DEPARTMENT OF PHYSICS & ASTRONOMY
College of Science

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

26TH DEPARTMENTAL CONFERENCE

Tuesday 25th August and Wednesday 26th August 2009

Science Lecture Block – S3

PROGRAMME

Tuesday 25th August

10.30 – 10:55	***MORNING REFRESHMENTS - S3***	
Session 1	**Chairperson:**	***Juergen Meyer***
	Welcome	*Jack Baggaley*
11:00 – 11:15	Giles Reid	Self-interactions of supernova neutrinos
11:15 – 11:30	Richard Graham	Scale factor corrections in ring laser gyroscopes
11:30 – 11:45	Pawel Kowalczyk	Scanning Tunneling Microscopy investigations of bismuth nanostructures
11:45 – 12:00	David McCarthy	Growth mechanisms of bismuth nanostructures
12:00 – 12:15	Cheng-Yang Lee	Different approaches to neutrino oscillations
12:15 – 12:30	Jidi Sun	2-Step Intensity Modulated Arc Therapy in the *PRISM* Treatment Planning System
12:30 – 1:30	***LUNCH***	
Session 2	**Chairperson**	***Robert Doesburg***
1:30 – 1:45	Peter Smale	Testing the inhomogeneous “timescape” cosmological model with standard candles
1:45 – 2:00	Dimitri Schritt	Uncovering the mysteries of Maxwell's equations
2:00 – 2:15	Nishanthan Rabeendran	Backscatter in Ring Lasers
2:15 – 2:30	Pubudu Senanyake	Thin film infra red emitters
2:30 – 2:45	Rachel Soja	The 7:2 resonance in the Taurid meteoroid stream
2.45 – 3.00	Jeffrey Simpson	Using a Fabry-Perot interferometer to determine chemical abundances in stars
3:00 – 3:30	***AFTERNOON REFRESHMENTS - S3***	
Session 3	**Chairperson:**	***Greg Betzel***
3.30 – 3.45	Masaed Almotari	Sintering of ZnO ceramic targets
3.45 – 4.00	Ewan Orr	Supervised learning with Turing Networks
4:00 – 4.15	Bryn Currie	Modelling losses in a ring laser gyroscope
4.15 – 4.30	David Mackenzie	Germanium atomic clusters: production and electrical properties

END OF DAY ONE

Wednesday 26th August

Session 1	**Chairperson:**	***Stuart Lansley***
9:30 – 9:45	Karen Pollard	The music of the stars
9:45 – 10:00	Andolsa Arevalo Torres	PSCs: the atmospheric labs for ozone depletion
10:00 – 10:15	Abdul Sattar	I-V characteristics of Sn cluster films
10:15 – 10:30	Young-Wook Song	Optical properties of p-type InN

10.30 – 11:00 MORNING REFRESHMENTS - S3

Session 2	**Chairperson:**	***Giles Reid***
11:00 – 11:15	Phil Butler	MARS-CT: using the energy information in x-rays for biomedical imaging
11:15 – 11:30	Rafidah Zainon	MARS-CT: atheroma plaques imaging with the MEDIPIX CT-scanner
11:30 – 11:45	Robert Doesburg	The Medipix2 camera: hardware and software
11:45 – 12:00	Anas Sedayo	Using MARS2-spectroscopic-CT scanner to distinguish fat from liver
12:00 – 12:15	Syen Nik	Optimal energy thresholds for biological material discrimination using Medipix detector.
12:15 –12:30	Greg Betzel	Operating parameters of a novel CVD diamond detector for x-ray dosimetry

12:30 – 1:30 LUNCH

Session 3	**Chairperson:**	***David Mackenzie***
1:30 – 1:45	Florian Maisonneuve	Spectroscopic mode identification of main sequence non-radially pulsating stars
1:45 – 2:00	Domagoj Belić	Size-controlled sputter-deposited bimetallic nanoclusters
2:00 – 2:15	David Wiltshire	Average observational quantities in the timescape cosmology
2:15 – 2:30	Stuart Lansley	Whereto next for diamond x-ray detectors?
2.30 – 2:45	Stephanie Hickford	Cascade analysis in IceCube
2:45 – 3:00	Nikolai Kruetzmann	Application of complexity measures to geophysical systems
3:00 – 3:15	Juergen Meyer	Research tools – PHYS407 Followed by conference wrap-up

CONFERENCE CLOSES

4:30 onwards	Retire to Staff Club for end-of-conference function and presentation of prizes. BBQ from about 5:15.

Tuesday 25th August

Giles Reid

Self-Interactions of Supernova Neutrinos

At the time of supernova 1987A the detection of a handful of neutrinos from the explosion was a major achievement. In the intervening 22 years detector technology and the theoretical understanding of supernovae and neutrinos have advanced tremendously. A similarly close supernova explosion occurring today would provide another great leap forward in understanding these violent events.

The defining property of neutrinos is their extremely weak interaction with everything in the Universe, which allowed the neutrinos from SN 1987A to travel unimpeded all the way to Earth. Although neutrino interactions with matter are extremely weak, they explain the Solar neutrino problem via the MSW effect. In recent years it has also been realized that the neutrino density near a supernova is so high that neutrino-neutrino scattering can become important, particularly when coupled with the matter interactions. I will explain the strange dynamics that arise in the extreme conditions of a supernova (and possibly nowhere else in the universe) and present some recent work on testing the robustness of the effects that occur due to these dynamics, with the ultimate aim of advancing our understanding of both supernova explosions and neutrino interactions through the observations of these most elusive particles.

