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Computers in Exams

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Outline

Standard Examinations in the UK

Computers in exams

- Question to extend the optics in exams

Implementation of computers in exams

- Practicalities - security and integrity
- Style of questioning

Student take-up and performance

Summary

Standard examinations in the UK

- Written examinations
- Time limited
- Often an element of question selection (eg select one from two)
- Closed book

*Friday 12th May 2006:
14.00 to 14.30*

Answer ONE question from each section.

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A Traditional Question

A typical question on the characteristics of a fibre Bragg grating

4. Forward and backward amplitudes emerging from a fibre Bragg grating of length L and pitch Λ may be described via

$$\begin{bmatrix} A^+ \\ A^- \end{bmatrix}_L = \begin{bmatrix} P & Q \\ Q^* & P^* \end{bmatrix} \begin{bmatrix} A^+ \\ A^- \end{bmatrix}_0$$

where $P = \cosh \Delta L + i\left(\frac{\delta\beta}{2\Delta}\right)\sinh \Delta L$, $Q = i\frac{\kappa}{\Delta}\sinh(\Delta L)$, $\Delta = +\left[\kappa^2 - (\delta\beta/2)^2\right]^{1/2}$, $\delta\beta = 2\beta - 2\pi/\Lambda$, $\beta = 2\pi n_{eff}/\lambda_0$, $\kappa = \pi\delta n_{eff}/\lambda_0$. All undefined symbols have their usual significance.

(i) Show that the grating reflectivity is given by

$$R(\lambda_0) = \left|\frac{\kappa \sinh(\Delta L)}{\Delta \cosh \Delta L + i(\delta\beta/2)\sinh \Delta L}\right|^2 .$$

Sketch this spectral function indicating how the spectrum changes (a) as L is increased, and (b) as κ is increased. Indicate clearly the filter bandwidth on all your sketches.
[6 Marks]

(ii) Reduce this to a much simpler formula when $\delta\beta = 0$, and thus show that the Bragg wavelength is given by $\lambda_0^{Br} = 2n_{eff}\Lambda$. Draw a sketch of the reflectivity at the Bragg wavelength vs. L.
[4 Marks]

(iii) The grating bandwidth is determined from the condition that $\Delta = 0$. Show that the bandwidth for the filter is therefore given by $2\Lambda\delta n_{eff}$.
[4 Marks]

(iv) Suggest suitable values of n_{eff}, Λ, δn_{eff} and L to make a grating for which the reflectivity is 99% centred at a Bragg wavelength of $\lambda_0 = 1.55\,\mu m$ with a bandwidth of 1nm.
[6 Marks]

Typical questions

Limitation

- Can get caught up in the maths
- Ask questions about simplified models (eg planar waveguide rather than optical fibre)
- Do not necessarily probe understanding of real optical systems
- Propagation of light in fibre and photonic structures provide examples of such situations

Computers in exams

Requirements of the questions

- The student should not need specialist knowledge of computer program to manipulate or extract data from the model
- It should allow the student to address real optical systems
- It should allow the examiner to probe the understanding of real optical systems

Software adopted was Matlab

- Many students familiar with this package
- Easy to manipulate parameter values
- Easy to generate graphical output

Implementation - practicalities

Security and integrity

- Computers to be used under examination conditions
- Computer to be blocked from communications (though network access may be needed by the software)
- Computer "desktop" to be clean
- Limited "write" permission required
- Commercial product NetOps School 4 was used – but required significant support from our ICT staff.

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Implementation

Initial approach

- Introduce for one of the option courses (Photonics Structures)
- Weave use of computer into traditional examination style
- Student provides “answers” as handwritten work in answer book
- Provide second choice question as a standard exam question.

Preparing the students

- Provided class sessions working through problems presented in same manner as the “exam”
- Offered training sessions on using the software

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The question (2006)

Note that the question

- still asks for demonstration of the students' knowledge
- still asks for demonstration of key manipulation/calculation
- uses the software to model much more involved optical systems
  - » Two gratings
  - » Adjust parameters for different applications

Need to remember that the students can view the code.

