Australian PHYSICS

July/August 2008 Volume 45 Number 4

A Publication of the Australian Institute of Physics

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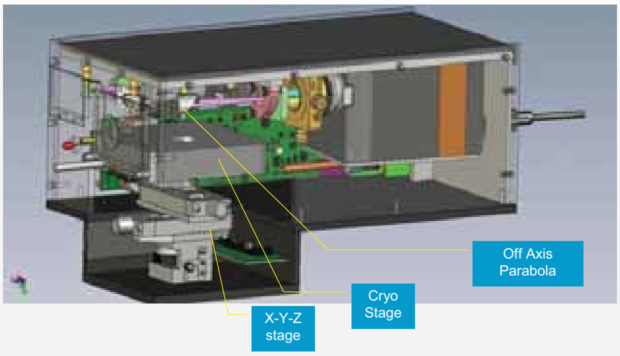

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Australian Physics
A Publication of the Australian Institute of Physics

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Cover Image:

Waiting for Sydney Observatory's time ball to drop at noon on its 150th anniversary celebrations, 7 June 2008. Read the article on page 122.

Picture Marinco Kojdanovski, courtesy Powerhouse Museum

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Submission Guidelines
All articles for submission to Australian Physics should be sent in electronic format. Word or rich text format are preferred. Images should not be embedded in the document, but should be sent as high resolution separate attachments in eps, tiff or jpg.

Authors should also send a short bio of themselves and a recent photo.

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President's Column

Commercialisation of physics research

When I did my PhD in physics, my understanding of the expectations on me was to undertake good quality and innovative research and publish it in international scientific journals. Some one else took these ideas and made new technologies out of them. When I joined CSIRO, there was an extra dimension that the research was to be applied in some way but the expectation was still to do good research.

In 1988, a review of CSIRO completed by McKinsie, resulted in massive changes. We went from a 100% government funded research laboratory to only 70% government funding. The missing 30% was to come from contracts and the commercialisation of our research. The idea was that by introducing the need to obtain external funding, CSIRO's research would be more focused and relevant to Australia. This occurred at the time that Australia was heading towards being a "banana republic" and the dawn of economic rationalism.

Suddenly the expectations on me changed from just doing research for the purpose of publishing said research, to doing research that is world class and to commercialise this research for the benefit of Australia (with a global reach).

This was also the time of the discovery of high temperature superconductivity; a research area I moved to and have been exploring ever since. High temperature (HT) superconductivity was announced at the 1987 American Physical Society March meeting. It was reported in the New York Times as the Woodstock of Physics and in May 1987 on the front page of Time Magazine as the "Superconductivity Revolution".

HT superconductivity carried with it the hype that billion dollar industries would soon develop its true potential and that, within 10 years, the world would be using superconducting technology in places other than science labs and hospitals thereby contributing billions of dollars to the world economy.

CSIRO embarked on a research program with initial funding under the federal government's Generic Industrial Research and Development (GIRD) grant, which we secured with companies Nucleus, BHP and AWA. The concept was to develop HT superconducting electronics that could be used for non-destructive evaluation of steel, biomagnetism or telecommunications.

We had to develop a method to produce electronic device quality thin films of the $Y_1Ba_2Cu_3O_{7-x}$ HT superconducting material and develop a method to create a Josephson junction, the critical structure that enables the detection of tiny magnetic fields (about 1 fT/Hz). By 1990 we had succeeded in demonstrating a HT superconducting quantum interference device (SQUID) that could detect 1 cm holes in steel plate - the state of the art at the time! BHP, one of our supporters and collaborators, presented these results at their annual internal science conference. Unexpectedly the geophysicists became very excited as a SQUID sensor was a "holy grail" for mineral exploration applications, particularly when looking for conducting ore bodies, which are notoriously difficult to detect by conventional means.

Working with BHP, initially, using the funding of a second GRID grant and then with direct BHP funding, my team at CSIRO developed the HTS SQUID magnetometer system we called LANDTEM™ to be a direct magnetic field sensor for the exploration technique transient electromagnetics (TEM). (See [1] for a detailed history and description of this system and technique).

Due to a down turn in the minerals industry during the 1990's, BHP decided to withdraw support for the SQUID system development. As we believed that the technology was of high benefit to the industry, CSIRO kept on seeking support independently hoping to attract mineral exploration contractor by taking the system to the Australian and USA Societies of Geophysics conferences and exhibited the system while continuing to improve the device quality by further system development undertaking detailed physics research on devices, materials, electronics development and the science of TEM.

Our big break came in 2000 when a former BHP Chief of Geophysics, now a US-based consultant, recommended our SQUID system to assist the Canadian mining company Falconbridge to try our SQUID system to delineate some nickel sulphide deposits in the Arctic [2]. Initially we took our experimental system housed in a Woolies plastic crate to the Arctic Circle and demonstrated its capability. They then paid for us to develop a *ruggedized* system that they could rent from us.

Eventually after further demonstrations of the system at the ASEG, an Australian contracting company, Outer Rim Geophysics, offered to start up a new company to make, rent and sell LANDTEM™. We licensed the system to them and they have manufactured more than 12 systems with production not keeping up with demand. This system has been identified as being involved with the development of over $6B worth of mines around the world [3].

There were definitely some lessons learned along the way about how to commercialise physics research. These included:

1. The technology developed must be based on the highest quality science, which has been peer reviewed as well as protected by patents.

continued on page 113

Editorial

First impressions can be a powerful influence on our attitudes and mindsets. I am not one to place high value in first impressions because no matter how captivating and sensitizing they are...sometimes they are wrong. A properly trained scientific mind must peer more deeply below the surface of superficial images and data to see what really lies beneath.

Take for instance this latest image of Echus Chasma from the High-Resolution Stereo Camera on board the European Space Agency's Mars Express. The ESA claims the image shows *"...one of the largest water source regions on the Red Planet."* Are these valleys on Mars really the geographic remnants of torrential rainwater now long gone, or maybe of ground water bubbling up from deep springs? The mental image of life-giving water flowing on another celestial object resonates strongly in our thoughts; the image is tantalizingly hopeful.

Nevertheless, even though *"[t]he majority of planetary geologists seem to favor the idea of water flowing on Mars surface in the past,"* there is still the possibility that rivers of magma carved these magnificent valleys from the Martian surface. Only by investigating further can we measure the success of our initial impressions.

Credits: ESA/ DLR/ FU Berlin (G. Neukum)

This current issue of *Australian Physics* is the first to incorporate a significant amount of colour throughout, a new standard font and other small changes that may go un-noticed by most readers. The proper use of colour, an eye-pleasing format and a captivating layout are intrinsically necessary for your reading comfort. If reading *Australian Physics* is not a visually appealing activity, then the cerebral content contained within its pages may be missed for its true value. Clearly it is the depth of the information presented, beyond what is seen immediately on the surface, that should be most important to you, and us.

More changes are on the way as we try to keep you engaged; however, as with first impressions it is hoped that the content published within these pages is more engaging than the manner in which it is published. After having a good look around the new layout, probe the articles more deeply to discover the 150 year history of the Sydney Observatory, the reasons behind the Australian physics community's high aspirations for OPAL, a review of a play written about Richard Feynman, a technique to measure environmental ultraviolet levels using digital photography, and another article in our series about life after, and outside of, physics.

John Daicopoulos

Submission deadline for the September/October 2008 issue is 25 August 2008

Submission deadline for the November/December 2008 issue is 20 October 2008

President's column – continued from page 111

2. The technology developed must have significant advantages over existing technologies.

3. It is really important to have close involvement with the industry from the first stages of development.

4. Having an industry-based champion being your advocate and giving you fully active references is required to break into any industry.

5. You need to engage fully with the industry associations/professional bodies with ongoing involvement. Don't expect turn up once and expect immediate industry adoption.

6. It is necessary to redo trials over and over again until you get the technology working completely. Proof of concept is usually not enough unless you have a partner able and willing to carry the high risk.

7. It takes a long time (15 or more years from the scientific breakthrough) [4].

8. We found that industry slow to adjust to idea of using SQUIDs and liquid nitrogen. For other applications it may be necessary to offer a "black-box" cooling technology for industry usage. Each industry will have different needs.

9. Having a close relationship and collaborate with the scientific applications area is essential (in our case CSIRO Mineral Exploration).

10. In this case a government research lab support was required- industry usually has little money for research of new tools with high risk of success.

11. You need to have a long-term commitment to have ongoing support of the technology. You can't license and forget! It was necessary for CSIRO to guarantee SQUID supply for 10 or more years. Also it has been necessary to keep doing the applications science even after the industry licensing for the next generation of the system.

Overall the development cost about $4M, led to over 30 journal publications, required a multidisciplinary team of theoretical physicists, experimental physicists, device fabricators, electronics, mechanical and software engineers and geophysicists. Over that time more than 20 different people were involved over 15 years.

Being involved in a research program that took a new discovery of 1986/7, undertaking fundamental research and than seeing it come to fruition of making a difference to an important Australian industry sector is very rewarding. Being a physicist has really enabled me to make a difference.

[1] C.P. Foley, K.E. Leslie and R.A. Binks, 'A history of the CSIRO's development of high temperature superconducting rf SQUIDS for TEM prospecting', Australian Earth Sciences Convention (AESC 2006), Melbourne, Australia (2006)

[2] R. T. Osmond, A. H. Watts, W. Ravenhurst, C. P. Foley and K. E. Leslie, 'Finding nickel from the B-field at Raglan: 'To B or not dB'', *CSEG Recorder* **27,** (9) 44-47 (2002).

[3] *Nature Physics*, **2**, 794-5 (2006)

[4] I have asked industry-based physicists in the USA, Germany, UK and Japan about the time from science breakthrough to selling this technology in the market place and each said 15 years. They said the challenge is to make this time shorter!

Write an article for Australian Physics

We are looking for articles covering all aspects of physics in Australia. Perhaps your area of Physics is not well known, is unusual in some way, or you work at a smaller univeristy; perhaps your career has developed in uncoventional ways; if so, why not write an article for Australian Physics? For more information contact editor-in-chief A/Prof Brian James (B.James@physics.usyd.edu.au).

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Letters

Dear Sir,
I read with interest *A Socratic Dialogue* by Sam Drake (February 2008), which propounds a view on why a sea-level equatorial atomic clock has the same rate as a sea-level polar clock, viz. the spinning Earth has an equipotential surface and since it is impossible to distinguish which is gravitational potential and which is centrifugal potential from within a closed chamber, the uniform effective potential makes all sea-level clocks tick at the same rate.

At first blush the view propounded by *A Socratic Dialogue* seems plausible, but upon reflection one realises that the equivalence principle cannot apply because the effective potential itself is not directly measurable in a closed chamber! More seriously, numerous spinning Mossbauer experiments have shown that centrifugal force (of itself) has no effect on the rate of a clock.

"...the real mystery is that the light medium is fine-tuned..."

Empirically, the parity of polar and equatorial clock rates is dependent on the uniformity of the sum of clock-slowing of two distinct kinds - (a) that caused by the clock's speed with respect to a frame of reference which is centred on the Earth's core and which is non-rotating with respect to the fixed stars, and (b) that caused by light reducing in speed when it is closer to the origin of the terrestrial reference frame.

To illustrate how this works, consider a light clock where a light ray is continuously reflected up and down within the clock. For a stationary light clock at the North Pole the ray goes up and down in the same place, but for a moving light clock at the Equator the up-and-down ray traces out numerous fine-pitched *saw teeth*, completing a serrated 12756 km diameter circle once every sidereal day. Clearly the Equatorial light clock will tend (a) to complete fewer cycles because by Pythagoras its light ray has slightly farther to go to complete each up-and-down cycle. However, the Equatorial light clock ends up having the same number of cycles as the North Pole light clock because (b) the light ray in the Equatorial clock is faster (and produces more saw teeth) by virtue of the equatorial bulge raising that clock's distance from the centre of the Earth by 21 km.

The motion-induced slowing of the Equatorial clock stems from simple geometry, but the relative increase in the speed of light in that clock vis a vis the Polar clock is dependent on a harder to understand "conditioning" of the terrestrial reference frame. Well, it is impossible to condition a mathematical artefact, so that which is being conditioned is a light medium (a notion which relies on no less an authority than A. Einstein). An alternative universe would work just as well if the light medium were conditioned to under or over compensate by 5 ns the 104 ns per day motion-induced slowing of the Equatorial clock, so the real mystery is that the light medium is fine-tuned to carry out that compensation exactly!

Jim Hodges, MAIP 4528
Ether Drift Club

Sam Drake replies:
[Jim Hodges] raises a number of interesting points that I wish to address directly. At the outset let me state that my article and this response letter addresses the development of the standard theory of general of relativity by way of the standard theory of special relativity and the equivalence principle. In particular we assume that light does not travel in a medium and therefore the speed of light is constant.

"...we assume light does not travel in a medium..."

The key objective of this paper is to show that the equivalence principle implies that gravity must affect clock speeds.

As I understand them [Hodges'] points are as follows:
1. The equivalence principle cannot be used because the effective potential cannot be measured directly.
2. Centrifugal forces of themselves do not cause time dilation.
3. As an alternative theory of relativity one can assume that the speed of light changes at the equator and the pole due to a property of the medium in which the light travels.

In regards to the first point the equivalence principle *can* be used precisely because the effective potential cannot be measured directly. Kim realises that he cannot distinguish between the gravitational and "centrifugal" forces and therefore, by the weak equivalence principle treats them as a single force or equivalently a single effective potential.

The second point is completely correct acceleration (of itself) does not cause time dilation. This is a crucial point, Kim realises that it is the total energy (kinetic plus potential that causes time dilation). Kim comes to this realisation by recalling a derivation of $E = mc^2$ that is achieved by multiplying the proper time interval by: $m^2 c^4$

In the appendix of the original paper published in the *American Journal of Physics* we show that time dilation can be approximated by the total energy. In the case of the Schwarzschild metric:

$$\begin{aligned} d\tau^2 &= (1-2M/r)^{-1}dt^2 - r^2 d\theta^2 - r^2\cos^2\theta d\phi^2 \\ &= (1-2M/r)^{-1}dt^2 - r^2\cos^2\theta\omega^2 dt^2 \\ &= \left((1-2M/r)^{-1} - r^2\cos^2\theta\omega^2\right)dt^2 \\ \frac{dt}{d\tau} &= \frac{1}{\sqrt{(1-2M/r)^{-1} - r^2\cos^2\theta\omega^2}} \\ &\approx 1 - M/r + 1/2\,r^2\cos^2\theta\omega^2 \\ &\approx 1 + E_{G+K}/m \end{aligned}$$

where E_{G+K}

is the sum of the gravitational and kinetic energies.

Importantly other forms of acceleration, for example a spring or electro-magnetic forces, do not affect time dilation in the same way, i.e.

$$\frac{dt}{d\tau} \neq 1 + V$$

where V is the potential of the driving force. Gravity is unique in that the acceleration it causes is independent of any property of the object being accelerated. The electric-magnetic field does contribute to the gravitational potential due to the equivalence between energy and mass but acceleration due to electromagnetic forces is considered independently. The unification of gravity with non-gravitational forces is something that has occupied physicist for many years.

The last point you make is in regard to an alternative theory of relativity in which light travels through a medium and the properties of that medium affect the speed of light. In particular you argue that the medium affects light in such a way that it precisely matches the special relativistic time dilation affects everywhere on the surface of the Earth! As you point out it is of course possible to vary the speed of light so that clocks tick at the same rate on the surface of the Earth, but one would have to ask why that would happen. The traditionally accepted formulation of general relativity requires no such coincidence and, therefore, in my opinion is a much more powerful theory. However in keeping with the practice of critical thinking I try to keep my mind open but my arguments tight and am therefore open to persuasion.

Sam Drake
Adjunct Associate Lecturer, School of Chemistry and Physics
University of Adelaide

On a somewhat related note...

General Relativity has been around for 93 years. With advances in technology, has come the ability to put the theory under some scrutiny. Recently, taking advantage of a unique cosmic coincidence, as well as a good telescope, astronomers looked at the strong gravity from a pair of superdense neutron stars and measured an effect predicted by GR. The theory came through with flying colours.

Einstein's 1915 theory predicted that in a close system of two very massive objects, such as neutron stars, one object's gravitational tug, along with spinning on its axis, should cause the spin axis of the other to precess. Studies of other binary pulsars had indicated that such wobbling occurred, but could not produce precise measurements of the amount of wobbling.

"Measuring the amount of wobbling is what tests the details...and gives a benchmark that any alternative gravitational theories must meet," said Scott Ransom of the National Radio Astronomy Observatory.

The astronomers used the National Science Foundation's Robert C. Byrd Green Bank Telescope to make a four-year study of a unique double-star system. The system is a pair of neutron stars which are seen as pulsars emiting beams of radio waves.

"Of about 1700 known pulsars, this is the only case where two pulsars are in orbit around each other," said Rene Breton, a graduate student at McGill University in Montreal, Canada. The stars' orbital plane is aligned nearly perfectly with their line of sight to the Earth, so that one passes behind a doughnut-shaped region of ionized gas surrounding the other, eclipsing the signal from the pulsar in back.

The eclipses allowed the astronomers to pin down the geometry of the double-pulsar system and track changes in the orientation of the spin axis of one of them. As one pulsar's spin axis slowly moved, the pattern of signal blockages as the other passed behind it also changed.

The pair of pulsars studied is about 1700 light-years from Earth. The average distance between the two is only about twice the distance from the Earth to the Moon. The two orbit each other in just under two and a half hours.

"A system like this, with two very massive objects very close to each other, is precisely the kind of extreme 'cosmic laboratory' needed to test Einstein's prediction," said Victoria Kaspi, leader of McGill University's Pulsar Group.

"It's not quite right to say that we have now 'proven' General Relativity," Breton said. "However, so far, Einstein's theory has passed all the tests that have been conducted, including ours."

The Universe Today and Jodrell Bank Observatory

Executive News

SUMMARY OF EXECUTIVE MEETING E274

Meeting held Wednesday June 25

Theoretical physics group

Enough members have expressed interest in the formation of a theoretical physics group for it to go ahead. A proposal will be put to the next Council meeting which will be held via a phone hook up..