Richard Graham

Scale Factor Corrections in Ring Laser Gyroscopes

The ring laser project at UoC has a 20 year history of building progressively more stable and accurate ring laser gyroscopes. In sensing rotations they are unmatched by any other technology. To date achieving this has meant increasing the size of the lasers, in one case up to 120 m perimeter. Recently we have come to an impasse with this approach, imposed by mirror technology and geometric instability.

This talk will discuss the most recent upgrades to the UG ring laser. These upgrades allow some interesting measurement techniques to be applied which allow measurement of deformations of the geometry of the ring. These deformations can be represented by a basis set of four fundamental deformations, each of which we are now sensitive to. The largest effect on the cavity geometry comes from strain due to tides of the solid earth. These can be calculated theoretically and show good agreement with measured strains.

Pawel Kowalczyk

Scanning Tunneling Microscopy investigations of bismuth nanostructures

Scanning Tunneling Microscope (STM) was invented in 1981 by Gerd Binnig and Heinrich Rohrer who at that time worked for IBM research laboratories in Zürich. Their leading idea was to measure locally tunneling spectra which was a step further than the commonly used sandwich technique which allowed to perform such measurements only globally. However, the microscope which they developed beside recording tunneling spectra was also able to record the “atomic” structure of metallic or semi-conducting surfaces. For developing the STM Binnig and Rohrer were granted the Nobel Prize in 1986 (this was the case of the shortest period of time between the discovery and the Prize in the history). The STM found its application in investigations of objects which belong to nano – world. It is capable of showing objects from single atoms up to structures of micrometer lengths. It is even able to manipulate some of these objects. One of the best systems of investigating by the means of STM are metallic islands deposited on the conducting substrate. Here, at the Department of Physics and Astronomy of The University of Canterbury we are mostly interested in bismuth islands deposited on Highly Oriented Pyrolitic Graphite (HOPG). Depending on evaporation conditions we are capable of growing structures which could be classified as one-, two- and three-dimensional. It gives us the possibility of studying behavior of electrons in systems of reduced dimensionality.

In my talk I will disscuss a few questions regarding STM and its operation principles such as how it works, what it sees/shows, etc. I will also present a few results recorded with STM (working in ultra high vacuum) on bismuth on HOPG. Our samples are characterized by different morphology (dimensionality) ranging from elongated rods (1-D) through large butterfly-like islands (2D) to the whole surface covered with pyramidal structures (3-D).

David McCarthy

Growth mechanisms of bismuth nanostructures

In this talk I will present examples of 1D and 2D bismuth nanostructures grown on graphite substrates, under different experimental conditions, and will discuss some of the mechanisms behind their growth. I will also discuss some of the motivations for our studies of bismuth nanostructures, for instance the predicted finite size effects, the increased importance of surface properties, and potential thermoelectric applications.

Cheng-Yang Lee

Different approaches to Neutrino oscillations

Neutrino oscillation is now a well-known phenomenon in particle physics and has been extensively studied in various theories and experiments. In this short presentation, we present some theoretical approaches to neutrino oscillations. These approaches are

- Standard quantum mechanical approach
- Wave-packet approach
- Quantum field theory approach to particle mixing

The standard approach to neutrino oscillation involves the too simplistic assumptions of equal-energy or equal-momentum for all mass eigenstates. These problems can be resolved by appealing to the wave-packet formalism. While these two approaches are self-consistent, and agree with experiments, the most natural way to study neutrino oscillation is in the framework of quantum field theory given that neutrinos are the lightest ultra-relativistic particles with non-zero mass.

Here we present some results obtained by assigning to each mass eigenstate a Gaussian wave-packets and give an overview on how neutrino oscillations are treated in quantum field theory. After understanding first two approaches, we plan to study neutrino oscillation in the presence of strong gravitational field via quantum field theory in curved space-time.

Jidi Sun

2-Step Intensity Modulated Arc Therapy in the *PRISM* Treatment Planning System

Introduction: Intensity Modulated Arc Therapy (IMAT) is a radiotherapy technique which can deliver radiation to the tumour continuously during the treatment gantry rotation. To maximise the benefit of such kind of rotational treatment, Bratengeier proposed the so called 2-Step IMAT in which at each angle an additional narrow beam is delivered near the critical organ to increase the dose coverage in the treatment target. In this project such treatment technique is being implemented into a treatment planning system and then investigated and compared with other approaches.

Method and Material: The software being used is called the *Prism* Treatment Planning System (University of Washington), which is written in Common Lisp programming language. The beam segment is generated based on the projected geometry in the beams-eye-view and maximally spares the critical organ by masking it. The results from plans on the geometric phantom were investigated dosimetrically with results from other plans.

Results: The 2-step IMAT technique was successfully implemented into the *Prism* Treatment Planning System. The beam segments were generated automatically to reduce the planning time. A significant dosimetry improvement was seen for 2-Step IMAT over single rotation technique.

Conclusion: Our approach is the first automated implementation of the 2-Step IMAT. The technique is comparable to standard arc therapy but is able to deliver more conformal dose distributions to the tumour while at the same time spare the critical organ. In future we want to apply automatic optimisation methods for this technique and then compare the results for clinical cases with other techniques.

