Optics Education in the United Kingdom

Robin Smith
Optics Section, Blackett Laboratory
Imperial College of Science, Technology and Medicine
London SW7 2BZ U.K.

1. INTRODUCTION

In this paper we review optics teaching at the postgraduate MSc level in the UK. We precede this with some personal comments based on 20 years teaching experience in the Applied Optics MSc Course at Imperial College, London.

As one might expect much of the MSc teaching in the UK is based at centres of research in optics. There are other centres of research where "modern" optics is only taught in undergraduate (BSc) option courses.

2. SOME COMMENTS ON OPTICS TEACHING

Optics has long been a major subject in University Physics teaching and in school physics courses . Earlier in this century lens design was strategically very important for civil and military applications and the emphasis in optics teaching was placed on geometrical optics and the design of optical instruments.

Text books stressed geometrical optics, physical optics taking second place. In school laboratories simple, and very useful, experiments could be carried out with very simple and cheap equipment, pins and mirrors; the observer's eye being the detector.

Today probably the first time school children meet optics is when they consider the simple geometrical optics of telescopes and cameras in general science courses. Optics features strongly in laboratory work for the óbvious reason of ease of demonstration and observation. Optics experiments are often shown to visitors for precisely this reason, the appeal of colour not being overlooked.

Physical optics experiments are usually done in the senior school and by the age of eighteen physics pupils do a more or less equal mixture of geometrical optics and physical optics.

At university most physics first degree programmes include one or two compulsory optics courses in the first and second years, the emphasis usually being on the physics rather than on what might be called optical engineering. Geometrical optics is generally squeezed to allow more "modern optics" and "atomic and laser physics". Physical optics covering interference and diffraction is generally well covered with the obvious instant appeal of holography in laboratory work. Most universities have a third year course called something like "modern optics".

In the United Kingdom the first centre for technical optics was at Imperial College where Professor Conrady was appointed to the principal teaching position in Technical Optics in 1917. In the 70 years since then a great many well known names in optics have passed through the department, many of them attending the courses which were forerunners of today's MSc Course in Applied Optics. I recently came across examination papers dated 1936 for the course in Technical Optics!

In Conrady's day computers were people who did ray tracing using log books. Since those days there have been enormous changes in computing power. The techniques of lens design have changed but the underlying theories of geometrical optics and aberrations still need to be understood. As we all know understanding does not come from just attending lectures and sitting examinations. Most people when faced with their first real problem in optics are brought down to earth and realise how little they know. "Know" here really means what they can do.

In his preface to "Applied Optics and Optical Design" Oxford University Press 1929 Conrady said that in writing his book

.......Every effort has been made to limit the subjects dealt with and the methods employed to what the late Silvanus P Thomson called "real Optics" and to exclude the purely mathematical acrobatics, which he called " examination optics"......

It is very easy to construct courses which just contain facts which students regurgitate for examination purposes. I am sure that none of us falls into this trap! MSc courses are taken by students who have already demonstrated to us in their undergraduate examinations that they can deal with mathematical and physical arguments. The purpose of the MSc course, apart from satisfying the University authorities, must be to equip the students with skills backed up by thorough understanding so that they can apply their optics with confidence.

Conrady's book now seems very old-fashioned, but the approach to acquiring skills is still valid. To learn optics you must experience optics. For example, although one can lay out of an optical system by computer there are great merits, at the learning stage, (and often later) in making a suitably scaled sketch to get a feel for what is happening. The value of diagrams and graphs cannot be overemphasised. The easiest way of finding out where to put folding mirrors is to fold up a layout diagram!

We recently introduced a practical optical system design project as part of the MSc laboratory. The students have six weeks in which to produce a prototype piece of equipment. They have access to all (or most!) of the optical and mechanical components they might need. An example of such a project is to build a bar code scanner, obtaining an output signal but excluding the signal processing electronics.

