dublin institute of technology
school of physics

final year degree projects in physics

2004
The yearbook content is written by the final year degree students of the DIT School of Physics who undertook a physics project.

Edited, designed and produced in the School of Physics by Des O’Mahony.
Foreword

This is the fourth edition of the DIT School of Physics graduates’ yearbook. In it you will find short summaries of the project work carried out during the final year of the programme in Physics Technology, as well a brief note about each student. There is also a short introduction to the courses we offer in the School of Physics.

The project topics that the students have chosen to work on are mainly Nanotechnology, Optics and Photonics, Spectroscopy and Medical Physics and include studies of radon gas, computed tomography and nanotube technology. In some cases the work forms part of a long-term project involving a number of research staff.

The yearbook is intended to give an idea of the work that research physicists do and to highlight the individual achievements of the students. We hope you will find it interesting and informative.

If you would like to know more about our programmes of study or the research activities of the School of Physics please visit our website at physics.dit.ie or telephone +353 1 4024559.

The students can also be contacted through the School.

Dr Vincent Toal
Head of School
May 2004
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Physics at DIT

The School of Physics at DIT is active in research areas from materials to optics to medical physics and has pioneered Problem-Based Learning (PBL) as a delivery method for undergraduate Physics. The School offers ordinary degree, honours degree, masters (MPhil) and doctorate (PhD) qualifications.

Undergraduate courses currently on offer include:

- FT212  BSc(Ord) Physical & Life Sciences (formerly DT273 Technician Diploma)
- FT222  BSc(Hons) Physics Technology
- FT229  BSc(Hons) Clinical Measurement
- FT224  BSc(Hons) Optometry

Problem-Based Learning

In September 2001 the School introduced a Problem-Based Learning approach to the teaching of physics in the first year of the Degree in Physics Technology. This method encourages students to engage in self-directed study in a group environment. Alongside embedding scientific skills, many other skills are developed including team work, report writing, communication skills, critical thinking, problem solving skills and presentation skills. The course also makes extensive use of the Virtual Learning Environment through the provision of interactive web-based resources using WebCT.

The feedback from students, staff and international peer reviewers has been very positive. Unlike traditional teaching practices in higher education, where the emphasis is on the transmission of factual knowledge, a problem based learning course consists of a set of problems that are carefully sequenced to ensure the students are taken through the curriculum. The students encounter these problem-solving situations in small groups that are guided by a tutor who facilitates the learning process by asking questions and monitoring the problem-solving process. The Virtual Learning Environment provides a platform for students to interact in a dedicated site as well as providing access to course material.

PBL is not just about problem solving!

In engineering and physics the use of problem-solving learning is well established, where students are first presented with the material, usually in the form of a lecture, and are then given problems to solve. These problems are narrow in focus, test a restricted set of learning outcomes, and usually do not assess other key skills. The students do not get the opportunity to evaluate their knowledge or understanding, to explore different approaches, nor to link their learning with their own needs as learners. They have limited control over the pace or style of learning and this method tends to promote surface learning. Surface learners concentrate on memorisation whereas deep learners use their own terminology to attach meaning to new knowledge.

In PBL the problems are encountered before all relevant knowledge has been acquired and serve as the context for new learning. Their analysis and resolution result in the acquisition of knowledge and problem-solving skills. The students determine their learning issues and develop their unique approach to solving the problem. The members of the group learn to structure their efforts and delegate tasks. Peer teaching and organisational skills are critical components of the process. Students learn to analyse their own and their fellow group members’ learning processes and, unlike problem-solving learning, must engage with the complexity and ambiguities of real life problems. It is ideally suited for the development of key skills, such as the ability to work in a group, problem-solving, critique, improving personal learning, self-directed learning, and communication.
FT212 BSc(Ord) Physical & Life Sciences

This programme was formerly DT273 Diploma in Applied Science. The course has a long history and was commonly referred to as a Technician Diploma in Applied Science. In 2004 the course was upgraded to the level of Ordinary Degree and the code and title changed to FT212 Physical & Life Sciences. The three-year programme is designed to meet the requirements of those students seeking an education and training for work as technicians/technologists or scientific personnel in the physical, chemical or biosciences fields. There is a common first year in which students study Physics, Chemistry and Biology. Additional subjects are Mathematics and Information Technology and Professional Development. Before commencing the second year the student chooses to specialise either in Physics, Chemistry or Biology for the remaining two years of study.

What does the Physics option involve?

In the second year of the Physics option there is an emphasis on laboratory work with regular laboratory practice in Physics, Electronics, Photography and Computer Aided Design. Physics modules include Heat and Thermodynamics, Mechanics, Optics, Materials Science, Radiation Physics, Photography. The third year of the Physics option concentrates on applications of Physics in industry and society. Physics courses include Applied Optics, Acoustics & Industrial Noise, The Industrial Thermal Environment, Environmental Physics, Materials Science, Vacuum Physics & Semiconductor Technology. An important part of the final year of the course is a six-week full-time research project that may take place within a research group of the School of Physics at DIT or may involve an industrial placement for the six-weeks. Students are encouraged to develop their own ideas for their projects.

What careers are available to graduates of the Physics option?

Graduates of this option will have experience and skill in handling instrumentation and in the analysis, interpretation, presentation and critical evaluation of data. These skills along with an up-to-date knowledge of their field makes them eligible for careers in industry and technology, as technicians or as research assistants. Sectors in which graduates of this course have found employment include the electronics industry, the computer industry, industrial or State analytical and research Laboratories, as technicians in teaching laboratories and many other areas.

What possibilities for further study are available to graduates of the Physics option of FT212 within DIT?

Candidates achieving appropriately high grades are eligible to apply for entry to the BSc (Honours) Degree in Physics Technology (FT222) which opens up the path to a career as a professional physicist.

FT222 BSc(Hons) Physics Technology

If you have an enquiring mind, always asking why things happen or how things work, then physics will help you find the answers. It forms the basis of most modern technologies and holds the key to improving all our futures. The 4 year programme in Physics Technology is designed to educate and train professional scientists in the area of Physics and Physics-related technologies. This is a full-time honours degree programme and aims to provide graduates with scientific and analytical skills in physics as well as a practical problem solving ability. IT and Computing form an integral part of the programme which is characterised by extensive practical and project components.

What sort of job can I get with a Physics Technology Degree?

There is a wide range of careers for which physics provides a good initial training, many of them using the methodology of physics: the logical approach, the ability to build and test models and the numerical and problem solving skills, which are inherent in any physics degree. The more obvious career directions for a graduate include academic and industrial research, working in technology-based industries.
such as electronics, alternative energy development or communications and the critical and growing area of medical physics. Physicists are also in demand, particularly for their analytical skills, in a range of financial, fund management and research roles, in the law, in management consultancy, as weather forecasters, computer programmers and, in a major shortage area, as physics and science teachers.

About one third of all physicists work in public service industries; one third in private industry and one third in secondary and higher education. Some physicists work on problems at the frontiers of knowledge; others tackle the challenging problems which arise in the application of physical ideas to industrial and engineering problems - offering personal satisfaction as great as that from work in ‘frontier’ physics. The highest paid sectors are finance, telecommunications and the electrical industry. The FT222 degree is fully accredited by the Institute of Physics as an eligible qualification for progression to the title Chartered Physicist (designatory letters CPhys) and Institute Membership (MInstP).

What do I learn in the Physics Technology Degree?
The course is broken down into a number of modules as follows:
Year 1: Physics through PBL, Applied Physics, Chemistry, Mathematics, IT and Computing, Laboratory Work, Professional Development.
Year 2: Physics, Applied Physics, Materials Science, Mathematics, IT and Computing, Laboratory and Project Work, Professional Development.
Year 3: Instrumentation and Electronics, Radiation and Environmental Sensing, Metrology, Condensed Matter, Electro Magnetism and Optics, Numerical Analysis, Vacuum Technology and Thermodynamics, Quantum Physics, Mathematics, Laboratory and Project Work.
Year 4: Core Subjects: Electromagnetism and Optics, Quantum Physics of Solids, Instrumentation, Computational Physics, Digital Systems, Sensors, Applied Optics, Quantum Technology; plus electives from Materials Science, Optical Communications, Electronic and Imaging Systems, Nuclear and Biophysics, Fluid Dynamics, Astronomy. In addition, Year 4 of the course features a substantial research or laboratory-based project on which the student gives an oral presentation and submits a thesis. As a laboratory based subject, students find the project work very challenging and rewarding.

FT229 BSc(Hons) Clinical Measurement

Clinical Measurement is the science behind measurements of physiological signals from the human body. In the first two years of this 4 year course, the students are taught how measurements are made, how physiology affects the signals, and how patients are treated for clinical problems. The third year of the course may include up to 25 weeks of hospital internship in hospitals around the country. In the final year of the course students can receive further hospital based training. The students are taught advanced clinical and measurement science, with a clinical based research project for 2 months.
Clinical Measurement looks at how to measure things like:

- ECG (electrical activity of the heart) e.g. in patients with coronary heart disease
- Blood flow using ultrasound e.g. in patients with vascular disease
- pH in the stomach and intestines e.g. in patients with reflux disease
- EEG (brainwaves) e.g. to test for epilepsy and motor neurone disease
- Air pressure and flow from the lungs e.g. in patients with asthma

**What can I do with the Clinical Measurement Degree once I have it?**

The discipline of Clinical Measurement is growing all the time as medical care improves. Graduates will mainly be employed as Clinical Measurement Scientists in hospitals both in Ireland and abroad, but many past graduates of the Certificate Course (K271) which this Degree courses replaces have been employed in industry, universities and in business, and some have gone on to change their career in a medical direction.

**FT224 BSc(Hons) Optometry**

This course is the only Optometry course offered in the Republic of Ireland. It is not possible to study optometry on a part-time or correspondence basis, either in Ireland or Britain. FT224 is a 4-year full-time DIT degree with honours classification. This course provides the education and training statutorily required for Optometrists (Ophthalmic Opticians) by the Opticians Act, 1956, and the Rules made by the Opticians Board. The course is approved by Bord na Radharcmhastóirí (the Opticians Board) which is the registration authority set up under the Act. Graduates must also satisfy the Association of Optometrists Ireland as to their clinical competence before being eligible to register with the Board.

The training of optometrists includes a period of at least 6 months of Supervised Optometric Practice with a practising optometrist. At present this takes place at the beginning of the fourth year of the course. However, this period may in the future take place later in Year 4 or following graduation.

**What are the Career Opportunities for Optometrists?**

There are opportunities for Irish-registered optometrists both at home and abroad. Most newly qualified optometrists are employed in larger practices, in individual private practice, or in partnerships. Their primary task is the examination and assessment of visual function, and advising and prescribing for visual defects. Optometrists may choose to specialize in fields such as contact lenses, environmental vision or care of partially sighted patients. (Note that optometrists are not entitled to treat eye disorders by either medical or surgical means. Persons wishing to become ophthalmologists or ophthalmic surgeons must first qualify as doctors and then take specialist qualifications.) Some opportunities exist for academic and industrial research, and for work as optometrists in eye hospitals (usually abroad). Registration with the General Optical Council as an optometrist in Britain and Northern Ireland is possible for those registered with the Opticians Board. Opportunities may occur in other European Union countries, and in some other countries.