Peter Smale

Testing the inhomogeneous "timescape" cosmological model with standard candles

In the two-scale "timescape" cosmological model of Wiltshire (2007), the universe consists of underdense expanding voids and gravitationally bound wall regions in which space is flat. Careful consideration is given to the domains over which particular values of the cosmological parameters such as the Hubble constant and the matter density are averaged. In this averaging scheme, the expansion rate, averaged on scales below that of homogeneity, will have a variance that contributes a "backreaction" term to the Friedmann equations governing the expansion of the universe. There is currently vigorous debate over whether this "backreaction" can account for the cosmic acceleration we infer from Type Ia supernovae observations.

The luminosity distance—the separation between us and a given event on the past light cone—determines the relationship between redshift and distance (represented on a Hubble Diagram) and can be tested against the distances of standard candles. In the timescape model, the luminosity distance parameters are the "dressed" Hubble constant and the present void fraction. Type Ia supernovae—secondary standard candles—in particular are of considerable interest because they are bright enough to be observed at high redshifts ($z \sim 1.5$), where the redshift-distance relationship becomes nonlinear—more distant supernovae occurred when cosmic expansion was faster, while "nearby" ones occurred when the expansion was slower. Recent work on gamma ray bursts (GRBs) suggests that they too might be used as standard candles, potentially extending the domain of the Hubble diagram to redshifts as high as 8.

In this talk I will discuss the application of the timescape luminosity distance in constructing Hubble diagrams based on observations of type Ia supernovae and GRBs.

Dimitri Schritt

Uncovering the mysteries of Maxwell's equations

Maxwell's equations have served very well over the past century and a half in describing electromagnetic phenomena. However well known, well established and well studied they may be, they still hold surprises for the theoretical physicist. Originally deduced from empirical observation, one may seek to gain a deeper understanding by providing a systematic derivation from some underlying fundamental principle. The present talk shall be devoted to this quest. It will be shown that studying the equation for a massless particle of spin one, instead of finding Maxwell's equations, one instead obtains a generalisation which may hold profound cosmological implications.

Nishanthan Rabeendran

Backscatter in ring lasers

In 1865 Christian Huygens noticed that two pendulum clocks mounted on the wall eventually synchronised themselves due to wall deflections. This phenomenon occurs in ring lasers through the coupling of the oscillators due to back-scattered light. This has a detrimental effect on the function of the ring laser as a gyroscope, by causing a slight error in the indicated rotation rate. This talk will outline current investigation on how to combat this problem. The back-scattered light can be considered to give differential-mode and common-mode amplitude injections into the two opposing beams, causing Sagnac frequency errors in opposite directions. This analysis will lead us to make corrections on the rotational rate caused by the back scattered light.

Pubudu Senanyake

Thin film infra red emitters

The goal of my research project is to grow and characterize rare earth doped thin films through the use of a Pulsed Laser Deposition (PLD) technique. Through the use of a co-doped system of trivalent Ytterbium and Erbium (Yb^{3+} and Er^{3+}) it is possible to achieve efficient emission of photons at a wavelength of 1.535μm, allowing the construction of a media that is thinner than the emitting wavelength itself. In this talk I will be giving a brief overview of the material properties of the hosts that have been chosen as well as the reasoning behind the use of a co-doped system. I will also present a summary of the PLD undertaken so far and the characterization techniques we will use in analyzing these films.

Rachel Soja

The 7:2 resonance in the Taurid meteoroid stream

The Taurid complex consists of a number of bodies, from sub-micron meteoroid particles to near-Earth asteroids. The presence of a resonant swarm within the Taurid stream, and associated with the 7:2 resonance of these orbits with Jupiter, has been theorised, and is supported by photographic and fireball meteor data studies. Here a numerical method is used to study the width of the 7:2 resonance at Taurid orbital elements, and is found to agree sufficiently with an analytic method. This resonance width is useful for determining whether such a swarm can be detected at lower mass scales, such as are found in radar datasets. Other factors that affect the resonance structure include variations in the mass distribution of particles injected into the resonance and radiation pressure effects on small particles.

Jeffrey Simpson

Using a Fabry-Perot interferometer to determine chemical abundances in stars

In this talk I will describe what I have did Masters and the direction that my Phd will take. As a continuation of my Masters research, my PhD will use the Fabry-Perot mode of the Robert Stobie Spectrograph of the Southern African Large telescope to image the globular cluster 47 Tucanae. Using these images, I will attempt to extract velocity and abundance information for several hundred stars. If the technique proves successful, then it will be applied to other spectral lines and other clusters.

Masaed Almotari

Sintering of ZnO ceramic targets

Zinc Oxide (ZnO) material is an intrinsically n-type semiconductor which has attracted great interest owing to its unique properties and potential applications in optoelectronics, gas sensors, LEDs and UV-lasing. These devices generally require the fabrication of thin films which can be done by several vapour phase growth techniques such as MBE, PLD and CVD. In our laboratory we use PLD as a growth technique as that has the greatest flexibility for variation of film composition. However, PLD requires a dense so that micron-sized particulates are not ejected by the laser pulse. Targets are manufactured by pressing a quantity of powder followed by heat-treatment called sintering. I will present an insight into our sintering process and how a proper procedure during sintering can help to get high density targets.

Ewan Orr

Supervised learning with Turing Networks

Scientific experiments are often complex resulting in vast data sets. Automating the process of rule discovery is important for science. This presents a great challenge yet an insurmountable task for one's PhD project. I am fortunate to have a project that introduces me to current techniques of scientific automation, requires new investigations, and offers achievable tasks. My project involves the creation and testing of computer programs that represent simple discrete neural networks and evolutionary computation of these networks. Because these networks are simple we can implement novel techniques, for example, employing symmetries of a given problem to improve the search for a network that is a solution to that problem. In this talk I introduce the discrete networks that we use. Also, I explain how these networks are trained using supervised learning.