When we were setting up this programme discussed how we would begin such a task. We concluded that we would (i) make a few sketches and rough calculations and (ii) as soon as possible find some simple equipment and do some simple experiments to get a feel for what the real optics problems were.

Often we get the optics sorted out in a few hours, but the next week is spent in getting everything correctly aligned! One of my recent PhD students refers to this as "The First Law of Optics" that no mechanical mount will ever be at the correct height!

It is most important that students of Applied Optics and Optical Engineering should be actively involved in laboratory or in classwork, so that they learn by experience. Passive learning will not give them the confidence to be able to apply their knowledge.

3. POSTGRADUATE EDUCATION AT MSc LEVEL

Since Conrady's day the arrival of the laser has revolutionised optics. MSc courses have to meet the needs of industry in applying and developing new technology. At Imperial College there are now strong research activities in Laser Physics, Non-linear Optics and Quantum Optics as well in the more traditional aspects of Applied Optics. The MSc course at Imperial covers all these fields.

Many of the recent MSc courses described below are in the areas of opto-electronics, communications and information technology. The fraction of what we might call traditional applied optics in these courses is by necessity rather small. As the aim is to give people the skills needed in these subject areas my comments on learning by doing also apply to these courses.

Currently there are eight main postgraduate MSc optics related courses in the UK. The emphasis in each course is different usually reflecting the research interests of the people involved in running them.

APPLIED AND MODERN OPTICS	Reading University
APPLIED OPTICS	Imperial College, University of London
LASERS AND THEIR APPLICATIONS	University of Essex
MICROWAVES AND MODERN OPTICS	University College, University of London.
OPTICAL INFORMATION TECHNOLOGY	University of Glasgow, Scotland
OPTOELECTRONICS	Newcastle Upon Tyne Polytechnic
OPTOELECTRONICS AND LASER DEVICES	St. Andrews and Heriot-Watt Universities, Scotland
OPTOELECTRONICS AND OPTICAL INFORMATION PROCESSING	Queen's University, Belfast, Northern Ireland

Lasers are a strong theme in all these courses. The link between optics and microwaves is made in the University College course. Optical Design is only covered in any detail at Imperial College and at Reading University, whose courses are similar.

Currently these courses are attended by students financed

(a) by grants from the UK research councils (SERC Advanced Course Studentships)
(b) by Companies
(c) overseas governments
(d) self funded.

The SERC Advanced Course Studentships cover the teaching and examination fees for the course as well as a student maintainance grant.

The courses are usually one year but students in suitable employment may attend part time over a period of two years with an appropriate modification to the examination and laboratory arrangements. The project work is usually carried out in association with the place of employment.

The universities' usual entry qualification required is First or Second Class Honours degree in Physics, Electrical Engineering, Engineering Science or Mathematics although students with a lower class of degree augmented by sufficent relevant industrial experience may be able to register for the MSc degree.

Typically there are between 15 and 30 students attending each course.

4. COURSE CONTENTS

Below we identify the principal features of the various courses. It must be stressed that this summary is very brief and full course details can be obtained from the addresses given in the appendix. Most include lectures, laboratory work and a summer project.

APPLIED AND MODERN OPTICS
UNIVERSITY OF READING

The aims of this course are " to give a broad but thorough grounding in theoretical, experimental and instrumental aspects of applied and modern optics . Emphasis is laid on the skills required for applications and industrial practice as well as for basic research". The lecture courses taken in the first two terms are structured as follows.

Fundamental Optics:	Diffraction, Polarisation, Molecular and Nonlinear Optics
Coherent Optics and Interference:	Holography, Coherence Theory, Coherent Optics, Interferometry, Thin Films
Optoelectronics and Lasers:	Detectors, Image Recorders and Intensfiers, Modulators, Deflectors, Fibre Optics and Applications, Fibre Optic Communications, Integrated Optics, Lasers and Laser Applications
Design of Optical Systems:	Gaussian Optics, Aberration Theory, Optical Design, Diffraction and Image Formation, Reflecting Prisms,Visual Optics

Computational and Mathematical Techniques in Optics:

In addition the students do laboratory work, tutorials, problems and case studies in optical design and a summer project.