**More Information?**

For more information on any course in the School of Physics, see our website at http://physics.dit.ie or contact any member of the school directly.
Optical & Electronic Properties of Magnesium Fluoride Layers

Denis Bade
Supervised by Dr Zillur Rahman

Personal Details
After completing an apprenticeship as communication electrician at STN ATLAS Elektronik, I began the study of Microsystems Engineering at the Fachhochschule Bremen, Germany. A requirement of this course is to do a year abroad. So I took the opportunity of transferring into the final year of the BSc in Physics & Physics Technology at the Dublin Institute of Technology. My academic interests include Optical Communications, Laser Physics and Signal Processing. My hobbies include reading, golf and soccer.

Project Summary
The aims of my project were to produce single- and multilayer thin films of magnesium fluoride (MgF$_2$) and to test some of their optical and electrical properties.

MgF$_2$ layers can be formed by PVD (Physical Vapour Deposition) techniques. The films were made using an Edwards AUTO 306, a resistance evaporator (see figure 1). A resistance evaporator works on a simple principle - heating a source generates a vapour flux of the desired film material (MgF$_2$) which then condenses upon a substrate (glass slide).

Firstly, a number of single layer coatings were made under the same evaporation conditions (same amount of magnesium fluoride, current and chamber pressure) but with different evaporation times. The thickness of each layer was then measured after the evaporation with a Dektak, a surface texture measuring system which analyses the vertical surface profile of a sample. A plot of the thickness over the time gave a straight line and was used as the calibration curve for further evaporations. Making just a single layer film could take well over three hours during which the sample and the chamber had to be observed at all times.

When the process was perfected, multilayer coatings with a thickness of 100nm were produced. The optical properties were tested using the Perkin Elmer UV-VIS spectrometer. The spectrometer was used to measure the transmission, absorption and reflectance of the films (for example, see figure 2 for transmission measurements). It measured the difference in transmission...
between a blank substrate and the sample.

All magnesium fluoride films have a good transmission over a large wavelength range. The transmission decreases when the film thickness increases. A wave pattern in the results was observed. This wave pattern is called “thin film interference”. Thin film interferences occur in a light wave when a beam of light travels from one medium to another, the change of index of refraction causes part of the beam to be reflected on the surface. The remainder of the light is transmitted and, if it is not absorbed, a portion of the transmitted light will be reflected at the lower surface again. Because of the wavelike nature of light, the reflections from the two interfaces may add together either constructively or destructively. It is possible to calculate the layer thickness with these interference patterns. Both measurement techniques, stylus-based and optical, show virtually the same results.

The electrical properties were then tested using both a Keithley I/V source and a four-point probe. For this, seven new multiplayer samples were produced, but with aluminium contacts on top and bottom of the magnesium fluoride layer.

The Keithley instrument provides a constant voltage source which can measure simultaneously the changes in current that occur. The resistance of the layer can be measured and the specific resistivity can be calculated in a quite straightforward manner from this data.

An alternative method for determining the resistivity is with the help of a four-point probe. The four-point probe consists of four equally spaced tungsten tips with finite radius. A high impedance current source is used to supply current through the outer two probes; a voltmeter measures the voltage across the inner two probes to determine the sample resistivity. The results of both measurements lie in the same region and are typical for a dielectric material.

Further work with this project could be to design multiplayer arrangements with different materials and test their electrical and especially their optical properties to design or produce interference filters. It is more common to measure the dielectric constant for an insulating material. So the dielectric constant for magnesium fluoride can be measured to make a statement over the purity of the layer.

One could also examine the optical properties of the film under the influence of an applied electric field. If there is an effect, one could observe the difference in properties when the current is varied or when the voltage is varied. In future, a student could take these suggestions on board before planning the production of particular types of films.
The Solubilisation of Single-Walled Nanotubes by Small Organic Molecules

Naomi Brant
Supervised by Dr Hugh Byrne

Personal Details
I completed the Technician Diploma in Applied Science (Physics Option) in 2002, for which I was awarded a Distinction. On completion of the Diploma I decided to continue with my studies and pursue a Degree in Physics & Physics Technology. My academic interests include Nuclear Physics and Medical Imaging with a small bit of Acoustics thrown in. My hobbies are reading, cinema and socialising a lot!

Project Summary
This project proposed to map quarterphenyl molecules onto the backbone of single-walled nanotubes (SWNTs). Due to the structure of the dye molecules they are proposed to have a tendency to interact with SWNTs which have a similar backbone structure (see figure 1). The quarterphenyl dye molecule consists of four benzene rings held together with carbon bonds. The outer rings have five hydrogen molecules attached and the two inner rings have four hydrogen bonds. The double bonds of the benzene rings are what give the dye its characteristic fluorescence. The dye can communicate along its axis to interact with the neighbouring molecules. Also the molecule can twist and bend around the single carbon bonds. If the dye maps onto the carbon nanotube it will do so in a planar fashion and have a high degree of conjugation.

The unique structure of single-walled nanotubes gives them a wide variety of unique properties. There are many potential applications for nanotubes - for example, it is reasonable to assume that the porosity and pore structure of these materials could be the basis for their applications as absorbents, catalyst supports and related materials. The main problem with SWNTs is that they are insoluble in most organic solvents such as toluene. However on the addition of quarterphenyl the nanotubes form suspensions that are seen to be stable over prolonged periods.

To study these proposed interactions, spectroscopic techniques were employed. The pure dye was characterised using UV/VIS and fluorescence as well as Raman spectroscopy. The composite dye and SWNT solutions were also characterised using fluorescence and Raman spectroscopy.

There are essentially two different kinds of atom-atom interactions in molecular structures. On one hand there are strong, covalent intramolecular bonds and on the other hand there are weak intermolecular van der Waals-like forces acting between the separate molecules. These intermolecular forces can cause the molecules to “stack” on top of each other as the concentration of the molecules is increased. This interaction means that as well as communication along the molecule there is also some degree of communication between the different molecules. There is an optimum value of concentration for which the dye molecules can constructively interact giving a maximum value for fluorescence.

When the SWNTs were introduced into solution along with the dye molecules there were noticeable changes to the fluorescence spectra obtained. The fluorescence was seen to either increase or decrease depending on the concentration of
the sample. Figure 2 shows the fluorescence of $1.562 \times 10^{-5}$ M solution with (black) and without (red) the presence of the nanotubes. A small decrease is noticed with the addition of the tubes. Figure 3 shows the fluorescence of $6.25 \times 10^{-5}$ M solution also with and without the nanotubes present. This graph shows a large increase in the fluorescence of the solution with the tubes present. This result implies that the nanotubes are inhibiting the dye molecule from aggregating.

Measurements of the dye and SWNT composite solutions were also taken using Raman spectroscopy. Spectra of the pure dye and the pure nanotubes were taken. The dye/SWNT solutions were drop-cast onto glass slides and composite spectra were obtained.

The Raman spectra of the composite solution (see figure 4) show that there are regions in the sample that are still either pure quarterphenyl (b), or predominantly tube (c). Spectrum (b) indicates that only quarterphenyl is present as the peaks occur at the same wave numbers as those of the pristine quarterphenyl. Even though the peaks are smaller they are still present in the spectrum. Spectrum (c) shows that only nanotubes are present as again the spectrum contains the same peaks as are seen in the spectrum of the pure nanotubes. The composite spectrum (d) is a unique spectrum and not a weighted summation of the dye and SWNT. It can be seen that there are new peaks in this composite spectrum that were not observed in the dye or SWNT pristine spectra.

The nature of the interactions which are observed is not fully understood. Examination of the RBMs of the Raman spectra would indicate if selective interactions were taking place in the solutions. This is because the RBM frequency is inversely proportional to the diameter of the tubes and from the diameter value the type of tube present can be deduced.

**Figure 2.** Fluorescence of $1.562 \times 10^{-5}$ M solution with and without tubes present.

**Figure 3.** Fluorescence of $6.25 \times 10^{-5}$ M solution with and without tubes present.

**Figure 4.** Quarterphenyl spectrum (a) and comparison of composite spectra (b,c,d) taken at 633nm.
Precision Electronic Measurements using an EG&G 5105 Lock-in Amplifier

Michael Byrne
Supervised by Dr Breandán Ó hAnnaidh

Personal Details
After successfully completing three years at DIT, I graduated with a Technician Diploma in Applied Science (Physics Option). After this I took a year out and travelled extensively throughout Australia and South-East Asia. On my return I decided to further my studies by applying for the Degree in Applied Sciences course (Physics & Physics Technology option). My main areas of interest would include Biophysics, Nuclear Physics and Optical Engineering.

Project Summary
A lock-in amplifier in its most basic form (see figure 1) is an instrument with dual capability: (1) it can recover signals in the presence of overwhelming noise background, (2) it can provide high resolution measurements of relatively clean signals over several orders of magnitude and frequency.

The objective of this project was to design experiments to demonstrate the validity of the above two statements.

A lock-in amplifier, in common with most AC indicating instruments, provides a DC output proportional to the AC signal under investigation. A special rectifier known as a phase-sensitive detector (PSD) forms the heart of the lock-in amplifier. This phase-sensitive detector performs the AC to DC conversion described above. The PSD is important because it rectifies only the signal of interest while suppressing the effect of any noise or interference which may be accompanying that signal. This noise appears at the output as an AC fluctuation and through filtering the desired signal response (now a DC level) can be separated from the noise accompanying it in the output.

For this detector to function correctly it must be “programmed” to recognise the signal of interest. This is achieved by supplying the PSD with a reference voltage of the same frequency and a fixed phase relationship to that of the signal. This is achieved by ensuring that they are both derived from the same source. The use of such a reference signal ensures that the instrument will “track” any change in the frequency of the signal of interest, since the reference circuit is “locked” to it.

Several experiments were carried out to investigate whether the lock-in could retrieve a small signal. This noise appears at the output as an AC fluctuation and through filtering the desired signal response (now a DC level) can be separated from the noise accompanying it in the output.

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signal from a noisy background. One experiment carried out showed how the lock-in amplifier could extract a small signal produced by a light emitting diode (LED) as it was moved away from a photodetector. The same procedure was then carried out on a digital multimeter and from these results a comparison could be made with the results obtained using the lock-in amplifier (see figure 2).

The main experiment in this project was to measure the resistance of a short length of constantan (55%Cu / 45%Ni) alloy wire. The resistance of the wire is so small that a digital multimeter would not be up to the task. An accurate reading would be impossible due to connectors and cable wiring between the sample wire and the voltmeter. With the lock-in, however, a reasonable attempt at calculating the resistance of the sample wire was made.

Using a simple resistor divider circuit as shown in figure 3, a set voltage $V_{in}$ was produced by a signal generator and the voltage across the wire $V_{out}$ was recorded using the lock-in amplifier. Knowing the value of $R_{series}$, the wire’s resistance could be calculated from Ohm’s law:

$$R_{wire} = \frac{V_{out}}{V_{in}} \cdot \frac{R_{series}}{1 + \frac{R_{wire}}{R_{series}}} = \frac{V_{out}}{V_{in}} \cdot R_{series}$$

From this voltage the resistance of a 0.08m length of constantan wire was calculated to be 133mΩ ± 2.7mΩ.