Bryn Currie

Modelling losses in a ring laser gyroscope

INTRODUCTION: Standard laser theory gives a scalar wave theory approach to modelling the electromagnetic modes that can oscillate inside an optical cavity [1]. These modes are typically given as an arbitrary transverse order (TEM_{nm}) with longitudinal variation taken as negligible. Continued existence of the TEM_{nm} modes depend on elements inside the cavity such as apertures. It is shown how these modes are modified by introduction of imperfections on a mirror surface that force a departure from the condition of specular reflection at the mirror interface. From the modification of the modes we can build a loss accounting model of an optical cavity.

METHODS & MATERIALS: A roundtrip “mixing coefficient” matrix formalism is developed using the standard Hermite-Gaussian paraxial wave approximation solutions in an optical cavity. This is motivated by modelling the surface of the optical cavity supermirrors as a fractal. This is coupled with a Gouy phase shift incorporating transmission matrix for the lengths of propagation between mirror elements. Rather than being of an ABCD or A2F matrix type formalism [2] we present a novel meta-number based matrix formalism. MATLAB® is used to generate 1024×1024 element matrices to represent both mirrors and TEM_{nm} modes.

RESULTS: Modelled fractal supermirrors are compared against measurements of variance as observed in the ring lasers in the Cashmere Cavern. These fractal supermirrors are then incorporated into the reflection matrix in a roundtrip “mixing coefficient” matrix. For a two mirror resonator with apertures introduced into the optical cavity we find losses of the order of that expected. Eigenvalues and eigenvectors are obtained and used to determine the frequency shifts and losses in a cavity.

CONCLUSION: Two mirror resonators have been modelled by the fractal mirror approach to define elements of the roundtrip “mixing coefficient” matrix. Further work is required to apply this approach to generating a polygonal cavity roundtrip “mixing coefficient” matrix that incorporates astigmatism and hence is generally applicable to the ring laser gyroscopes in the Cashmere Cavern.

REFERENCES:
[1] A. E. Siegman, *Lasers*, University Science Books, 1986
[2] B. E. Currie *et al*., *Laser stability and beam steering in a nonregular polygonal cavity*, Applied Optics, 41(9), pp 1689-1697, 2002

David Mackenzie

Germanium atomic clusters: production and electrical properties.

One of the main goals of modern applied physics research is to analyse the novel properties of materials whose physical dimensions fall between those of bulk material and atoms. Atomic clusters are ideal for applied nanotechnology because of their nano-dimensions, ease of size selection and size-dependant properties [1].

Germanium was chosen for its semiconducting properties and hence potential to create transistor devices. Germanium clusters were produced using an inert-gas-aggregation source [2]. The cluster diameters were able to be controlled by varying the source temperature and/or the inert-gas flow-rate: the range of cluster diameters was 20-70nm. During deposition, the conductance between electrical contacts was monitored and deposition was stopped when a non-zero level of conductance was measured.

The cluster films were electrically characterized whilst in vacuum. The temperature dependant conductance was measured from liquid helium to room temperatures and exhibited typical behaviour for a semiconductor with a transition from intrinsic to extrinsic conduction occurring at ~220K.

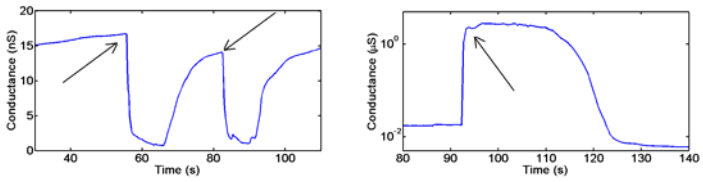

Fig. 1. Germanium cluster-film response to (left) ultra-high-purity helium and (right) wet air. Arrows correspond to one second of exposure to gas.

As the sample was vented to atmosphere, the electrical conductance of the film increased by two orders of magnitude. The increase in conductance was due to surface-states being induced by oxygen. The films then showed gas sensitive behaviour: exposure to a dry gas (helium) decreased surface-states and hence conduction while exposure to wet air produced an increase in surface-states and conduction. The responses for dry and wet gas are shown in Figure 1.

References
[1] H. Haberland, Clusters of atoms and molecules: theory, experiment, and clusters of atoms; Spring-Verlag (1994).
[2] R.Reichel, J.G. Partridge, A.D.F Dunbar, S.A. Brown, O. Caughley and A. Ayesh, Journal of Nanoparticle research, 8 (2006), p405.

Wednesday 26th August

Karen Pollard

The music of the stars

Many stars, including our own Sun, 'ring' like bells and show patterns on their surfaces like those on a drum that has been struck by a drumstick. The pattern of surface vibrations is governed by the internal properties of the star and results in each star having a unique musical 'voice'. The analysis of these tiny surface vibrations, used to deduce the internal structure of the star, is known as asteroseismology.

In this talk I will describe our Marsden-funded research project which is using the 1.0m telescope at the Mt John University Observatory to obtain precise measures of stellar surface motions in several groups on non-radially pulsating stars. These observations allow us to deduce the modes of vibration and hence deduce information about interior properties of these stars.

