Queen's University of Belfast Master of Science course in Opto-Electronics and Optical Information Processing

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ABSTRACT

The aims and curriculum of a one-year Master's course, designed to give a specialised introduction to the field of Opto-Electronics, are summarised. The course was instituted in 1968, when the subject matter was mainly laser physics, laser systems and their applications. Subsequent reviews of the course material, most recently in 1987, have increased the emphasis on optical communications, image processing and other IT material.

The course comprises 180 hours of lectures arranged in six 30-hour units: Electromagnetic radiation and design of optical imaging systems; Optical and opto-electronic materials; Photon sources; Photon detectors and image storage; Information theory and optical information processing; Modern optical systems. Practical classes are at the rate of 10 hours per week for two terms. Students also carry out a literature survey and write an essay on a topic of current opto-electronic interest. Following written examinations, successful students carry out a three-month research project in an industrial laboratory or in association with one of the Department's research divisions.

Statistics on the recruitment, qualifications and funding of students are presented, together with information on the initial placement of graduates in the optical industry and elsewhere.

1. INTRODUCTION

The Queen's University of Belfast is one of two universities in Northern Ireland. Since 1988 all degree-level instruction and research in Physics has been concentrated at Queen's. Whilst much of Northern Ireland's economy is based on agriculture, local industry includes firms in the shipbuilding, aerospace, electronics and telecommunications fields. Many of these look to the Physics Department at Queen's to provide qualified manpower at the BSc, MSc and PhD levels.

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Two wider dimensions should be mentioned. Firstly, Queen's is part of the university system of the United Kingdom, and is subject to exactly the same criteria of research rating and funding as are universities in England, Wales and Scotland. Financial support comes from the Universities Funding Council (UFC) and the Science and Engineering Research Council (SERC). Secondly, in geographical terms, Northern Ireland is the nearest neighbour of the Republic of Ireland. In recent years there has been an increasing interaction with the Republic, both at the level of the recruitment of students and also in relation to co-operation between institutions. This interaction has been stimulated by the European Community membership of both the UK and the Republic of Ireland.

Queen's has offered an MSc Course in Opto-Electronics since 1968. At that time the major research effort of the Physics Department was in Laser Physics, under the leadership of Professor Dan Bradley. The MSc course was introduced to provide an introduction to, and specialist training in, laser physics and opto-electronic devices. It has been recognised by SERC since its inception. Under the arrangements for accreditation of SERC courses the syllabus, examinations, and statistics of student recruitment and graduate employment are scrutinised every two years. Additional input is provided by the Industrial Liaison Committee, membership of which includes representatives from local and national industry, and from the Government Department of Economic Development. As a result of these procedures, the course has been regularly up-dated, the most recent restructuring being in 1987, with the effect of increasing the content of material on information technology, optical communications and signal processing. The course is now entitled Opto-Electronics and Optical Information Processing.

2. AIMS OF THE COURSE

The aims of the course are:

- To provide a thorough theoretical and practical training in Opto-Electronics and Optical Information Processing for recent graduates, to fit them for employment in the Optics, Electronics, Communications and Information Technology industries.

- To provide the opportunity for graduates who already have some industrial experience to update their knowledge, or to re-train.

- To provide training in the methods of research.

- To provide training in the writing of scientific reports.

- To expose students to recent advances in research, development and production techniques.

3. CURRICULUM

The course is designed for graduates in Physics, Electronics or Electrical Engineering. The admission requirement is at least a Lower Second Class Honours degree, or the equivalent. Applicants without an appropriate Honours degree may be accepted for a preliminary year's study, in the form of the Graduate Diploma in Pure and Applied Physics, to provide a background of Honours standard in appropriate areas. Alternatively, students may be permitted to enrol as Graduate Diploma students on the Opto-Electronics course. Satisfactory performance in the written examinations and in the laboratory class allows subsequent transfer to MSc enrolment.

The MSc course can be taken either full-time, over a period of twelve months, or part-time, over two or three years. The curriculum comprises lectures, laboratory work and a research project. The full-time course commences in September with a Practical Training Course, including electronics and mechanical workshop practice, microcomputers, and instruction in safety procedures. The lecture syllabus is arranged in six units, each of thirty hours, shown in Table 1 below.