This highlighted the capabilities of the lock-in approach as the value of resistance for this small length of wire could not have been calculated with such accuracy using conventional methods.
Spectroscopic Analysis of Products of UV Exposure in Skin Cell Cultures

Lisa Connolly
Supervised by Aidan Meade, Dr Hugh Byrne and Dr Fiona Lyng

Personal Details
After being awarded a Diploma in Applied Physics in 2002 I decided to continue my studies and enrolled for the Degree in Physics & Physics Technology. My academic interests include nuclear physics, spectroscopy, physics of materials and sensors. In my spare time I practice Yoga, read, go to the cinema and listen to music. I also enjoy traveling and socialising.

Project Summary
Raman spectroscopy can be used to probe the molecular makeup of many biological samples in a non-invasive and non-destructive way. As each Raman active molecule has a unique fingerprint spectrum it follows that changes in the molecule in the cell post irradiation should show changes in its spectrum which could be indicative of cellular damage. UV radiation is thought to be the main carcinogenic factor for skin cancer, however the exact molecular mechanisms of how the UV radiation interacts with the skin are not known.

Raman spectroscopy has its origin in the inelastic scattering of monochromatic radiation in the IR to UV range from molecular materials, due to non-symmetrical vibrations in the bonds in these molecules. Changes in the bond structure in the molecules result in shifts in the bond vibration energies observed during Raman spectroscopy. Since water is a largely symmetrical molecule it has a low Raman signature. As biological samples are mainly comprised of water Raman is a good method for the examination of them.

In this project the amino acids Phenyalanine, Tryptophan and Tyrosine, the protein Lysozyme and skin cell cultures from a human keratinocyte cell line (HaCat cells) were examined using Raman spectroscopy. Each of the amino acids is a chromophore in the UV region and is involved in DNA replication. Therefore changes in the structure of any of these molecules in in-vitro HaCat cellular samples post irradiation, and in pure powdered samples could shed light on the mechanism and extent of cellular damage via UV radiation.

The samples were irradiated for varying times using a solar simulator (Q-Sun irradiator) and were examined pre and post UV irradiation. The output spectrum of the Q-Sun equates to an average irradiance value of 0.5Wm$^{-2}$nm$^{-1}$ in the UVA-B spectral band. The total irradiance in the respective bands is approximately 77Wm$^{-2}$ in the UVA and 6.5Wm$^{-2}$ in the UVB giving a total of 83.5Wm$^{-2}$ in the UVA-B region. As 1W is equal to 1 Joule per second, the time in seconds that the sample was irradiated for is simply multiplied by 83.5Wm$^{-2}$ which gives the energy incident on the sample in Joules per meter squared.

Preliminary work was undertaken at the beginning of the project. During the course of this work the Amino acids and the protein were exposed to irradiances of both 451kJm$^{-2}$ and 1353kJm$^{-2}$ in the UV A-B region. The objective of this work was to see if any primary structural changes would be observed in the samples post irradiation. None of the samples showed any...
spectral changes post irradiation. Subsequently the absorption spectra for the amino acids and the Lysozyme were obtained using the UV/VIS spectrometer. These spectra showed that the samples absorbed minimally if at all in the region of wavelengths to which they were exposed. This explained why no changes occurred to their molecular structure.

Two sets of cells were irradiated for various energies. The first set of cells were irradiated in culture medium and the second set in PBS buffer solution. The reason for this was that the UV/VIS was used to measure the absorption of the culture medium and the PBS. The PBS buffer was found to be the best medium in which to irradiate the cells as it is transparent over the range of wavelengths incident on the sample. The culture medium absorbed up to 80% of the UV radiation present in the output spectrum of the solar simulator.

Some notable differences were observed between irradiated and non-irradiated cells. There was however no difference between the spectra taken from the cytoplasm and the nuclei of the cells. There were increases in CH\textsubscript{2} bending modes (1445 cm\textsuperscript{-1}) and a new peak appeared in the C=C stretch (1645 cm\textsuperscript{-1}) region (see figure 2). This change is thought to be associated with changes in the secondary structure of proteins contained within the sample, since no changes in the spectra of the powdered chemical samples was obtained, indicating that the structural changes were not primary in character. The morphology of proteins is determined by secondary hydrogen bonds, which are much weaker than primary bonds, the energy associated with a hydrogen bond is approximately 0.1 eV whereas that of a C=C bond is 4.9 eV. The highest energy contained in the solar spectrum is 3.5 eV at 300 nm therefore the energy simply is not available to break primary bonds.

The new peaks were seen after 55 kJ m\textsuperscript{-2} when the cells were irradiated in PBS buffer solution whereas it took 65 kJ m\textsuperscript{-2} of UVA-B energy to cause the same changes in the spectra of the cells irradiated in the culture medium. This proved that UV radiation had some effect on the cells at a molecular level even though the energies it contained were not strong enough to break primary bonds, and are more likely to be secondary in character. Further work in this area could be to examine other constituents of the cell such as lipids, carbohydrates, and DNA.

![Figure 2. Spectra of cell cytoplasm that had been exposed to radiation for 15 minutes.](image-url)
Measurement of Radon in the Workplace and Estimation of the Risk of Lung Cancer

Robert Doyle
Supervised by Dr Tom Cantwell

Personal Details
After finishing my Diploma in Applied Science I decided to continue my studies by enrolling in the Physics & Physics Technology Degree course. My academic interests are mainly in areas such as renewable power systems and environmental science. Next year I am hoping to take a year out to be a volunteer in either South America or India and on my return complete my studies in Newcastle University. My hobbies include travelling, swimming, football, films and camping.

Project Summary
My final year project focused on the measurement of radon concentrations and the assessment of the risk posed by exposure to radon in the workplace. The basic idea of the project was that 50 radon detectors were placed in the Mid Western and Southern Health Boards by a final year Environmental health student.

The detectors were then returned to the Radiological Protection Institute of Ireland (RPII) and the radon concentrations calculated using Electronic Imaging Techniques. The concentrations calculated by the RPII were then compared to those obtained using manual counting techniques carried out in the School of Physics Laboratory at DIT (see figure 1).

The manual counting of the concentrations provided several insights into the process involved in radon detection using the CR-39 detector. One key observation was that the raw experimental data follows a Poisson distribution as seen in figure 2. This allowed for the calculation of the uncertainties present in the measurements obtained using the manual system. The results of the manual counting were then compared to the results obtained using the automatic system. The results shown in figure 3 indicate that the results are in good agreement.

Most radon measurement laboratories typically quote uncertainties in their measurements that are in excess of those calculated using the manual system. These lead to the overall conclusion that the major uncertainties present in radon measurements are not due to the counting procedures used in the processing of detectors. The uncertainties originate more from lack of precision in the handling/processing of the detectors. These include factors such as lack of compensation for the radon exposure during the time spent in transit between the workplace and the measurement service provider, bad quality control practices.

The second part of the experiment focused on the assessment of the risk posed by exposure to radon in the workplace. This involved understanding the data and models developed by international agencies such as the International Commission on Radiation Protection (ICRP).

Using the risk estimates calculated by the ICRP, it is estimated that roughly 48 people per year die in the Republic of Ireland from terminal lung cancer due to exposure to radon in the workplace. The estimate was based on the overall working
population and the average radon level for Ireland of 77 Bq m$^{-3}$.

The figure seems alarmingly high but in reality the true figure for the number of deaths due to radon exposure in the workplace may be far higher. It is possible that many workers are exposed to a level that is far in excess of the average radon level. The measurements taken in the health boards showed that nearly 50% of workplaces measured had radon levels above the national average. If this trend was repeated in workplaces across the country then the total number of deaths due to radon would be much higher than 48 per year.

Irish legislation demands that employers must ensure that the radon concentration on their premises is below the reference limit of 400 Bq m$^{-3}$. Workers who are exposed to the reference level for their entire working life stand a one in 180 chance of developing lung cancer.

However, this report demonstrates that in Ireland 48 people per year may develop lung cancer from concentrations far below the reference limit.

The measurements taken in the Health Board premises indicate that overall there will be very few workplaces above the reference limit. This indicates that current government legislation will not be able to significantly reduce the number of people who may die from radon exposure in the workplace. The vast majority of people who will develop lung cancer from radon exposure will do so in workplaces that are below the reference limit.

The results of the measurements in the Health Boards show that in one workplace the measured radon concentration was above that stipulated by the Ionising Radiation Act, 1991. The actions based on this measurement are that the employer has been written to by the RPII indicating that the workplace is over the reference limit. The RPII will conduct further testing to confirm that the radon concentration is above the reference limit.

If the results of the second set of measurements confirm that the radon concentration is above the reference limit then the employer must take action to reduce the radon level. Failure to lower the radon level could lead to legal action.
An Atmospheric Solar Irradiance Model

Joseph Farrell
Supervised by Dr James Walsh

Personal Details
In 2002, I successfully completed the Technician Diploma in Applied Science (Physics Option). I then decided to take the opportunity to further my studies and pursue a Degree in Physics & Physics Technology. During my time in DIT, I have studied a wide range of subjects. My academic interests include Optical Communications, Remote Sensing, Radiation and Nuclear Physics.

I am also very interested in Environmental Science. My hobbies include reading, music, sports and cinema. On completion of my degree, I hope to travel while developing my career.

Project Summary
The main objective of this project was to construct an Atmospheric Solar Irradiance Model for direct, diffuse and global irradiance at the earth’s surface for clear days using MATLAB software. This was based on a paper by Richard E. Bird entitled “A Simple, Solar Spectral Model for Direct-Normal and Diffuse Horizontal Irradiance”.

Solar radiation reaching the top of our atmosphere is called extraterrestrial solar radiation. The amount of radiation hitting the top of our atmosphere (typically 1.37 kW/m²) is called the solar constant. The extraterrestrial radiation has a similar shape to the blackbody curve emitted by the sun, as the radiation does not undergo any attenuation processes as it travels through space.

However, as solar radiation passes through the atmosphere, it is attenuated by scattering. The radiation reaching the earth’s surface is described as global, direct and diffuse. Global is the total amount of radiation measured at the ground and is the sum of the direct and diffuse components. Direct radiation is radiation measured coming directly from the solar dish. Diffuse radiation is all radiation coming from the sky except radiation coming directly from the direction of the sun. Radiation which is scattered to the ground is part of the diffuse component, this radiation can be reflected from the surface back to the atmosphere where it can be scattered/reflected back to the ground. All these separate components combine to form diffuse radiation.

Solar radiation models are used to simulate the processes in the atmosphere, which attenuate solar radiation passing through it. These models became very important upon the observation in 1985 of the Antarctic ozone hole. The amount of radiation reaching the surface varies widely around the globe. Several factors account for this variation at any given location, which include scattering (Rayleigh, aerosol) and absorption (ozone, aerosol, and water vapour) processes. There are also variations in zenith angle/air mass which govern the scattering and attenuation processes. The combination of these variables result in large fluctuations in the amount of radiation reaching the surface. This is the main reason behind the construction of solar radiation models.

Aerosols are tiny particles suspended in the atmosphere, responsible for both scattering and absorption of solar radiation. Aerosols attenuate direct radiation, but increased scattering can lead to more diffuse radiation at the surface.

A consistent attenuator of solar radiation is Rayleigh scattering. It is present when molecules/particles in the atmosphere have diameters much smaller than the radiation wavelength. This explains the blue sky on a clear day when UV radiation (blue) is scattered more than radiation of longer wavelengths.