AIP foundation

Plans are in progress for the formation of an AIP foundation. Such a foundation must be used only for a designated purpose. The proposal is to have a fund that can be used for student scholarships and activities. Donations to the fund would be tax deductible.

Review of higher education

The AIP will be making a submission to the government review of higher education. The executive is in the process of drawing up a response. Input from the membership would be welcomed.

Tax deductions for retirees

Verbal advice has been given that subscriptions paid by retirees are partly tax deductible. Written confirmation of this advice is being sought so the AIP can advise members.

HECS rates

The government has decided to reduce the HECS rates for science students. However, universities will have to cover the costs. The executive is concerned that this could have a negative impact on science courses. A response to the government is to be discussed with FASTS.

Corporate membership

There has been a proposal to update the corporate membership grade. This is being developed to make it attractive for companies to take up this grade while not impacting the sponsorships for the AIP Congresses.

Student link scheme

A number of universities have given support to the proposed student link scheme. Responses from other universities are now being sought. Once a majority have agreed to participate, the scheme will be set up.

Database

Discussions about the setting up of a new database are continuing. The secretariat is looking at several databases that could be used for a number of the organizations it services. A fully costed proposal is still to be submitted to the AIP by its administrators at IMEA.

Student travel grants

Criteria are being developed for the awarding of student travel grants. When the criteria have been agreed, there will be a call for applications. There will be two rounds of travel grants each year.

Science policy

In the process of keeping the science policy up to date, attention is now being given to energy policy. An important part of this policy will be on energy efficiency. It was thought useful to have a preamble to the energy policy along the same lines as that developed for the environment policy.

Conference funding

It has been resolved that that the AIP will recoup the interest lost on seed finds provided to conference organizers. Consideration is being given to returning some of the profit to conference organizers.

2008 Congress

Planning for the 2008 Congress is proceeding well. The SA branch is confident that the budget predictions will be met.

2010 Congress

No applications have been received for running the 2010 Congress. This is being followed up.

Heads of department meeting

It has been resolved to hold a physics heads of department meeting during the Congress. This will take place on the Wednesday evening, when there are no other activities.

Branch operation

It is clear that activities that are successful in some branches do not work in other branches. Circumstances have changed considerably since the branch structure was originally set up. It has been resolved to undertake a review of the branch activities with the view of examining whether nor not the current role and activities are the best means of achieving the aims and objectives of the AIP.

Web site

It was considered that the web site is very important, both for members and as an interface with the public. It is particularly important that the site is appealing to the younger generation. A proposal for the redevelopment of the web site is being drawn up. It was considered that this should include a strong emphasis on careers.

Next meeting

Meeting E275 was scheduled for September 4 in Perth.

Ian Bailey, Hon secretary.

Are you a physicist working in an industrial/commercial environment?

We would like to publish more articles about physics and physicists in industry or commerce. If you would like to write an article for Australian Physics on your area and activities to inform the Australian Physics community please contact editor-in-chief A/Prof Brian James (B.James@physics.usyd.edu.au).

Council News

SUMMARY OF COUNCIL MEETING C60

Summary of Council meeting C60 held February 11/12 2008

Switkowski report: It was felt that a statement made in the minutes of the previous Council meeting about the Switkowski report was overly negative. Council was not going to take a stance on the nuclear power issue, although it was thought that the AIP should be a reference source of factual information.

Executive Reports

President: Dr. Cathy Foley reported that she had been impressed with the views of people about the AIP in that it was considered to be an authoritative reference source. Members were not aware of the high esteem in which the AIP is held. The past year had seen the executive have three main priorities – services to members, educational issues and publicity for physics. Work on these will continue, but in the next 12 months the focus will shift to boosting membership, connecting with the younger generation, and developing modern ways of communication.

Vice-President: Prof. Brian James said that his major role had been acting as the link in the changeover of editor of Australian physics from Corinna Horrigan to John Daicopoulos. Corinna's work had been appreciated. It had been resolved that in future, it would be the role of each vice-president to be the chief editor of Australian Physics.

Treasurer: Dr. Marc Duldig reported that although the accounts for the previous year showed a surplus of $32,000 this was illusory as some major cost items had not been paid within the financial year. The real outcome was close to a balanced budget. With the increase of 10% in fees, the budget presented to Council for next year anticipated a balanced outcome.

Registrar: There had been a small decline in the number of members. The database was giving problems and this needs to be fixed. Three accreditations had been carried out in 2007, and one deferred to 2008. The priorities for the coming year were to sort out the database, encourage universities to have courses accredited, and getting a member from Queensland on the accreditation panel.

Secretary: Dr. Ian Bailey reported that work has been done on the development of a policies and procedures manual but it is in very rudimentary form and it would be very useful for the future to have practices recorded in extensive form. The AIP also needed to give attention on how materials were to be archived.

Immediate past President: Prof. David Jamieson identified the work done with the vice-President on the RFDC codes as a highlight of his year's activities.

Special Projects Officer: Dr. Olivia Samardzic had taken over the role of organizing awards. She was working on refining the awards schedule and increasing the recognition given to medal winners. There was a marked disparity of awards given to students in various States and it was resolved that the executive would look into this and achieve a greater consistency.

Science Policy Convener: Dr. Judith Pollard reported that policy was in a constant process of revision and updating. It was important that the policies agreed accurately reflected the views of members. The meeting made it clear that the place of the policies was to have just policies and not to take any stance on actions.

Australian Physic Editor's report: Dr. John Daicopoulos had only recently taken over the position and was still in the process of familiarizing himself with the production process. Production had been erratic and he was making plans so that after the next couple of issues, they would appear on schedule.

2008 Congress: Prof. Roger Clay reported that planning for the 2008 Congress, to be held in Adelaide, was proceeding well. The venue was to be the University of Adelaide.

Physics Olympiad: Chris Stewart was now the coordinator of the Physics Olympiad program. It was proving difficult to raise the finance necessary to support the team and requested the assistance of the AIP. However, the AIP was not in a position to provide any significant funding, although a small amount could be provided for team members, and it could also help in establishing contacts.

Branch reports: The South Australian branch is operating well. The main reason for its success was that the branch had very active interaction with undergraduates. The Victorian branch has an active lecture program and there was also a strong physics education program. The ACT branch had experienced considerable success with its Physics for the Future program. The major problem for the branch was that many of the branch members were non-tenured. They had also run a useful 'adopt a physicist' program. The Tasmanian branch had run a series of very successful public lectures. The student quiz was also well supported and there were plans to expand this to even more venues. They also ran a teacher development program in conjunction with RACI. The NSW branch has run an extensive marketing and advertising program. There was a very successful physics in industry day. The Nobel lecture has also been a high profile event. The WA branch had run a physics in industry day that had attracted a great deal of interest. The Queensland branch had run a very successful youth lecture tour and a switch on to physics program.

Group reports

Quantum Interference, Coherence and Concepts group: Dr. Andrew Greentree reported that after a hiatus, the group had reinvigorated and would recommence production of the newsletter. Council suggested that a section in Australian Physics be used for presenting news on groups and Cognate Socireities.

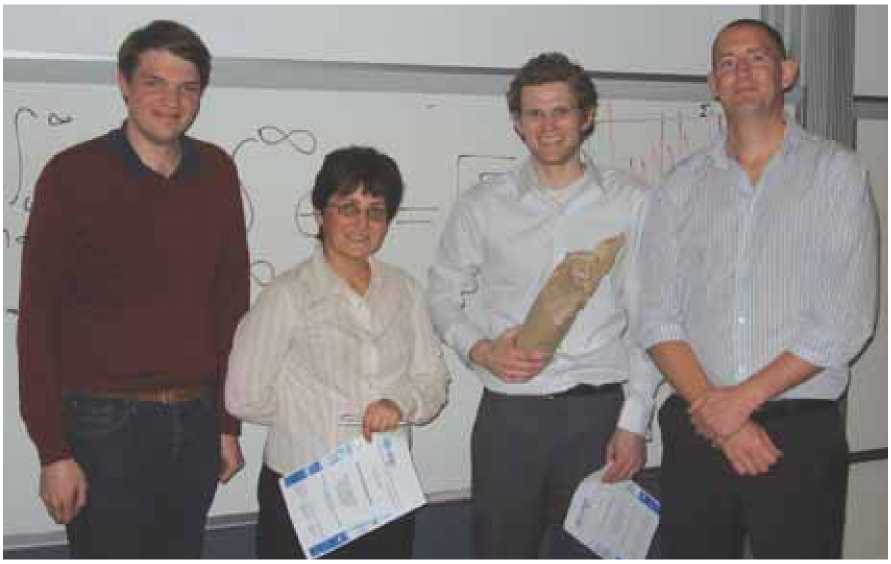
Solar, Terrestrial and Space Physics group: Prof. Iain Reid said the group had been involved in a number of meetings, including international ones. There had been a very productive climate group meeting, at which the limits of solar control on climate had been clearly demonstrated. The meeting of the International Union of Geodesy and Geophysics is to be held in Australia in 2011.

Council News continued on page 168

Branch News

Victoria

The May meeting of the Victorian branch of the AIP featured talks by three recent recipients of Australian Postdoctoral Fellowships. The aim of the meeting was to highlight work undertaken by researchers at relatively early stages in their research career. Dr Chris Ticknor (Swinburne University), Dr Angus Johnston (Melbourne University) and Dr Nicoleta Dragomir (Melbourne University) each gave 15-minute overviews of their work. The topics of the talks included universal dipolar scattering, the engineering and assembly of bioinspired nanostructures and quantitative polarization phase microscopy.



May branch meeting presenters (left to right) Dr. Angus Johnston, Dr. Nicoleta Dragomir and Dr. Chris Ticknor, and Assoc. Prof. Andrew Peele (Vic Branch chair).

Assoc. Prof. Andrew Peele (Vic AIP Branch chair) presenting Martijn Jasperse with the Laby medal.

At the June meeting, Martijn Jasperse of Melbourne University was presented with the Laby Medal for a thesis entitled "Quantum Squeezing by Four Wave Mixing in Rubidium Vapour". The Thomas H. Laby medal is awarded annually to the outstanding Honours Physics student(s) in Victoria from the preceding year. Following the award Dr. Mohana Yethiraj gave a talk on the OPAL reactor at Lucas Heights in south Sydney and results of research undertaken on the Verwey transition in Magnetite.

Tasmania

The Branch has held two more Public Lectures in its winter McAuley series. On May 29th about 75 people heard Dr Ken McCracken speak about *Tales of a foot-loose physicist*. Ken gave his view of the valuable role physicists can play in many fields, principally because they are trained to be highly adaptable and to not unquestionably accept conventional wisdom. In Ken's case, he did his PhD in Cosmic Rays at the University of Tasmania and then went to MIT as a Post Doc, working with Bruno Rossi. Spacecraft borne experiments were then underway. Rules in force at the time said that electronic components couldn't be used in spacecraft unless they had previously been flown and proved. Catch 22 for Integrated Circuit components! Ken managed to get around the problem and was responsible for a number of the major successful investigations of the time. Returning to Australia, Ken then became involved in X-Ray observations both from balloons and from Skylark rockets flown at Woomera.

Around that time most geophysics technology used in Australia was imported. Techniques developed for glaciated terrain in the northern hemisphere were not well suited to ore-body searches in the very different geological conditions found in Australia. CSIRO decided that a new Division led by an experienced space-science experimentalist should be able to tackle the problem, so Ken was appointed as the foundation Chief of the Division of Mineral Physics. Again his interest was in doing things that, according to conventional wisdom "couldn't be done". High in this category was the detection of ore-bodies from aircraft. The e/m frequencies then used were too high and did not penetrate deep enough into the ground. Altering the frequency, and changing from sequential to simultaneous measurements, brought about a hundred-fold increase in sensitivity.

Another method of ore-body detection is via their gravitational signature. Direct measurements via airborne accelerometers are impracticable at the sensitivity required. However, physicists are experienced in the use of differential measurements. These eventually worked, enabling fast surveys of large areas.

Ken spoke of other aspects of his varied career and now, in retirement, has returned to the cosmic rays he started investigating 50 years ago. It was a fascinating evening.

A month later, on the cold and wet evening of June 26th, 35 people turned out to hear Professor Bob Vincent from the University of Adelaide tell us about the relationship between *Atmospheric Waves and Climate Change*.

Planetary wave generation depends on topography and land/sea contrasts. There is stronger forcing in the northern hemisphere (which Bob typified as the 'Land' hemisphere) than in the southern (which he typified as the 'Ocean' hemisphere). The weaker waves in the southern hemisphere cause colder temperatures in the Antarctic winter, setting up the pre-conditions for severe atmospheric ozone loss when other factors intervene.

Waves are also involved in energy and momentum transfer. The momentum they shed when they dissipate causes forces to act on the atmosphere, resulting in circulation from summer towards winter poles with air rising over the summer pole and falling over the winter one. The quite different topography in the two hemispheres (Bob referred to the northern hemisphere as being the land hemisphere whilst the southern one is the ocean hemisphere) results in different circulation patterns in the two, in particular the formation of the southern vortex and the relative isolation of the southern polar atmosphere through its winter. It is important to include wave effects in numerical weather and climate models.

Bob went on to discuss current work involving superpressure balloons floating at isopycnic (constant density) levels in the atmosphere. The balloons can float for several months, circling the Antarctic continent several times on fairly irregular paths. They are cut down if they drift too far north. Two flight levels are used, 50 hPa (~ 18.5 km) and 70 hPa (~ 17 km). The balloons carry instruments measuring atmospheric parameters and positions via GPS, and download their data via satellite links every 15 minutes. Data received from them will increase our knowledge of atmospheric processes in southern polar regions.

South Australia

On May 1st, the SA branch presented a public lecture by Prof. Dr Harald Fritzsch, Chair of High Energy Physics in the Department für Physik, Ludwig-Maximilians-Universität, Munich, on "The Big Bang - Physics of the Beginning of our Universe". Starting with the well-known "Deep Field" picture taken by the Hubble Space Telescope, Prof. Fritzsch described the astronomical phenomena of the expansion of the universe, dark matter and energy, and the cosmic background radiation. The developing study of these was well illustrated with historic photographs, including one of Einstein with Hubble. Prof. Fritzsch then gave a broad-ranging introduction to particle physics, including Feynman diagrams, the strong force, and the families of quarks and related particles, proceeding to SU10 symmetry and the proton lifetime. He then linked this to the Big Bang, zones of cooling with time, inflation, and the concepts that the observable universe may be a small part of a larger but still finite universe or of a "multiverse".

The picture shows A/Prof. Eva Bezak with the prize winners for the 2007 academic year: Sophie Underwood (right) of the University of Adelaide, and Ashleigh Schofield (left) of the University of South Australia.

The lecture was well received by an audience of about 140 people. For the presence of more than one third of these we must thank Paul Curnow. Though not a member of the AIP, Paul nevertheless advertises our lectures by email to a large number of people in South Australia who are interested in scientific events and lectures.

On June 5th, the branch presented its annual Claire Corani Memorial Lecture, this year by A/Prof. Eva Bezak, the Chief Physicist in the Department of Medical Physics at the Royal Adelaide Hospital. In a talk entitled "Exposure to radiation is not all bad news!", she reviewed the historical development of public attitudes to radiation, from the initial phase of "radiophoria" through to the "radiophobia" that emerged later. She discussed various theories as to whether radiation damage is proportional to dose. A/Prof. Bezak then described Radiation Oncology – the field of medicine in which various types of radiation are applied in the treatment and management of cancer – and the role of medical physicists in this field. Finally, she described how the Royal Adelaide Hospital has been involved in the development of a so-called transmitted in-vivo dosimetry technique, using 2-dimensional flat panel detectors made of liquid ionization chamber arrays.

In memorial to Claire Corani, a young physicist who died in tragic circumstances some years ago, a fund was set up from which a prize is awarded to the best female 2nd-year physics student at each SA university.

NB: In the SA branch report (March-April 2008, p 47) for the Claire Corani awards given last year we neglected to mention that Lee Van Dongen was the recipient from the University of South Australia for 2006.

New South Wales

The May meeting of the NSW branch of the AIP was held at the University of Sydney on Tuesday 27 May 2008 and featured Dr George Collins, Chief of Research at the Australian Nuclear Science and Technology Organisation (ANSTO). Although no longer an active researcher, he is committed to ensuring the success and relevance of the multidisciplinary research activities he facilitates. George obtained a PhD in plasma physics from the University of Sydney and spent 4 years in fusion related plasma physics at the Centre de Recherches en Physique des Plasmas within the Ecole Polytechnique Federale de Lausanne in Switzerland.

George has worked at ANSTO since 1986 and having been in his current role since February 2005, was in an

excellent position to give an expert, current account of the 'state of affairs' at ANSTO. His talk was entitled "*ANSTO-Australian Physics in Action*" covering the range of research activities undertaken by ANSTO as well as the wide range of research facilitated by the techniques that ANSTO provides for the Australian research community. While physics is fundamental, the applications are broad – in environmental research, radiopharmaceutical development, materials engineering as well as advancing the understanding of the structure and function of materials at the atomic, molecular and nano levels.

He described ANSTO as an international centre of excellence in nuclear science and technology whose overriding purpose is to benefit Australia through a number of roles, many of which have strong links with physics. ANSTO also provides strategic advice to the government on a range of important long-term issues, including climate change, power generation and counter-terrorism. ANSTO applies nuclear science to address Australia's environmental challenges and increase the competitiveness of Australian industry.

George then went on to talk about the wide range of research facilitated by the techniques that ANSTO provides for the Australian research community as well as the broad range of activities undertaken by ANSTO. One of the most important of these includes manufacturing and advancing the use of radiopharmaceuticals to help in the diagnosis and treatment of a range of serious illnesses.