Table 1: Lecture syllabus

Unit 1:	Electromagnetic radiation and the design of optical imaging systems	
1.1	Design of optical systems	10 hours
1.2	Thin film optics	10 hours
1.3	Non-linear optics	5 hours
1.4	Integrated optics	5 hours
Unit 2:	Optical and opto-electronic materials	
2.1	Solid-state physics of opto-electronic materials	20 hours
2.2	Materials, fabrication and processing	10 hours
Unit 3:	Photon sources	
3.1	Spectroscopic sources and techniques	7 hours
3.2	Laser physics	13 hours
3.3	Laser systems	10 hours

Unit 4: Photon detection and image storage

4.1	Photon and particle detectors	8 hours
4.2	Photographic recording	4 hours
4.3	Photoelectric imaging devices	8 hours
4.4	Holography and holographic applications	10 hours

Unit 5: Information theory and optical information processing

5.1	Signal detection and processing	6 hours
5.2	Information theory	10 hours
5.3	Image evaluation	7 hours
5.4	Optical information processing	7 hours

Unit 6: Modern optical systems

6.1	Optical devices	15 hours
6.2	Planar and fibre optical waveguides	10 hours
6.3	Optical fibre communication systems	5 hours

Courses 3.1, 4.1, 5.1 and part of 2.1 comprise a Basic Techniques course, which is taken by all new postgraduates in the Department, both MSc and PhD.

These units are supplemented by a series of talks by visiting lecturers from industry, giving a review of contemporary applications, techniques and processes involving optical systems, materials and communications.

Full-time students take the six units during the Michaelmas (October - December) and Hilary (January - March) terms, and also in this period do about 180 hours of laboratory work designed to introduce them to basic opto-electronic techniques and phenomena. Students carry out five short (20-hour) and two long (40-hour) experiments from those listed in Table 2.

Table 2: Laboratory experiments

Short experiments

S1	LEDs and displays	S6	Planar waveguides
S2	Optical characteristics of LEDs	S7	Gaussian optics
S3	Photomultipliers	S8	Microcomputer interfacing
S4	Ray trace program	S9	CCD detector
S5	Image processing	S10	Diode array detectors

Long experiments

- L1 Modulation transfer function
- L2 Holography
- L3 Dye laser
- L4 Second harmonic generation
- L5 Fibre optics
- L6 Helium-neon laser

As examples of these experiments, we give further details of S6 and L4. The Planar Waveguide experiment (S6) is based on a suggestion by Phelps and Sambles[1]. The objectives are to demonstrate the way in which light propagates along planar dielectric structures and to carry out quantitative studies which relate observations of the angular positions of optical modes to the physical thickness and refractive index of the dielectric material. In this case, the dielectric material is a piece of "cling-film", and the phenomenon is observed using a prism as a coupler, and a helium-neon laser as a light source. (The advantage of using cling-film is that it has relatively low refractive indices, of the order of 1.5; although the index of the prism coupler must be greater than that of the film, a glass prism is satisfactory.) Besides observing the phenomenon and making quantitative measurements, students learn the use of the Abbe refractometer, and also write a simple computer program to solve the modal equation and match the experimental values of the propagation constants to the theoretical.

In the Second Harmonic Generation experiment (L4) the crystal investigated is urea[2], H_2NCONH_2. To observe the phenomenon, the student learns to vary a number of parameters (the intensity of the input laser beam at the crystal, the plane of polarisation of the laser radiation, the phase matching angle, and instrumental factors) in a controlled and systematic way. Experience is gained in the wavelength calibration of a double grating monochromator, and in the use of a photomultiplier as detector of the second harmonic output.

Associated with the laboratory instruction is a literature survey. Students are required to write a fully-referenced essay or report on a topic of current opto-electronic interest. Two weeks' laboratory time (20 hours) is allocated to this task.

Written examinations are taken in late April. Successful students proceed to a three-month research project. This may involve working in an industrial or government research laboratory, or in an appropriate Research Division of the Department (Laser Interactions and Opto-Electronics, Astrophysics and Planetary Science, or Condensed Matter Physics). The results of the project are presented in a short report. To show the variety of research undertaken, a few titles from recent courses are listed:

- Machine vision analysis of destructively tested bonds on surface mount printed circuit boards (at Digital Equipment Corporation, Galway)

- Intra-building communications using retroreflectors (at British Telecom Research Laboratories, Martlesham Heath)

- The development of a linearly tunable filter for use in astronomical imaging

- Optical and magneto-optical properties of Co-Ti substituted single crystals of barium ferrite

The research project provides training in methods of research (often in an industrial context), and also in the preparation of a scientific report.

The course terminates in late September.

Regulations allow for the course to be taken on a part-time basis, over a period of two or three years. Part-time students follow a minimum of two lecture units each year, with associated laboratory and project work.