SECTION J: PHOTONIC STRUCTURES

1. (i) For a fibre Bragg grating, write down formulae for:

(a) the Bragg wavelength $\lambda_0^{(Br)}$,
(b) the bandwidth $\Delta\lambda_0^{(Br)}$ and
(c) the grating reflectivity R at the Bragg wavelength. *(If you cannot remember the formulae, you may find the formulae below useful.)*

[5 Marks]

(ii) A fibre Bragg grating of length 5.3 mm is required to have $\lambda_0^{(Br)} = 1.55\,\mu$m, $\Delta\lambda_0^{(Br)} = 0.3$ nm and $R = 99\%$. Calculate the required values of

(a) the effective index perturbation δn_{eff},
(b) the grating period Λ, and
(c) the effective index n_{eff}.

(You must show all your working).

[7 Marks]

(iii) Two filters are fabricated in series with the above parameters. By irradiating one of the gratings with UV light its n_{eff} is increased slightly so that its Bragg wavelength shifts. Show that Δn_{eff}, the change in n_{eff} required to shift the Bragg wavelength by half the bandwidth is given by $\Delta n_{eff} = {}^{\delta n_{eff}}\!/_2$. Run the code 'double_grating.m' to observe the reflection spectrum of the combined structure prior to irradiation. Type figure(2) in the command window. By changing the value of neff_2 in the code 'double_grating.m', plot the reflection spectrum when n_{eff} for one grating is increased to (a) $n_{eff} + \Delta n_{eff}$ (b) $n_{eff} + 3\Delta n_{eff}/2$, and $n_{eff} + 2\Delta n_{eff}$. In each case draw a sketch of the spectrum and suggest a possible use for the resultant filter. *Your sketches must be annotated to show the location, height and bandwidth of the Bragg peaks, and the heights of the sidebands.*

[8 Marks]

(You may find the following useful: the reflection spectrum of a fibre-Bragg grating of length L is given by

$$R(\lambda_0) = \left|\frac{\kappa\sinh(\Delta L)}{\Delta\cosh\Delta L + i(\delta\beta/2)\sinh\Delta L}\right|^2,$$

where, $\Delta = \left[|\kappa|^2 - (\delta\beta)^2\right]^{1/2}$, $\kappa = \pi\delta n_{eff}/\lambda_0$ *and* $\delta\beta = 2\pi n_{eff}/\lambda_0 - \pi/\Lambda$.*)*

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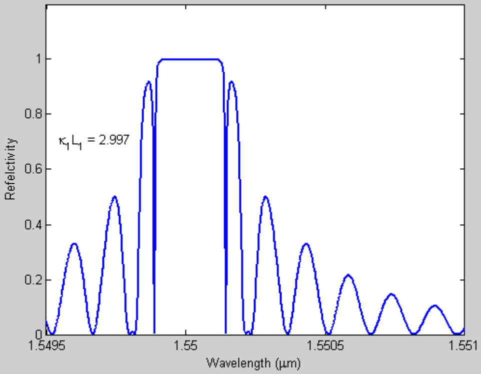
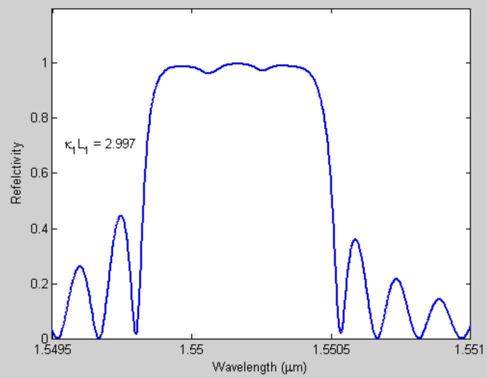
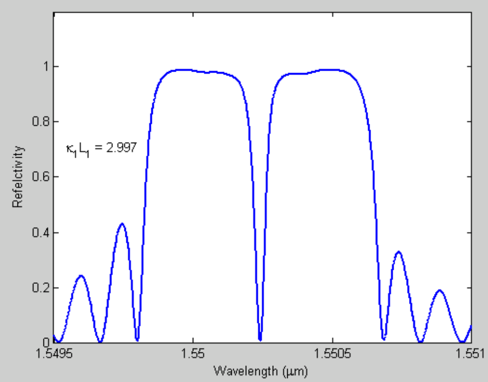
The answers