George also spoke about the major facilities run by ANSTO, which include the new OPAL reactor, which is the single largest investment in Australian science. It has twice the power (20MW) of the old HIFAR reactor. OPAL offers enhanced safety, between four and ten times the irradiation capability, far superior neutron scattering abilities, and includes some of the most sophisticated neutron scattering instruments in the world. OPAL will also boost ANSTO's capacity to produce beneficial radioisotope products and irradiation services, and help Australian industry to compete more successfully. ANSTO also runs the National Medical Cyclotron, which creates short-lived isotopes, and 2 particle accelerators, ANTARES and STAR. These significantly assist the study of the environment, nuclear safeguards, geology, archaeology and palaeontology. They can also be used to measure, monitor and characterise air particles to give us accurate pollution reports.

Finally, George spoke about overcoming the problems with the new reactor, which was off-line for 299 heart-wrenching days. The talk was very well received and geared to scientists and members of the public alike with many discussions continuing later during dinner.

The Australian Institute of Physics thanks Dr Collins for his outstanding lecture!

Dr Graeme Melville
AIP NSW Branch Secretary

Photo: From left to right, Mr Griffin receiving the AIP prize from Dr Fred Osman (AIP Branch Chair) at the USYD prize giving ceremony.

NSW Branch (Student Prize Giving)

The NSW Branch has been very active each year in acknowledging prizes for the best graduating students from each University in recognition of their outstanding achievements in Physics. This initiative has been set-up to recognize and target students to be involved in future AIP initiatives. On Tuesday 27 May the AIP Chair Dr Fred Osman awarded the USYD prize and presented a $400 cheque and an AIP certificate to this year's winner Mr Tom Griffin for his outstanding recognition in Honours. Tom's father accepted the awarded on his son's behalf. The AIP congratulates Tom on this achievement.

Dr Frederick Osman
AIP NSW Branch Chair

Photo 1: From left to right, Dr Fred Osman (AIP Branch Chair), Dr George Collins and Dr Graeme Melville (AIP Branch Secretary).

News

Synchrotron science reveals Phar Lap mystery

Specialist synchrotron techniques have been used to reveal the mystery of Phar Lap's untimely demise. Research results released at Melbourne Museum, the home of Phar Lap, confirm preliminary findings that Phar Lap died from arsenic poisoning.

The final stages of this forensic investigation was funded by the Australian Synchrotron and the Victorian Government enabling access to a microspectroscopy beamline to validate preliminary findings by Dr Ivan Kempson from the University of South Australia and Dermot Henry, Manager, Natural Science Collections at Museum Victoria.

Dr Ivan Kempson used the high resolution only available from a synchrotron light source to detect the concentrations and distributions of arsenic. Using a microprobe that is a mapping scanning spectrometer able to probe minute intact samples, such as hair cells, he was able to create maps showing the spatial distribution and chemical properties of arsenic in the sample. The analysis showed that Phar Lap had ingested a large dose of arsenic in the last 30 to 40 hours of his life. Australian Synchrotron

Robotic clarinet wins orchestra competition

An Australian-designed robot clarinet player has won first prize at an international orchestra competition.

The Australian entry performed The Flight of the Bumblebee and Bolero in the final, beating a Dutch developed guitar-picking robot and a Finnish piano-playing machine.

John Judge, a senior research engineer at NICTA, led the development of the clarinet player. The project team included UNSW computer science and engineering student, Mark Sheahan, NICTA Senior Research Engineer, Peter Chubb, Kim Son Dang and Dr Jay Katupitiya from UNSW's Mechanical & Manufacturing Engineering School, Jean Geoffroy, Paul Santus, John Smith and Professor Joe Wolfe from UNSW's School of Physics.

Dr Judge describes the robot as "an embedded computer system connected via specially constructed electronics to actuators that control the keys and mouthpiece of the clarinet."

Researchers at the Music Acoustics Lab will use the robotic clarinet to better understand the gestures of human players. "It was a big rush to get a robot to play in time for the competition" says Prof Wolfe, "and we didn't have time to include a lot of what we know from research on human players. This instrument was a beginner with fast fingers. Next year's model will be a much better musician: we'll teach it, and it will teach us about the details of musicianship, too." UNSW

New website for physics teachers

The Physics Education Research group at the University of Sydney has spent 18 months putting together a website for physics teachers.

Teachers, science communicators, physics academics, university students, and online learning specialists from the University of Sydney and high schools around New South Wales have worked together to create over 50 multimedia resources titled AMPS – Australian Multimedia for Physics Students.

Students and academics within the Sydney University Physics Education group spent years studying the best use of classroom video. The videos in AMPS are short and snappy. Common student misconceptions are addressed, and easy to use lesson plans are provided. The website was created with funding under the Australian School Innovation in Science, Technology, and Mathematics (ASISTM) initiative and supported by the School of Physics, University of Sydney.
www.hscphysics.edu.au/home
USyd

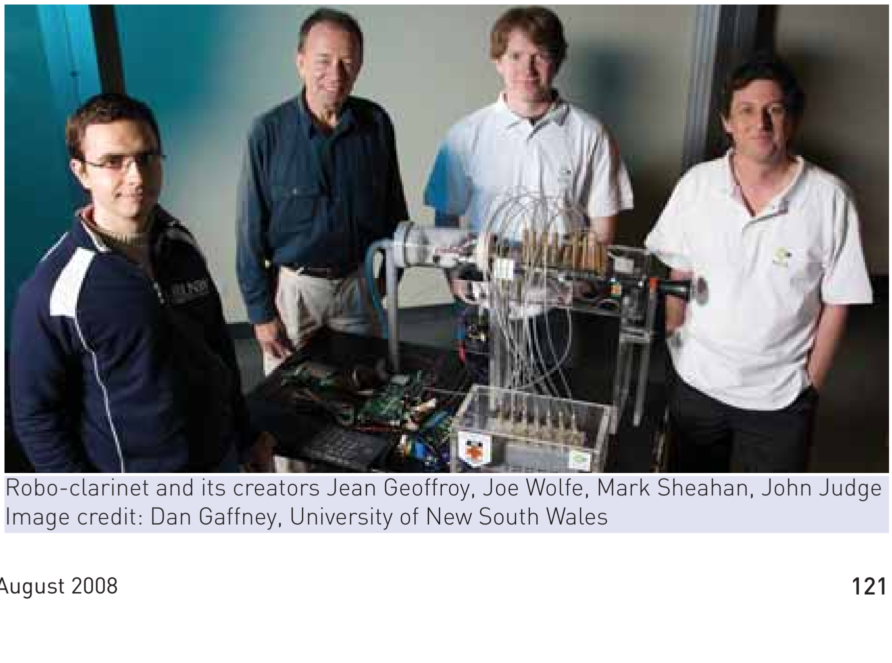
International award for Physclips

International award for physics clips Physclips, a set of multimedia learning and teaching materials developed for introductory physics, has won the Physics division of the 2007 Pirelli Prizes for Science Communication.

Funded by the Australian Learning and Teaching Council (ALTC), Physclips was developed by George Hatsidimitris and Joe Wolfe of the UNSW School of Physics in Sydney, Australia.

Physclips is a set of learning and teaching resources for introductory physics, currently mainly mechanics. A series of multimedia tutorials give brief overviews, using film clips and animations. Hyperlinks take the user to broader and deeper treatments.

Physclips receives about 1,500 unique visitors a day, with each visitor downloading typically 30 files. Overall, there are typically 40,000 hits a day. The 2007 Pirelli Prizes for Science Communication are part of the Pirelli International Award - the world's first and most prestigious internet multimedia award aimed at the diffusion of scientific and technological culture worldwide.
www.physclips.unsw.edu.au/
UNSW



Robo-clarinet and its creators Jean Geoffroy, Joe Wolfe, Mark Sheahan, John Judge
Image credit: Dan Gaffney, University of New South Wales

Sydney Observatory turns 150

Dr Nick Lomb
Curator of Astronomy
Sydney Observatory/Powerhouse Museum

With Australia's relatively short European history, it is not too often that an institution reaches the grand old age of 150 years. Sydney Observatory, Australia's oldest extant observatory, celebrated its 150th anniversary on 5 June 2008 with three days of festivities. Though its emphasis changed from research to education in 1982 when it became part of the Museum of Applied Arts and Sciences, now better known as the Powerhouse Museum, its concentration on astronomy has been undiminished over the years.

The reason for the establishment of the Observatory was to provide time for ships in Sydney Harbour. Helped by the discovery of gold, Sydney was a bustling town by the 1850s with a busy harbour. An important need for the ships in that harbour was to have a way of obtaining the correct time in order to check the chronometers used onboard for navigation. On 31 March 1855 Governor-General Sir William Denison obtained agreement from the Executive Council for the establishment of an observatory with a time ball that would give a visual indication of the time at a predetermined hour to ships as well as to any interested Sydneysiders. As Denison stated, it would not have been enough just to install a time ball by itself as an astronomer was needed to make observations to determine the correct time.

Reverend William Scott, a Cambridge mathematician, became the first Government Astronomer (1856-1861), arriving at the beginning of November 1856. A few days later he inspected the proposed site of the Observatory with the Governor-General and agreed with the choice of location at Fort Phillip, which was the highest spot in the town. Building

Reverend William Scott, the first Government Astronomer at Sydney Observatory. Courtesy Powerhouse Museum

Sydney Observatory in about 1900. Picture Kerry and Co. Courtesy Powerhouse Museum

work began with the final form of the Observatory due to Colonial Architect William Dawson whose design is in the asymmetrical "Italian villa" style. The working part of the Observatory with a telescope dome, slits for transit telescopes and the tall time ball tower is to the west, while the residence for the Government Astronomer is to the east. As befitting the importance of the Observatory it was built of stone using Sydney sandstone.

Scott moved into the residence in early 1858 and first dropped the time ball at 12 noon on 5 June 1858, switching to 1 pm a few months later. He could not do all the work expected of him on his own and he appointed a top graduate in mathematics and physics from the newly built Sydney University, Henry Chamberlain Russell, as his "computer". Russell would go on to become the most significant Government Astronomer in the history of Sydney Observatory. On taking charge in 1870 he redirected the resources of the Observatory towards the transit of Venus in December 1874. The success of the large observing effort that he organised for the transit helped cement the reputation of the Observatory both locally and internationally.

Russell (1870-1905) began Sydney Observatory's greatest scientific task when he attended the conference in Paris in 1887 that formulated the international astrographic catalogue project. The idea of the project was to photograph the entire sky with identical telescopes and then to measure the resultant plates to produce an extensive catalogue of star positions. Each observatory was allocated an appropriate zone and Russell on behalf of Sydney Observatory undertook photography and measurement of a large zone of the southern sky. Work on the catalogue began in Sydney in 1890 when the 33-cm photographic lens arrived from Howard Grubb of Dublin for installation on a mounting of Russell's design. Progress was slow as Russell, his successors and their staff not only had to take good quality plates and have them measured by a team of young women, they also had to obtain a suitable number of reference stars for each plate and, finally, compute for each plate the conversion from x, y coordinates to the standard astronomical right ascension and declination

coordinates. The last data catalogue of the Sydney Zone of the Astrographic Catalogue was not published until 1964 in the time of the second last Government Astronomer, Dr Harley Wood (1943-1974).

The work on the Astrographic Catalogue largely dominated the history of Sydney Observatory. In 1926 when the NSW Government tried to close the Observatory and managed to dismiss the then Government Astronomer William Ernest Cooke (1912-1926), it was saved by protests from local scientific organisations on the basis of the international commitment represented by the catalogue. On the negative side though the large effort involved in the catalogue work prevented the Observatory branching out into the more modern field of astrophysics.

The idea of the project was to photograph the entire sky with identical telescopes and then to measure the resultant plates to produce an extensive catalogue of star positions.

During the late 1950s Sydney Observatory began photography with a modern astrometric lens for a new star catalogue to cover most of the southern sky. Again progress was slow and it was only in the early 1980s that the measurement process was streamlined with the help of minimal automation provided by a programmable calculator. However, in 1982 the NSW Government decided to take advantage of the approaching retirement of Government Astronomer Bill Robertson (1975-1982) to make the Observatory part of the Museum of Applied Arts and Sciences, effectively closing it as a research institution. Another trigger was the letter written in the previous year by the chair of the Observatory's Board of Visitors strongly urging moving the Observatory's main telescope to Siding Spring and (over?) stressing the problems of light pollution at its current location.

By 1982 all of the approximately 1500 plates of the new catalogue had been taken, but only 1/3 of those had been measured. During the next 12 months the two "young" astronomers that had been working at the Observatory, David King and the author, managed to convert these measured plates into the Sydney Southern Star Catalogue, published in the Journal and Proceedings of the Royal Society of NSW and still available online through the website of the Strasbourg Astronomical Observatory. By coincidence the extent of the published catalogue exactly matches the Sydney Zone of the Astrographic Catalogue.

Subsequently, the emphasis of the Observatory switched to public education. It has established an important role in astronomical education in Sydney with about 150,000 visitors a year. The visitors come during the day to look at exhibitions and come at night to look through the telescopes - through the historic 29-cm lens telescope dating from 1874 in the south dome and a modern computer-controlled 40-cm Schmidt-Cassegrain reflector in the north dome. For school students there are special educational sessions during term times and there are numerous children's activities during school holidays.

There was much activity at the Observatory in the period leading up to the 150th anniversary. The grounds were newly landscaped, the 1874 refractor was restored and repainted, the historic Signal Station next door to the Observatory was carefully restored by the NSW Department of Commerce and one of the giant flag staffs that used to flank the Signal Station was reinstalled with the help of the Bruce and Joy Reid Foundation. The 30-metre tall flagstaff daily flies not only the Australian flag, but, probably uniquely in the world, specially-designed astronomical flags indicating the phase of the Moon, the planets visible and the most prominent constellations.

Sydney Observatory has changed greatly in the 150 years since Reverend Scott first dropped the time ball. Though the old Observatory has many scientific achievements to its credit during that long period, arguably its greatest achievements are that it has survived, it still has an astronomical role, it has still an important role in modern Sydney and it can look forward to the next 150 years.

Sydney Observatory at its 150th anniversary.
Picture Sotha Boorn, courtesy Powerhouse Museum

OPAL – a Flagship for Australian Physics

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Abstract
Australian science is entering a new "golden age", with the recent startup of bright new neutron and photon sources in Sydney and Melbourne, in 2006 and 2007 respectively. The OPAL reactor and the Australian Synchrotron can be considered the greatest single investment in scientific infrastructure in Australia's history. They will essentially be "sister" facilities, with a common open user ethos, and a vision to play a major role in international science. Fuel was loaded into the reactor in August 2006, and full power (20MW) achieved in November 2006. The first three instruments in operation are a high-resolution powder diffractometer (for materials discovery), high-intensity powder diffractometer (for kinetic studies) and a strain scanner (for mechanical engineering and industrial applications). These will be closely followed by four more instruments with broad application in nanoscience, condensed-matter physics and other scientific disciplines. Instrument performance is competitive with the best research-reactor facilities anywhere. To date there is committed funding for 9 instruments, with a capacity to install a total of ~18 beamlines.

1. Introduction
On 20th April 2007, the Prime Minister of Australia formally opened the new OPAL Reactor in Sydney. This followed first criticality on 12th August 2006 and first operation at full power (20MW) on 3rd November 2006. The first neutron diffraction pattern was taken on 18th December 2006, on the ECHIDNA high-resolution powder diffractometer, and the second of our instruments took its first data on 24th February 2007. User proposals were called for on both of these instruments, on 30th March 2007. The first research paper from OPAL was published in mid-2007.

The OPAL reactor itself is a multi-purpose facility and has excellent irradiation facilities for radiopharmaceuticals, neutron activation analysis, and transmutation doping of Silicon, in addition to the neutron beam facility.

"We made the choice to name our instruments after Australian fauna"

There is good separation between the neutron-beam user facility and reactor operations and we envisage a relatively open access regime, like that at NIST in the USA or the ILL in Grenoble, France. OPAL is a light-water-cooled swimming-pool reactor, with a 4x4 array of low-enriched-uranium MTR fuel elements. The core is surrounded by a heavy-water reflector, which is contained within a complicated zircalloy weldment. Within the reflector, there is a 20-litre liquid-deuterium thermo-syphon cold neutron source, and a position for a future graphite hot-neutron source. These sources provide Maxwell-Boltzmann distributions of neutron energies characteristic of their operating temperatures, 20K and 2000°C respectively, rather than the 300K characteristic temperature of the main heavy-water reflector. The cold-neutron source has been operating reliably at full reactor power since 4th April 2007. The reactor itself is designed to make heavy use of neutron guides for both cold and thermal neutrons, with initial supermirror coatings with critical angles for reflection up to m=3 (where m=1 refers to natural nickel, the best of the solid elements). Neutron guides function rather like optical fibres, with total reflection confining the neutron beam to within the guide. Our guides are rectangular in cross-section with the dimensions given in Table 1. Supermirrors are continuously graded Bragg mirrors with alternating layers of Ni and Ti deposited on float glass, to give broadband reflectivity. Table 1 lists the predicted performance in terms of flux and spectra in both thermal- and cold-neutron beams. Initial indications are that the measured thermal fluxes are ~15% above these values, which may be due to better guide coatings and/or alignment than assumed

Figure 1. Aerial View of the OPAL Reactor (upper left), the Neutron Guide Hall (center top), Visitors Centre (center bottom) and the Bragg Institute Building (lower right).