4. ASSESSMENT AND CERTIFICATION

Assessment during the course is by written and oral examinations, by a laboratory grading, and by the examination of the report on the research project. There is an open-book examination in January on the Basic Techniques course (100 marks). The written examination for the degree of MSc consists of three 3-hour papers (100 marks each), and is taken in late April. The laboratory grading, based on reports on the experiments carried out, is also out of a maximum of 100 marks. To proceed to the research project, students need to score a minimum of 250 out of 500 marks. Students who score less than 250 but more than 200 terminate the course at that stage with the qualification of Graduate Diploma. The Graduate Diploma may also be awarded to a student whose research project fails to reach the MSc standard.

5. STUDENT STATISTICS

Since the course was instituted in 1968, more than 200 students have graduated. We give below information on the country of origin, qualifications on entry, and funding of students on the five courses commencing in 1986-87 through 1990-91. In this period a total of 64 students enrolled, giving an average class size of about 13. Of the 48 students from 1986-87 through 1989-90, 47 were awarded either the MSc or Graduate Diploma qualification.

Table 3: Country of origin of students 1986-87 through 1990-91

Country	% of entry (64)
UK	73
Republic of Ireland	10
Other EC countries	3
Overseas	14

Table 4: Academic qualifications on entry 1986-87 through 1990-91

Class of degree	% of entry (64)
First	6
Upper Second	27
Lower Second	56
Third	6
Pass or General	5

The majority of students enter the course direct from their first (Bachelor's) degree; although one of the aims of the course is to provide the opportunity of re-training and updating for those already in industry, only 8% of the entry in the years 1986-90 had industrial experience.

Table 5: Student funding 1986-87 through 1990-91

Funding source	% of entry (64)
UK Research Councils/ Government Departments:	
SERC studentships	17
DENI studentships	52
Other	3
European Community:	
ESF traineeships	6
Overseas Institutions/ Scholarships	8
Private	14

The recognition of the course by SERC brings with it an allocation of Advanced Course Studentships, covering the payment of tuition fees and a maintenance grant. Advanced Course Studentship funding is also provided by the Department of Education for Northern Ireland (DENI). European Social Fund (ESF) Traineeships, also covering tuition and maintenance, were available for the first time in 1990-91.

The enrolment for the 1991-92 course, for which only provisional figures are available at the time of writing, shows significant changes from those for 1986-90. The number of students on the course will be at least 32, more than double the average for the previous five courses. The main reason for this increase is the fact that a substantial number of ESF traineeships has been allocated to the course, allowing wider recruitment from countries of the European Community (particularly the Republic of Ireland).

Table 6: Enrolment for 1991-92 MSc/Graduate Diploma Course

	Students	(% of entry)
Country of origin:		
UK	20	(63)
Republic of Ireland	7	(22)
Other EC countries	1	(3)
Overseas	4	(12)
Academic qualifications: class of degree		
First	2	(6)
Upper Second	7	(22)
Lower Second	15	(47)
Third	6	(19)
Pass or General	2	(6)
Funding:		
SERC	2	(6)
DENI	6	(19)
ESF	20	(63)
Overseas Institutions/Scholarships	2	(6)
Private	2	(6)

It is expected that enrolment will continue at this level in subsequent years.

In a recent survey[3], Davies and Davies show that demand by UK industry for postgraduates in the fields of Image analysis and processing and Signal processing and communications far exceeds the total MSc and PhD output of the UK universities. On the other hand, output in Geometrical and physical optics (including lasers) is in excess of demand. These three areas (Optics and lasers, Image analysis and processing, Signal processing and communications) effectively include the whole content of the QUB course. Summing the survey figures for the three areas shows that in 1989 demand

(474) exceeded supply (397) by about 20%. Demand for Queen's University MSc graduates has remained strong since the inception of the course, and is expected to continue.

Table 7: First destinations of MSc graduates 1986-87 through 1989-90

Type of employer	% of graduates (47)
UK industry	55
Further postgraduate study	28
Overseas employment	13
Unknown	4

Many of the UK students who obtain the MSc qualification have taken employment in the communications, aerospace, optical, electronics and laser industries. A number of graduates continue with research towards a PhD, or take a Graduate Certificate in Education course to prepare themselves for a teaching career. The pattern of employment of overseas students is rather different. Some are members of staff of overseas universities who have been granted study leave in order to obtain the MSc; on completion of the course they return to their posts.

6. CONCLUSION

For over 20 years, Queen's University has provided specialised postgraduate instruction in Opto-Electronics and Optical Information Processing, meeting the demand from local and national industry for trained personnel. Support for the MSc course from the Science and Engineering Research Council, the Department of Education for Northern Ireland, and the European Social Fund has helped to ensure its continuation.

7. REFERENCES

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