Ozone absorption is responsible for the attenuation of shortwave radiation (UV) and is due to a 3nm layer of ozone spread throughout the stratosphere. Here it forms a shield preventing radiation of wavelengths below 295nm from reaching the surface.
Water vapour absorption also causes absorption. Depending on one's location, the amount of water vapour contained in the atmosphere can be from 0%–4%. Water vapour attenuates long-wave radiation.

The final attenuation process is due to uniformly mixed gases (oxygen and carbon dioxide). Oxygen attenuates shortwave radiation and carbon dioxide long-wave radiation.

All of these individual attenuation processes are dependent on an important factor, zenith angle which determines air mass. Zenith angle is the angle of the earth relative to the sun. This factor is important because when the sun is directly overhead (Z = 0°) we expect to receive maximum radiation at the surface. However, when the sun is low in the sky close to sunrise/sunset we expect to receive minimum radiation. Solar radiation is subject to basic laws of physics and Beer’s law is one of the most fundamental. Simply it states that the greater the amount of absorbing material encountered by radiation on its path from start to end point, the less radiation which will reach that end point. Because of this, air mass is extremely important. It is the pathlength through which radiation has to travel to reach the ground. At Z = 0°, air mass is at a minimum value of 1.0 and increases reaching a maximum of over 10 when the sun is close to sunrise/sunset (see figure 1).

In this project, an atmospheric solar irradiance model for cloudless days was constructed using Matlab software. The model used simple mathematical expressions to simulate direct, diffuse and global irradiance at the earth’s surface. The model was expected to have the ability to be applied to a broad range of atmospheric conditions. Inputs to the model included extraterrestrial radiation, zenith angle/air mass, atmospheric turbidity, amount of water vapour, amount of ozone and the air/ground albedo. The results were analysed for variations in all of these conditions. The model successfully simulated all the processes that alter the solar radiation as it passes through the atmosphere (see figure 2). The model was compared to two published models and was found to compare well.

This model is now in a position to be the basis for further work by the Metrology and Optical Sensing Laboratory at DIT, providing an important tool for current and future research.
Chaos in a Dripping Tap

Stephen Fisher
Supervised by Dr Cathal Flynn

Personal Details
Upon successfully completing the first year of the Applied Sciences and Computing degree, I chose Physics as a subject for second and third year ahead of Maths and Chemistry. At the beginning of fourth year, I again chose Physics, ahead of Software Engineering, as a degree subject. Along with Physics, I chose both Computer Science and French as final year subjects. French was useful because I spent the second half of third year on the Erasmus program in the south east of France, studying in the IUT Chateau Neuf, Bayonne.

Project Summary
Chaos is an emerging scientific discipline with its origins dating back to the 1960s. It is the irregular, unpredictable behaviour of deterministic non-linear dynamical systems. Three of the most common ways in which a system becomes chaotic is quasiperiodicity, intermittency and period doubling.

The aim of this project was to construct a PC-interfaced apparatus to show the period doubling route to chaos in a dripping tap. The apparatus was to be constructed so that it could be used as a future third year laboratory experiment. The project was designed to study the time-interval of drips falling from a tap when the dripping rate was increased. The drip rate was the control parameter of the system.

An apparatus to replicate a dripping tap was built to provide the dripping conditions and a circuit was constructed to provide the data acquisition and storage. The main components of the circuit were a GaAs infrared LED, TSL250 detector and a 555-timer. The circuit was set up in such a way that when the beam travelling from the LED to the detector was broken, the 555-timer produced an output pulse determined by an RC network. The idea behind the circuit was that when a drip passed through the LED/detector path an output pulse was produced. The time between these pulses would constitute the time between the drops. A pipe was used to hold the LED and detector and allow for greater mobility of the apparatus.

Upon completion of the circuit a Marriott’s Flask was used to replicate the set-up of a dripping tap. The output of the flask contained a nozzle that provided the well-controlled dripping conditions. The water would exit the Marriott’s Flask and fall through the pipe that contained the LED and detector producing a pulse for each drop. a photo of the set-up can be seen in figure 1.

The pulses were sent to the computer via a data acquisition card. A program was written in Labview that accepted the data and stored the results. Results were recorded for drip-rates ranging from 1.8 drips/s to 10 drips/s. For each set of results a graph of ‘Time Interval’ versus ‘Drop Number’ and a graph of ‘Time Interval’ versus ‘Preceding Time Interval’ was produced.

Figure 1. A picture showing the vertical pipe containing the LED and detector along with the dripping apparatus above it.
For low drip rates the system was seen to be periodic with most of the time intervals occurring close to the mean value. This can be seen for a drip rate of 1.8 drips/s in figure 2. As the drip rate was increased, the system showed elements of period doubling for a drip rate of 3.57 drips/s. In this state, a long time interval was followed by a short time interval. A long time interval then followed once more. As the drip rate was increased further, the system progressed further still on its route to chaos. Figure 3 shows the results for a drip-rate of 5.5 drips/s. The drip intervals could now be seen to occur over a range of 50 milliseconds. The drip interval is now unpredictable. The system had now progressed from a periodic state to a chaotic state.

It was hoped to show a clear indication of period doubling in the dripping tap. However only elements of period doubling could be seen. The reason for this was the sensitivity of the nozzle that controlled the drip rate. For period doubling to be shown, a change of approximately 10 milliseconds was required in the drip rate. This sensitivity was not possible with the apparatus.

Upon obtaining the results, the system was also modelled using a set of first order differential equations. Time limitations resulted in this work being incomplete. Future work in this area could model the dripping tap further and to compare the results with those obtained experimentally.
Demonstration of the Principles of Computed Tomography

Barry Haycock
Supervised by Dr Des O’Mahony

Personal Details
Having completed a Certificate and Diploma in Applied Physics and Instrumentation in the Institute of Technology in Tallaght, I decided to undertake the Degree in Applied Sciences course in DIT, taking the Physics & Physics Technology option. Over the three years in IT-Tallaght and the two years spent in DIT, I have continually maintained a part time job and travelled as much as possible. I’ve worked in the US, on a J1 visa, and I have visited Budapest, Paris, London, Edinburgh, and parts of Turkey. From next year I hope to travel more while developing my career. My academic interests include Organic Electronics, Physics of the Solid State, Optics, Communication Theory, Quantum Technology, Instrumentation and Medical Imaging. My hobbies include photography, computer simulation, cinematography, electronics and music. I also enjoy reading and writing.

Project Details
My project was based on instrumentation, medical imaging and some maths. Essentially I had to build an experiment that could be carried out by third or fourth year students that would show the basics of Computed Tomography (CT). This was based on a paper by Delaney & Rodriguez entitled “A simple medical physics experiment based on a laser pointer”, from the American Journal of Physics, Oct 2002. As a potential student laboratory experiment, the built apparatus and programs had to be simple to explain and use, the system had to be robust and “student-proof” and it needed to be easy to upgrade and repair.

There are many applications of Computed Tomography. It allows non-destructive imaging of almost anything. It has been applied to Magnetic Resonance Imaging (MRI), Ultrasonic Imaging, mapping of underground resources and has even been used in astronomy and electron microscopy. Its growing importance makes it essential for Physics and Clinical Measurement students to understand the principles behind it and, perhaps more importantly, its limitations.

Basically, CT is the principle in which a series of 1D projections is reconstructed into a 2D image and these can then be amalgamated into a 3D image. A projection is the radiation detected as an emitter-detector pair pass on either side of a sample (see figure 1).

Backprojection is the method of image reconstruction used in this project. The reconstruction worked by applying the equation below repeatedly. In the equation, x and y are the co-ordinates a pixel in the matrix, s is the sample number, \( \theta \) is the angle of sampling (projection angle) and D is the distance the ray described by \((\theta, s)\) pass by \((x, y)\):

\[
|y \cos(\theta) - s - x \sin(\theta)| = D
\]

This equation determines the distance a ray

Figure 1. As the emitter and detector pair travel past the object, regular samples (rays) are measured. These rays form a projection of the sample, which is combined with projections at other angles (rotating the table) to create an image.
passes from a pixel in the image matrix, if it passes close enough to that pixel, its attenuation value is added to that pixel. In plain English, this means that for each ray in a projection the distance it passes to each pixel in the image being reconstructed is found. If this distance is less than a half a pixel width from the centre of the pixel, then the value of that ray is added to that pixel.

One of the limitations of backprojection is that once an image has been reconstructed, there are some errors that emerge. More specifically, a “star formation” always appears to extend from any object in the image. If the image is constructed from a large number of projections, this star formation becomes more like a blurring of the edges around an object, the effect of which falls off at a rate of $1/r$ where $r$ is the distance from the object in the image.

To correct for this, a convolution filter is added to the reconstruction algorithm. In mathematical terms this is called a “kernel”. The filter used came from a paper published in 1971 by Ramachandran and Lakshminarayanan. This filter made the produced images much more defined. Figure 2 shows an image of a ball before and after the application of the Ramachandran – Lakshminarayanan filter.

Rather than using an x-ray source, as in most medical CT systems, the radiation emitter was a laser source and the detector used was a photodiode. A chart recorder was salvaged from the lab and was used to support the sample table and automate the translation of it through the laser beam – photodiode detector pair. This method was more convenient although in real medical systems the sample stays in one place and the emitter and detector pair translate past it.

The apparatus that was built is illustrated in figure 3. It was almost completely controlled by the computer, including resolution and scanning settings. This made the system simple to use and easy to explain and allows the user to measure how long the computer takes to reconstruct different images and make measurements on images produced.

The system can now easily be used in a laboratory demonstration situation and should be effective in helping the student understand CT principles.
Phase Change in Plethysmography Signals

Fiona Hughes
Supervised by Aidan Meade & Dr Pat Goodman

Personal Details
Having completed the Technician Diploma in Applied Science in 2002, I decided to continue with my studies and pursue a Degree in Physics & Physics Technology. My main areas of academic interest include Nuclear Physics, Medical Imaging and Acoustics. My hobbies include playing camogie, athletics and socialising.

Project Summary
The main objective of this project was to develop a method for the detection of health problems such as peripheral vascular disease and arterial occlusive disease. This study investigated plethysmographic pulse waveform shapes, at two sites in the body, using Power Spectral Analysis as a means of identifying circulatory problems in the lower peripheries. Diagnosis using physiological signals generally involves empirical evaluation, by a Clinical Measurement Technician, of changes in the signal relative to their experience of a 'normal' one. These changes in signal profile generally involve phase and/or frequency shifts in high frequency components of the signal. Power Spectra of physiological signals offers a more quantitative means of analysing these changes since the physiological signal generally consists of a low-frequency constant area CA and a high frequency predictive area PA. Previous studies have evaluated changes in signal profile via evaluating the area under the CA and PA spectral peaks. Normal values for the CA/PA ratio are then established (via epidemiological studies) and in practice the CA/PA ratio for a patient is compared to the normal range in order to determine the patients deviation from normality. It was hoped that for this study the existence of a CA and PA would be determined, and some ‘normal’ PA/CA ratios could be determined.