APPLIED OPTICS
IMPERIAL COLLEGE, UNIVERSITY OF LONDON

This course has existed in one form or another for about 50 years. In the early days the course was mainly concerned with lens and optical instrument design but over the years it has been extended to cover "modern" optics especially lasers, non-linear and quantum optics.

The students attend core lecture courses which include about 10 lectures given by speakers from industry, and a selection of option courses. The laboratory work and lens design exercises are important features of the course. There is a three-month summer project.

Core Lectures

Geometrical Optics and Aberration Theory
Diffraction and Image Formation
Lens Design
Testing Optical Systems and Interferometry
Thin Films
Quantum Electronics
Introductory Non-Linear Optics
Optical Hardware

Option Courses

Advanced Lens Design
Holography and Optical Image Processing
Partial Coherence
Detection and Noise
Integrated Optics
Advanced Non-Linear Optics
Optical Communications
Physiological Optics
Electron Optics

The laboratory work includes a compulsory optical system design project.

LASERS AND THEIR APPLICATIONS
UNIVERSITY OF ESSEX

This course is " to provide students with a thorough understanding of the principles of laser action and an up-to-date knowledge of a wide variety of laser systems and their applications." In the Autumn term the students take "Background Courses". This is followed in the Spring term by five intensive one week "Laser Workshop Courses" of about 15 lectures each on a range of topics which can vary from year to year given by experienced speakers from industry, research institutions and staff from other universities as well as the University of Essex.

Background Courses
Physical Optics
Spectroscopy
Radiation and Matter
Optical Properties of Solids
Principles of Lasers
High Power Lasers
Radiation Detectors
Non-Linear Optics
Safety in the Laser Laboratory

Laser Workshop Courses
Laser Cutting, Welding and Materials Processing
Lasers in Medicine
Non-Linear Optics and Signal Processing
Optical Methods in Engineering Metrology
Advances in Optical Communications

The course includes practical work and a series of industrial visits.The students also carry out a literature survey on a suitable topic concerned with lasers.

MICROWAVES AND MODERN OPTICS
UNIVERSITY COLLEGE, UNIVERSITY OF LONDON

The aim of this course is to provide " an understanding of microwave and optical devices and systems. The subjects are studied to a level which should enable a student to undertake individual research or development work." The core course taken in the first term covers

Electromagnetic Theory and Quantum Electronics
Networks and Components
Measurements
Microwave and Optical Systems

Students choose four from the seven option courses.

Microwave Semiconductor Devices
Quantum Electronics and Opto-Electronic Devices
Computer Modelling of Fields
Terrestrial and Satellite Communications
Antennas and Radar
Fourier Optics and Optical Signal Processing
Remote Sensing of the Earth.

The rest of the time is devoted to project work.

OPTICAL INFORMATION TECHNOLOGY
UNIVERSITY OF GLASGOW

This course, introduced in 1984, "broadly covers bulk and guided-wave optics with applications in optical communications and signal processing systems". The lecture courses are divided into "Fundamental Concepts",

Communication Theory
Semiconductor Theory

and "Advanced Applications",

Integrated Optical Systems
Laser Physics and Nonlinear Optics
Optical Signal Processing
Optical Transmission Systems
Optical Waveguide Theory

Part of the practical work is an intensive two week exercise in Optoelectronic Device Fabrication during which an integrated optoelectronic device is made and tested. The students undertake a research project over the summer either in the Department or in an industrial research laboratory.

OPTOELECTRONICS
NEWCASTLE UPON TYNE POLYTECHNIC

This course developed out of shorter courses given at the Polytechnic initially designed to train unemployed people for industry. These proved to be very successful and the current MSc course has CNAA recognition (Council for National Academic Awards) The aims include " to provide a theoretical and experimental training in Optoelectronics for graduates, to suit them for work in an industrial research and development environment".

