Version TDW/3

EGT3
ENGINEERING TRIPOS PART IIB

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26 April 2017 2 to 3.30 pm

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
Single-sided script 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

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

1 (a) The far field diffraction pattern is related to its hologram via a Fourier transform. Use a simple diagrammatic proof to find the structure of the far field diffraction pattern of a periodic binary amplitude grating, where the period of the zero state is the same as that of the transmissive state. State any assumptions made. [35%]

(b) An important technology in applications that use computer generated holograms are Liquid Crystal Over Silicon (LCOS) Spatial Light Modulators (SLMs). One of the problems with this technology is deadspace. Explain why there must always be deadspace with these SLMs and use the same analysis used in (a) to demonstrate the effect of this deadspace in the hologram replay field. [25%]

(c) If the hologram displayed on the LCOS SLM has been designed for use with binary phase modulation, what other effect might be seen in the replay field due to its deadspace? How could this problem be avoided? [20%]

(d) The binary phase LCOS SLM is intended to be used in a single mode fibre to fibre optical switch. Give two reasons why minimising the SLM deadspace is critical to the switch performance. [20%]

2 (a) Explain what is meant by the term retardance when referring to a liquid crystal modulator. If a liquid crystal cell has two pixels filled with a planar aligned nematic liquid crystal, derive an expression for the retardance between the two pixels if one pixel has no voltage applied to it and the other has a voltage high enough to switch the pixel fully homeotropic. State any assumptions made. [25%]

(b) The device in (a) has two major limitations when being considered for use in an optical switch. Explain how these limitations arise from the choice of liquid crystal and explain why a Surface Stabilised Ferroelectric Liquid Crystal (SSFLC) does not suffer from these same limitations. [25%]

(c) The Jones matrix *W*, for a general retarder of retardance Γ and with its extraordinary axis oriented with respect to the *y* axis by an angle ψ, is given below. Using Jones matrices and a suitable diagram of the pixel architecture, show how a SSFLC pixel can be set up to perform binary phase modulation. [35%]

$$W = \begin{pmatrix} e^{-j\Gamma/2}\cos^2\psi + e^{j\Gamma/2}\sin^2\psi & -j\sin\frac{\Gamma}{2}\sin(2\psi) \\ -j\sin\frac{\Gamma}{2}\sin(2\psi) & e^{j\Gamma/2}\cos^2\psi + e^{-j\Gamma/2}\sin^2\psi \end{pmatrix}$$

(d) Using the result from part (c) derive the optimal properties of a SSFLC material for use as a binary phase only spatial light modulator to be used in an optical switch. Comment on the feasibility of obtaining these properties in a real material. [15%]

3 (a) Sketch the optical architecture of a $1/f$ Joint Transform Correlator (JTC). Use the basic principles of Fourier optics to show how the resulting correlation plane is formed, stating any assumptions made. [30%]

(b) What sort of Spatial Light Modulator (SLM) would be best suited to this architecture? Explain your decision and discuss what the limitations of this choice might be. What inherent feature of this architecture allows the impact of these limitations to be partially minimised? [30%]

(c) The capabilities of the $1/f$ JTC has allowed alternative applications to be explored using optical correlation. Give an example of one such application and describe how the correlation function can give new information to the results of this application and how they are interpreted. [30%]

(d) How might a custom silicon chip be used to further enhance the performance of the $1/f$ JTC? [10%]

4 (a) Give three examples of optical systems where adaptive optics would improve the performance of the application. In each case, briefly discuss how the adaptive optical system might be implemented and whether they would be open or closed loop systems. [30%]

(b) A key element of any adaptive optical system is the ability to detect the wavefront aberration that has to be corrected. One such detector is the Shack-Hartmann wavefront sensor. Sketch a diagram of how this sensor works and discuss three limitations of its performance. [30%]

(c) One application which uses the adaptive capabilities of free space optics is in board to board optical interconnects. Sketch a basic diagram of how this type of interconnect works and explain its overall operation. Is it an example of a closed or open loop system? [25%]

(d) If the adaptive element of the board to board interconnect were to be displayed on a ferroelectric liquid crystal spatial light modulator, how might the inherent symmetry of the architecture be used to enhance its performance? [15%]

END OF PAPER

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