Plethysmography is the term given to the measurement of a change in limb or digit volume in the body. Abnormal changes in digit volume may be indicative of restriction to blood volume flow rate to the digit or limb. There are various ways in which to measure these volume changes, impedance plethysmography, venous occlusion plethysmography and the method used in this study, photoplethysmography (PPG). PPG can be performed by either measuring the intensity of transmitted or reflected infra-red light (IR) from a digit or limb. The intensity is influenced by the red blood cell volume in the limb/digit and is thus influenced by blood flow rate, which also changes the limb/digit volume. There are two types of PPG probes, a reflection probe and a transmission probe. The reflection probe has both a light emitting and sensing part. This is the type of probe used in this study. Figure 1 shows a schematic diagram of a reflection probe. The photosensor detects the backscattered light. The transmission probe has the photosensor located opposite the light emitting part.

Twelve subjects volunteered to take part in this study. Their blood pressure was recorded before and after the PPG measurements so as to verify that it was a non-invasive technique. The PPG signals were recorded for all subjects at two sites on the body, the middle finger and the great toe. PPG signals were recorded while the subject was breathing spontaneously and then while holding their breath. Subjects had PPG signals recorded from their right and left finger and toe, and also

Figure 1. The operation of a reflection PPG probe.
signals were recorded while the subjects were in a seated and a supine position. The power spectra of all the recorded signals were then analysed by obtaining the geometric integral under each peak. A student paired t test was performed between the two sets of data i.e. the finger peak integrals and the toe peak integrals.

Figure 2 shows a typical PPG pulse waveform. The notch on the downward slope is referred to as the dicrotic notch and it was more defined in younger subjects. The power spectrum of the subject breathing spontaneously included a breathing frequency of 0.25Hz, while the spectrum of the subject holding their breath excluded any such respiratory variations. The spectra comparing left and right finger and toe showed a frequency phase shift between the two sides of the body. This phase shift occurred in the power spectra of the subjects while they were seated and also while they were in the supine position. It was suggested that the probe positioning and the interfering ambient light caused this phase shift. Four peaks were found in the power spectra of the majority of subjects (figure 3). This is a new development as previous studies showed only one peak. Finally by comparing p-values from the paired t test, it was found that peaks 1 and 4 represented the CA in the spectra and peaks 2 and 3 represented the PA.

It is obvious that this study offers so much more for future work. Some possible ideas would be to a) increase the number of subjects - this would make the statistical analysis more viable; b) change the measuring technique - the movement and placement of the probes was a major factor in the frequency phase shifts; c) change the protocol - it would have been interesting to test a subject suffering from peripheral vascular disease where proper comparisons could have been made so as to detect early stages of the disease in other subjects; d) carry out wavelet analysis and squared coherence analysis of the power spectra rather than determining the peak integrals.

This project is seen as a stepping stone for future work: it has introduced a new method for pulse waveform analysis that can be used for the detection of health problems.
Spectroscopic Studies of Quantum Dots

Ronan Keaney
Supervised by Dr John Doran

Personal Details
In 1995, I completed the Diploma in Applied Sciences course (Physics Option) at DIT. During my studies I undertook work experience placements under the Summer Student Work Scheme. The first of these, in 1994, was with Prof. Coey at Trinity College Dublin where I was involved in producing fine powders of intermetallic compounds for permanent magnet production. I also collected powder X-ray diffraction patterns and participated in an experiment of magnetic sintering of cobalt. In 1995, I worked at DIT Kevin Street on a project that endeavoured to recharge used dry-cell batteries.

In January 1996 I began working as a lab technician in Blackrock College, where I was responsible for seven labs. I also taught Junior Certificate Physics there, until I left in May 1998. I returned to college in September 2001 to study for a Degree in Applied Science. I have also worked as a live sound engineer and a transport technician. My academic interests include environmental science, acoustics and materials science.

Project Details
There is a need to reduce the cost of photovoltaic cells. Presently it is not cost effective to make large, high quality cells for domestic or commercial use. Light concentrating systems are giving promising results, but many depend on direct sunlight with tracking mechanisms.

Quantum Dots are semi-conductor or metal structures where the conducting electrons are confined in all three dimensions. They can be fabricated by lithographic or chemical techniques and consist of an insulating material surrounding a conducting region of approximately 5 nm. At this scale quantum mechanical effects become apparent. These effects are due to the confinement of electrons and holes in the material and can be understood by using the theory applied to quantum wells (figure 1). The position of the electron and hole, the charge carriers, are also important. They contribute to the overall energy of the system ($E^e$ and $E^h$ in figure 1). The total energy emitted is equal to the band-gap plus the energies of the bound electron-hole pair. The energy is dependent on the physical size of the well or dot, which can be controlled in the fabrication. Quantum dots are part of a new technology. This technology is being used to advance opto-electronic communication and other similar industries as a broader range of wavelengths is devised.

From the experimental work it was concluded

This report attempts to analyse the spectroscopic properties of quantum dots and suggest applications for a design of a concentrator solar cell. Presently, these type of solar cells endeavour to focus electromagnetic energy from the sun onto a photovoltaic (PV) cell using organic dyes to absorb the energy and re-emit it. The advantage of this system is that smaller cells are needed and the emitted energy can be designed to be at a wavelength at which the cell is most responsive. Various layers respond to different wavelengths as they pass through. Also, diffuse as well as direct radiation can be utilised. It has been found that these dyes can break down in sunlight, so a more durable material is required to further this type of technology. Research into quantum devices may deliver the answer.

Quantum Dots are semi-conductor or metal structures where the conducting electrons are confined in all three dimensions. They can be fabricated by lithographic or chemical techniques and consist of an insulating material surrounding a conducting region of approximately 5 nm. At this scale quantum mechanical effects become apparent. These effects are due to the confinement of electrons and holes in the material and can be understood by using the theory applied to quantum wells (figure 1). The position of the electron and hole, the charge carriers, are also important. They contribute to the overall energy of the system ($E^e$ and $E^h$ in figure 1). The total energy emitted is equal to the band-gap plus the energies of the bound electron-hole pair. The energy is dependent on the physical size of the well or dot, which can be controlled in the fabrication. Quantum dots are part of a new technology. This technology is being used to advance opto-electronic communication and other similar industries as a broader range of wavelengths is devised.

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This report attempts to analyse the spectroscopic properties of quantum dots and suggest applications for a design of a concentrator solar cell. Presently, these type of solar cells endeavour to focus electromagnetic energy from the sun onto a photovoltaic (PV) cell using organic dyes to absorb the energy and re-emit it. The advantage of this system is that smaller cells are needed and the emitted energy can be designed to be at a wavelength at which the cell is most responsive. Various layers respond to different wavelengths as they pass through. Also, diffuse as well as direct radiation can be utilised. It has been found that these dyes can break down in sunlight, so a more durable material is required to further this type of technology. Research into quantum devices may deliver the answer.

Quantum Dots are semi-conductor or metal structures where the conducting electrons are confined in all three dimensions. They can be fabricated by lithographic or chemical techniques and consist of an insulating material surrounding a conducting region of approximately 5 nm. At this scale quantum mechanical effects become apparent. These effects are due to the confinement of electrons and holes in the material and can be understood by using the theory applied to quantum wells (figure 1). The position of the electron and hole, the charge carriers, are also important. They contribute to the overall energy of the system ($E^e$ and $E^h$ in figure 1). The total energy emitted is equal to the band-gap plus the energies of the bound electron-hole pair. The energy is dependent on the physical size of the well or dot, which can be controlled in the fabrication. Quantum dots are part of a new technology. This technology is being used to advance opto-electronic communication and other similar industries as a broader range of wavelengths is devised.

From the experimental work it was concluded
that the quantum dots were absorbing at discrete wavelengths, which is consistent with their relation to quantum wells. The emission of the dots was also of interest. A peak of 548.5 nm occurred when the sample was exposed to excitation radiation of higher wavelengths. This peak re-occurred despite different excitation wavelengths and therefore it can be concluded that it is a definite property of the sample.

The absorption and emission of the quantum dots can be plotted together to get an overall picture of their properties as they relate to this project (see figure 2). The sample absorbs at 288 nm, 387 nm and 522 nm and emits at 548.5 nm. In terms of a solar concentrator, these are the wavelengths at which direct and diffuse electromagnetic radiation will be absorbed and re-emitted.

This is what is desired, i.e. the sample absorbs different wavelengths to what it emits.
An Evaluation of CODE V
Optical Software

Brian Kenny
Supervised by David O’Brien

Personal Details
This year I will be completing my Degree in Applied Sciences; I hope to continue with my studies by enrolling in a postgraduate course in the optics field of physics. My hobbies and interests include sports, leisure and the Arts.

Project Summary
I chose an optics project that involved performing an evaluation of Code V optical design software. The evaluation was performed with a view to using the software as a potential undergraduate optics study, such as an optics experiment or course subject like the Applied Optics course that is a subject in the Physics Technology option of the Applied Sciences course.

Optical Research Associates (ORA®) is a leader in the optics industry, both as the largest independent optical engineering services organization, and as the developer of the world’s leading optical design software packages, CODE V. CODE V is the world’s most advanced lens system design software with state-of-the-art capabilities for lens optimisation, analysis, and tolerancing. CODE V is ORA’s comprehensive program for optical design, analysis, illumination calculations, and fabrication support. It is used by organizations around the world to design a wide range of optical systems for a variety of products, including photographic equipment, video cameras, medical instruments, aerospace systems, and much more. CODE V’s advanced features are combined with outstanding flexibility and ease of use, and ORA’s excellent technical support makes the program even easier to use.

Photographic lenses are a “classical” application of design software, and improved lenses continue to be designed and built, often with the help of CODE V’s excellent local and global optimisation features. Zoom lenses are widely used in video and film cameras as well as in still photography. Requirements for high image quality, long zoom range, light weight, low cost, and more are often in conflict, making zoom design extremely challenging. CODE V has special zoom design features that make it the premier tool in this difficult work. Engineering projects are generally confidential, but the “Hubble first servicing” generated wide publicity and a number of technical papers that cited ORA’s work on Hubble, so we can make an exception and mention our participation in various projects and committees that contributed to the servicing mission. CODE V files were a convenience to the many organisations that worked on the Hubble first servicing mission, allowing them to easily and reliably share data for the many subsystems involved.

Spectrometers, multispectral cameras, imaging radiometers and dozens of other scientific instruments have been designed with CODE V. Engineers in industry and government use ORA software to design, analyse, and troubleshoot instruments for many space and terrestrial applications. ORA engineers have worked extensively on many such systems (ORA received a special NASA award for optically related work on many projects for the US space program). Laser scan-
ning systems are used in supermarket product code readers, in laser printers, and in many other applications. CODE V has Gaussian beam analysis and other features that help in the design and analysis of scanners.

I began the project by familiarising myself with the general operations and core software features in CODE V. A helpful Test Drive manual and Users manual accompanied the software, assisting me with any problems that arose with any unfamiliar terms or concepts employed in the software. A lot of the theory I had already encountered prior to my introduction to CODE V in the Applied Optics course in my Physics Technology option that used the Winlens Linos software for optical design. The software uses classical optics theory, basic first and third order theory and geometrical optics was employed for ray tracing in CODE V.

Upon completing procedures outlined in the Test Drive manual, I started to model small basic systems in Code V. I began by modelling the object point and entrance pupil, which governed the amount of light that is allowed to enter the system. Inserting components and lenses into systems was relatively easy; a lens could be modelled from scratch in CODE V using the New Lens Wizard software feature in CODE V. I was easily able to progress on to modelling double and triple lens systems, and use both spherical and non-spherical surfaces quite easily in different systems designs.

