Large Panel Hologram Display at Questacon

Eidola Suite at Questacon
Safe nuclear power plants
Snapshot: Peter Hannaford
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- Green 532/527nm - 5W to 40W
- UV 355/351nm - 2W to 20W
- Deep UV 266/263nm - 1W to 6W
- TEM00 Beam with M² < 1.1
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Cover image: A montage showing Paula Dawson's Eidola Suite Triptych of holograms at Questacon. See the article on page 9 for more information. Photo credit: Questacon

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President's Column

Even harder to measure is how physics impacts on the quality of life. Does attracting a large crowd to a public lecture on a fundamental question in Physics show we are contributing to the quality of life for the general citizen?

How do you recognise quality when you see it? I have just been to a really high quality conference: The 2006 International Conference on Nanoscience and Nanotechnology (ICONN) held in Brisbane from July 3-7. It's sometimes difficult to identify what elements of a conference contribute to an assessment of quality. For me these elements include: interesting topics, experience and enthusiasm of the speakers, high quality presentations and smooth organisation. Somewhere in there should also be value for money.

Of course "high quality presentations" and "value for money" begs further questions on what constitutes a high quality presentation and value for money. For the former I would list: accessibility of the presentation content (good if I understood the point of the work and at least appreciated the Physics involved), the style of the speaker (sufficiently entertaining to maintain interest) and the technical excellence of the presentation. Not all of my colleagues are in uniform agreement with the need for technical excellence - or entertainment for that matter. ICONN definitely combined all these elements and there was a significant buzz generated by the large numbers of Australian and overseas delegates who gave presentations of high quality on interesting work. A strong interdisciplinary flavour also contributed to the buzz.

It's hardly worth noting that all ICONN presentations were fully electronic. There was not a single overhead projector in sight. In this field the days are long gone when hand written overhead transparencies were acceptable. Curiously enough, physicists working at the deepest level of theory and with the most sophisticated mathematics insist on clinging to the most primitive of presentation methods. By contrast to ICONN, a recent equally excellent conference I attended dealt with Physics at its most fundamental, but almost all delegates employed hand-written transparencies. Perhaps they, like I, worry a lot about the dominance of a single software package (Microsoft PowerPoint) in Physics today. Uniformity is certainly convenient, but lack of competition surely will lead to a suppression of innovation and inevitably reduce quality.

In a more general sense, measurement of quality is not like doing a physics experiment. Criteria for quality are often highly subjective or activity specific. As I mentioned before, many of my colleagues would strenuously disagree with the inclusion of the level of technical wizardry in the assessment of the quality of any presentation. Entertainment is another issue where people hold divergent views. I tell my undergraduate students that with three 50-minute physics lectures per week I cannot hope to do much education. Education, yes. Mastery of Physics requires building on the formal education with much further inquiry and study. I'm sorry, but you have to do that in your own time. So quality outcomes in education require the strong cooperation of the students.

Criteria for quality have been developed for commerce. In my view, these do not translate well to physics research or education. The ISO 9000 quality standards specify processes and record keeping requirements to maintain quality. These are sufficiently generic to apply across many different industries. Many of these are based on financial considerations. Manufacturing greater numbers of widgets that have more functions at a lower cost per widget with fewer staff could indicate an improvement in quality. Provided, of course, the widgets do not generate expensive after-sales nightmares of warranty claims. Translating these ideas to physics creates difficulties. I do not think increasing the student-staff ratio in a teaching institution or measuring the quality of outcomes from research grants by the number of publications are objective measures of quality. Less tangible assessments are definitely required.

But intangible assessments can be very labour intensive and are often ignored in favour of less labour intensive "objective" assessments that can be performed by applying a formula to an electronic database. One example of this is the H-index for measuring the impact and perhaps quality of an individual researcher. Inventor of the H-index, Jorge Hirsch, a physicist from the University of California in San Diego, is clearly a man of diabolical ingenuity.

Inventor of the H-index, Jorge Hirsch, a physicist from the University of California in San Diego, is clearly a man of diabolical ingenuity. Hirsch's idea is very simple. Just list your publications in order of decreasing numbers of citations and find the publication with the same number of citations as its order in the list. The number in the list is your H-index. Just a few mouse clicks on the Web of Science reveals your quality. Aspiring Noble Laureates should have an H-index of 110. Young aspirants should aim to increase their H-index by 4 each year to avoid expiring before becoming eligible. Too bad if your work is not captured in an electronic database or is not available for referencing by other people.

