Version TDW/3

EGT3
ENGINEERING TRIPOS PART IIB

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26 April 2023 2 to 3:40

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.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Write on single-sided paper.

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

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

You may not remove any stationery from the Examination Room.

1. A computer generated hologram (CGH) is to be designed so that it forms a two dimensional image by the process of optical diffraction.

(a) Explain what is meant by the terms CGH, pixel and replay field in the context of forming this image. Use a diagram to demonstrate the relationship between them in an optical system. What are the important properties of each pixel that dictate the formation of the image? [20%]

(b) Show that the overall size and structure of the replay field for a CGH, formed using a lens with positive focal length f, is dependent on the pitch of CGH pixellation, Δ as well as the wavelength of illumination λ. State any assumptions made. [30%]

(c) Explain what is meant by the term apodisation when using a CGH to form an image. Describe possible sources of apodisation and their overall effect on the replay field of the image created. Why is this a serious limitation when using CGHs as beam steering elements in optical switches? [30%]

(d) An N by N pixel CGH is designed for use in an optical switch. The CGH is then repeated K by K times on a regular square grid. Describe the effects of this repetition on the structure of the replay field of the new CGH. What does this do to the effects of apodisation? [20%]

2 (a) Describe, in simple terms, how both nematic liquid crystals and ferroelectric liquid crystals can be used to modulate light. What are the advantages and disadvantages of each electro-optical effect? [35%]

(b) Which of the two electro-optical effects would you use in the following applications? Explain your choices.

i) An optical correlator.

ii) A single mode fibre to fibre optical switch.

iii) An optical packet switch. [20%]

(c) An optical switch is to be designed using a liquid crystal over silicon (LCoS) spatial light modulator (SLM). Sketch the basic structure of an LCoS SLM and define the elements that make up its structure. How would the design of the device differ for a nematic liquid crystal versus a ferroelectric liquid crystal? [30%]

(d) Given it is relatively easy to integrate a photodetector onto the silicon backplane of a LCoS SLM, how might the electronics on the backplane be used to enhance pixel functionality? [15%]

3 (a) Define the terms *loss*, *efficiency* and *crosstalk* in the context of a single mode fibre to fibre holographic beam steering optical switch. What is meant by the term fan-in loss for a 1 to *n* holographic beam steering optical switch? [25%]

(b) Show that for a 1 to *n* port holographic beam steering optical switch, with a *N* by *N* pixel binary phase hologram with efficiency η, that the bounding value for the crosstalk can be derived as

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

Define all of the variables in the equation and state any assumptions made. [25%]

(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 effect 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 its crosstalk? What is the penalty for this change and how will it alter the bounding crosstalk value? [25%]

4 (a) Sketch the optical architecture of a joint transform correlator (JTC) based on an optically addressed spatial light modulator (OASLM), explaining the role of each component in the system. If the OASLM is modelled as a simple square law detector, show how the correlation of two images (*r(x,y)* and *s(x,y)*) is formed by the JTC and find the location of the correlation. [40%]

(b) How does the nonlinearity of the OASLM alter the quality of the optical correlation? Give an example of how the choice of liquid crystal used within the OASLM could enhance the performance of the JTC. [20%]

(c) Unfortunately, when the OASLM was fabricated, there was a large variation in both the thickness of the liquid crystal layer as well as the thickness of the glass used in its structure. How would these imperfections alter the performance of the JTC? [20%]

(d) Could an adaptive optics approach be used to eliminate the effects of the imperfections in the OASLM when fabricated? Explain how this might be done. [20%]

END OF PAPER

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