Each design made in CODE V could be plotted very easily in CODE V in a range of different plotting options in both 2D and 3D dimensions. The Optimisation feature available in CODE V was also very helpful in improving a system designed in CODE V, the software used algorithms and arrays to recognise different error effects that may have crept into a system during design replacing any of the surfaces or components in the system that may cause these errors with more suitable components from any of the large databases available in CODE V. The systems designed in CODE V were then subjected to various analysis techniques; this method of evaluating the performance of systems designed is probably CODE V’s most powerful feature.

I had intended on properly testing CODE V against corresponding systems designed in the lab using an optical bench however due to time restrictions I was unable to follow through with this area of the project. I feel that the software holds a lot of potential as an educational tool for undergraduates. It is very powerful and versatile software capable of being implemented in many different fields of study and application and would make an ideal postgraduate tool.
De-Roping of Carbon Nanotube Bundles

Jennifer McCartin
Supervised by Elizabeth Gregan

Personal Details
After successfully completing three years at DIT Kevin Street, I graduated with the Technician Diploma in Applied Science (Physics Option) for which I was awarded a Distinction. Following this I decided to further my studies and pursue a Degree in Physics & Physics Technology. My main areas of academic interest include nuclear physics, biophysics, acoustics, solid-state physics and the physics of materials. Outside of college my hobbies would include tennis, reading, cinema and socialising.

Project Summary
Carbon nanotubes were first discovered by the Japanese electron microscopist S. Iijima in 1991. Since their discovery extensive research has been carried out in laboratories all over the world. Single-Walled Carbon Nanotubes (SWNTs) have an impressive list of attributes. They can behave like metals or semiconductors, can conduct electricity better than copper, can transmit heat better than diamond and they rank amongst the strongest materials known. SWNTs can be considered as one-dimensional structures because of their large length to diameter ratio. The length of a carbon nanotube is on the micron scale and the diameter of nanotubes typically ranges between 0.7nm and 2nm (1nm is about 1 ten-thousandth the diameter of a human hair). Carbon nanotubes are formed when a graphene sheet, which is a single atomic layer of graphite, is curled into a cylinder and the carbon atoms join seamlessly to each other.

As carbon nanotubes form, they typically aggregate into bundles, termed ropes, which consist of SWNTs held together by weak van der Waals attractive forces. For successful applications of carbon nanotubes the exfoliation of nanotube bundles into individual tubes is necessary (see figure 1).

The aim of this project was to use solvents and surfactants combined with ultra-sonication techniques to separate the tubes from their aggregated bundles. Raman spectroscopy was used as the principle diagnostic tool for determining any debundling that may have occurred.

Raman spectroscopy is a form of vibrational spectroscopy and is the dominant experimental technique used for studying SWNTs, as it is able to probe and characterise nanostructures. The spectrum for the SWNT is a simple and well-established Raman signature, which makes it easy to examine. Regardless of the tube type (semi-conducting or metallic), the net result of debundling is an apparent up-shift in the RBM frequency for SWNTs using the same excitation frequency.

Figure 2, shows the Stokes spectra for the variation between the raw HiPco sample and those that were treated with solvent at excitation energy of 488nm. From theory it is known that ultra sonication with the addition of solvent causes the tubes within a sample to become more dispersed. The solvent influences the stability of the dispersed tubes in the system. From figure 2, it can be seen...
that the G-line of the raw HiPco sample displays both metallic and semiconducting properties whereas the treated samples display only semiconducting properties. An explanation for this could be that the solvent is dissolving only the semiconducting tubes. If the solvent dissolved the semiconducting tubes, these tubes would remain at the surface of the solutions whereas the metallic tubes would fall to the bottom. The samples that were drop cast onto the glass slides for Raman analysis where all removed from the surface of the solutions.

Figure 3 shows the Stokes region RBM of both the raw and treated HiPco tubes. The spectral shape of the RBM for the raw sample is quite similar to that of the sample dissolved in ethanol, but upshifted. The dominant peak of the raw sample occurs at 202cm⁻¹ and the dominant peak of the sample dissolved in ethanol occurs at 205cm⁻¹ indicating that the ethanol did cause some dispersion of the bundles to occur. The shape of the RBM for the nanotubes in toluene differs considerably from the raw sample but there is an observable upshift in the lower peak. The lower peak for the raw untreated sample occurs at 162cm⁻¹ and the lower peak for the sample dissolved in toluene has been upshifted to 171cm⁻¹; this again shows that some debundling did occur.

Similar behaviour could be seen between the raw HiPco tubes and the solvent treated tubes at other wavelengths. Debundling was also seen in the surfactant treated tubes at each of the laser wavelengths employed. The overall conclusion that can be taken from this project is that Raman spectroscopy can be used to detect debundling within SWNT samples.

Figure 2. Stokes spectrum of raw HiPco tubes and the spectra for the tubes treated with solvents at excitation energy of 488nm.

Figure 3. Variation in the Stokes RBM between the raw HiPco tubes and those treated with solvent at excitation energy of 488nm.
Self-Assembly Process of Polysaccharides for the Purification of Carbon Nanotubes

Jonathan Moghal
Supervised by Dr Gordon Chambers

Personal Details
Having completed the Technician Diploma in Applied Science (Physics Option) in 2002, I decided to continue with my studies and pursue a Degree in Physics & Physics Technology. The subjects I have studied in my final year include Acoustics, Nuclear Physics, Biophysics, Quantum Mechanics and Solid State Physics.

I enjoy travelling and have spent summers living in America and travelling around Europe. I am interested in soccer and am manager of the Shelbourne under 12 team. I also enjoy socialising with friends and swimming.

Project Summary
Carbon nanotubes since their discovery have been the focus of much publicity due to their potential to revolutionise biotechnology and nanotechnology. Carbon nanotubes are rolled up sheets of graphite. They can have different chirality depending on the way in which they are rolled as shown in figure 1.

Some of the properties which makes this tubes interesting is that they have a Young’s modulus of 5TPa, they have a strength to weight ratio 500 times greater than that of steel, high current capacity approximately 109 A/cm$^2$ and they are ideal for field emission. However the key to unlocking their potential has yet to be found due to difficulties in processing and manipulating individual tubes.

This project attempted to assess the potential of a natural matrix, starch, to interact with the surface of carbon nanotubes in an ordered fashion through specific hydrophobic and hydrophilic interactions along the tubes’ surface. Polysaccharides are known to interact with carbon nanotubes and starch in particular has been suggested to wrap helically around the tube in a self-assembly type of mechanism.

In this study two starch-based complexes were formed. The first was produced via starch interaction with Iodine which produced the well known blue-black complex. The starch coils around the Iodine in a self assembly process as shown in figure 2. When the carbon nanotubes were introduced and the solution was centrifuged and sonication, the Iodine was displaced and a new complex formed between the carbon nanotubes and starch as shown in figure 3.

This complex was studied using a range of spectroscopic techniques (such as UV/VIS/NIR, FTIR and Raman) and it is proposed that contrary to literature that the starch has a destructive effect on the tubes unique structure.

The second complex was also formed via sonication and centrifuge but with Bromine as opposed to Iodine was also assessed spectrocopically and no evidence of any type of destruction to the

Figure 1. The different ways of rolling a sheet of graphite to make various different types of nanotubes.
tubes was observed.

Rather a new novel tertiary complex consisting of Starch-Bromine-Carbon nanotubes is proposed to have been produced. Such tertiary composites would be fully biocompatible opening up a new phase of nanotube research in which the electronic and mechanical properties of the carbon nanotubes are coupled with molecular specificity of biological molecules providing a potential route towards an ideal miniaturised biosensor.

This was the first spectroscopic report on the intermolecular interactions between carbon nanotubes and starch complexes.
Detection of Low Frequency Electromagnetic Radiation in the Laboratory

Jarlath Molloy
Supervised by Dr Cyprian Feeley

Personal Details
After completing the Diploma in Applied Science (Physics Option) in 2002, I transferred into the Degree in Physics & Physics Technology. I took most of the subject options available in final year. I was class rep for both the Diploma and Degree courses. I have been continually involved in many areas outside the academic field, while in college. My interests and hobbies include music, reading, swimming, cycling, aviation, neolithic history, archaeo-astronomy, cinema and socialising.

Project Summary
A detection system for Extremely Low Frequency (ELF) and Very Low Frequency (VLF) electromagnetic radiation was constructed and its performance between 0 – 45 Hz was examined. An octoloop antenna and associated circuits were constructed. Different software packages were tested for capturing and analysing the signal. Data was recorded and analysed using the investigated software.

Results showed large quantities of low frequency background radiation in the environment of the laboratory. The majority of it was generated from electrical devices in the laboratory and in the surrounding vicinity. It was not possible to identify specific sources or emitters of electromagnetic radiation.

Electromagnetic energy is radiated in the form of a wave as a result of the acceleration of electric charges. A moving charge gives rise to a magnetic field and if the motion oscillates, then the magnetic field varies and in turn produces an electric field. The configuration of these fields varies in space and time and propagate as traveling waves of a wide range of frequencies.

Sources of LF are both natural and artificial. Electrical devices and power lines emit EM fields and pulses of varying intensities. The main natural sources of electromagnetic radiation are the Sun, the Earth and where they interact in the magnetosphere. The magnetosphere is a cavity above the ionosphere generated by the interaction of Earth’s magnetic field and solar wind.

It is known that natural resonant cavities exist in the magnetosphere and they are sources of particularly low frequency radiation. The plasmas contained within the cavities of the magnetosphere are dispersive. The effect of this is that when an electromagnetic wave propagates within cavities, its different frequency components travel at different velocities. The waves propagating in these cavities range in frequency from 1 Hz to 100 MHz. They are detected as radio signals and are known as sferics. Others when converted to audio can be heard as tones of decreasing frequency, know as whistles. Sferics are the snap, crackle and pop of lightning storms and whistlers are sferics that have become dispersed in time to the point of becoming a descending tone. It was hoped at the outset to detect such phenomena.

A shielded octoloop antenna was constructed. It had a diameter of 2.45m. It was built on a wooden frame that was mounted on a tripod and the frame was gimbaled so it could be rotated in order to null out noise. The effective length of wire in the antenna was almost 300m and the antenna had an effective aperture of 170m².

Two circuits were constructed; a tuning circuit and a amplifier circuit. The receiver-amplifier circuit was used in the experiment. It had a cut-off frequency around 47 Hz. Four software packages were tested for recording and analysing the captured signal. None worked perfectly however due to time constraints, the better of the packages was used for the analysis procedure.

A magnet was rotated in front of the antenna, which induced a regular magnetic field and the
responsiveness of the apparatus was tested. This resulted in a visible change in antenna output signal, as captured by the computer (see figure 1).

The software plotted two sets of results; an upper user-defined spectral plot of the signal versus intensity and a lower waterfall plot of the frequency spectrum versus time versus intensity – in colour. Black and blue indicates low intensity, red, orange and yellow represents high intensity and green represents medium intensity, relative to the two extremes.

Large amounts of low frequency background radiation were detected, particularly during the daytime (see figure 1). Very large transient power spikes were detected when the relatively small circuit was switched on / off. Other obvious transients detected were computer monitors being turned on or off in the lab. Background levels were much lower at night-time (see figure 2).