Andolsa Arevalo

PSCs: the atmospheric labs for ozone depletion

When several decades ago, inhabitants of the Arctic Circle observed for the first time a group of unusual iridescent clouds very different to the typical ones (tropospheric clouds made of water vapour), they could not have imagined the role that these clouds would have in stratospheric ozone depletion. These clouds, formally known as Polar Stratospheric Clouds (PSCs) play a number of vital roles in stratospheric ozone depletion processes.

A number of ingredients are necessary for PSC formation, in particular cold temperatures and suitable concentrations of nitric acid and water vapour, and the subsequent chlorine activation which occurs when PSC surfaces are exposed to sunlight. The activation of the chlorine reservoirs which are found in the atmosphere and dominated by the emission of man-made pollutants (better known as chlorofluorocarbons) switches on when the surfaces are exposed to sunlight and this process is necessary for the chemical reactions that catalytically destroy ozone in the spring. Without the presence of these ingredients, PSCs do not occur and without PSCs chorine activation cannot take place. This presentation will detail work on determining the spatial and time distribution of PSCs in the Antarctic Polar Vortex region from satellite data. Preliminary work on identifying chlorine activation is also detailed.

Abdul Sattar

I-V characteristics of Sn cluster films

I-V characteristics of Sn nano cluster films deposited on SiN substrate with prefabricated Au/NiCr electrodes were investigated. It was found that the I-V curve does not follow a linear trend. The conductance of the films jumps in a discrete step wise fashion (Fig. 1). A ramping voltage between -10V to 10V was applied to see the voltage dependence of this stepping behavior. Moreover the conductivity was also measured by changing applied voltage in a staircase like waveform. Results clearly show that the jumps, between different conductivity levels, were much frequent at higher voltages compare to lower voltages. On many occasions value of conductivity was found to be integral multiple of quantum conductance $(G_0=2e^2/h)$ where e is the elementary charge and h is plank's constant. This stepping behavior is a manifestation of conductivity variation of individual necks between adjacent Sn particles. Some of these necks may be critical current pathways in complex resistor network formed by these Clusters. Though decrease in conductivity in quantized steps can be explain with break junction theory but it is not possible to describe the increase in conductivity. However both increase and decrease in conductivity can be attributed to coulomb blockade. The stepping behavior inhibits at low temperatures.

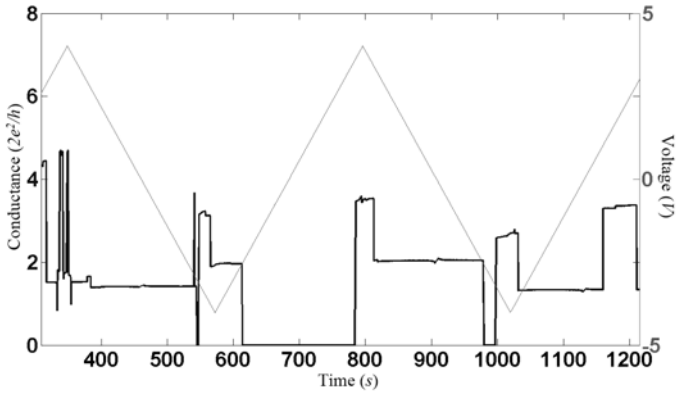

Figure 1: Step wise conductivity variation in Sn cluster films. Conductivity in G_0 units (bold line). Applied voltage (gray line).

Young-Wook Song

Optical properties of p-type InN

Indium nitride attracted considerable attention in 2002 with reports indicating its bandgap energy is near 0.6 eV, in sharp contrast to the previously accepted value of 1.89 eV. This allows the bandgap of group-III nitride semiconductors to span from ultraviolet to near infrared by proper alloying. Therefore, research interest has been increased to fabricate p-type InN which is essential for the realization of the near infra-red optoelectronic devices. The indirect evidence of p-type conductivity InN through in-situ Mg doping has been reported by number of different groups. However, a high density surface electron accumulation layer interferes with attempts to measure the p-type conductivity. Furthermore, comprehensive studies of the optical transitions have not been possible due to unexpected quenching of the photoluminescence (PL) in p-type doped InN.

We have investigated the optical properties of Mg doped InN epilayers grown by plasma-assisted molecular beam epitaxy. The Mg concentration was determined by secondary ion mass spectrometry (SIMS) using an ion-implanted standard. In order to clarify potential acceptor transitions, we performed PL measurements on a series of InN films with Mg concentrations varying over several orders of magnitude. Strong variation in PL intensity was observed, with the more heavily doped films showing very little emission. Time-resolved differential transmission (TRDT) measurements show that the origin of luminescence quenching in InN:Mg may be ascribed to the onset of Auger recombination. Recently, the effect of the wavelength of excitation source on the PL properties of InN:Mg films were also explored. Most films show blueshifted transitions with the longer excitation wavelength largely due to Burstein-Moss effect. Noticeable change in PL intensity was observed and some heavily doped films were no longer quenched. This phenomenon may indicate the PL quenching mechanism only affected to certain transitions.

Phil Butler

MARS-CT: using the energy information in x-rays for biomedical imaging

I will review the MARS-CT project, its whys and wherefores. UC first took an interest in the Medipix detector in 2003. We now have about a NZ team of about 25 staff, students and visitors (from Canterbury, Otago and Auckland universities, and from Christchurch Hospital) working with the CERN Medipix 2 and 3 Collaborations developing the detector and its applications.

Four P&A thesis students will give talks on particular aspects. My goal is to present a broad overview and explain why there is so much interest in our project.