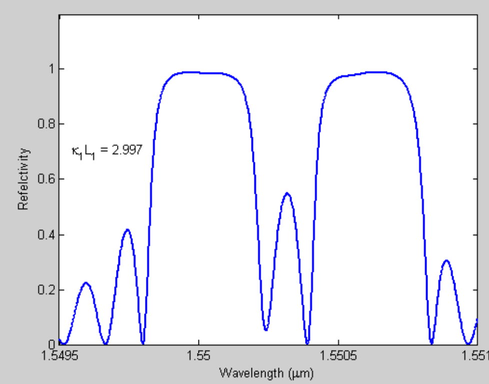


Increasing irradiation of second grating



Students must then interpret these





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First experiences

From the students

- Students are very open to new forms of assessment
- The exam format was not too different
- No negative comments about the format or process

From Staff

- Gives greater latitude of the questions that can be set
- Still differentiates student knowledge, understanding and interpretation
- Setting up is more involved that initially anticipated

First experiences (2)

From the results

- All students attempted the “computer” questions (15 students)
- Average mark was maintained at a level typical of previous MSc examinations (perhaps a bit higher…)
- Two students failed

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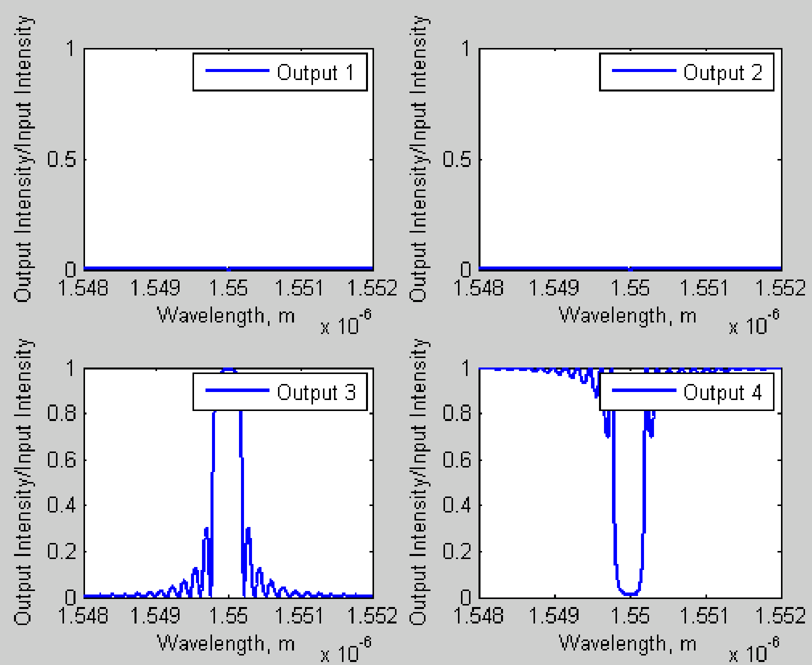
Further examinations

2007

- 60% of students took this question
- Average mark lower than 2006



SECTION J: PHOTONIC STRUCTURES

1. This question concerns an Add-Drop Multiplexer (ADM) whose function can be modelled using the code "*adm.m*". The code assumes all the light is incident to a single port (Port 1). The graphs displayed on running the programme show the output spectra (in the vicinity of the Bragg wavelength) at all four ports.

(i) Briefly describe, with the aid of a diagram, the operation of "dropping" a channel using an add-drop multiplexer (ADM) consisting of two fibre couplers and two Bragg gratings. Your description should also include a sketch of the output obtained by running the code "*adm.m*". Briefly describe how a different configuration of the device can be used to "add" a channel instead.

[8 marks]

(ii) Suppose, for the ADM considered in part (i), a Bragg grating is present in just one arm of the interferometer. What parameter needs to be set to zero in "*adm.m*" in order to model this situation? Set this parameter to zero in the code, run the code and sketch the output. What are the maximum signals obtained in ports 1 and 3? With reference to the first equation below, explain why they take these values.

[6 marks]

(iii) Now both Bragg gratings are present. Light is incident at port 1 as before, but unfortunately the fibre in one arm of the interferometer breaks at a point such that light no longer reaches the grating in this arm. Model this situation by modifying appropriate parameter(s) in the code, run the code, and sketch the results. With reference to the equations below, and your knowledge of the reflection/transmission spectrum of a Bragg grating, explain the form of the spectra.