Electrical earthing and shielding was an issue with the circuit. The noise factor in the data sampled was at times almost as large as the signal detected. The gimbal wasn’t effective due to the quantity of EM noise in the area surrounding the antenna. No atmospheric interactions were sampled during the experiment due to the quantity of background radiation in the area.

Figure 1. Signal response from regular induced magnetic field. Note daytime background levels of radiation before and after induced magnetic field and harmonics at 10, 20, 30 and 40 Hz.

Figure 2. Night-time signal response. Note average low frequency EM levels are much lower.
Image Noise Analysis for Medical X-ray Images

Camilla O’Beirne
Supervised by Aidan Meade & Colin Walsh (St. James’s Hospital)

Personal Details
In 2000, I entered the Degree in Applied Sciences and Computers. In first to third year of the course, the subjects involved computers, physics, maths, french and management studies. In my fourth year I decided to continue with computers, physics and french. In third year, I took part in the Socrates program, which meant that I spent six months in France, completing the course work in college there. It was a great experience and really enjoyable.

Project Summary
The aim of this project was to investigate the relationship between subjective and objective image quality assessment in images produced by an X-ray Image Intensifier TV system. Subjective image quality assessment involves determining the number of visible objects of decreasing contrast and/or resolution within test phantoms while objective image quality assessment assesses image quality using mathematical parameters (such as MTF).

In this project, the subjective measure of image quality was Threshold Contrast Detail Detectability (TCDD), which is assessed using the Leeds TO.10 test object. TCDD is related to SNR2 (signal-to-noise ratio squared), which is an objective measurement of image quality but there is as yet no defined link between these two assessments. A measurement of TCDD measurement gives an overall assessment of image quality since it comprises assessments of contrast and resolution (see figure 1). The Leeds TO.10 test object which comprises of an opaque perspex plate, which has 108 discs of different diameter and x-ray attenuation coefficient (contrast) mounted within it. For each of the twelve discs diameters, there are nine contrast levels (discs of different thickness). Each row of the image was viewed separately and the number of discs visible was counted. The corresponding threshold contrast, CT, and area of the disk, A, was taken from a table provided. These values were used to calculate the threshold detection index, HT, of a disk using the formula

$$H_T(A) = [C_T(A)A^2]^{1/2}$$

The TCDD was found from plotting a graph of square root detail area against threshold detection index (see figure 3). These TCDD curve were converted into a quality index, Q (Gallacher, BJR, 2003) which distils each graph into a single figure measure of overall image quality with respect to a standard TCDD curve. This project investigated the subjective perception of degradation in image quality (Q) with increasing image noise variance (from $v=0.01$ to $v=0.1$). TO10 images were imported into Matlab where multiplicative noise was added to the images. Multiplicative noise was used as it closely mirrors the noise added in image intensifier TV systems.

To first assess the degradation in image quality post-importation of the images into Matlab, the histogram of the greyscale values was checked

Figure 1. Leeds TO.10 test object.
and compared for both the original and exported image. The original images were in the standard DICOM format, and were viewed using a standard DICOM viewer (OSIRIS). The DIT version of Matlab is not DICOM compliant and so the images were converted into JPEG format.

To investigate whether this transportation affected image quality, a histogram of frequency against greyscale values was created for images pre and post importation. The histogram graphs of the original and exported images are shown in Figure 2. It is clear that the data shows some image quality degradation. To assess whether this degradation was visible, 4 TO10 images pre and post importation into Matlab were scored by 6 observers, and the quality index, Q, calculated for each image was compared pre and post importation using the Student t-test. This statistic indicated that the image visibility was comparable to above the 60% level, which is above the level of acceptability for comparison (Marshall, Phys. Med. Biol., 2001).

The TO10 images with noise added were then compared in the same way by using 6 observers to view 4 TO10 images each with increasing noise level. The quality index, Q, was then calculated for each assessment with increasing noise, and each Q-value was compared to that for the unmodified original image using the student t-test. This indicated that the images with noise variance of 0.01, 0.02, and 0.04 were only comparable to the level of 29%, 17%, and 9% respectively. This indicates that the TCDD measure can discriminate noise increases at a slight level (v=0.01) from an original unmodified image. This is an interesting and encouraging result, which indicates that TCDD is related well to SNR decreases in an image. Further work on a larger scale will need to be conducted to verify and increase the accuracy of this result.

Figure 2. Graph of the histogram of pixel values for the original and exported image.

Figure 3. Graph of the TCDD for the exported image and images of increasing noise.
Performance Assessment of a Digital Mammography System

Barbara O’Connell
Supervised by Dr Tom Cantwell &
Tom Heary (Beaumont Hospital)

Personal Details
I completed the Technician Diploma in Applied Sciences (Physics Option) in 2002 in DIT Kevin Street. I then transferred into the Degree in Applied Science, Physics & Physics Technology option. I studied nuclear physics, biophysics, acoustics and fluid dynamics as part of the course in my final year. Throughout my years in DIT I have kept a part-time job in a pharmacy. This involved working Saturdays and holidays. My hobbies include going to the cinema, music, travelling and socialising.

Project Summary
Radiologists use X-rays to produce medical images of the human body. Firstly X-rays are produced in an X-ray tube. The cathode provides a supply of electrons; these electrons strike the anode causing them to decelerate rapidly. The electrons interact with the target atoms in the anode and X-rays are produced.

When X-rays pass through a human body several interactions can occur; elastic scattering, the photoelectric effect and Compton scattering. Elastic scattering occurs when an electron takes up energies of vibration when they pass close to an atom. Only a certain amount of elastic scattering occurs at all X-ray energies and it never counts for more than 10% of the total interaction process in diagnostic radiology.

The photoelectric effect is the most important interaction, from a diagnostic point of view, between X-rays and bound electrons. In this process the incoming photon is completely absorbed and an electron is dislodged from its orbit around a nucleus. The photoelectric effect depends on the atomic mass Z of the tissue it passes through. In mammography soft tissue and cancerous tissue are very similar but their atomic number differs, therefore the photoelectric effect is the most important interaction in mammography.

The Compton Effect involves the interaction with unbound electrons. It is also known as inelastic scattering. It is the most important effect in radiology that involves unbound electrons. The photons interact with unbound electrons in a biliard ball type collision.

Mammography is a specific type of imaging that uses a low-dose X-ray system for examining the breast. Early detection of breast cancer leads to successful treatment. Mammography plays a very important part in early detection of breast cancer because it can show changes in the breast up to two years before a patient or doctor can feel them. There are two types of mammography systems, standard mammography and the new digital mammography system.

In standard mammography the breast is positioned on a special film cassette and then gently compressed with a paddle. This compression flattens the breast so that the maximum amount of tissue can be imaged and examined. X-rays are radiated through the compressed breast and onto a film cassette positioned under the breast. The X-rays hit a special phosphor coating inside the cassette. This phosphor glows in proportion.

Figure 1. (a) The process of standard mammography, (b) The process of digital mammography.
to the intensity of the X-ray beams hitting it, thus exposing the film with an image of the internal structures of the breast. Highly sensitive film and special X-rays are used for mammography to create the highest quality images at the lowest exposure. The resulting “exposed film” inside the cassette is then developed in a dark room much like a regular photograph is developed.

As the X-rays pass through the breast, they are attenuated (weakened) by the different tissue densities they encounter. Fat is very dense and absorbs or attenuates a great deal of the X-rays. The connective tissue around the breast ducts and fat is less dense and attenuates or absorbs far less X-ray energy.

Digital mammography is similar to standard mammography in that X-rays are used to produce detailed images of the breast, but the image is recorded by means of an electronic digital detector instead of the film (see figure 1). This electronic image can be displayed on a video monitor like a TV or printed onto film. This is similar to digital cameras that produce a digital picture that can be displayed on a computer screen or printed on paper. The radiologist can manipulate the digital mammogram electronically to magnify an area, change contrast, or alter the brightness.

The aim of this project was to carry out quality control tests on a new €500,000 digital mammography system in Beaumont hospital, the Senographe 2000D (see figure 2) in order to make sure that the system was working to a high standard. The tests carried out were on the performance of the X-ray tube accuracy and reproducibility. This was to ensure that the peak voltage at which the tube was operating was accurate and could be reproduced. The Half-Value Layer (HVL) of the system was also measured. The HVL measures the amount of aluminium required to reduce the original X-ray beam to half its original value. The Mean Glandular Dose (MGD) was also measured; this is the average amount of radiation received by the radiation sensitive tissue in the breast.

From this project it was concluded that the peak voltage accuracy and reproducibility were within the allowed parameters. The HVL results were within the acceptable limits. The calculated MGD values were also found to be acceptable.
Particle Size Determination using Mie Scattering

Gráinne O'Donnell
Supervised by Dr Fran Pedreschi

Personal Details
After having successively completed the Technician Diploma in Applied Science (Physics Option) in 2002, I decided to further my studies and pursue a Degree in Physics & Physics technology. My academic interests include Nuclear Physics, Biophysics and Medical Imaging Systems. My hobbies include reading, going to GAA matches, and socialising with friends.

Project Summary
The first aim of this project was to construct an apparatus capable of determining the size of microscopic particles using Mie scattering. Once construction was completed, the second aim of the project was to perform measurements on various dilute water suspensions containing the approximately spherical particles and to determine their size using laser light.

Scattering is the process whereby “small particles suspended in a medium of different indices of refraction diffuse portions of the incident light in all directions”. Mie scattering occurs when the particles are the same size or slightly larger than the wavelength of radiation in contact with them. Gustave Mie first obtained a solution for the scattering of plane waves from a sphere when the sphere's diameter is slightly larger than the wavelength of light. The Mie Theory provides exact solutions of scattered intensity from spherical particles to a given angle – the angular scattering distribution.

The construction of the apparatus started with the discovery of the ‘shell’ of a spectrometer. This provided a means of mounting a photo detector in the rotatable arm of the spectrometer and thus to measure scattered light at angles, while at the same time provided a means of mounting a laser in the other arm of the spectrometer. A glass slide was introduced to the set up so that the laser beam was split in two different directions. One of the beams was directed through a cuvette of sphere suspensions which was in turn directed to the rotatable photodetector, while the other beam was directed to a reference photodetector so that a comparison could be made between the signal from it and that of the scattered beam (see figure 1). Filters were affixed to each of the photodetectors, which were compatible with the wavelength of the laser, to provide adequate screening of the room lights.

The apparatus was tested on a material were the size of the particles that it contained were known in order to conclude whether the apparatus worked correctly or not. Fat in milk occurs as droplets where the size of the droplets in cow’s milk is 6µm. The scattering measurements for the milk droplets were taken as function of emission angle at vertical polarisation of the incident laser light. Once all the required parameters were obtained analysis of the experimental data was then

![Figure 1. Experimental set up. Note that the rotatable photodiode is directly facing the diode laser, which is housed in the arm of the spectrometer set-up. The cuvette is in position in the centre of the spectrometer table. In taking measurements the above shows only the initial position of the rotatable photodiode i.e. at the 0° position.](image)
preformed. This was achieved using Mie Scattering utilities in the form of the \textit{mietable}, \textit{Snell} and \textit{fitmie} programs. These are programs especially written for sizing droplets by Mie scattering measurements. The output of the \textit{fitmie} program is the dimensionless size parameter $x$ from which the size of the droplets is determined using the following equation:

\[
x = \frac{\pi d n}{\lambda}
\]

where $d$ is the diameter of the particles, $n$ is the refractive index of the medium surrounding the particles and $\lambda$ is the wavelength of the laser. The experimental data and the calculated data (obtained by executing the aforementioned programs) were then plotted (see figure 2). The \textit{fitmie} program outputted a dimensionless size parameter of 33.5 and a CHI 2 value of 0.001. Using the equation outlined above, the corresponding diameter of the scatterers was determined to be 5.37$\mu$m. On comparing this value to the expected value of 6$\mu$m only a 10\% deviation between both of the values has occurred. It was thus concluded that the apparatus was capable of determining the size of microscopic particles to a sufficient degree of accuracy. One should note that the difference between the experimental data and the calculated data in the graph is accounted for the number of scattering spheres. The experimental data is taken from a sample containing a range of sphere sizes. The \textit{fitmie} program allows for this but only the output of a monodisperse solution of the best fit size parameter is shown.