Rafidah Zainon

Atheroma plaques imaging with the Medipix CT-scanner "MARS-CT"

INTRODUCTION: A spectroscopic CT scanner that can take multiple-energy CT image of small animal and pathology specimens was built and it is at the currently being operated and tested at the Bioengineering Lab; Department of Radiology, Christchurch Hospital. It incorporates Medipix, a photon counting energy selective x-ray detector which provides both spatial and energy resolution and so has been dubbed Medipix All Resolution System CT (MARS-CT). Spectroscopic x-ray detectors, such as Medipix, are opening the door to the widespread use of energy selective biomedical x-ray imaging [1]. It has good energy resolution in the diagnostic x-ray range and high spatial resolution, 0.055 mm. With dual energy computed tomography quickly becoming the clinical standard, spectroscopic imaging is a likely next step.

METHODS: The scanner takes 3D images at 43 micron resolution with a user definable number of energy bins. A femoral atheroma plaque and carotid artery with bifurcation which were set in resin were scanned using Medipix, a hybrid semiconductor pixel detector consisting of a CMOS sensor chip bonded to GaAs. For the scan, 303 projections were taken, each containing six vertical detector positions. For every detector location, eight low energy thresholds were obtained; 14.45, 18.00, 21.50, 25.00, 28.60, 32.00, 35.60 and 39.20 keV. Images obtained from multi-energy MARS CT were processed and back projected into a 3 dimensional volume data set. Projection data was transformed using cone beam reconstruction with linear interpolation and a regular Fourier filter. Reconstructions used a source detector distance (SDD) of 125 mm, a source object distance (SOD) of 100 mm and a centre of rotation of 608 pixels. Spectral analyses of calcified and non-calcified plaque were performed using the energy bins.

RESULTS: The high resolution MARS CT shows the morphology of the calcium, and the plaque's internal structures. Spectral analysis of calcified and non-calcified plaque shows that the attenuation values of both plaques are increasing at energy bins 14.45-18.00 keV to 25.00-28.60 keV. This is because the Medipix-2 detector suffers from charge sharing between pixels. However, the plaque with calcium is clearly distinguishable from the non-calcified plaque both the magnitude of the attenuation values and also spectroscopically. The application of multi-energy scans shows promising results for further work.

DISCUSSION & CONCLUSIONS: The foundations of the multi energy MARS CT are that the new imaging modality can generate high-quality data sets with high energy and high spatial resolution. Our study shows promising early results with the use of multi energy MARS CT and in turn meaningful diagnosis of the internal structure of plaque.

REFERENCE:

[1]A.P.H. Butler, N.G. Anderson, R. Tipples, N. Cook, R. Watts, J. Meyer, A.J. Bell, T.R. Melzer, P.H. Butler, "Bio-medical x-ray imaging with spectroscopic pixel detectors", *Nuclear Instruments and Methods in Physics Research*, **A**(**591**), pp. 141-146, 2008.

Robert Doesburg

The Medipix2 camera: hardware and software

The MARS-CT project has produced an x-ray CT scanner with up to 30 μm spatial resolution in 3 dimensions and spectral sensitivity of a few % in the range of 8-80 keV. The Medipix2 x-ray detector, designed by a CERN Collaboration, is a hybrid photon-counting assembly built using the "flip-chip" method. It has a semiconductor sensor layer with 64k 55x55 μm2 pixels in a square array. The sensor layer is bump-bonded to an ASIC with analog pulse height signal processing and counting circuits, one per pixel. Several semiconductor sensor layers are being assessed in the MARS-CT project specifically for use with x-rays: silicon, cadmium telluride (CdTe) and gallium arsenide (GaAs).

Readouts for the Medipix2 chip include a compact USB device from IEAP in Prague, and the high performance MUROS system from NIKHEF in Amsterdam. The MARS-CT project began by employing these commercially available readouts, but has now developed the MARS-Camera, a readout that supports six contiguous Medipix2 chips. The MARS-Camera is accessible by PC using UDP/IP over gigabit ethernet. Utility software for the PC supports programming of the camera in Python, Matlab or compiled code. The first production units have been assembled and are being tested. A demonstration will be given.

Anas Sedayo

Using MARS2-spectroscopic-CT scanner to distinguish fat from liver

Fatty liver is one of the most common diseases of the digestive system. The condition is being detected more frequently with the increased use of CT. The condition can be improved with treatment and by diet; otherwise liver cirrhosis may be the final result. It is very important to know the extent of fatty liver (the content of fat in liver tissues) effective treatment plan and the result of treatment evaluated. Although CT is very useful for diagnosis of focal fatty infiltration of the liver with diffuse fatty liver showing low attenuation, biopsy of liver tissue is the most effective modality. However, biopsy is invasive. This project will evaluate the images produced by the MARS-CT scanner and analyse the data by different techniques such as principle component analysis.

Research Methodology:

The methodology of this research will be as following steps:

1. The next part of this research will focused on the background readings of MARS-CT scanner (system components, functions, operations and controls), image processing and manipulating images.
2. Further literature reviews on MARS-CT scanner and the different techniques used to quantify the liver and fat such as dual energy (ongoing process).
3. Understanding Principal Component Analysis (PCA) for image enhancement and the underlying physical principles involved.
4. Review the previous work calibrating Medipix detectors. I intend to calibrate the GaAs, CdTe and Medipix 3 systems and use both to get images.
5. Improving the scanning technique to hold the sample of fat and liver and implement proper techniques to do calibration curves at different energies. I will test how this helps to distinguish different materials.
6. Compare my results with the preliminary results of Kyra Berg et al (2009) on the linear attenuation coefficient of fat and liver. Also to use the information from the back projection of the image using Octopus software to construct an image
7. The overall result will be assessed as to whether or not spectroscopic CT can be used by radiologists to distinguish between liver and fat.