[6 marks]

Useful information:

The transmission function of each coupler is described via:

$$\begin{bmatrix} A(L) \\ B(L) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & i \\ i & 1 \end{bmatrix} \begin{bmatrix} A(0) \\ B(0) \end{bmatrix}.$$

Transmission through two channels when one channel is blocked is described by the matrix

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A(0) \\ B(0) \end{bmatrix}.$$

End

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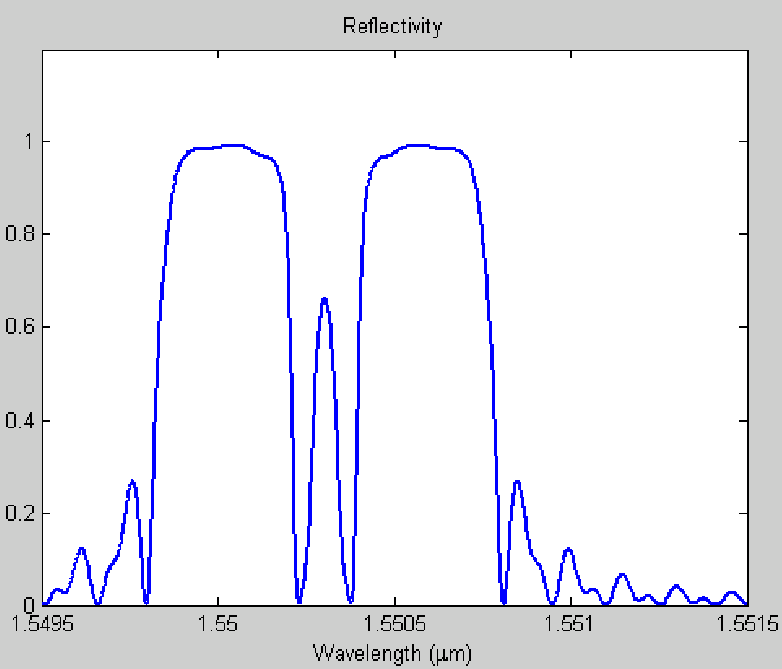
Further examinations

2008

- 25% of students attempted this question
- Average comparable with 2007



SECTION J: PHOTONIC STRUCTURES

1. The coupled wave equations describing forward/backward propagation of waves through a Bragg grating are:

$$\frac{d}{dz}\begin{bmatrix}A^+\\ A^-\end{bmatrix} = \begin{bmatrix}0 & i\kappa e^{-i\delta k z}\\ -i\kappa e^{i\delta k z} & 0\end{bmatrix}\begin{bmatrix}A^+\\ A^-\end{bmatrix}, \qquad (1)$$

where κ is the grating coupling constant, and δk is the detuning (both assumed real).

(i) Show that the total power $P_z = |A^+|^2 - |A^-|^2$ is independent of z.

[3 Marks]

(ii) The code provided calculates the resultant reflection spectrum from two gratings in series based on solutions to Eq. (1). Run the code. Explain why the maximum between the two Bragg zones is so high. [1 Mark]

(iii) Note down the observed Bragg wavelengths and Bragg bandwidths of the two gratings, and check by means of simple calculations based on the grating parameters given in the code, that these values are consistent with what you expect (*you may find some lines in the code to help you do this if you wish*). Complete a table in your answer book of the form:

	Estimate from graph	*Calculated value*
λ_1^{Br}		
λ_2^{Br}		
$\Delta\lambda_1^{Br}$		
$\Delta\lambda_2^{Br}$		

Explain which formulas you used in making your calculations.

[4 Marks]

(iv) By switching off each grating in turn, determine how many side-lobes outside the Bragg zone overlap with the Bragg zone of the absent grating. Illustrate your answer with a brief sketch in your answer book. Explain briefly how you were able to switch off each grating. [4 Marks]

(v) It is now required to broaden the Bragg zone of the longer wavelength grating (whilst keeping its reflectivity constant), so that a narrow transmission spike (or reflection dip) exists between the two zones. By modifying the length and index perturbation of the longer wavelength grating, and running the code a few times, report the values of L_2 and δn_2 that best achieve this. Explain your strategy in arriving at these values.

[4 Marks]

(vi) With the composite structure configured as in (v), the shorter wavelength grating is stretched with the result that its period increases slightly. By modelling this effect in the code and running the program, estimate the fractional dilation that is detectable by monitoring the composite reflection spectrum. [4 Marks]

End

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Summary

We have introduced the use of computers in exams which

- have had acceptable uptake with the students
- have overcome the practical issues of security
- allow staff to probe understanding in new and alternative ways
- allow us to set questions around real physical situations/systems

We are looking into extending this to further exams.