Part I

Optics and Laser Physics
Solid State Physics and Opto-Devices
EM Theory and Fibre Optics
Fourier Optics
Digital Electronics and Microprocessors

Part II

Optoelectronic Devices and Optomechanisms
Fibre Optics
Laser Systems and Applications
Either Image Processing or Signal Processing

The students regularly attend about 4 seminars per week and carry out laboratory work. In the summer there is an industrially based project.

OPTOELECTRONICS AND LASER DEVICES
ST. ANDREWS AND HERIOT-WATT UNIVERSITIES, SCOTLAND

This course started in 1981-82. "Graduates gain an understanding of the fundamental properties of optoelectronic materials and experience in the technology and operation of a wide range of laser and semiconductor devices ".

The host university alternates between St. Andrews and Heriot-Watt Universities. The students move their accommodation from the host to the other university in April. The course comprises core lectures, lectures on specialist and advanced topics, laboratory work and a three month industrial project.

Core Topics

Laser Physics
Resonator and Beam Optics
Nonlinear Optics
Semiconductor Physics
Fourier Optics

Specialist and Advanced Topics

Gas Laser Discharges
Far Infra-red Optical and Heterodyne Techniques
Pico/Femtosecond Techniques
Solid State Devices
Modern Laser Systems I
Modern Laser Systems II
Optical Computing
Optical Engineering
Communications

OPTOELECTRONICS AND OPTICAL INFORMATION PROCESSING
QUEEN'S UNIVERSITY, BELFAST, NORTHERN IRELAND

This course started in 1968 and consists of lectures, practical work and a three-month research project carried out in one of the University research groups or in a Government or industrial research laboratory. The lectures are organised as follows.

Design of Optical Imaging Systems
Thin Film Optics
Non-linear Optics
Integrated Optics

Solid -State Physics of Opto-Electronic Materials
Materials, Fabrication and Processing

Spectroscopic Sources and Techniques
Laser Physics
Laser Systems

Photon and Particle Detectors
Photographic Recording
Photoelectric Imaging Devices
Holography and Holographic Applications

Signal Detection and Processing
Information Theory
Image Evalvuation
Optical Information Processing

Optical Devices
Planar and Fibre Optical Waveguides
Optical Fibre Communication Systems

APPENDIX. ADDRESSES for the UK MSc COURSES.

Please note the name of the contact person is for the year 1988-9 and may change in the future. We recommend that correspondance be addressed to the "Organiser for the MSc course in .... "

APPLIED AND MODERN OPTICS Dr J MacDonald, Physics Department, University of Reading, Whiteknights, P.O. Box 220, Reading RG6 2AF, U.K.

APPLIED OPTICS Dr R W Smith, Optics Section, Blackett Laboratory, Imperial College, London, SW7 2BZ U.K.

LASERS AND THEIR APPLICATIONS Dr P Townsend, Department of Physics, University of Essex, Wivenhoe Park, Colchester CO4 3SQ U.K.

OPTICAL INFORMATION TECHNOLOGY Dr J M Arnold, Department of Electronics and Electrical Engineering, University of Glasgow, Glasgow G12 8QQ, U.K.

MICROWAVES AND MODERN OPTICS Dr R S Cole, The Department of Electronic and Electrical Engineering, University College London, Torrington Place, London WC1E 7JE, U.K.

OPTOELECTRONICS Dr I D Latimer, Department of Physics, Newcastle Upon Tyne Polytechnic, Ellison Place, Newcastle Upon Tyne NE1 8ST, U.K.

OPTOELECTRONICS AND LASER DEVICES Dr I Firth, Department of Physics, University of St. Andrews, North Haugh, St. Andrews, KY16 9SS, U.K.

OPTOELECTRONICS AND OPTICAL INFORMATION PROCESSING - Dr C H B Mee Department of Pure and Applied Physics, The Queen's University of Belfast, Belfast BT7 1NN, Northern Ireland.