Beam	Planned Neutron Beam Instruments	Guide characteristics	Calc.* flux (n/cm²/sec)	Peak l (Å)
TG1	• WOMBAT High-Intensity Powder Diffractometer [6] • ECHIDNA High-Resolution Powder Diffractometer [7]	• 300mm x 50 mm • m=3 supermirrors • radius of curvature 4.5km	~2.4 x 10^9	1.3
TG2	(initially only to reactor face)	• 150mm x 50 mm • m=3 supermirrors • radius of curvature 4.5km		
TG3	• KOWARI Residual-Stress Diffractometer [8] • KOALA Thermal-neutron Quasi-Laue Diffractometer			
TG4	• TAIPAN Thermal-neutron 3-Axis Spectrometer [9]	100mm → 50 mm m=3 supermirrors sides 140mm →180mm non-reflecting top & bottom	~1.6 x 10^{10}	1.1
CG1	• PELICAN Time-of-flight Polarisation-Analysis Spectrometer • QUOKKA Small-Angle Neutron Scattering instrument [10]	• 200mm x 50 mm • m=3 supermirror coating top and bottom and m=2 supermirror coating on sides • radius of curvature 1.3km	~5.7 x 10^9	3.9
CG2	(initially only to reactor face)			
CG3	• PLATYPUS Time-of-Flight Neutron Reflectometer [11] • Ultra Small Angle Neutron Scattering [12]			
CG4	• SIKA cold-neutron 3-Axis Spectrometer⁺	• 200 mm height, 100 mm → 50 mm width, m=3 supermirrors	~1.3 x 10^{10}	3.3
HB1 & HB2	Undecided	• 200mm x 50 mm • collimators only (no reflecting coatings)	~3 x 10^{10}	1.1

Table 1: Summary of the neutron beam lines at OPAL, along with instrument locations. The solid circles show instruments in our initial set of 10 leading-edge instruments.
* ANSTO's calculated flux figure;
⁺ funded by National Science Council, Taipei.

Figure 2. Views of our 35 x 65 m^2 guide hall: left – artists impression with seven instruments shown on both thermal guides and cold guides; right – photograph as of September 2004, prior to guide and instrument installation.

in our original modeling. Previous papers on the OPAL Reactor and its instruments can be found in Refs. 1-11.

We made the choice to name our instruments after Australian fauna [13], and the full list of instruments is given in Table 1. Further details, along with the first data, can be found in Section 3 below. There are 8 initial instruments funded by the Australian government, a 9th (cold 3-axis spectrometer) funded by the National Science Council of Taiwan, and a 10th (ultra small angle neutron scattering) in the conceptual-design stage. The two 3-axis spectrometers are on the large reactor face holes (TG4 and CG4), and all other instruments are on guides in the guide hall. The present building configuration can handle an eventual complement of around 18 instruments. Our largest guide is 30-cm high, to our knowledge the largest guide put into any reactor in the world. The guide hall is 35 x 65 m^2 in area with a single 20-tonne bridge crane serving the whole floor area. There are individual 1-tonne jib cranes for each instrument position. Along the sides of the guide hall, there is excellent provision of support labs and instrument cabins. The facility was designed from the outset to accommodate a second similar guide hall, and this could well be added after 10 or 15 years of operation if there is sufficient demand and funding.

"The reactor was taken critical on 12 August 2006 with fourteen fuel assemblies loaded as predicted."

2. Reactor design, commissioning and early operation

The OPAL reactor is designed to remain safe during normal operation, after shutdown from power operation and in response to many postulated initiating events that may take the reactor into an abnormal state. Those events were analysed and incorporated into a rigorous safety case that formed part of the licence application for operation of the facility. Key design features that enhance safety include two completely independent and diverse protection systems and reactor containment.

Reactor commissioning was divided into three stages (A, B and C). In Stage A, cold commissioning tests, including full system tests with dummy fuel assemblies in the reactor core, were undertaken. An important component of the testing was to verify plant function and procedures for reactor transitions, for example from Shutdown state to Power state. In Stage B1 hot commissioning commenced where fuel assemblies containing uranium were progressively loaded into the core. Nine of the sixteen full core fuel assemblies were loaded initially and for each subsequent fuel assembly loaded the control rods were withdrawn and the sub-critical multiplication factor was determined. The reactor was taken critical on 12 August 2006 with fourteen fuel assemblies loaded as predicted. In Stage B2 hot commissioning, the full core was loaded and 22 low-power tests (up to 400kW) were carried out over 25 days to measure key nuclear and reactivity parameters of the core. The calculated power peaking factor (2.42) was checked by gold wire irradiations and good agreement obtained. Other key design parameters that were measured are shown in the table.

Variable	Value	Design Criteria
Isothermal Feedback Coefficient	-15.74 [pcm/°C]	< 0
Void Feedback Coefficient	-222.89 [pcm/% Void]	< 0
Power Feedback Coefficient	-0.74 [pcm/kW]	< 0
Power Peaking Factor	2.48 [-]	< 3
1st Shutdown System Margin(a)	10067 [pcm]	> 3000
1st Shutdown System Margin (Single Failure)	6276 [pcm]	> 1000
2nd Shutdown System Margin(b)	10461 [pcm]	> 1000
Safety Factor of Reactivity	2.01 [-]	> 1.5
1st Shutdown System Margin (at 0.5 sec)	9966 [pcm]	> 2000
SSS Reactivity worth in 15 sec	8488 [pcm]	> 3000
Control Rod Plate Reactivity Insertion Rate	19.6 [pcm/sec]	< 20

Table 2: Stage B2 Design-Verification results
(a) 1st Shutdown System
(Insert all 5 control plates)
(b) 2nd Shutdown System
(Dump half the heavy water from the reflector vessel

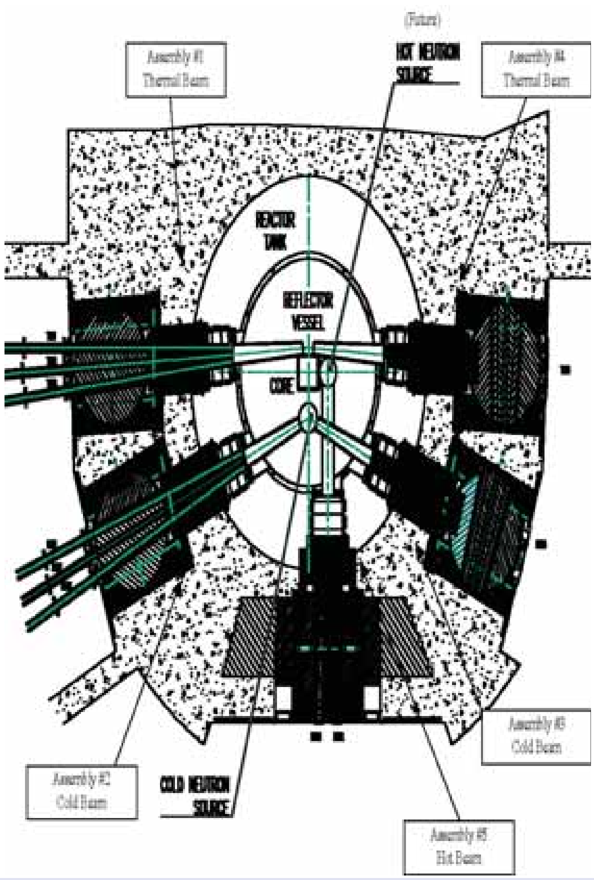

Figure 3. Plan view of the core layout for the OPAL Reactor, showing the core (square at centre), thermal, cold and (future) hot neutron source positions, guide bundles emanating to the left and cylindrical shutter assemblies. The shutters for the (future) hot beams rotate about a horizontal axis, while the others rotate within the horizontal plane. The guide hall is to the left in this drawing.

All of them complied with the design criteria. In Stage C commissioning the reactor power was increased in steps up to full operational power of 20 MW.

Early operation of the reactor concentrated on proving that the irradiation and beam facilities were functioning and the reactor was capable of being operated for long periods at full power. Two significant issues arose in this period. The first was identification of a light water leak from the reactor pool into the reflector vessel, affecting the isotopic purity of the heavy water. The source of the leak was determined to be a non-structural seal weld associated with the neutron beam tube connections to the vessel, but the reactor continues to be operated at full power whilst different repair strategies are investigated.

The second issue identified in July 2007, during a routine video camera inspection of the core, involved the observation that some fuel assemblies had displaced fuel plates. The reactor was shutdown and ultimately restarted again in May 2008 following a fuel re-design and approval from the nuclear regulator that the fuel plate displacement was unlikely to occur again with the new type of fuel in use.

3. Neutron Beam Instruments at OPAL

The detailed decision making of choice, scope and conceptual design of the instruments took place in conjunction with the Australian user community, via both workshops and ongoing Instrument Advisory Teams. The thinking on the technical issues and technology choices is given below. The performance of the reactor, its neutron sources and neutron guide systems was modelled with Monte-Carlo simulations and optimised to deliver the highest possible neutron flux to the neutron beam instruments. Each instrument conceptual design included detailed Monte-Carlo simulation of instrument performance against overseas benchmarks to provide early forecasts of competitiveness. The detailed engineering and procurement of instruments is being undertaken with the support of an integrated team of in-house engineers, draftsmen and technicians.

ECHIDNA: High-Resolution Powder Diffractometer

This instrument is directed at "materials discovery", as in important new electronic materials like superconductors, of minerals and so on. Our goal was to have a high-resolution powder diffraction capability with d-spacing resolution at least as good as that of the best current reactor instrument in the world, D2B at the Institut Laue Langevin in Grenoble ($[\Delta d/d]_{min} = 0.0006$). The machine is on an m = 3 30-cm high thermal guide, downstream of the high-intensity powder diffractometer. The first diffraction pattern was recorded on 18 December 2006, with a fully refined pattern by March 2007. The first refereed article [14] from ECHIDNA was submitted on 22nd August 2007 (see Fig. 4).

WOMBAT: High-Intensity Powder Diffractometer

Our goal has been to have a high-intensity powder diffraction capability that will enable time-resolved kinetics studies, or structure refinements on samples as small as 10 mg. This will involve a capability similar to that available on the D20 high-intensity powder diffractometer at the ILL. The instrument

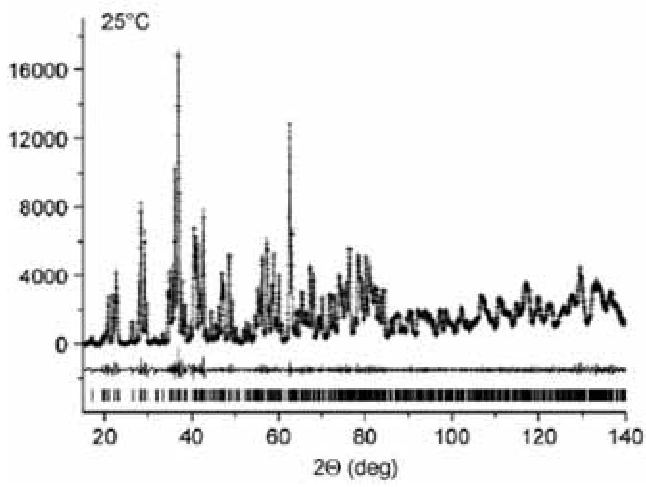

Figure 4. A high-resolution powder diffraction pattern taken on $SrAl_2O_4$, a material used in luminescent materials and with potential application in solid-oxide fuel-cell membranes, on the ECHIDNA powder diffractometer. The data and Rietveld-refinement fit are at the top, with residuals and individual Bragg-reflection markers below (from Ref. 14).

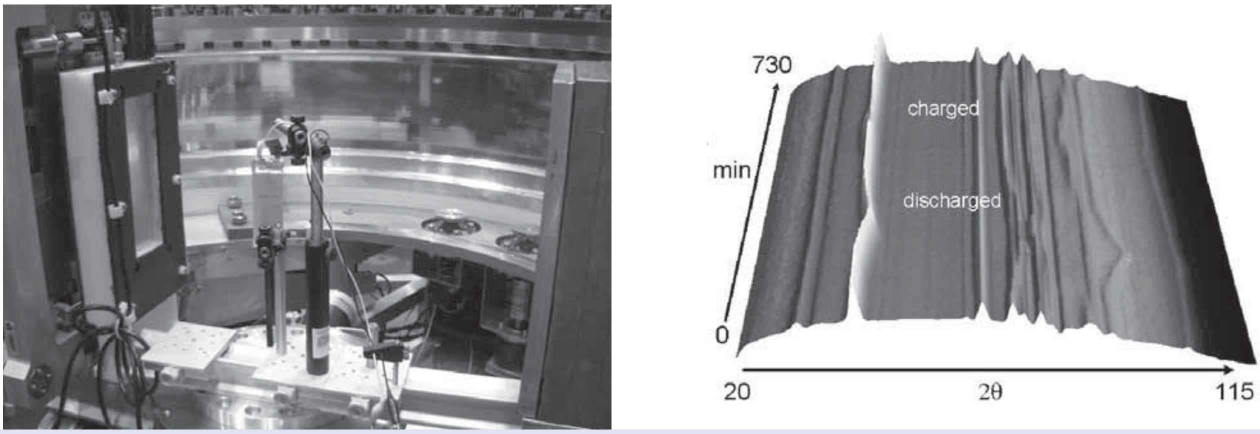

Figure 5. A time-resolved powder diffraction pattern taken on a commercial mobile phone battery during a complete charge-discharge cycle, on the WOMBAT high-intensity powder diffractometer. The right-hand panel shows the data, with intensity plotted against scattering angle and time, revealing both lattice parameter changes as the graphite intercalates and de-intercalates lithium and the growth of another phase (LiC_6). The left-hand panel shows the battery mounted on the sample stage, with neutrons entering from the left, the beamstop to the right and the curved aluminium window of the detector in the background. (courtesy of Andrew Studer, Margaret Elcombe and Vanessa Peterson).

uses a large 2-dimensional multi-wire position-sensitive electronic detector, built specially for us by Brookhaven National Laboratory. So far, in addition to calibration standards like alumina, we have: (1) taken publishable data on a 20-mg sample of geophysical interest, produced in a diamond-anvil cell; (2) demonstrated that we can collect a full pattern on a steel sample in 20 ms, in preparation for kinetics experiments at high temperature; (3) taken data on a mobile-phone battery as a function of charging and discharging; and (4) measured diffuse scattering from a single crystal of fast-ion conductor, using the 2-D detector (see Fig. 5).

KOWARI: Strain Scanner

World-wide, demand for strain scanning of engineering components using neutrons is on the increase and we see an excellent opportunity in Australia for this activity together with the major research institutes, like CSIRO, AMIRA, DSTO and the Australian universities. The residual-stress diffractometer will be equipped with a modern double-

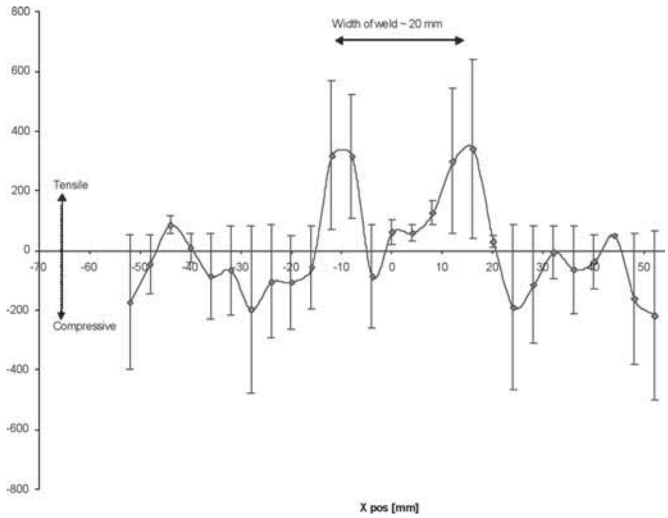

Figure 6. Our first full strain scan on KOWARI, across a weld in steel, using a gauge volume of 2 x 2 x 20 mm^3 (courtesy of Oliver Kirstein and Vladimir Luzin).

focussing monochromator to achieve small gauge-volumes, which is particularly important for the study of turbine blades, railway heads or new materials/alloys containing aluminium, zirconium or magnesium. Texture patterns can be obtained by using a 2-dimensional position-sensitive detector, and a 100 kN load frame offers the possibility of doing in-situ fatigue measurements. At the time of writing, we had measured the strain profile across a weld in steel, in addition to taking the first calibration scans (see Fig. 6).

"...the new OPAL Reactor is on track to have a full user program operating in 2008..."

KOALA: Thermal Quasi-Laue Diffractometer

We have installed a pink-beam quasi-Laue diffractometer, similar in design to the VIVALDI diffractometer at ILL, on a thermal end-guide position. The main focus will be on small-molecule chemical crystallography, particularly with relation to hydrogen bonding problems. KOALA should allow studies of crystals ten times smaller than has been the norm previously. At the time of writing, two calibration samples had been run on KOALA, with one data image from the second shown in Fig. 7.

PLATYPUS: Time-of-Flight Vertical Scattering Plane Reflectometer

Australia has a strong user community in soft matter, polymers and colloids, and there is already clear demand for a neutron reflectometer capable of studying liquid-air interfaces. To this end we have constructed a vertical-scattering-plane time-of-flight reflectometer, on an end-guide position. The machine will also have a polarised-beam/polarisation-analysis option. At the time of writing, we had just observed neutrons reflected from a solid surface in the 2-D position-sensitive detector (see Fig. 8).

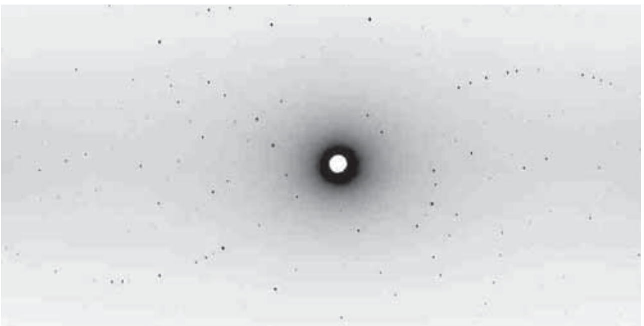

Figure 7. A Laue diffraction pattern from K_2MnO_4, taken in June 2008, as part of commissioning tests on KOALA (courtesy of Ross Piltz and Alison Edwards).

QUOKKA: Small-Angle Neutron Scattering
Our goal was to have a small-angle neutron scattering capability at least as good as the current best in the world. To us, this means a 40-m pinhole geometry machine (20 + 20m), with at least one detector of area $1m^2$. We intend to use focussing refractive lenses, to reach smaller Q_{min} values (<0.0008Å-1), and provision will be made for the use of polarised neutrons and polarisation analysis. In many ways the back end of the instrument is very similar to D22 at the ILL, while the front end is more like the implementation at NIST. It features a carousel for 4 different guide/aperture/optical element devices.