Results obtained from further analysis on other samples containing particles with diameters in the order of microns, further highlights the potential of the experimental configuration as a quick and easy method of sizing particles.
Photophysical Investigation into the Role of Vibrational Coupling in π-Conjugated Oligomers using Infrared Spectroscopy

David Owens
Supervised by Dr Hugh Byrne

Personal Details
During the course of my degree I studied Chemistry, Physics, Management Studies, and German. As I enjoyed both chemistry and physics in my third year, I opted for the Physics and Chemistry option for the final year. My main areas of academic interest include Materials Spectroscopy, Nuclear Physics, EM and Lasers and Solid State in Physics, and in Chemistry, Surface Chemistry, Industrial Chemistry, Organic, Inorganic and Photochemistry. I also enjoy traveling and have been to America, North Africa and throughout Europe. My other interests include football, swimming, karate, music and socialising

Project Summary
The aim of this project was to use light to observe how vibrational coupling effects Stokes’ shift (which measures the amount of nonradiative decay) of the acene and phenyl oligomer series. A series of π conjugated oligomers containing 2 to 5 monomers were studied. Two different families of oligomers the acene and phenyl series were used for the study. Both of these series can be seen in figure 1. The monomer (or simple repeating unit) in each series is a benzene ring. The two differ in how the benzene rings are bonded to one another. The acene series are fused rings whereas the phenyl series are bonded through a carbon to carbon single bond.

The spectroscopic techniques used in this study were UV/Vis, fluorescence and Infrared spectroscopy. Each of these techniques looked at different aspects of the molecules, such as exciting a molecule with energy (absorption) and measuring the emitted light (luminescence), thus information can be obtained about the molecule. The Stokes’ shift can also prove valuable in that it is a measure of the absorption maximum to the fluorescence minimum. The red shifting of the molecular orbitals in the absorption spectra can be seen in figure 2 for the phenyl oligomer series. That as the conjugation length of the molecules is increased the absorption maximum of the compounds is red shifted to a longer wavelength

![Figure 1. The acene and phenyl oligomer series.](image1)

![Figure 2. The absorption spectra of the phenyl oligomer series.](image2)
(lower energy) corresponding to a smaller molecular energy gap of the molecule. The same can be said for the fluorescence of the same series. This can be seen in figure 3.

This Stokes’ shift can be used as a measure of how much nonradiative decay occurs. The calculated Stokes’ shift for the phenyl oligomer series can be seen in figure 4. Otherwise if there was no nonradiative decay then the fluorescence spectra will be the same as the absorption spectra, (known as Resonance Fluorescence) and if this happened then the Stokes’ shift would be zero. The transition from the Franck Condon state to the ground vibrational state, within the excited electronic state, involves loss of energy to the surroundings or to other internal degrees of freedom such as other normal vibrational modes in the case of polyatomic molecules. The number of modes of vibration in a linear molecule is governed by $3N - 5$, where $N$ is the number of molecules in the molecule. This nonradiative relaxation step takes place readily in large molecules.

This nonradiative decay can be measured with the use of Infrared spectroscopy. This again used light to measure the strength of bonds, and gives information on the number of modes of vibrations in a molecule. As the conjugation length of the molecules increases so does the number of modes of vibrations. Because of this the longer the chain length the greater the number of modes which energy can be dissipated over (nonradiative decay). This can prove important if the molecules are being used as LEDs or other such lasing materials as unwanted energy losses may be obtained if this nonradiative decay is not looked at.
To Assess the Feasibility of a Simple Analogue Continuous Phase Modulation Circuit for Use as an Undergraduate Lab

Andrew Quirke
Supervised by Art O’Hare

Personal Details
I wanted to work with innovative technology. As today’s Physics is tomorrow’s engineering, I chose to study Physics & Physics Technology. I felt this would give me a multi-disciplinary broad foundation in Physics and Engineering. This is where my interest lies – applying physics to the real world. I began in the degree program in 2000.

My academic interests include: Laser Physics, Computational Physics, Signal Processing, Information Theory and Quantum Technologies. I also have a number of interests outside of college.

Project Summary
One of the things that fascinated me when I was younger was radio. It seemed like a magic trick. Instead of a magician pulling a rabbit from a hat, the radio was pulling sound and music from still air. My project, in a round-about way, involved this process; modulation.

We have all seen the graphical representation of waveforms that are produced by oscilloscopes. My work involved being able to manipulate these signals, electronically and simply, in order to transmit information (like music or pictures). Such control of a waveform to encode it with information is termed modulation.

Modulation is a conceptually simple process. Some instantaneous property of a high frequency carrier wave is dynamically changed in direct proportion to the instantaneous magnitude of an information bearing waveform. There are various types of modulation, some of which are familiar (at least by name). Such modulation schemes as FM (Frequency Modulation) and AM (Amplitude Modulation) are commonly used for radio communications. The modulation scheme is named after the property varied in order to send information.

A less known form of modulation is Phase Modulation (PM)- see figure 1. Its less known because it is less frequently used. It is also harder to explain because we never directly experience or sense the phase of a wave. We can’t see it or hear it because our eyes and ears detect intensity, not phase. If they didn’t, every time you heard a reflected sound wave or saw a reflected

![Figure 1. Visualisation of FM and PM obtained using MATLAB: (a) carrier wave (b) Phase modulated wave (c) Information bearing wave and (d) frequency modulated wave. Note that PM and FM are very similar. PM is FM shifted (delayed) by 90°. As a result, PM can be considered a special case of FM - both are examples of Angle Modulation.](image-url)
light wave, it would appear different due to its reflection. All these facts conspire to make phase modulation more difficult to explain, understand and implement.

The aim of the project was to create a method that would demonstrate continuous PM using simple analogue electronics. The carrier is usually in the radio frequency range but in order to make the modulation circuit compatible with existing lab equipment the carrier had to be in the audio range. This made the project more difficult as no previous work was available regarding continuous phase modulation in the audio region. Usually discrete modulation is used (by computer modems) at audio frequencies. After a lot of perseverance, a simple method that worked was found.

This project was extremely interesting, and rewarding, due to the combination of theory and practical hands on lab work.
A Spectroscopic Study of the Curing Process of Contact Lenses

Florian Roick
Supervised by Dr Robert Howard

Personal Details
After studying Microsystems Engineering for three years in Germany I decided to join the fourth and last year of the Physics & Physics Technology Degree Course at the DIT Kevin Street in Dublin. While I studied in Germany I was a part time employee in a semiconductor company that produces sensors and micromechanical actors on silicon.

My academic interests include optical communications, laser physics, sensors, quantum technologies and information processing.

Project Summary
The curing process of contact lenses is achieved by photoinitiated radical chain polymerisation. Photopolymerisation is the process of converting a liquid monomer to a solid polymer by using ultraviolet radiation. This photochemical process starts by the absorption of ultraviolet light by a photosensitive chemical compound (photoinitiator). The photoinitiator then starts the polymerisation process by producing free radicals. Free radicals are highly reactive species, like electrons, anions or cations, which break up carbon-carbon double bonds (C=C bonds) in molecules in the monomer that undergoes polymerisation. By this process of destroying carbon-carbon double bonds, the molecule itself becomes highly reactive and links itself to another highly reactive molecule. By this forming of very long macromolecules the liquid monomer changes to a solid polymer that can have totally different properties from the liquid monomer. The speed of the polymerisation process is highly dependent on the number of free radicals that the photoinitiator provides by dissociation under ultraviolet radiation.

The first aim of this project was to measure the absorptivity of near ultraviolet radiation at 375nm of two different photoinitiators. Ultraviolet-visible molecular absorption spectroscopy (UV-VIS) was employed to assess their ability to dissociate while exposing them to ultraviolet radiation of 375nm. The absorption spectroscopy technique used in this project basically is the measurement of the absorbance of a solution containing the analyte and some sort of solvent which is then compared to a absorption measurement of the solvent alone. By comparison, the absorbance of the analyte is obtained. The result of the measurement is shown in Table 1 for various concentrations of the photoinitiator in acetonitrile.

<table>
<thead>
<tr>
<th>Photoinitiator</th>
<th>Absorption at 375nm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.01%</td>
</tr>
<tr>
<td>Irgacure 651</td>
<td>0.006</td>
</tr>
<tr>
<td>Irgacure 1800</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Table 1: Absorption measurement of the photoinitiators for concentrations of 0.001%, 0.01% and 0.1% (from left to right) in acetonitrile

The theory is that the higher the absorption of these photoinitiators for UV radiation at 375nm, the faster that polymerisation occurs and the higher the degree of conversion of the liquid monomer to a solid polymer. This leads to the second aim of the project, which was to actually polymerise each of the two photoinitiators dissolved in the monomer 2-Hydroxyethyl methacrylate (HEMA) and to record the polymerisation process using Raman spectroscopy.

Raman spectroscopy is the measurement of quantised vibrational changes in molecules, which can be polarised by an external electric field. One measurement of the curing process using Raman spectroscopy can be seen in figure 1, where the photoinitiator Irgacure 651 was under investigation. Here the left peak is related to the C=C bond and the peak height can be referred to the number of these C=C bonds in the sample. The
decrease of the peak height over time shows that C=C bonds have been broken up and hence can no longer be detected. The peak on the right was used a reference and is related to the carbon-oxygen double bond in HEMA.

From the two Raman spectra, rates of polymerisation were deduced - basically a plot indicating how many monomers were converted into polymers. This rate of polymerisation was the third and last aim of the project and should show the dependence of the polymerisation process on the absorptivity of the photoinitiators for UV radiation, especially for 375nm.

The curing rates for the photoinitiators Irgacure 651 and Irgacure 1800 are shown in figure 2.

In conclusion, using UV-VIS absorption spectra it was determined that each photoinitiator had a different effect on polymerisation due to its own specific absorption of UV radiation of 375nm. This was then validated by the rate of polymerisation experiment. The rates showed a relatively large difference in the speed and conversion level of polymerisation for the two photoinitiators - Irgacure 651 with a qualitative absorption value of 0.374% and Irgacure 1800 with a qualitative absorption value of 0.233%, both with a concentration of 0.1% in acetonitrile.

![Figure 1. Raman spectra of the polymerisation process of 0.2% of Irgacure 651 dissolved in HEMA over 28 minutes (4 minutes time resolution between each spectra).](image)

![Figure 2. Verification that the higher the absorption of the photoinitiator, the faster curing proceeds and that a higher degree of polymerisation is achieved.](image)
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