Version TDW/4

EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 28 April 2021 1:30 to 3:10

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 and at the top of each answer sheet.*

STATIONERY REQUIREMENTS
Write on single-sided paper.

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed.
You are allowed access to the electronic version of the Engineering Data Books.

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

The time taken for scanning/uploading answers is 15 minutes.

Your script is to be uploaded as a single consolidated pdf containing all answers.

1 (a) A transmissive ferroelectric liquid crystal spatial light modulator (SLM) is to be used to display phase only computer generated holograms (CGHs) in an optical system. The light source for the system is based on a single mode fibre pigtailed laser diode. Sketch an optical system, labelling all components, to show how this laser and SLM can be used to form the replay field of the CGH. [25%]

(b) The SLM in part (a) has an N x N array of pixels with pitch Δ. Explain how the two parameters N and Δ dictate the structure of the information to be projected in the replay field. What other properties of the system will also dictate the structure in the replay field? [30%]

(c) The SLM in part (a) is to be used to create a full colour holographic two-dimensional projector. In order to create the full colour image, three laser diode sources are required, red (670 nm), green (532 nm) and blue (450 nm). Describe how the hologram generation algorithm must be modified in order to accommodate the 3 laser sources. What other components in the system might also need to be modified to create a reliable full colour image? [25%]

(d) Briefly explain how the projector could be modified in order to display a three-dimensional image. [20%]

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 a nematic liquid crystal material be used to make an OASLM, and what sort of modulation would be possible? [30%]

(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 650 nm and the liquid crystal has birefringence of 0.11, calculate the optimum thickness of the liquid crystal layer. [20%]

(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) Sketch the overall layout of a binary phase only matched filter (BPOMF) using two ferroelectric liquid crystal (FLC) spatial light modulators (SLMs). Identify the key components and explain why such a correlator is difficult to build. [20%]

(b) The BPOMF in part (a) has the following parameters. SLM1 has N_1 x N_1 pixels of pitch Δ_1, SLM2 has N_2 x N_2 pixels of pitch Δ_2 and the laser has wavelength λ. Show that for perfect alignment of the BPOMF, the focal length of the main Fourier transform lens f must be set at [20%]

$$f = \frac{N_2 \Delta_2 \Delta_1}{\lambda}.$$

(c) In many cases, the focal length calculated in part (b) often leads to an impractically large value which cannot be built. Sketch a layout to show how three lenses can be used in place of the one in (b) to remedy the problem. Clearly label the relevant focal lengths. Show that the three lenses can be chosen using the following criterion [30%]

$$\frac{f_3}{f_2} = \frac{N_2 \Delta_2 \Delta_1}{f_1 \lambda}.$$

(d) Given that lenses are only available in certain discrete focal lengths, explain, using an example, how the criterion of part (c) can be implemented. What are the main pros and cons of this lens system? [30%]

4 (a) In an adaptive optical system, one of the most important functions is to be able to detect the distortion of the wavefront due to aberration. Describe with the aid of a diagram the basic way in which a Shack Hartmann wavefront sensor achieves this function. What are its main limitations? [20%]

(b) A plane wave passing through an optical system is subject to aberration which has a Gaussian structure with a maximum distortion of 2π in the centre of the optical axis. Roughly sketch both the resulting wavefront and what the output from the central row of an 11 zone per row Shack Hartmann wavefront sensor might look like when illuminated by this wavefront. Explain any assumptions made in your analysis. [35%]

(c) A monochromatic holographic projection system has been designed using a ferroelectric spatial light modulator. The holograms have been designed using a simple direct binary search algorithm. Describe briefly how this algorithm works and discuss what the limitations of this algorithm might be. [25%]

(d) How would the direct binary search algorithm in part (c) be modified to minimise the effects of the aberration seen in part (b)? [20%]

END OF PAPER

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