ordered structure in the replay field. [30%]

(b) A 256x256 pixel computer generated hologram (CGH) with 10μm square pixels, has been designed to generate a centred, square, 7x7 array of spots of equal height in the replay field with five zero pixels between each spot. The replay field is generated by uniform illumination of the CGH through a 300mm positive focal length lens, with a 670 nm wavelength laser diode. The replay field is then captured on a charge coupled device (CCD) camera.

i) Sketch the layout of the optical system and the image captured on the CCD [15%]

ii) Why will the spots of the CGH in the replay field be of different heights? Sketch the first row of spots in the replay field array. [15%]

iii) Calculate the ratio of the intensity in the top rightmost spot to the central spot in the 7x7 array. State any assumptions made. [25%]

(c) Why is direct binary search not the ideal algorithm to generate this CGH? [15%]

2 (a) Sketch the physical construction and basic operation of the binary phase 1/f joint transform correlator (JTC). Explain the role of each component in the optical system and the overall operating principle of the system. [30%]

(b) Show, with the aid of diagrams how a binary phase 1/f JTC can be used as a head tracking system in the cockpit of a fighter aircraft. [30%]

(c) An accurate head tracking JTC must have at least 20% overlap between consecutive video frames in order to correlate reliably. Given a correlator operating at 50 correlations per second, a video camera with a 20° field of view and a distance of 1.3 m between the pilot and the cockpit console, estimate the maximum allowable angular speed of rotation of the pilot's head. [25%]

(d) What will happen when the pilot looks out of the canopy of the aircraft? Suggest a possible modification to the system to prevent this problem. [15%]

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

Compare the significance of loss and crosstalk for the following switches:

i) a holographic beam steering optical switch [10%]

ii) a shutter based crossbar optical switch [10%]

(b) Show that for a 1 by n port holographic beam steering optical switch, with a NxN binary phase hologram of efficiency η, that an approximate value for the crosstalk can be derived as:

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

State any assumptions made. [15%]

Calculate the approximate crosstalk figure for an n by n port holographic beam steering optical switch. [5%]

(c) Give three reasons why the expression for the 1 by n switch derived in part (b) is in fact a very optimistic bound on the actual crosstalk. [20%]

(d) Explain how the crosstalk and scalability of the holographic beam steering optical switch can be greatly improved. What is the main penalty for this improvement? [20%]

4 (a) Explain what is meant by the term mode in conjunction with an optical waveguide structure. What is the difference between a multimode and a single mode waveguide structure? Which one is easier to make and why? [25%

(b) Describe, in general terms, how Maxwell's equations for the propagation of electromagnetic radiation in a medium can be used to derive the modal structure of a waveguide. What is the significance of the boundary conditions and how can these be used along with the geometry to derive a solution? [25%

(c) What techniques can be used if there is no analytical solution to Maxwell's equations? Briefly explain how one such technique might work. [20%

(d) Sketch the basic structure of an arrayed waveguide generator (AWG) and describe each part of its construction. What might an AWG be used for in an optical communications system? [30%

END OF PAPER