TAIPAN: Thermal 3-Axis Spectrometer
Although condensed-matter physics has been somewhat neglected in Australia, in contrast to other developed countries, we have built a state-of-the-art thermal-beam 3-axis spectrometer. It is projected to have the 2^{nd} highest incident flux in the world, and initial indications are that it will attract leading groups from North America and Asia, in addition to the domestic demand. TAIPAN is placed on a thermal beam at the reactor face, using a double-focussing monochromator. There will be provision for a polarised incident beam and polarisation analysis.

PELICAN: Time-of-Flight Polarisation-Analysis Spectrometer
Largely through the efforts of Trevor Hicks's group at Monash University, Australia has been a pioneer in the use of polarised neutrons for the study of disordered magnetic materials like spin glasses. This tradition will be continued, and extended into soft matter and chemistry, via a state-of-the-art time-of-flight spectrometer along similar lines to the IN6 spectrometer at the ILL in Grenoble, but designed from the beginning to work with polarised neutrons, and to do wide-angle polarisation analysis. The incident beam will be polarised using supermirrors, while the scattered beam will be analysed using laser-pumped polarised ^3He gas.

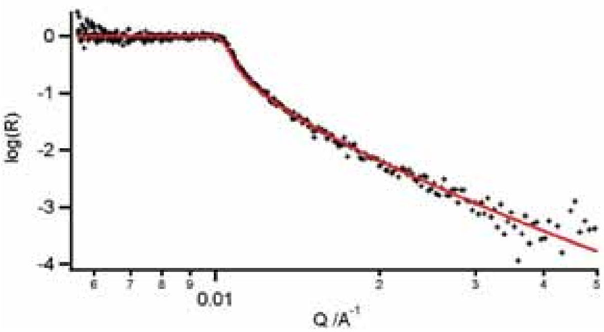

Figure 8. The first reflectivity curve from the PLATYPUS reflectometer, showing the simple Fresnel reflectivity profile from an air-silicon interface (courtesy of Andrew Nelson, Michael James and Frank Klose).

Ultra Small Angle Neutron Scattering
We have decided to pursue so-called Ultra Small Angle Neutron Scattering or USANS, either via the classical interferometric Bonse-Hart method, or via the spin-echo method. The Bonse-Hart method uses multiple perfect silicon crystals as collimators before and after the sample, while the spin-echo uses a polarised neutron beam, in conjunction with magnetic fields, to precess the neutron polarisation before and after scattering, and pick up the angle of scattering via changes in the field integral along the neutron's whole trajectory. This will allow studies of objects in the micron size range, extending the range already covered by our pinhole SANS machine QUOKKA. The major interest in Australia is in porous sedimentary rocks of interest to the oil and gas industry, cements and polymers.

Computing Infrastructure
The instruments have their own common local-area network, segregated from the main ANSTO network, in order to provide better user access to the experiments and their data, better access from outside ANSTO for our instrument scientists and for off-site diagnosis of problems with the instruments. We have a common data-acquisition system for all instruments that will be flexible enough to accommodate future growth and developments. We will adopt the NeXus standard for raw data files, and for archiving.

3. Conclusion
In conclusion, the new OPAL Reactor is on track to have a full user program operating in 2008 with the 7 initial instruments. Two further instruments are funded and under design, with conceptual design work under way on a tenth. All instruments, with the exception of two high-performance triple-axis spectrometers at the reactor face, are on high-m guides in the guide hall. The 20-litre liquid-D_2 cold source is working reliably, and at the time of writing both powder diffractometers are running well and taking data. Proposals have been called for, and initial indications are, that demand within Australia and South-East Asia is strong. Indeed, some of the instruments have performance high enough to attract users from North America, Europe and Eastern Asia.

The OPAL reactor, buildings, cold-source and guides were completed for less than A$400M in current dollars, including A$35M for the initial suite of instruments. It will operate 340 days per year in cycles of 33 days on, and 2 days off. Access for experiments will be free for non-proprietary research, which will be reviewed electronically, as at NIST, with oversight by a Program Advisory Committee, which met for the first time in May 2007. Users from around the world are welcome.

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8. All feature articles should be submitted to the Editor-in-Chief and Editorial Board for approval. Submit articles to Brian James at: B.James@physics.usyd.edu.au

QED - a play about Richard Feynman

In June a group of eighty odd physicists, communicators and hangers on attended the Peter Parnell play QED about Richard Feynman's life and times. The evening, organised by the Australian Science Communicators and the University of Sydney's School of Physics, included an introduction to QED from Dr Steve Bartlett from the Quantum Computing Centre over dinner, and a chat with the actors after the show.

Phil Dooley reports...

"If a hundred photons go through a window, four of them bounce back" says Richard Feynman in Peter Parnell's play, QED. "How does a photon decide whether to go through or bounce back?! Me, I can't decide anything!!"

"I couldn't act that cold and still engage an audience for two and a half hours..."

The play is set in Feynman's office, and offers a sample of his life, one Saturday afternoon. In the intimate Ensemble theatre in Sydney's Kirribilli – only 6 rows deep – we all feel that we're right there in the office, as Feynman, played by Henri Szeps takes us on a rollicking stream of consciousness ride through his thoughts and memories, pulling out stamps from Tuva, Senate papers and old letters, interspersed with explanations on the blackboard, bongo playing, constant phone calls from doctors and knocks on the door from a very persistent female graduate student (played by Ivy Mak). "Women!?" He exclaims, after she finally leaves, "I gotta be real careful, cos I looove women!"

In a more pensive counterpoint to his flirtatious encounters, Feynman fields calls from his doctors about his advancing cancer. They want to operate the following Monday, despite a very low chance of success. Contemplating the prospect of death, Feynman, for all his perception in the world of Physics, doesn't offer much in the way of philosophical insight, other than to lambaste the make-believe faith of churchgoers.

Meeting with the audience after the show Henri Szeps explains: "He was a real cold bastard, didn't let his emotions out. A fantastic performer and lecturer, but kept his emotions completely in check." Szeps points out the only slight flaw in his own performance, "I couldn't act that cold and still engage an audience for two and a half hours, so I think a bit too much Henri Szeps comes through."

Perhaps true; certainly Henri Szeps' character is very likeable, perhaps at odds with the famously irascible real-life Feynman. But this is splitting hairs, as Szeps has certainly done his homework, listening to hours of Feynman lectures to perfect the accent. Szeps also went back to his Alma Mater, The University of Sydney, to bone up on quantum electrodynamics with an old classmate, Associate Professor Bob Hewitt, who went on to become the Head of School at Physics during the nineties. Szeps is also quick to point out "booboos" in the script: "It was commissioned by Alan Alda, and I think it was written in a hurry." Szeps has taken the liberty of changing physical and medical facts from the script and replacing blackboard diagrams with those Feynman actually used in his lectures.

Szeps' adjustments to the script ring true, agreeing with the pre-show intro to QED given to us over dinner by Dr Steve Bartlett, from the Centre for Quantum Computing at the University of Sydney's School of Physics. Faced with an audience of 80 odd ranging from professors down to art students, Bartlett's elegant analogies of electrons with phase stopwatches, and conducting a census to explain integration problems, left us all feeling we'd gained a little mastery over the subject.

Adding that to the captivating performance by Henri Szeps of the delightful mix of rigorous physics and tangential sidetracks of Parnell's play and we all went home feeling in a small way that we'd really taken part in Feynman's life.

Some of group of eighty odd physicists, communicators and "hangers on" who enjoyed themselves at the Peter Parnell play QED about Richard Feynman's life and times

Imaging the environmental ultraviolet

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Abstract
A technique has been developed to visually represent measured environmental ultraviolet radiation using a digital photograph and measurements of the UV and visible light intensity. The method involves the use of a personal pocket UV meter, an optional lux meter and a simple image processing technique to present visual images that are weighted to the ambient ultraviolet, providing images that highlight regions of high ultraviolet intensity that can be compared with a visible photograph. The technique described, provides a method students can follow to better develop an understanding of the potentially harmful ultraviolet irradiance with respect to visible daylight, indicating that the ambient ultraviolet and visible environment are not directly related, with ultraviolet intensity being dependent on many different factors and not the visual brightness of the location alone.

Introduction
The ultraviolet radiation (UV) incident at the Earth's surface that has the potential to cause harm to humans falls within the range of 280 to 400 nm. Visible radiation incident at the Earth's surface lies within the range of 400 to 700 nm, with peak human visual acuity and colour sensitivity varying according to brightness and individual perception. Peak visual sensitivity can be taken in daylight to be in the green region and quoted tentatively at 555 nm (CIE 1931) although it should be noted that there are different human eye responses to visible radiation (Schanda et al 2002, Sharpe et al 2005). Sunlight incident at the Earth's surface does not have the same irradiance over all wavelengths and is dependent upon absorption at certain wavelengths by various chemical elements in both the Sun's and Earth's atmosphere. Furthermore, scattering and absorption in the Earth's atmosphere varies with wavelength over the continuum. Oxygen absorbs almost completely all UV radiation below 280 nm, with the absorption of UV light above 280 nm being moderated by stratospheric ozone (O_3). Atmospheric Rayleigh scattering plays a major role in the intensity of the radiation received from the sky, with the shortest wavelengths being scattered more prominently than longer wavelengths with the degree of scatter defined proportionately:

$$\propto \frac{1}{\lambda^4} \tag{1}$$

For visible light, the sky appears blue due to increased scattering of shorter wavelengths, likewise in the shorter ultraviolet range the degree of scatter is greater than in the visible. Typically, depending on the position of the sun, scattered (or diffuse) skylight makes up about half of the total received UV radiation incident at the Earth's surface, with the remainder coming from direct sunlight. Measurements of the total received UV and visible light therefore contain both a direct (solar beam) and diffuse (skylight) component. Measurements made on a horizontal plane, take both the direct and diffuse components into account. Such measurements are referred to as Global measurements. For the activity presented here, global measurements of UV and visible light are made with sensors held in a horizontal position. The sensors used were an Edison personal pocket UV meter and a lux meter. Both meters are available commercially from electronics suppliers.

Figure 1. Year 11 Hervey Bay State High School Students, Natalie Marsh, Brittney MacDougall, David McKie, and Samantha Dos-Santos photograph and measure global UV and visible light intensity using a personal pocket UV meter and a lux meter.

Measurements of UV or visible light radiation at the Earth's surface depend on the local environment. Reflections and absorption by various surface objects can reduce or enhance the measured surface radiation and affect the rate at which humans sunburn. Due to variation in absorption, reflection and scatter in both the atmosphere and at the surface, visual perception of brightness has no direct relationship with the received UV. Likewise the feeling of heat due to incoming solar infrared radiation has no bearing on the received short wavelength UV. For these reasons, humans have difficulty in perceiving the UV environment and have no internal mechanism that can be relied upon to determine excessive UV exposure beyond noticing a sunburn which occurs post-exposure.

Measurements made by instruments calibrated to record radiation in the UV waveband are the only reliable way to determine the UV intensity in any given location. Measurements made by the Edison personal pocket UV meter employed for this activity were made in the sunburn weighted UV in units of mW/m^2 to replicate the response of the human sunburn (or erythema) reaction to incident global UV (CIE 1987). Such a measurement is known as an Erythemal Irradiance, and measures the erythemally effective UV incident over a square meter. The received erythemally effective energy can be determined:

$$\frac{mJ}{m^2} = \frac{mW \times s}{m^2} \tag{2}$$

A Standard Erythema Dose (SED) is further defined as 100 J/m^2 of erythemally effective UV (Diffey et al 1997), where 2 SED is approximately the erythemally effective UV required to cause a mild sunburn in fair skin 8 to 24 hours following the UV exposure (Diffey 1992). Thus the measured unit of mW/m^2 can also be expressed as:

$$\frac{mJ}{m^2} \times \frac{1}{s} = \frac{mSED}{s} \div 100 \qquad (3)$$

This unit conversion is useful and has been employed throughout this activity as measurements are given as the equivalent number of SEDs received per second allowing for a simple calculation to determine the length of time required to receive 1 SED by finding the reciprocal of the determined SED / s. That is, to determine the time to receive 1 SED based on any given global UV measurement made with the personal pocket UV meter:

1. Measure UV irradiance in mW/m² (includes automatic erythema weighting)
2. Convert to mSED/s by dividing by 100
3. Convert to SED/s by dividing by 1000
4. Invert the result to determine the time in seconds required to receive 1 SED

The units used for the measurement of UV irradiance, however are not the same as those used to measure visible light intensity. The reason is due to the measurement of visible light intensity being weighted to the human eye response (photometric response), such that measurements of visible light intensity provide a reasonable estimate of light intensity as seen by the human eye. The unit of visible light intensity is the lux, where 1 lux is the equivalent of 1 lumen / m² of visible light intensity.

Figure 2. Light intensity measured at each of the approximate middle top, bottom, left and right edges of the photograph frame. The image is shown with respect to the global visible intensity and in this case appears very dark.

Comparisons between UV (radiometric) measurements and visible (photometric) measurements are difficult and cannot be made directly. The two are generally considered separately but are provided here to determine variation in image brightness in the two wavebands. There is no direct relationship that can be found between the two measurements of visible and UV radiation intensity and for this reason, the use of UV meters is required to determine estimates of the local ambient UV. This is an important outcome that students should gain from the activity.

Specifically the aims of this paper are to:

1. Provide students with experience in measuring visible and UV light intensity;
2. Develop an understanding of simple image processing techniques;
3. Compare visible and UV radiation intensity and;
4. Draw conclusions about the local visible and UV environments.

Method

Photographs, being digital or otherwise are made with visible light and cannot easily be taken with standard cameras in the UV light range. The method presented here uses both measurements of the global visible and global UV intensity to convert standard visible images into UV image estimates. Such a technique is valuable in determining regions of high UV intensity that may not be immediately obvious in visible light. Further, comparisons between visible and UV images highlight variations in the nature of light received at the Earth's surface and emphasise the narrow range of the human eye response.

Visible measurements will be presented here, although they are not required for the successful completion of the activity and may be ignored if the only purpose is to produce UV images. It should also be noted that although a simple image processing technique was applied to digital photographs for this activity, similar results can be achieved using a photograph and overhead transparency film, making the activity easily accessible to large classes that do not have ready access to computers.

Selecting the study site and initial measurements

The activity requires students to photograph a site of interest. This may be a typical playground setting, or an image taken near buildings. Heavily shaded sites should be avoided, as UV measurements may not register. The activity is best suited to groups of three or four students, depending on whether or not visible lux measurements are required. Students will need:

1. A personal UV meter
2. A lux meter (optional)
3. A digital camera
4. Access to computer (or alternatively felt pens and transparency film)
5. Hat and sunscreen protection

Figure 1 shows a group of high school students taking a photograph of a site of interest while on excursion. A standard digital camera with a set infinite focal depth was used in automatic shot mode. Note that while the photograph was being taken, global measurements of the visible and UV were also being recorded. For this activity, it is important to take all measurements within as short a time period as possible to eliminate variations that may be caused by changing cloud conditions. Global measurements should be taken so that the light sensitive areas of each recording instrument are orientated in a horizontal position and held as far from the body as possible to eliminate shadow and increase instrument sensitivity to the sky view at the location.

Processing the image

Following the initial measurements, both lux meter and UV meter readings were taken with instrument sensors oriented toward the approximate middle top, bottom, left and right

	1	2	3	4	5	6	7	8	9
A	102.6	102.6	102.6	102.6	***102.6***	102.6	102.6	102.6	102.6
B	94.0	93.9	93.9	93.8	93.8	93.7	93.7	93.6	93.6
C	85.3	85.2	85.1	85.0	85.0	84.9	84.8	84.7	84.6
D	76.7	76.5	76.4	76.3	76.1	76.0	75.9	75.7	75.6
E	***68.0***	67.8	67.7	67.5	67.3	67.1	67.0	66.8	***66.6***
F	56.5	56.3	56.2	56.1	56.0	55.8	55.7	55.6	55.4
G	45.0	44.9	44.8	44.7	44.6	44.5	44.4	44.3	44.3
H	33.4	33.4	33.3	33.3	33.3	33.2	33.2	33.1	33.1
I	21.9	21.9	21.9	21.9	***21.9***	21.9	21.9	21.9	21.9

Table 1a. Interpolated light intensity matrix for each numeric horizontal image position and alpha-numeric vertical image position based on the measurements in figure 2. The bold Italic numbers are actual measurements. The units of measurement are klx.

frame regions of the taken photograph. The sensors need to point toward the frame regions of the photograph and are not global measurements in this case. Typically frame measurements will be lower than the global measurements taken previously.

In some cases, frame measurements may be higher than the recorded global measurements. This may be due to changing atmospheric conditions or frame orientations being taken closer to the direct solar beam. This will not affect the results and such measurements should be accepted. Figure 2 shows the photograph taken in figure 1, with lux measurements taken oriented toward the photograph frame edges. Units are given in kilolux. For later comparison with the UV image the visible image brightness requires adjustment with respect to the global visible lux measurement. For the case shown, the maximum image brightness was recorded at 102.6 klx (image top) compared with a global measurement of 970 klx, therefore the image brightness was reduced by 89% to depict the scene relative to the global visible measurement and the image appears darker than the scene would have appeared originally. Image adjustment can be performed by adjusting the brightness setting using any digital image software. In the figure 2 image, the city skyline can just be made out. In some cases image brightness may need to be increased depending on the maximum image brightness with respect to the measured global visible intensity.

	1	2	3	4	5	6	7	8	9
A	11	11	11	11	***11***	11	11	11	11
B	10	10	10	10	10	10	10	10	10
C	9	9	9	9	9	9	9	9	9
D	8	8	8	8	8	8	8	8	8
E	***7***	7	7	7	7	7	7	7	***7***
F	6	6	6	6	6	6	6	6	6
G	5	5	5	5	5	5	5	5	5
H	3	3	3	3	3	3	3	3	3
I	2	2	2	2	***2***	2	2	2	2

Table 1b. Interpolated light intensity matrix expressed as a percentage of the measured global visible light intensity (970 klx) for the interpolated intensity estimates of table 1a.

