Version TDW/3

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 19 April 2016 2 to 3.30

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) Explain what is meant by the terms Computer Generated Hologram (CGH), replay field and Fourier transform. Use a diagram to demonstrate the relationship between them in an optical system. State any assumptions made. [20%]

(b) Show that the overall structure of the replay field for a computer generated hologram is dependent on the pitch of the pixelation Δ as well as the wavelength of the illumination λ. How does the number of pixels N in a hologram effect its replay field? [25%]

(c) A 256 x 256 pixel binary phase CGH with 10 μm square pixels, has been designed to generate a centred, square, 7 x 7 array of spots of equal height in the replay field with five zero-value pixels between each spot. The replay field is generated by uniform illumination of the CGH through a 300 mm 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) 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%]

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

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

2 (a) Describe how the properties of a planar aligned nematic liquid crystal can be used to modulate the phase of a light source. Clearly list the parameters that are required to perform phase modulation and sketch the configuration of a reflective cell. [25%]

(b) One of the main limitations of the nematic liquid crystal phase modulator is its inherent polarisation dependence. Explain why this limitation occurs and why simple solutions such as the twisted nematic structure do not solve the problem. [25%]

(c) Jones matrices are often used to model the propagation of polarised light through bulk birefringent material. Given the generalised matrix of an optical retarder, W (below) with retardance Γ and orientation with respect to the vertical axis of ψ, derive an expression for a quarter waveplate oriented at 45 degrees to the vertical axis. [25%]

(d) Using the result from part c) show how a quarter waveplate can be used to make a reflective planar nematic liquid crystal cell polarisation insensitive. [25%]

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

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. [30%]

(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? [30%]

(d) The matched filter architecture can be modified to perform a simple optical derivative function. Use simple Fourier theory to show how the filter can be derived and discuss how the basic architecture of part (a) can be modified to implement it. [15%]

4 (a) In an adaptive optical system, one of the key principles governing system performance and functionality is phase conjugation. Use a simple sketch of a closed loop adaptive optical system, identifying the key elements, to show how phase conjugation can greatly improve the optical quality of the system. [30%]

(b) In an adaptive optical system, Zernike polynomials are often used to express the aberration function. What are the key properties of Zernike polynomials that make them useful? Use a simple sketch to show their basic structure and explain why they are particularly suited for use with deformable mirrors. [30%]

(c) A 1 to 16 fibre holographic optical switch has been designed using a transmissive ferroelectric liquid crystal spatial light modulator. Sketch the overall structure of the optical system and identify points in the system where aberrations might occur. [25%]

(d) How might the inherent features of the spatial light modulator in part (c) be used to both detect and correct for these aberrations? [15%]

END OF PAPER

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