Preliminary results:

The sample was prepared in small Plexiglass tube and designed in such way to fit in the scanner.

The sample was scanned and the image processed and then the image was reconstructed by using the Octopus software, the image showed different in gray scale that can be distinguish between different tissues by visualization.

The Hounsfield unit was measured and the results showed small difference between the liver and fat.

Syen Nik

Optimal energy thresholds for biological material discrimination using Medipix detector

The objective of my PhD project is to evaluate the benefits of spectroscopic imaging in discriminating biological materials. We will start with the fundamental characterisation of x-ray source and Medipix 2 & 3 detectors using known materials and well-defined geometry before moving on to the measurements of specially-built 2D phantoms with known geometry. Monte Carlo (MC) modelling of the above source and the detectors as well as the phantom will be validated by means of physical measurements. The MC model will provide a means to investigate the effects of beam filtration and variations in energy bins on basic imaging parameters, such as scattered radiation and photon counting statistics. This will lead to the optimization of scan parameters for a given x-ray dose in order to maximise image information. At the end of this project, we want to be able to answer the overall question, which is "What are the benefits of spectroscopic imaging and how can we best achieve them?"

In this talk, I will focus specifically on the optimal positions of energy thresholds in the Medipix detectors. At this beginning stage, an ideal energy resolution of 1 keV is assumed for the detector, whereas the x-ray spectrum is taken to have the same number of photons at all energies. Preliminary results from the first four months work will be presented.

Greg Betzel

Operating parameters of a novel CVD diamond detector for x-ray dosimetry

INTRODUCTION: A novel clinical radiation detector based on commercially available single crystal diamond film made via chemical vapor deposition was investigated to determine optimal operating parameters for clinical dosimetry. This study examined how changes in applied electric field affected dosimetric performance, and determined a preferred operating voltage within the limits of clinical dosimetry equipment.

MATERIALS & METHODS: A 3 × 3 × 0.5 mm^3 single crystal synthetic diamond was used as the sensing material. The detector was designed to adapt to a water-equivalent plastic slab phantom setup used for routine dosimetry of clinical linear accelerators. A Keithley 6430 SourceMeter was used as a high-voltage source (±210V) and to measure detector current. A 2570/1 Farmer Dosimeter, a standard electrometer used in dosimetry systems, was used to measure charge with available voltages of ±30.8, ±62.5, ±125.0 and ±248.0 V. Irradiation measurements were performed at Christchurch Hospital using a pulsed 6 MV x-ray beam with a 10 × 10 cm field size from a Varian Clinac 600C linear accelerator. Nominal dose rates from the accelerator ranged from 50 to 250 MU min^{-1} in 50 MU min^{-1} increments. Dosimetric analysis included leakage current, response dynamics such as rise and fall times, sensitivity, polarity and dependence on dose and dose rate.

RESULTS & DISCUSSION: Leakage currents were negligible for all voltage settings tested (< 2.5 pA) and compared well with literature. Overall, as accelerator dose rates increased, photocurrent rise times fell. However, an increase in voltage resulted in an increase in rise times with the best rise time of 2 s for 62.5 V. An encouraging result was that all fall times were < 1 s. Ratios of photocurrent to leakage current ranged from 2100 to 7200 for 30.8 to 248.0 V. A nonlinear trend was observed for sensitivities, which ranged from 10 to 135 nC Gy^{-1}. No clear trend was found over the range of voltages tested when evaluating dose dependence (linear fit of $R^2 = 1$ for 1-10 Gy) and dose rate dependence ($0.95 \leq \Delta \leq 1.01$ where ideally $\Delta = 1$).

CONCLUSION: The results of this study indicated a preference for using a setting of 62.5 V due to its minimal rise time of 2 s yet sufficient sensitivity of 21 nC Gy^{-1}. At this voltage, a wider range of dose may therefore be recorded with charge collecting instruments than at higher voltages. The highest voltage setting of 248.0 V resulted in the highest sensitivity of 135 nC Gy^{-1}, but corresponding rise times of ≥ 7 s may limit the use of this detector in more complex clinical radiation fields.

Florian Maisonneuve

Spectroscopic mode identification of main sequence non-radially pulsating stars

We are undertaking an extensive observational campaign of a number of non-radially pulsating stars using the high-resolution HERCULES spectrograph on the 1-m telescope at MJUO. This is part of a large world-wide multi-site campaign to improve mode-identification techniques in non-radially pulsating stars, particularly for g-mode pulsators. This presentation outlines our campaign and presents preliminary results for our two main targets: the gamma-Doradus star HD 40745 and the beta-Cephei star HD 61068.

Domagoj Belić

Size-controlled sputter-deposited bimetallic nanoclusters

AgAu nanoclusters have been fabricated in our ultra-high vacuum sputtering system from the alloy sputter target by means of inert gas aggregation (IGA). Samples have been produced by varying the aggregation length and Ar to He ratio in plasma, and characterized by *in situ* mass spectrometry, scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X-ray spectroscopy (EDS), and selected area electron diffraction (SAED). Results presented here show we have successfully deposited $Ag_{0.85}Au_{0.15}$ nanoclusters ranging 4 – 8 nm in diameter, with their size governed by the experimental conditions.