The visible measurements recorded above provide an indication of the light intensity received by the camera when the picture was taken. The image was then divided into even areas or segments and the approximate light level given for each segment. Although only four measurements are provided here, additional measurements could be taken oriented within the photograph frame, to supplement the frame measurements and improve accuracy in subsequent segment averaging. For the data presented here, the image was divided into a 9 by 9 segment grid. Simpler grids could also be used. In table 1a, it was assumed that the light intensity would be the same across the entire top and bottom of the image, therefore these segments are all of the same value. The left and right frame edges were interpolated vertically. All inner segments were then interpolated horizontally from the left and right frame edge interpolations. The method of interpolation is left to individual teachers, with a simpler averaging technique being perhaps more beneficial to lower year levels and more complex techniques being suited to senior students. Obviously different results can be achieved for different

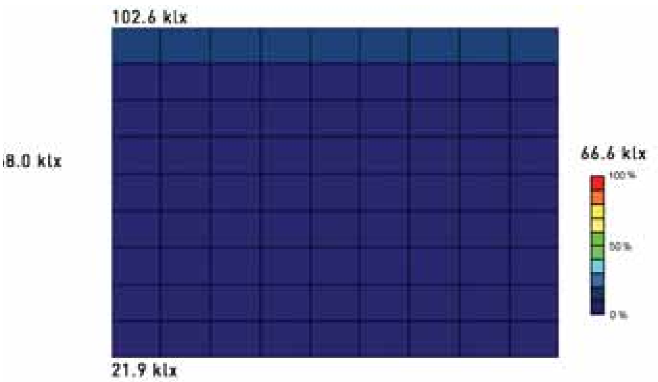

Figure 3. Visible intensity divided over a 9 by 9 element matrix. Colour levels are determined as a percentage of the global visible light intensity and are listed in table 1b. The coloured matrix indicates regions of greatest brightness relative to the received global intensity for the location photographed in figure 2 which for this case was below 11 %.

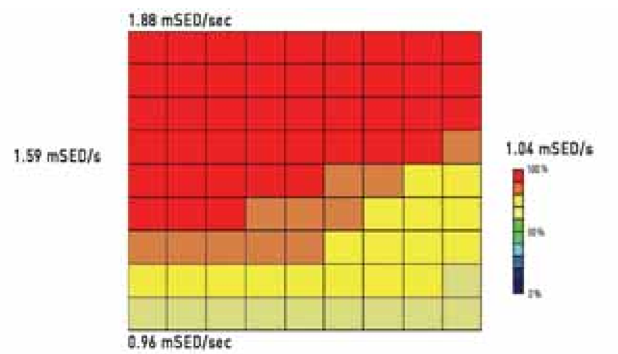

Figure 4. UV intensity for the location photographed in figure 2 divided over a 9 by 9 element matrix. Colour levels are determined as a percentage of the global UV measurement and are listed in table 2b.

	1	2	3	4	5	6	7	8	9
A	1.88	1.88	1.88	1.88	***1.88***	1.88	1.88	1.88	1.88
B	1.81	1.79	1.77	1.76	1.74	1.72	1.70	1.69	1.67
C	1.74	1.70	1.67	1.63	1.60	1.56	1.53	1.49	1.46
D	1.66	1.61	1.56	1.51	1.46	1.41	1.35	1.30	1.25
E	***1.59***	1.52	1.45	1.38	1.32	1.25	1.18	1.11	***1.04***
F	1.43	1.38	1.33	1.28	1.23	1.18	1.12	1.07	1.02
G	1.28	1.24	1.21	1.17	1.14	1.10	1.07	1.03	1.00
H	1.12	1.10	1.08	1.07	1.05	1.03	1.01	1.00	0.98
I	0.96	0.96	0.96	0.96	***0.96***	0.96	0.96	0.96	0.96

Table 2a. Interpolated UV intensity matrix for each numeric horizontal image position and alpha-numeric vertical image position based on measurements made by the personal pocket UV meter at the approximate middle top, bottom, left and right edges of the photograph frame of figure 2 (Units of measurement are mSED/s).

methods of interpolation. This may be useful to trial with different student groups for further discussion.

Image segments were then converted into percentages relative to the received global lux measurement. For the case shown the received global measurement was 970 klx. The light intensities in each interpolated segment of table 1a were then expressed as percentages of this measurement (table 1b).

Estimated segment percentages can be expressed as specific colours on the 9 by 9 (or appropriately selected) grid. Note that the grid selected should match the dimensions of the printed photograph, allowing for easy comparison with the image. This can be done using a prepared grid and computer or performed more simply using a segment grid drawn onto overhead transparency film. The grid was divided into 10 % colour levels. Depending on the desired detail, finer colour levels could be chosen. A coloured representation of the visible image brightness of the figure 2 image is shown in figure 3. Note that higher image brightness occurs along the top of the image as expected with decreasing brightness found toward the bottom of the photograph. This is to be expected as visible light intensity decreases with absorption by surface objects. For this case there is little variation in visible brightness as is evident in table 1b. The coloured analysis is however a good representation of the photograph's changing brightness levels with respect to the measured global visible intensity.

	1	2	3	4	5	6	7	8	9
A	131	131	131	131	***131***	131	131	131	131
B	126	125	124	123	122	120	119	118	117
C	121	119	117	114	112	109	107	105	102
D	116	113	109	105	102	98	95	91	87
E	***111***	106	102	97	92	87	82	78	***73***
F	100	97	93	89	86	82	79	75	71
G	89	87	84	82	80	77	75	72	70
H	78	77	76	75	73	72	71	70	69
I	67	67	67	67	***67***	67	67	67	67

Table 2b. Interpolated UV intensity matrix as a percentage of the measured global UV (1.43 mSED/s) and interpolated intensity estimates of table 2a.

The process is repeated for measurements made in the UV. Note that meter readings presented here were converted to mSED/s. This is a convenient unit to use as the time to receive an exposure of 1 SED is easily calculated. The time for an equivalent exposure of 1 SED for the location and time in figure 2 was calculated as follows:

Global measurement of UV: 143 mW/m² = 1.43 mSED/s

Global time for 1 SED = 1 / (1.43x10⁻³) = 699 s = 12 mins

Such a calculation is a suitable way of evaluating the UV in each photographed environment. Processed images were then compared with this value to show locations within the image of high UV intensity. To calculate the UV irradiances over the image, tables 2a and 2b were produced. Figure 4 is the estimated image segment percentages relative to the received global UV.

Using a similar process to that used to produce the figure 4, the visible photograph can be further divided into a 9 by 9 segment grid and the brightness of individual segments adjusted according to the percentage levels given in table 2b. Figure 5 represents the same location photographed in figure 2 as it might appear in UV light. Individual image segments were adjusted in brightness according to the percentage levels provided in table 2b using a simple cut and past method that can be replicated with standard photo-adjustment software.

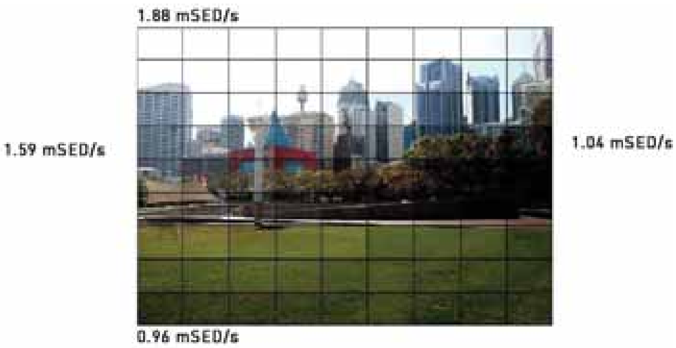

Figure 5. Estimated UV intensity imaged over a 9 by 9 element grid. The relative brightness of each element was determined by adjusting element brightness according to the percentages listed in table 2b. The image is an estimate of what the above location might look like in UV light and highlights regions of greatest UV intensity.

Discussion

The technique that has been presented here allows visible images to be converted with the use of real UV measurements into UV intensity estimates in a scene to provide a permanent visual record of the UV intensity. Comparisons between the UV intensity and visible image brightness can also be made. Images of the UV environment

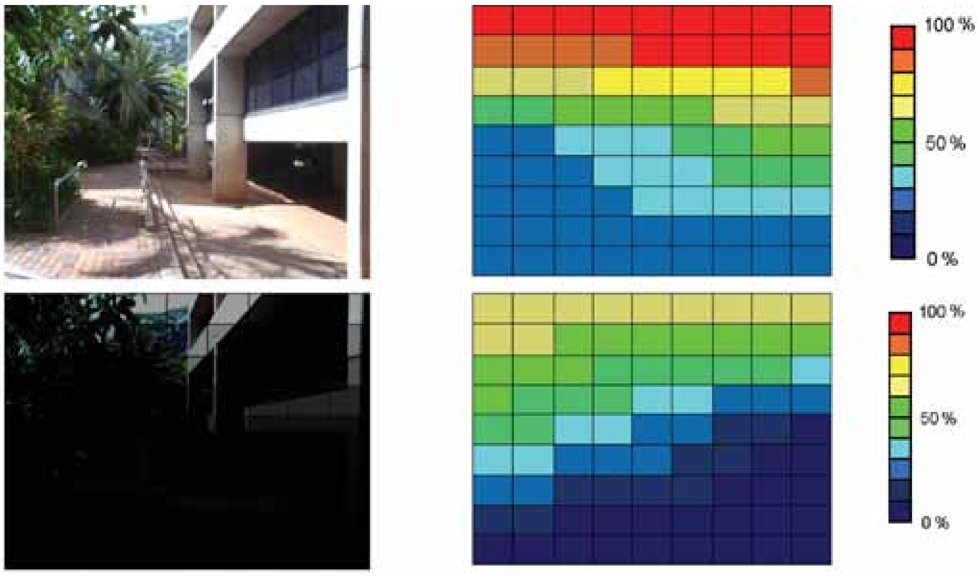

Figure 6. Near Building: Top left: visible photograph, top right: light intensity as a percentage of the measured global visible intensity (7.6 klx), bottom left: UV image, bottom right: UV intensity as a percentage of the measured global UV (1.06 mSED/s)

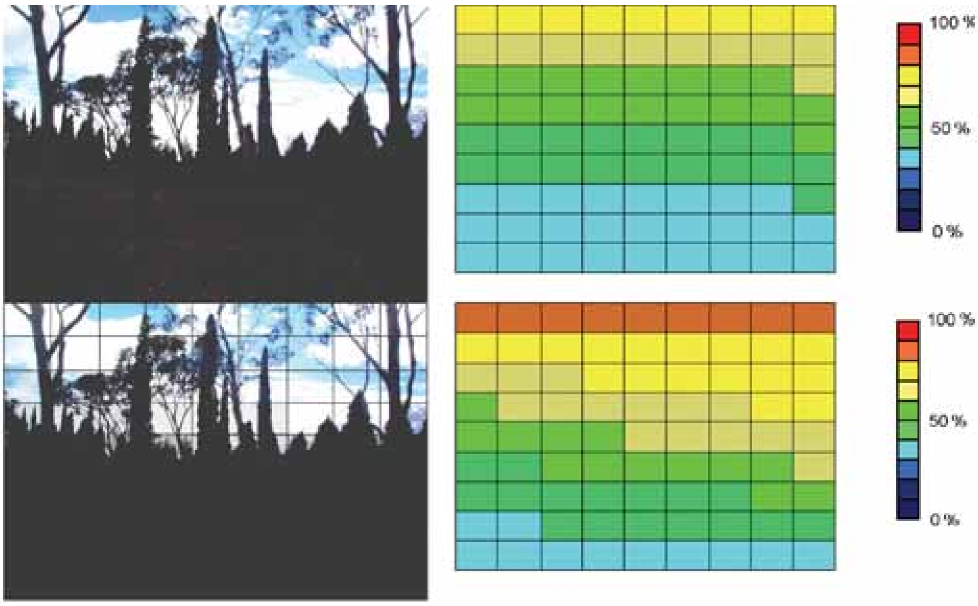

Figure 7. Tree shaded area: Top left: visible photograph, top right: light intensity as a percentage of the measured global visible intensity (33.2 klx), bottom left: UV image, bottom right: UV intensity as a percentage of the measured global UV (0.73 mSED/s)

are possible for a variety of different settings and locations. Figures 6 and 7 highlight variation in the visible and UV environment near buildings and in a lightly shaded environment. Both the figures show variation in the distribution of UV intensity compared with visible measurements. Regions of high UV intensity are indicated by higher brightness levels in photograph segments. For the cases shown here, UV intensity near the building site appears darker than the corresponding photographed visible image, while for the tree shade site, UV intensity is higher (brighter) than its respective visible image. However, comparing with global measurements of the UV, the environment photographed near the building recorded a higher UV intensity compared to the tree shade location. This indicates that image brightness is solely an indicator of the UV intensity at each specific location and should not be taken as an absolute indicator of the UV intensity in each environment for direct comparison. That is, UV images taken in different locations should not be directly compared to each other as images are shown relative to the respective global UV measurement recorded at each site.

Further detail of each environment could be examined by photographing each location in a series of photographs taken at the same site facing different directions. In this case, UV images could be directly compared with each other provided location images were shown relative to the same global UV measurement recorded at a particular site.

Conclusions

- A technique has been developed to present visible photographic images in UV light using measurements of UV and visible radiation.

- The activity enables students to evaluate both the visible and UV radiation intensity and draw conclusions about the local environment and its potential to cause harm due to excessive UV exposure.

- The activity provides students with an understanding of simple image processing techniques and has been designed to supplement the high school science curriculum studies of environmental and physical sciences and can further benefit students studying computational and statistical methods.

Acknowledgements

The authors would like to thank the staff and students of Hervey Bay State High school for their ongoing commitment to UV research.

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Alfio Parisi

Alfio Parisi is an associate professor in the Faculty of Sciences at the University of Southern Queensland. His research interests include developing techniques to better understand the solar ultraviolet environment that humans are exposed to during their normal daily activities.

Life After Physics

by Ken Simpson

I completed my undergraduate qualification at the University of Adelaide, undertaking a double major in theoretical and experimental physics. Having always had an interest in, and some aptitude for, mathematics I naturally gravitated towards more theoretical topics. This culminated in a very enjoyable Honours year (I can say that now!) in which I worked on a project on bound states of scalar quantum field theories under the supervision of Tony Williams. The project involved considerable amounts of numerical work in addition to the requisite analytical toil and helped me to develop strong computational skills which were to stand me in good stead later.

"At the end of my PhD I found myself in...a quandary as to my next move."

Following Honours, I stayed on in the Theoretical Physics group to do a PhD. At the time I had high hopes of forging a career as a theorist but after a few months doubts began to emerge about the viability of such an option in view of the difficulties I was hearing about from colleagues and from friends of colleagues. I briefly considered applying for industry positions at this stage but was reluctant to leave the warm bosom of academia just yet, and was also (to be quite frank) totally ignorant of the types of jobs that theoretically trained physicists might apply for. I instead decided to convert to a more experimental PhD project, the rationale being that it would help to develop skills complementary to those from my theoretical experience. This led to a project with Roger Clay and Bruce Dawson as a member of the High Resolution Fly's Eye collaboration (HiRes).

HiRes, which has now been decommissioned, was an experiment designed to measure the highest energy cosmic rays, those having energies of 10^{17} eV and above. My little piece of a particularly indigestible pie was to attempt to infer the chemical composition of these cosmic rays in a fairly narrow energy window in which events were measured in coincidence with another detector called CASA-MIA. Although my project was by no means a spectacular success, it taught me a lot about management and analysis of large data sets as well as programming; it also helped me develop my technical writing and presentation skills. All of these have continued to be of great value in subsequent pursuits. At the end of my PhD I found myself in the same situation as at the beginning, and in a quandary as to my next move.

Over the following months I made several ill-advised, and ultimately unsuccessful, applications for jobs for which I was poorly suited. I then happened to have an email exchange with a physicist friend who had ended up as a Bioinformatician in a medical research institute. Without quite understanding exactly what he did, I found myself intrigued and did enough research to decide that Bioinformatics (the application of computational and statistical methods to biological problems) might be an area I would like to work in. By sheer chance, his current employer had a vacancy at the time, and before long I was headed to Melbourne, and to the Walter and Eliza Hall Institute (WEHI) to begin a postdoc.

Not unexpectedly, given the complete change of field, things were quite difficult at first as I tried to bring myself up to

The photo was taken last year shortly after starting my current position at Watermark Patent and Trade Mark Attorneys.

speed. On my first day I was given a computer account, a pile of papers and an invitation to ask questions should I run into difficulty. My role at WEHI was twofold: to collaborate with biologists trying to make sense of the unprecedented volumes of data being spawned by the new generation of high-throughput experimental platforms, in particular gene expression microarrays; and to do independent research on new analysis methods for these platforms.

Microarrays (sometimes called "DNA chips") are substrates about the size of a microscope slide to which millions of RNA or DNA fragments are anchored. Each fragment corresponds to part of a gene, or to a section along the genome. It is possible to obtain a measure of the activity of every single gene in an organism using a single microarray, or to look for variations in a DNA sequence (from that expected in the rest of the population) across the entire genome of an individual. Experiments are typically performed by isolating RNA or DNA fragments from an individual (for example, via a blood sample) and attaching a fluorophore to each fragment. The fluorescently labelled fragments may then bind ("hybridise") to their complementary sequences on the microarray. The number of copies of a particular sequence fragment is proportional to the relative concentration of the corresponding gene in the original sample. This can be measured by scanning across the microarray with a laser, and detecting the resultant fluorescence with a photodetector, usually a single photomultiplier tube or sometimes a CCD camera.