The Google algorithm offers a very 21st C measure of influence that includes impact and quality. Web sites that are referenced by the greatest number of external web sites are surely authoritative. Hence Google puts them first on the list of search results. On a personal note, I find this highly satisfactory as a Google on "David Jamieson" will show. Organisations in search of quality ratings have been slow to take notice Google technology.

Even harder to measure is how physics impacts on the quality of life. Does attracting a large crowd to a public lecture on a fundamental question in Physics show we are contributing to the quality of life for the general citizen? How about physics-intensive handy ideas and gadgets that entertain the iPod nano, inform the world-wide-web, and...
Global warming; rising petrol prices; conflict in the Middle East – all these have played a part in bringing the debate about energy production and usage to the foreground of national consideration. No matter what your views on the subject, there can be no doubt that it’s a debate that’s long overdue.

Among the things which ought to be considered are: providing enough energy to meet people’s needs (not so easy in this increasingly energy-hungry world), safety, environmental impact, longevity, waste disposal and cost. What weight you put on any factor depends on your viewpoint – an economist is likely to have different views to an environmentalist – but they are each important and any discussion needs to address all of them.

Scientists need to play an important role in the energy debate. And, of course, we need to ensure we are informed ourselves.

For some time, I have felt that this issue is one on which it would be good to have some open discussion within the pages of Australian Physics. Consequently, I was very pleased when Dr Hashemi-Nazhad offered me his article on accelerator-driven sub-critical nuclear reactors (published in this issue). It certainly seems to address many of the problems that people see with current reactors.

However, the energy debate isn’t just about nuclear power. There are many other sources and many constraints. For example, I don’t think a great number of us will want to give up our personal transport devices. I’d like to see responses to this article, but I also harbour the hope that others out there working in other energy fields might be prepared to submit articles enlightening us about other energy options. Let’s get informed and let’s have a debate!

In this issue: As well as the paper mentioned above, we have an article about the Eidolon Suite of holograms at Questacon and the lasers now used to display them. In addition, Ragbir Bhatal has produced another in his series of snapshots of eminent Australian scientists: this time it is Peter Hannaford in the spotlight.

Corinna Horrigan

Deadline for next issue: 25 August 2006

Submission guidelines
All articles for submission to Australian Physics should be sent in electronic format. Word or rich text format are preferred, but other formats, such as PDF, may also be accepted. Please check with the editor if your article is in a different format. Images should not be embedded in the document but should be sent separately in high resolution JPEG or TIFF format.
Letters

Letter to Editor:

The letter to the editor from Dan Shanahan criticising my paper re the repeated experimental detection of 3-space fails on several grounds. So far 7 experiments have reported the detection of motion relative to 3-space. Of these, 5 were Michelson 2nd order in v/c gas-mode interferometer experiments and another two were coaxial cable 1st order in v/c experiments. All agree. Only when the gas is absent do the interferometer experiments give a null result. So irrespective of theory one is seeing non-null effects. This is the main flaw in Shanahan's criticism; it is illogical to claim that according to some theoretical analysis these experiments could never have worked. In science repeatable and consistent experiments reign supreme. It is also not the case that these experiments invalidate Lorentz symmetry. But what has happened is that we now understand that the variables x,y,z and t in the Lorentz transformation refer to measurements made by clocks and rods whose readings have not been corrected for length contraction and time dilation effects caused by their motion relative to 3-space, which was the view first proposed by Lorentz, and which is now confirmed by experiment. The discovery of 3-space, albeit somewhat belatedly, has required the generalisation of the Maxwell equations and others. Again the consequences of that are confirmed by experiment. At present we are conducting experiments that again detect motion relative to this 3-space. These are so simple that they will probably become undergraduate experiments in the near future.

Reginald T. Cahill
Flinders University
Adelaide

President's Column

continued from page 67

diagnose (MRI imaging), transport (hybrid vehicles), power (photovoltaics), compute (personal computer chip), navigate (GPS) or explain (cosmology)? How do these affect the quality of life?