David Wiltshire

Average observational quantities in the timescape cosmology

The timescape cosmology is my alternative to a homogeneous isotropic universe with smooth dark energy. A number of independent studies of "dark energy" are being made by researchers worldwide. They derive diagnostics for which equivalent expressions can also be determined in the timescape model. Three tests performed by different groups, which have some tension for the standard model with cosmological constant, turn out to be remarkably consistent with the expectations of the timescape model.

Stuart Lansley

Whereto next for diamond x-ray detectors?

Diamond has been proposed as a material for the construction of radiation detectors for many years. For radiotherapy applications, the tissue equivalence of diamond is seen as an advantage; the atomic number of carbon ($Z = 6$) is close to that of tissue ($Z \approx 7.4$). Diamond also has high radiation hardness, its response is expected to be fairly independent of x-ray energy and dose rate, and being a solid state material with a high atomic density it should be possible to realise small volume detectors suitable for obtaining measurements with high spatial resolution.

Greg has already discussed the operating parameters of some diamond x-ray detectors. I will describe the direction in which this work is heading, including beam profiling and comparison with other clinical detectors and simulations (PRISM treatment planning system & EGSnrc Monte Carlo), novel electrode materials, and the possible application of diamond detectors to Microbeam Radiation Therapy and Medipix assemblies.

Stephanie Hickford

Cascade analysis in IceCube

IceCube is a neutrino telescope currently under construction at the South Pole in Antarctica. When completed in 2011 it will be a cubic kilometre in volume capable of detecting extraterrestrial neutrinos of all flavours. IceCube will consist of over 4800 digital optical modules (DOMs) deployed under the ice on 80 strings. These DOMs house photomultiplier tubes that detect the Cherenkov light from charged particles produced when neutrinos interact with nucleons in the ice.

One type of event that can be detected when a neutrino interacts with a nucleon is a cascade of particles. This signal is a spherical pattern of light inside the telescope. Monte Carlo simulation of background and signal is produced, and used to develop a series of algorithms that reduce the background while retaining high signal efficiency. These algorithms are then carried out to search for neutrino induced cascades within the data. Results from the first level of these algorithms will be presented, showing the current work in identifying cascade events in data from 2008.

Nikolai Kruetzmann

Application of complexity measures to geophysical systems

In snow and ice, internal layers are created by changes in the ambient conditions at the time of deposition, and represent contrasts in density, electrical conductivity, and ice crystal orientation. By identifying and tracing internal layers in ground penetrating radar (GPR) measurements of the Antarctic snow cover, these layers can be used to measure snow accumulation over time. This is particularly relevant for determining the Antarctic mass balance in the context of climate change, as the areal coverage can be greatly expanded from the common, but potentially unrepresentative, point measurements from firn-cores, snow pits, or stake farms.

I will present some initial results of the GPR analysis of data from the Ross Ice Shelf and the slopes of Mt. Erebus, Antarctica, including information on sub-surface snow morphology, surface roughness, and annual accumulation estimates. The acquired data combined with a follow-up measurement campaign during the 2009/2010 season, will provide high-resolution ground-truth information required for the validation of CRYOSAT-2 satellite mission, which is due to be launched in December 2009.

Juergen Meyer

Research tools – PHYS407

At the beginning of this year we introduced a new paper called PHYS407 Research Tools. What was originally intended to be a Medical Physics paper that came into existence from the change from 20 to 15 point courses, has now evolved into a course suitable for all physics postgraduate students.

The idea of the paper is to teach transferable skills that many academics and employers expect postgraduate students to have but in my view they are not taught to the extent necessary. The philosophy of the paper is “hands-on” and “learning-by-doing”. The formal lectures are kept to a minimum and the emphasis is shifted from teacher-centred to student-centred learning through self-directed tutorials rather than instructor-driven lectures. The paper covers a wide range of topics relevant for all physics students such as scientific writing skills, Matlab programming, image processing, linear and non-linear curve fitting, optimization and “how to write a thesis in LaTeX?“. The final part of the paper is split into 2 streams, one for the medical physics (MDPH) students and one for the other students (PHYS). The MDPH stream covers computerised treatment planning and Monte Carlo radiation transport modelling. The PHYS stream covers random number generation and the Monte Carlo method, distributions (Gaussian, Poissonian, and Lorentzian) and application of Monte Carlo techniques to different problems in physics.

Most of the learning modules are computer based and assessment is through homework assignments only.

NOTES FOR SPEAKERS

1. Please keep your presentation to the allocated time of 10 minutes.
   5 minutes is allowed for discussion after your talk.
2. A computer and data projector will be available. Please load your presentations onto it before the start of your session from a memory stick or CD.
3. Talks will be recorded for educational and historical purposes. If you do not want your talk recorded please let the chairman of your session or Juergen Meyer know as soon as possible.

RESEARCH STUDENT TALKS

The B.G. Wybourne prize will be awarded for the best research student talk while the Department will be awarding prizes for 2nd, 3rd and 4th placed research student talk.

Last year the B G Wybourne Prize went to James Talbot and the Department prize was shared by Cheng-Yan Lee, Clare Worley and Mike Lee.

AFTER-CONFERENCE GATHERING

Members of the Department are all welcome to attend the end-of-conference BBQ and prize-giving to be held at the Staff Club following the last talk.