"I found patent law interesting enough to think it might be a good option to pursue"

Microarray technology can be very powerful comparative tool. For example, when comparing samples from diseased individuals to samples from healthy individuals, it can quickly identify a number of genes that may be implicated in the disease, whereas traditional biological methods involve painstaking study of one or a few genes at a time. Naturally follow-up experiments must always be done, but as a method for rapidly identifying genes of potential interest and sorting the wheat from the biological chaff, microarrays have revolutionised molecular biology research. They are also gradually moving towards acceptance as a diagnostic tool. I had very little formal training in mathematical statistics before I started, and even less biological education behind me (that is to say, none). Luckily, my biologist collaborators were all very patient with my naïve questions, and attendance at copious numbers of seminars, combined with some spare-time reading, meant the fog eventually cleared enough for me to contribute something useful. Over the course of five years in Bioinformatics I analysed a huge variety of data sets in contexts ranging from embryonic stem cells to the life cycle of the malaria parasite. My previous experience in dealing with large data sets was crucial in analysis and interpretation of the data, as were my newly acquired skills in statistical modelling, biological sequence analysis and interacting with biological databases.

Although the move into Bioinformatics had been a good one, I was still in an academic setting and consequently still found myself needing to make a decision about the longer term future, with the funding prospects in my chosen field being none too encouraging. While pondering the options I remembered that several colleagues from both physics and medical research had become patent attorneys, and I sought their views on the profession. I was not completely convinced at this stage that it was a career which would suit me, and so to test the waters, enrolled to study a Masters in Industrial Property (which encompasses the subjects needed to qualify as an Australian patent attorney) part time, while continuing to do Bioinformatics research.

I had never studied law previously and quickly realised that I was in for a serious challenge. As a scientist I was always looking for an objective truth; in the law, this may not exist and success can depend largely on how skillfully a case is argued, regardless of its merits. Studying patent law therefore required a change in mindset and the ability to see both sides of an argument.

I found patent law interesting enough to think it might be a good option to pursue, and so began looking for trainee patent attorney positions. As the profession is quite small – there are only about 600 registered attorneys in Australia, and a relatively small number of firms – this met with little initial success. After several months and a round of emailing my CV to the major Melbourne firms, a trainee position eventually appeared, and after two rounds of interviews and a written test in which I had to describe a paper clip dispenser in great detail without recourse to diagrams, I had my foot in the door of the profession.

As a trainee patent attorney I am still completing the educational requirements for registration, whilst gaining on-the-job experience. During the course of a typical day I am often called on to use my technical knowledge in conjunction with my knowledge of intellectual property law, usually to overcome an objection from a patent examiner. I also rely heavily on other skills from my physics background – critical thinking, problem solving and clear and precise communication, both with clients and with associate firms who handle our clients' cases in overseas jurisdictions. Most of the matters I handle are in relation to physics inventions or are in the mechanical area, although I have dealt with some biotech related inventions as well. The vast majority of my work is done on behalf of a client who operates in the area of optical security devices.

Although I often draw directly on my technical knowledge in order to understand an invention, there are of course times when I will encounter a technology that is outside my usual expertise. As patent attorneys we are often expected to be instant experts and so it is not unusual to have to consult textbooks and journal articles to better understand a complex invention, if only to be able to penetrate the jargon used by the patentee (or rather, their attorney). As a result I am constantly being challenged and gaining knowledge in a wide variety of technical fields. This is a very appealing aspect of my new career.

Wagga Wagga

2009

First Notice

33nd Annual Condensed Matter and Materials Meeting
Charles Sturt University, Wagga Wagga, NSW
3rd – 6th February, 2009

You are invited to join us under the big tree at the Convention Centre at Charles Sturt University, Wagga Wagga, NSW for the 33nd Annual Condensed Matter and Materials Meeting. Arrival formalities will commence from 4.00pm on Tuesday, 3rd, with scientific sessions commencing 8.50am Wednesday, 4th and concluding with lunch on Friday, 6th February, 2009. Accommodation will be available on the University campus near the Convention Centre. At less than $300 (incl. accommodation for three days) this is surely the best value-for-money conference anywhere in Australia!

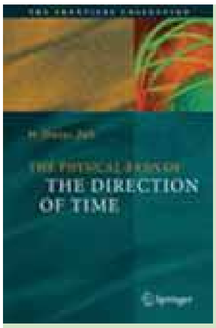
Abstracts: Contributed papers are encouraged in all areas of condensed matter study. Further details of abstract format together with template files are available at the Wagga2009 website: *http://www.acpo.csiro.au/wagga09/*

Conference Proceedings: Participants will be invited to submit a manuscript for publication in the conference proceedings which will be peer-reviewed and published electronically on the website of the Australian Institute of Physics.

Dates:	Distribution of Second and Final Notice:	1st October 2008
	Abstract and Registration deadline (with payment):	28th November 2008
	Notification of oral/poster presentations:	15th December 2008
	Manuscript submission:	3rd February 2009

Further Information: *http://www.acpo.csiro.au/wagga09*
or contact: Tim Bastow, CSIRO Materials Science and Engineering
Tel: (03) 9545 2657
email: *wagga09@csiro.au*

Reviews



Prompt Critical

The Physical Basis of the Direction of Time
H. Dieter Zeh
Springer-Verlag, Berlin 2007
viii + 231 pp.,
EUR 39.95 (hardbound)
ISBN 978-3-540-68000-0

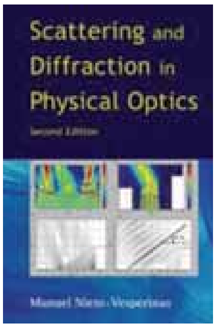
Zeh has taken this title to a fifth edition and one of the reasons (I submit) is that the topic is one of endless fascination. Additionally, as more insight is teased and wrested from theoretical paradigms, the corollary of time's nature is also revealed.

This book is not for a novice reader as it covers all aspects of time's march from radiation through thermodynamics, quantum mechanics to quantum cosmology with embedded mathematical expressions. Nonetheless, the detailed arguments present a compelling case for the forward direction of time and provoke thought on detail such as time reversed synchrotron radiation and wonder with the discussion of how "white holes", i.e. time reversed black holes, would have to work their magic.

Zeh has woven this fabric well with threads starting in earlier chapters emerging and tied into latter chapters as one would expect.

In the Australian context, this is a graduate level book but one with a general interest as it is such a fascinating topic.

John Holdsworth
University of Newcastle



Scattering and Diffraction in Physical Optics
2nd Edition
Manuel Nieto-Vesperinas
World Scientific Publishing, Singapore 2006
Xix + 434 pp, US$86 (hardcover)
ISBN 981-256-340-7

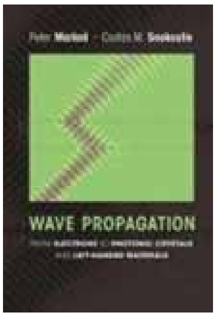
This is an interesting book that discusses the classical electromagnetic theory of scattering and diffraction. The second edition of a text that originally appeared in 1990, it has not only its typos and other errors corrected, but also has a new chapter on Near-Field Optics, a topic that has come to the fore in the intervening period.

The book is superbly produced, has no remaining typos as far as I can tell and, most importantly, the arguments are rigorous, well discussed and explained so that the reader is almost taken through by the hand. Nonetheless, I agree with the author's statement in the Preface that the book is meant for postgraduate students and researchers.

In an Australian context, good Honours students may be able to cope with it as well, but they would need a sound mathematical background. Apart from the new chapter, other topics include discussions of Diffraction theory, the S-matrix, Scattering from Rough Surfaces, and Phase Conjugation, amongst others, none but the first of which are covered in the standard text book *Principles of Optics* by Born and Wolf. On the other hand, readers interested in near-field optics should probably check the specialized text *Principles of Nano-Optics* by Novotny and Hecht.

All-in-all, I like this book for its combination of rigour and accessibility, and I do recommend it to researchers working in the field of electromagnetic optics.

Martijn de Sterke
CUDOS and School of Physics
University of Sydney



Wave Propagation. From Electrons to Photonic Crystals and Left-Handed Materials.
Peter Markoš, Costas M. Soukoulis.
Princeton University Press, Princeton, 2008
xi + 352 pp., US$ 65.00 (hardbound)
ISBN: 978-0-691-13003-3

As a postgraduate student working on semiconductor superlattices I used the transfer matrix method. I remember having to find out about it in various textbooks and having to re-invent wheels I knew had been invented many times before. I am therefore very enthusiastic about this new textbook by Markoš and Soukoulis.

It is a nice description of the transfer matrix method with many applications in condensed matter and optics, including left-handed materials. With detailed explanations, it is exactly the type of book I could have used in my student days. In the preface the authors state that the book is suited for senior undergraduate and first year postgraduates.

While the level and topic area are appropriate for this target audience, I was disappointed by some apparent thoughtlessness in the basic definition of the complex field amplitudes. For example, according to p331 and p333 $\exp(-i\pi t)$ time dependence is used, but the authors state explicitly on p335 that they use $\exp(+i\pi t)$. The expressions in the book imply the former. The relation between the complex amplitude and the actual field is never given; is it Re{….} or twice that? It is also almost never explicitly stated whether they deal with the field itself or its complex amplitude. Of course, for an experienced reader this is not a problem, but I can imagine the target audience getting terribly confused over issues like this.

In summary, I think this book satisfies a real need. It will be even better once the authors deal with a few minor issues.

Martijn de Sterke
University of Sydney

Samplings

The secrets of random packing
http://physicsworld.com/cws/article/news/34416

Image credit: Roger Smith

For centuries, physicists and mathematicians have been trying to work out the most efficient way of packing spheres in order to minimize wasted space. They think they know how to maximise efficiency in uniform packing, for example when stacking oranges. But they know less about how to improve random packing, a process that describes the behaviour of a wide range of granular materials such as sand and marbles. Now, a group of physicists in the US has modelled this random process statistically and has calculated that it can never be used to fill more than about 63.5% of available space.

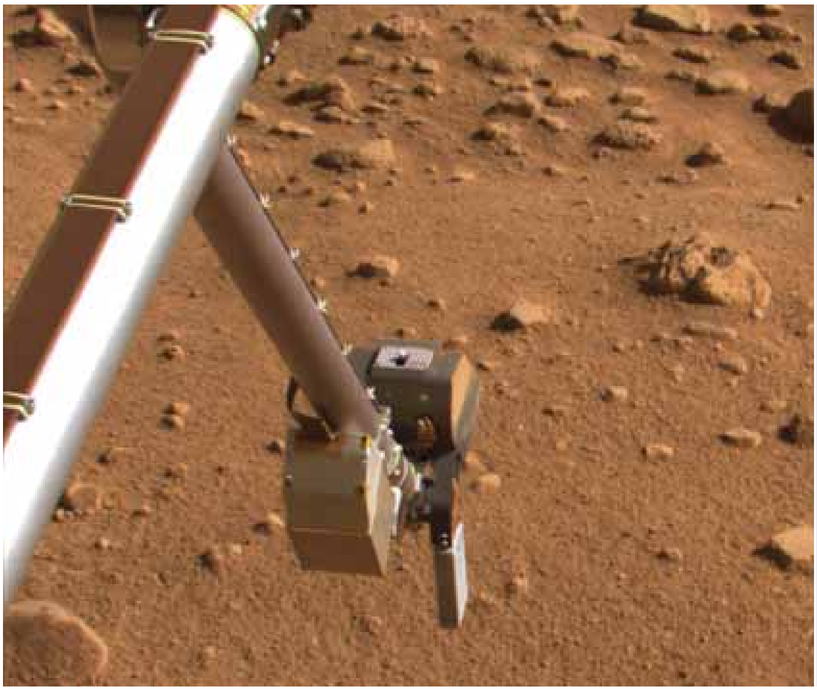
Technique probes nanoscale magnetism
http://physicsworld.com/cws/article/news/34433
Researchers in Japan have used a new technique to measure the magnetic and electronic structure of subsurface atomic layers in a material for the first time. The technique, dubbed diffraction spectroscopy, will be crucial for understanding nanoscale magnetism and developing high-density "perpendicular" magnetic recording materials.

Fumihiko Matsui and colleagues of the Nara Institute of Science and Technology and other Japanese institutions, combined two existing techniques to make theirs: Auger electron diffraction and X-ray absorption spectroscopy. They analysed "forward focusing" peaks that appear in the spectra along the directions of atoms on the surface of a sample. By examining the intensity of the peaks, they could distinguish the magnetic and electronic structures of individual layers (Phys. Rev. Lett. 100 207201).

Extreme UV light made easy
http://physicsworld.com/cws/article/news/34482
A new system to generate coherent extreme-ultraviolet (EUV) light has been developed by researchers in Korea. The device, based on a nanostructure made of bow-tie shaped gold "antennas" on a sapphire substrate, is smaller and cheaper than existing systems and might allow an EUV source the size of a laptop computer to be made. Potential applications for the source include high-resolution biological imaging, advanced lithography of nanoscale patterns and perhaps even "X-ray clocks".

The researchers report that a bow-tie nanostructure of gold – measuring around 20 nm across – can enhance the intensity of femtosecond laser light pulses by two orders of magnitude. This is high enough to generate EUV light with a wavelength of less than 50 nm directly from a small pulse with an energy of 1011 W/cm^2 injected into argon gas. The energy needed is about 100 times less than in traditional approaches.

The technique works thanks to "surface plasmons" (surface excitations that involve billions of electrons) in the "gap" of the bow-tie gold nanostructures. When illuminated with the correct frequency of laser light, the surface plasmons can begin to resonate in unison, greatly increasing the local light field intensity. This phenomenon, known as resonant plasmon field enhancement, is already exploited in imaging techniques, such as surface-enhanced Raman scattering, which is sensitive enough to detect individual molecules on a metal surface.



NASA's Phoenix spacecraft landed on Mars on Sunday, May 25th, to begin three months of examining an arctic site chosen for its likelihood of having frozen water within reach of the lander's robotic arm.

This image, taken by the Surface Stereo Imager on the 49th Martian day of the mission, shows the silver coloured rasp protruding from the Phoenix Mars Lander's Robotic Arm scoop. The scoop is inverted and the rasp is pointing up. Shown with its forks pointing toward the ground is the thermal and electrical conductivity probe, at the lower right. The Robotic Arm Camera is pointed toward the ground.

The Phoenix Mission is led by the University of Arizona, Tucson, on behalf of NASA.
Updates of progress can be found at: www.nasa.gov/mission_pages/phoenix/main.

Image NASA/JPL-Caltech/University of Arizona/Texas A&M University

Multi-particle entanglement in solid is a first

http://physicsworld.com/cws/article/news/34499

An international team of physicists has entangled three diamond nuclei for the first time. The development promotes solid-state systems to a rank of quantum systems including ions and photons that have achieved entanglement for more than two particles.

Entanglement lies at the heart of fields such as quantum computation and quantum teleportation. At its most basic level, if two particles are entangled a measurement of the state of one reveals something about the state of the other, regardless of the distance separating them.

But entanglement is difficult to achieve. It requires quantum states to be manipulated while preventing them from interacting with their environment, which tends to degrade the quantum system into a classical state. Now, a team led by Jöerg Wrachtrup of the University of Stuttgart, Germany, has demonstrated that two or three diamond nuclei can be entangled.

'Excitonic integrated circuit' is a first

http://physicsworld.com/cws/article/news/34675

Physicists in the US have created a new kind of integrated circuit that can switch light without first converting it into an electronic signal.

The light is instead transformed into a quasiparticle called an "exciton", which consists of an electron bound to a hole. The excition can then be manipulated within a semiconductor chip before being converted back into light.

A problem for optical communicationns networks, and the development of optical computers is that there is currently no practical way of performing logical operations on light itself. Some physicists believe that the solution lies in a compromise of sorts — converting light into excitons, which behave like both photons and electrons.

Samplings by Don Price CSIRO

Table-top experiment could explain why continents drift

http://physicsworld.com/cws/article/news/34715

Physicists in the US have performed a simple table-top experiment that could provide new insight into why the Earth's continents drift apart and then move back together over several hundred-million years.

Jun Zhang and Bin Liu of New York University tracked the motion of a handful of millimetre-sized balls at the bottom of a heated tank containing a mixture of water and glycerol. They found that convection currents in the tank caused the balls to pack together tightly in a clump — before drifting apart to form another clump on the opposite side of the tank.

About 200 million years ago most of the Earth's landmass existed in the form of the "supercontinent" Pangaea, which has since broken up into the seven continents known today. This process appears to be cyclical and Pangaea was probably formed when the remnants of an earlier supercontinent were drawn together.

Many geophysicists believe that this cyclical pattern could be related to regular disruptions in the convection currents in the Earth's mantle, upon which the continents float. However, scientists have had little practical understanding of how the presence of solid objects affects convection. Now, Jun Zhang and Bin Liu have done a simple table-top experiment that reveals that the presence of solid objects can have a significant effect on convection (Phys Rev Lett 100 244501).

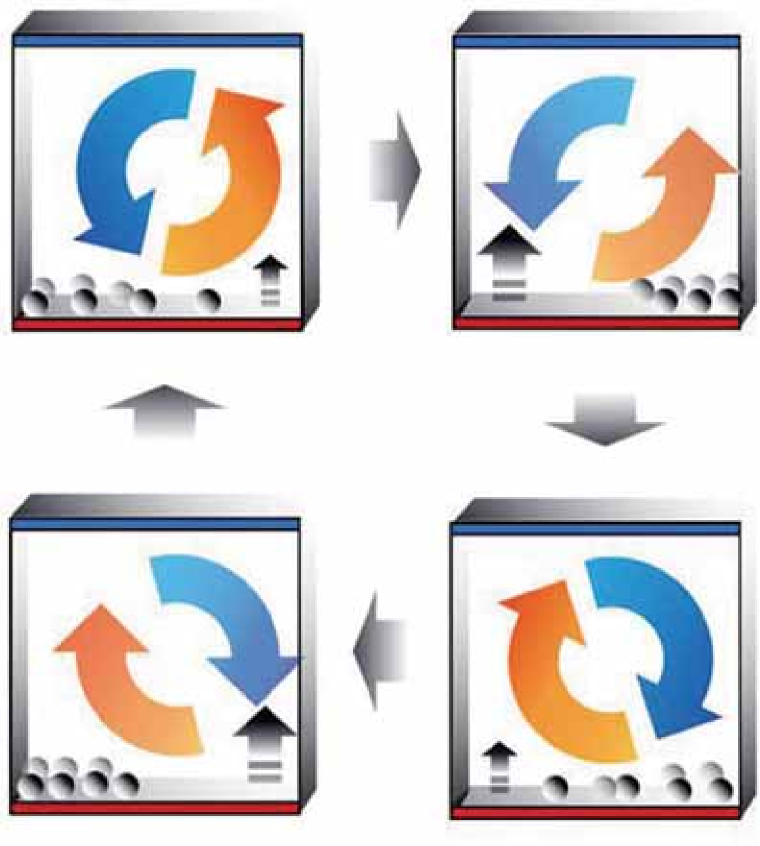


Diagram showing how the spheres disrupt convection: At the top left is an anti-clockwise convection cell where the balls are starting to be pushed from left to right. The top right shows the system after the flow has packed the balls into the right side of the tank. The upward flow of heat (black arrow)has shifted to the left side of the tank because the carpet of balls is insulating the hot bottom plate from the liquid. This causes the flow to reverse (bottom right), causing the balls to move to the left (bottom left). The process begins over again. Courtesy: American Physical Society.

