EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 24 April 2024 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
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 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 in the replay field by the process of optical diffraction.

(a) The CGH is to be made from an array of N by N pixels with a pitch of Δ. An initial calculation of the CGH is shown in Fig. 1(a). Use either a mathematical derivation or a graphical technique to show what the resulting replay field would look like, stating any assumptions made. [30%]

(b) A second iteration of calculations results in the CGH shown in Fig. 1(b). Explain how the structure of the replay field is changed by this second iteration. [20%]

(c) The CGH in part (b) is illuminated with light from a fibre laser with a Gaussian mode profile and wavelength λ. The combination of the laser beam and the collimation lens means that only two thirds of the CGH pixels are illuminated. Describe what effect this have on the structure of the light in the replay field. [30%]

(d) The N by N pixel CGH is designed for use in an single mode fibre optical switch. Describe how the effects of the illumination of the CGH described in part (c) will impact on the functionality of the optical switch. How might these problems be minimised in the design of the switch? [20%]

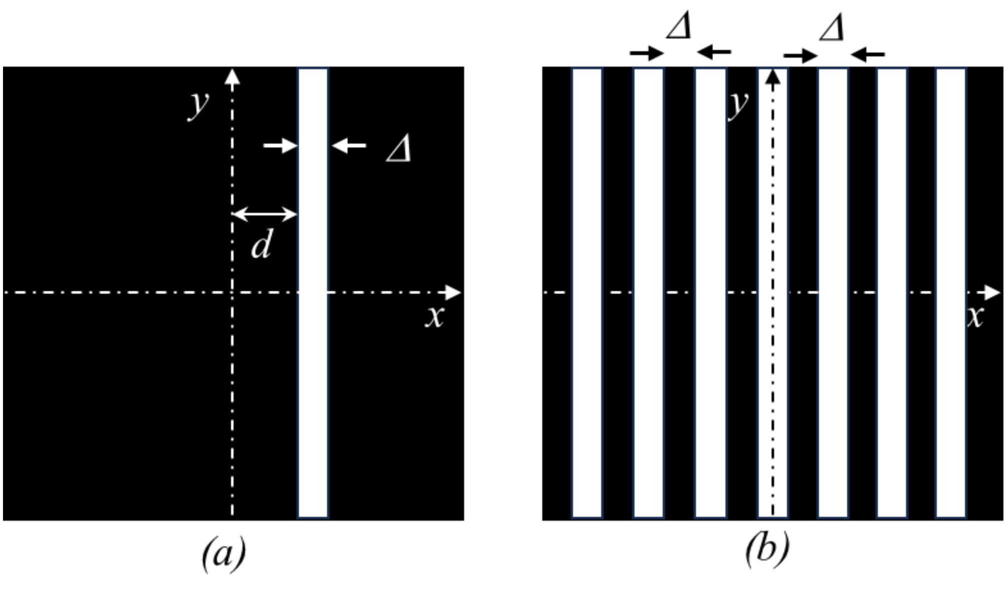

Fig. 1 The white areas represent amplitude 1, black areas 0.

2 (a) An important technology for use in applications such as holography is the Liquid Crystal Over Silicon (LCOS) Spatial Light Modulator (SLM). Explain, with the aid of a diagram, how an LCOS SLM is constructed and identify the key parameters in its fabrication. Explain how a nematic liquid crystal LCOS SLM would differ from a ferroelectric liquid crystal one. [35%]

(b) One of the problems encountered with an LCOS SLM is pixel deadspace. Explain why there must always be deadspace with these SLMs. Using a graphical analysis, demonstrate the effect of pixel deadspace on the structure of a hologram replay field. [30%]

(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. [15%]

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3 (a) Sketch the basic architecture of a matched filter and describe the process by which it operates. What are the main advantages and disadvantages of a matched filter over other forms of optical correlator? [25%]

(b) How is the filter generated for the matched filter architecture and what is the main limitation of this process? Give two ways in which the performance of the filter can be improved and discuss any potential drawbacks from these techniques. [25%]

(c) One of the main limitations of a matched filter is scale invariance. Show how a Synthetic Discriminant Function (SDF) based filter can be designed to overcome this limitation. Why might the processes discussed in part (b) limit the effectiveness of the SDF? [25%]

(d) The matched filter is to be displayed on a ferroelectric liquid crystal spatial light modulator (SLM). How does this choice of modulator effect the functionality of the overall matched filter system? Given that choice of SLM for the filter, what other sort of algorithm could be employed to generate a scale invariant filter? [25%]

4 (a) Describe with the aid of a diagram, the basic operation of a Shack-Hartmann wavefront sensor and show where it might be used in an adaptive optics system. What are the main limitations of this type of wavefront sensor? [40%]

(b) Figure 2 shows a single row scan from a plane wave that has been distorted by an optical aberration. Sketch what the output from the corresponding row of a 10 zones per row Shack - Hartmann wavefront sensor might look like when illuminated by the wavefront in Fig. 2. Explain any assumptions made in your analysis. [20%]

(c) The aberration detected in part (b) has been detected within the input optics of a matched filter. The matched filter is to be displayed on a binary phase spatial light modulator. Explain how the matched filter calculation algorithm can be modified to include and correct for the measured optical aberration. What are the limitations of this technique and can it be applied to the output optics of the matched filter? [20%]

(d) Explain how a binary phase hologram might be used to perform the same task as the Shack - Hartmann wavefront sensor. [20%]

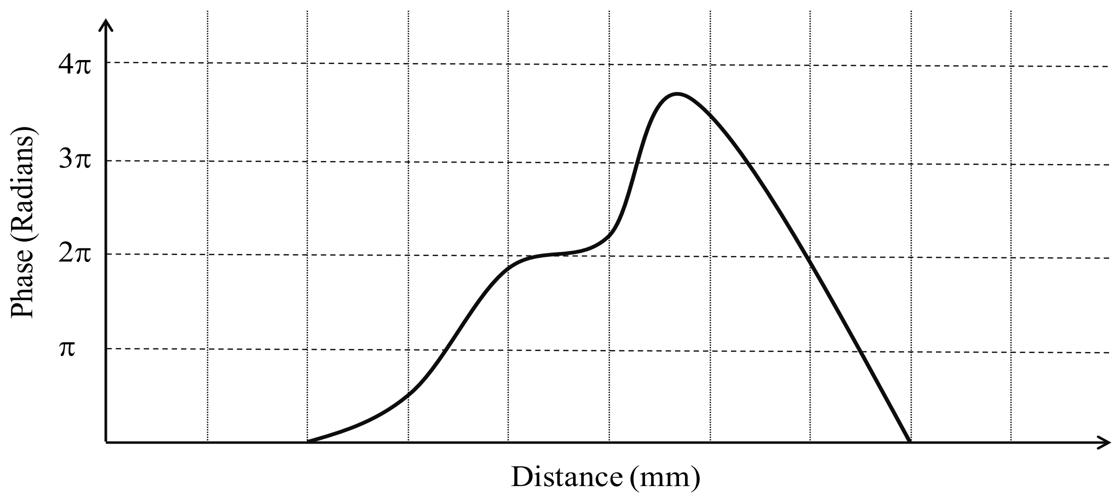

Fig. 2

END OF PAPER

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