Version TDW/3

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 22 April 2014 9.30 to 11

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

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

1 (a) A binary phase hologram, $h(x.y)$, contains N by N pixels and is designed to generate a replay field $H(u,v)$. Define the three main limitations on the quality of the image in the replay field generated by this hologram and explain why these limitations occur. [30%]

(b) The hologram described in part a) is to be displayed on a $2N$ by $2N$ pixel spatial light modulator (SLM). In order to display the hologram, it must be replicated on a 2x2 grid. Use a simple sketch to show how this replication process works and describe mathematically the effect on the structure of the replay field due to the replication process. [30%]

(c) An alternative way of displaying the hologram described in part a) on the $2N$ by $2N$ pixel SLM is to resample the original hologram at the SLM's resolution. Give a qualitative description of how this resampling could be implemented and discuss the effect it would have on the replay field of the hologram. [20%]

(d) If a zero state of modulation was also available, describe a third way in which the hologram could be restructured in order to use the full $2N$ by $2N$ available pixels on the SLM. How does this affect the replay field? [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? [30%]

(b) Explain which of the two electro-optical effects in part (a) you would use in the following applications:

(i) A single mode fibre to fibre optical switch.
(ii) An optical packet switch.
(iii) A matched filter optical correlator.

[20%]

(c) Sketch the basic structure of a liquid crystal over silicon spatial light modulator (SLM). How would the design of the device differ for a nematic liquid crystal versus a ferroelectric liquid crystal? [25%]

(d) Explain what is meant by a smart pixel SLM. How could such a device be used to improve the performance of an optical joint transform correlator? [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 opto-mechanically difficult to implement. [25%]

(b) In a BPOMF, the first SLM has N_1xN_1 pixels of pitch Δ_1 and the second SLM has N_2xN_2 pixels of pitch Δ_2 and the laser has a wavelength λ. Explain why the pixellation of the two SLMs is a limitation in the construction of the BPOMF and show that for perfect alignment of the filter, the focal length of the first lens in your proposed system must be set at:

$$f = \frac{N_2 \Delta_2 \Delta_1}{\lambda}$$ [25%]

(c) Sketch a layout to show how three lenses of different focal lengths (f_1, f_2, f_3) can be used in place of the one in part (b) to remedy these limitations. Show that the three focal lengths can be chosen using the following criterion:

$$\frac{f_3}{f_2} = \frac{N_2 \Delta_2 \Delta_1}{f_1 \lambda}$$ [25%]

(d) Explain the best methodology behind choosing suitable lenses for the design in part (c) assuming only a limited supply of catalogue lenses are available. [25%]

4 (a) In an adaptive optical system, one of the key principles governing performance and functionality is phase conjugation. Draw a simple sketch of an adaptive optical system and show how phase conjugation can greatly improve the operation and quality of the system. [25%]

(b) List four potential sources of aberration in an optical system that could be improved by the process of phase conjugation. How can these optical aberrations be expressed mathematically? [30%]

(c) The optical system in part (a) has an incoming optical wave $s(x,y)$ which passes through an optical medium with a transfer function $g(x,y)$ and then through an optical imaging system with transfer function $p(x,y)$. Calculate the amount of phase conjugation required. Give two examples of modulation technologies that could be used to implement this phase conjugate. [25%]

(d) A holographic projector is designed using the same optical components as the system in part (c). Explain how the process of phase conjugation can be implemented in this system without any additional optical components. [20%]

END OF PAPER

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