Product News

Lastek

SPMMini: High Performance, High Gain APDs

The SPMMini is the first solid state alternative to the long established Photomultiplier Tube (PMT). It combines the high gain (10^6) and high quantum efficiency of the PMT with the well appreciated benefits of silicon including size, low operating voltage, robustness, reliability, magnetic field insensitivity, tolerance of excess/ambient light, and suitability for miniaturization. In addition, the detector has high signal to noise and fast timing properties.

The SPMMini includes transimpedance preamplification, a Peltier cooler driver circuit to enable cooling to -30C and integrated power supply as standard. A variety of add-on options to enhance functionality are provided, including C-mount (male) adapter and a fiber coupler (adapter and fiber cable included).

Features
- High gain (10^6)
- Low bias voltages (30V)
- Low cooled dark count rate (typically 10-100 KHz/mm^2)
- High S/N
- Not damaged by excess/ambient light
- Large area up to 9mm^2
- Minimal electronics requirement
- Compact, rugged and stable
- Insensitive to magnetic fields
- Integrated power supply
- C-mount adapter (option)
- Fiber Coupler including connector adapter and lensed fiber cable (option)
- 3-Year Extended Warranty (option)

HRMTime: High Resolution Timing Module

SensL's HRMTime module is the first portable USB high resolution timing module on the market. It is a highly functional system incorporating high end timing functions in an easy-to-use, flexible and high performance module. Most importantly its timing circuitry enables a time bin sizes down to 27ps and is available in one, two, or four channels.

The system design is optimized for use together with SensL's photon counting sensor products but it is compatible with any photon counting sensor (with a TTL output). The HRMTime comes with Multichannel Averager/Scaler, Multi Dimensional Time Correlated Single Photon Counting (TCSPC), Time-Binning, Time-Tagging (Micro and Macro) and Auto/Cross Correlation operating modes as standard.

Combining this functionality in a single platform together with a range of display, statistical analysis and data export tools makes the HRMTime the ultimate timing module.

Features
- USB Portability
- High Resolution: 27ps
- Multiple Channels: 1, 2 or 4 channels
- Histogram, FIFO, and TCSPC operating modes
- LabVIEW drivers, DLLs and SensL GUI
- Accepts External Clock Source

For more information contact Lastek at *sales@lastek.com.au*

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web: *www.lastek.com.au*

Coherent

Fibre-based Picosecond Laser for Micromachining

Coherent has released Talisker – a new family of pulsed fibre lasers with high peak power and high average power, designed for precision micromachining.

Talisker delivers picosecond pulses, which minimise thermal damage and allow smaller feature sizes to be achieved in critical applications such as silicon machining, wafer dicing and solar cell manufacturing.

The laser is available in three versions as follows:

Infrared : 18W average power at 1064nm
Visible : 8W average power at 532nm
UV: 4W average power at 355nm

The choice of wavelengths allows a wide variety of materials to be processed including silicon, polyamide, metals and glass.

The laser includes software and a graphical user interface for easy integration into machine tool designs as well as research applications.

For more information please contact Paul Wardill on *sales@coherent.com.au*
Coherent Scientific Pty. Ltd.
116 Sir Donald Bradman Drive
Hilton SA 5033

Coherent

New Focus introduce High Speed Servo Controller for laser

Implementing a high-speed, low-noise wavelength/frequency lock is a requirement for many laser applications, such as atomic spectroscopy, metrology, quantum computing and the generation of frequency combs.

New Focus have expanded their laser product line with the LB1005 High Speed Servo Controller to provide a simple and reliable one-box solution to this often frustrating requirement.

The LB1005 features
- High-speed, low-noise all-analogue electronics with a 10MHz bandwidth: sufficient for a wide range of applications
- Proportional-Integral loop filter with adjustable gain (-40 to +40dB) and corner frequency (10Hz - 1MHz)
- Inverting, non-inverting and differential modes
- Sweep control for locating and locking to resonant features
- High-bandwidth error monitor output for an undistorted view of the error signal
- Affordable price to allow dual and multiple lock configurations.

For more information please contact Fadhly Amri on *sales@coherent.com.au*
Coherent Scientific Pty. Ltd.
116 Sir Donald Bradman Drive
Hilton SA 5033

Warsash

IMRA Femtolite Fibre lasers for microscopy applications

Warsash Scientific is pleased to present the new generation of ultrafast, ultracompact, and economical lasers from IMRA America, the Femtolite Ultra series. The Femtolite Ultra series of lasers are highly stable and use Erbium doped fibres to deliver femtosecond pulses at 780nm, 800 nm and 1560nm.

Femotosecond pulse lasers offer the combination of high peak power (1-100kW) and low average power (10-1000mW) which is ideal for inducing nonlinear optical processes. Two non-linear processes, namely two-photon and third-harmonic generation (THG) are revolutionising the field of microscopy, particularly for biology, medicine, and neuroscience research.

In contrast to traditional single-photon methods, these non-linear processes enable; (1) natural sectioning without the need for a confocal de-scanned aperture; (2) greater penetration depth in scattering media due to use of longer wavelengths, and; (3) reduced photo-toxicity due to smaller excitation volume, resulting in longer viewing time of living cells and organisms.

All models in the Femtolite Ultra series are compact, turnkey, maintenance free, feature a rugged design and operate without the need for external cooling. These features enable easy integration with microscope systems, in contrast with their solid state counterparts. Engineered for commercial, OEM and research applications, IMRA's pulsed fibre lasers are setting the standard for reliability and long life time. Features and benefits:
- Highly stable output
- Ultracompact laser head (145mm x 98mm x 40mm)
- Turnkey operation
- Maintenance free
- Does not require external cooling
- Repetition rate: 50MHz

For more information on this or other IMRA America laser products contact;
Warsash Scientific Pty Ltd
Tel: +61 2 9319 0122
Fax: +61 2 9318 2192
sales@warsash.com.au
www.warsash.com.au

Anti-vibration workstations from Kinetic Systems

Warsash Scientific is pleased to present the wide range of vibration-isolation workstations from Kinetic Systems. Sturdy, versatile, and ergonomic, they feature automatic leveling and low natural frequencies for excellent vertical and horizontal isolation efficiencies. Kinetic Systems workstations can be configured for a wide variety of applications where external vibrations could adversely affect the operation of sensitive equipment.

The Standard High-Performance Workstation is the ideal choice for the majority of user applications. A Heavy/Moving-Load Workstation is available to effectively isolate loads up to 2800 pounds, including equipment with high centers of gravity.

The Personal Workstation is an economical solution for small labs and other tight spaces. A Variable-Height Workstation allows the user to raise or lower the tabletop to accommodate the work being performed and the height of the user. The Cleanroom Workstation is designed specifically for use in Class 1 and Class 10 cleanrooms.The MK26 Workstation, a recent addition to the Kinetic Systems product line, utilizes the Minus K stiff spring and negative-stiffness mechanism to achieve low net vertical stiffness, ultra-low natural frequencies, and high internal structural frequencies without affecting the static load supporting capability.

Tabletops range in size from 24" x 24" to 60" x 72" and can be constructed of steel, ferromagnetic stainless steel, composite, or granite, with or without mounting holes; lightweight "honeycomb" cores; and plastic, antistatic, or stainless-steel laminate.

Further information on this and other Kinetic System products available from:
Warsash Scientific Pty Ltd
Tel: +61 2 9319 0122
Fax: +61 2 9318 2192
sales@warsash.com.au
www.warsash.com.au

Samba High Power DPSS laser available from Warsash Scientific
Warsash Scientific is pleased to announce the release of the high power Cobolt Samba, 532 nm single-mode CW solid-state laser. The Cobolt Samba™ is a continuous-wave solid-state laser operating at 532 nm and is now available with an output power of up to 300 mW.

The Cobolt Samba is a true single-longitudinal mode laser with a measured linewidth of <1MHz and features very low noise with excellent beam quality, over a wide temperature range. Demonstrating high wall-plug efficiency, the full system typically consumes less than 25 W of electrical power. The laser is based on Cobolt's proprietary PPKTP doubling technology and is manufactured in a compact and robust hermetically sealed package providing high tolerance to demanding environmental conditions.

These features make the Cobolt Samba ideal for power and stability demanding applications such as high-resolution Raman spectroscopy, particle sizing, holography, flow dynamics and high-speed fluorescence analysis.

Cobolt's range of high performance CW DPSS lasers are also available at wavelengths of: 473 nm, 491 nm, 515nm, 561nm lasers, as well as combined 491+532 nm. Features and benefits:
- Now available with up to 300mW CW output power
- Very low noise (<0.3% rms)
- Excellent beam quality (M2<1.1)
- Wide temperature range (10-40oC)

Further information on this and other Cobolt DPSS laser systems available from:
Warsash Scientific Pty Ltd
Tel: +61 2 9319 0122
Fax: +61 2 9318 2192
sales@warsash.com.au
www.warsash.com.au

NewSpec
Newport High Gain Avalanche Photodiode Detectors

Newport's SPM Series High Gain Avalanche Photodiode Detectors (APD), also known as Silicon Photomultipliers (SPM or SiPM), are a new solid state alternative to the older Photomultiplier Tube (PMT) technology. These devices combine the high gain (10^6) and high quantum efficiency of the PMT with the well appreciated benefits of silicon based devices including small size, low operating voltage, robustness, reliability, magnetic field insensitivity, tolerance of excess/ambient light and suitability for miniaturization.

In addition, a novel design allows a high signal to noise ratio and a very fast pulse response. Whether your application is a large area radiation detection, a benchtop instrument or a full-scale laboratory analysis instrument, the SPM Series detectors will provide significant benefit over existing detector platforms.

– Compact, rugged and stable detector supplied with integrated power supply and TE cooler (-20 ˚C)
– High gain (10^6) resulting in similar detection capability of PMTs
– Not degradable due to excess/ambient light like PMTs
– Low bias voltages (30V)
– Low dark count rate (<1MHz)
– Large area up to $9mm^2$

Please contact Neil at NewSpec for more information Tel: 08 8463 1967
sales@newspec.com.au

Newport Photon Counting Detectors
Newport's PCD Series Photon

Counting Detectors provide a complete detection solution in a single module, which means it is no longer necessary to be an optics or electronics expert to implement high resolution photon counting. The sensors used feature a novel quenching architecture that provides state-of-the-art timing-jitter, thereby exceeding the typical sensing performance of Photomultiplier Tubes in all key parameters such as Photon Detection Efficiency, Dark Count, Timing-Jitter and After-Pulsing.

The PCD series is the first miniature photon counting system on the market and is ideal for lab use. Its integrated counter functionality eliminates the requirement for a separate data acquisition system. The sensor is housed in a hermetically sealed TO8 can and mounted on a two-stage Peltier cooler. During normal operation the detector is cooled to –20°C allowing for greater performance over room temperature operation as the dark count is typically reduced by an order of magnitude. The PCD Series sensors are supplied with an integrated power supply and can be post-mounted via a tapped hole located on the bottom of the housing.

– Low Timing-Jitter (< 100ps) and low after-pulsing
– Excellent Photon Detection Efficiency at blue/red wavelengths (> 40%)
– TTL output (pulse indicates photon arrival time)
– Low operating voltages (<35V)
– Integrated TE cooler for dark count reduction
– Integrated wall mounted power supply
– Modules available in 20 or 100 μm versions, with optional fibre coupled output
– USB Interface with integrated software environment and DLL libraries

Please contact Neil at NewSpec for more information at:
Tel: 08 8463 1967
sales@newspec.com.au

Newport High Performance BenchTop Single / Dual Channel Optical Meter
Newport's new model 1936-C (single channel) and 2936-C (dual channel) optical power and energy meters are one the most sophisticated meters currently available. These new instruments combine the superb femtowatt level sensitivity of the 1931-C/2931-C series and the extreme versatility of 1935-C/2935-C series, resulting in a revolutionary meter that literally does everything. No matter what the application, or how demanding the measurement, this meter coupled with the appropriate Newport detector head, will do the job.

All Newport 918D and 918L Series semiconductor-based low power, 818P Series thermopile, and 818E Series pyroelectric detectors are fully compatible with the new instruments, and are hot-swappable, so there is no need of recycling the power if a different sensor needs to be used.

Power measurement range: 11 fW – 20 kW (with appropriate detector heads)
Energy measurement range: 7 mJ – 20 kJ (with appropriate detector heads)
Measurement rep-rates up to 10 kHz (with appropriate detector head)
Frequency measurement of pulses up to 250 kHz (with appropriate detector heads)

Please contact Neil at NewSpec for more information at:
Tel: 08 8463 1967
sales@newspec.com.au

Courtesy of NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

Conferences

October 8 - 10
The Third International Conference on Women in Physics
Seoul, Korea,
icwip2008.org/

October 10 - 18
Critical Stability of Quantum Few-Body Systems
Erice, Sicily, Italy
lpsc.in2p3.fr/Indico/conferenceDisplay.py?confId=29

October 26 - 28
7th WSEAS Int. Conf. on Non-Linear Analysis, Non-Linear Systems and Chaos (NOLASC '08)
Corfu, Greece
www.wseas.org/conferences/2008/corfu/nolasc

November 17 - 20
14th International Conference on Thin Films
Belgium, Ghent
/www.ictf14.ugent.be/

Nov 30 – Dec 5
18th National AIP Physics Congress
Adelaide, South Australia
www.aip.org.au

December 1- 5
XVI Conference on Non-equilibrium Statistical Mechanics & Nonlinear Physics (MEDYFINOL'08)
Uruguay
medyfinol08.fisica.edu.uy

December 12 - 13
2nd International Conference on Science and Technology (ICSTIE'08)
Penang, Malaysia
www.icstie.com

2009

June 29 – July 5, 2009
The 6th International Conference on Non-Accelerator New Physics (NANP'09)
Dubna, Moscow region, Russian Federation
nuweb.jinr.ru/~nanp

September 7 - 11
9th International DYMAT Conference on the Mechanical and Physical Behaviour of Materials under Dynamic Loading
Brussels, Belgium
www.dymat2009.org

Council News continued from page 117

Condensed Matter and Materials Group: Dr. Glen Stewart said the major activity of the group was the annual conference at Wagga. A conference in New Zealand has been proposed.

Physics Education Group: Dr. Alex Merchant said the next major project was to make an examination of graduate destinations. There was a battle to resolve the conflict between conducting research and promoting excellence in teaching. There was concern about the effects of casualization on teaching.

Women in Physics Group: Dr. Cathy Foley announced that Tanya Munro had been appointed as the Women in Physics lecturer for 2007/2008. Once a target for the participation of women in physics had been achieved, this program will be discontinued. Networking was a major function of the group.

Media Liaison: Niall Byrne reminded Council that the relationship between ScienceinPublic and the AIP had commenced in the Einstein International Year of Physics. A major aim was then, and continued to be, adding value to activities that were already happening. The newsletter was being put out regularly and it was essential that he was advised in advance of activities being planned. Work will also be done on updating the membership application process. The International Year of Astronomy was an important event that could be used for promotion.

Cognate Societies

Australasian College of Engineers and Physicists in Medicine: Dr. Tomas Kron advised Council that there was a shortage of medical physicists in the country. The college could see opportunities for greater collaboration among societies.

Astronomical Society of Australia: Dr. Warrick Couch said that astronomy had received a large amount of funding in the last year. There was concern about the future of Siding Springs since the UK finished its involvement in 2010.

Australasian Society for General Relativity and Gravitation: Prof. Susan Scott said the Society was keen to be involved in the International Year of Astronomy. The main activity last year had been the international conference held at Darling Harbour.

Australasian Radiation Protection Society: Dr. Don Higson said the Society was very active internationally. The main problem was the shortage of qualified people, especially in physics. It was resolved that the AIP would act to inform members about the activities of ARPS and opportunities available in radiation protection.

Free student memberships: It had become clear that students who took up free memberships were not continuing. The program therefore had been discontinued. It was resolved that the AIP would replace it with a student liaison program, whereby information and some limited services would be provided to students in universities.

Web site: Council supported the more extensive use of the web site as this is where many people obtain information about the AIP. There were many opportunities for presenting physics in everyday life to both the public and teachers. Sections on the site could be accessible only by members. The executive would look into the redevelopment of the web site.

Ian Bailey,

Hon secretary.

Spectra-Physics

A Division of Newport Corporation

Ultrafast Laser Solutions from Spectra Physics

Solstice™ One Box Ultrafast Amplifier

> more than 2.5W of output power
> for Ultrafast micro-machining

TOPAS™ Automated Ultrafast OPA

> tuning from 189nm to 20um
> for Ultrafast, time-resolved Spectroscopy

Matisse® Single Fequency Ti:Sapphire and Dye Ring Lasers

> for High-resolution Spectroscopy and Atom Cooling

Mai Tai® DeepSee™ Ultrafast Ti:Sapphire

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> for Multiphoton Microscopy

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