If your contribution to Physics has a high impact on society does this automatically mean it is of high quality? I can think of examples of very high quality work in physics that had very little impact (General Relativity was in this area for decades after it was formulated), work of very high impact but of low quality (hypothetical physicist guest appearance in the Big Brother house) or work that is of both high quality and high impact (leading perhaps to commercial spin-offs that found new industries).

Perhaps the only reliable way of judging quality is that we know it when we see it, but defining how we know this with a reliable objective metric may be an impossible task.

Prof. David Jamieson
People

Neutrino pioneer dies
Pioneering physical chemist and physics Nobel laureate Ray Davis has died at his home in New York. Davis, who spent most of his career at the Brookhaven National Laboratory, shared the 2002 Nobel Prize for Physics for his contributions to neutrino astrophysics. He passed away on Wednesday aged 91 due to complications from Alzheimer's disease.

PhysicsWeb

Short Notes

Plastics go metallic
Polymers that conduct electricity are now of huge interest in the quest for cheap, tough and flexible electronic circuits. But although some of these materials conduct as well as any true metal, they do not pass as metals in other respects. In particular, their conductivity does not rise as they are cooled, which is the hallmark of metallic behaviour. Now, however, physicists in Korea and the US have developed a new technique that gives a certain polymer -- polyaniline -- many of the physical characteristics of a real metal. (Nature 441 65).

PhysicsWeb

Two new Pluto moons named by the IAU
The two small Pluto moons with temporary designations S/2005 P 1 and S/2005 P 2, discovered in mid-May 2005 with the Hubble Space Telescope (Weaver et al., IAUC 8625), have now been named respectively Hydra and Nix by the IAU.

In Greek mythology Nyx was the goddess of darkness and the night, a very appropriate name for a moon orbiting Pluto -- the god of the underworld. To avoid confusion with the asteroid (3908) Nyx, the Egyptian spelling Nix was chosen. Hydra is the serpent with nine heads that guarded the underworld.

IAU Website

Ice freezes at room temperature
Water has been found to form ice at room temperature if it is placed between a tiny tungsten tip and a graphite surface. Joost Frenken and colleagues at Leiden University in the Netherlands have found that the water effectively acts like a glue in this situation, even though water is normally thought of as a lubricant. The finding could be useful to researchers studying micro- and nanoelectromechanical systems, which can fail if the friction between the surfaces is too high. (Phys. Rev. Lett. 96 166103).

PhysicsWeb

Australian Radio Features STEREO Mission
Ray Gard is producing a series of radio reports following the build-up and launch of the STEREO mission -- some of which have been broadcast on the ABC Radio in Western Australia.

NASA/STEREO media release

Old ships shed light on geomagnetic field
Geophysicists in the UK have used a mathematical model based on old ships' logbooks to show that the observed decline in the strength of Earth's magnetic field may only be a recent phenomenon -- and not a fixed trend as commonly thought. David Gubbins and colleagues at Leeds University say that our planet's magnetic field was stable until the mid-1800s and has been weakening steadily since then. The decline is caused by magnetic flux reversals in the Southern Hemisphere and could point to a geomagnetic flip of the Earth's poles sometime this millennium. (Science 312 900).

PhysicsWeb

From the present to the past
Cambridge physicist Stephen Hawking and his CERN colleague Thomas Hertog have proposed a radical new approach to understanding the universe that studies it from the "top down" rather than the "bottom up" as in traditional models. The approach acknowledges that the universe did not have just one unique beginning and history but a multitude of different beginnings and histories, and that it has experienced them all. But because most of these other alternative histories disappeared very early after the Big Bang to leave behind the universe we observe today, the best way to understand the past, they say, is to trace our knowledge back from the present. (Phys. Rev. D 73 123527).

PhysicsWeb

Friction at a Distance
Friction at a distance, the friction between close objects that aren't in contact, is poorly understood. Seppe Kuehn and his colleagues at Cornell have set out to change this.

First, what does contact mean? Kuehn suggests that when two objects are less than about 1 nanometer apart they are said to be in contact. One can think of contact friction as being a sort of microvelcro process -- atomic "hills" in one surface scrape past atomic "valleys" from the other surface. To observe non-contact friction, the friction between two surfaces separated by more than 1 nanometer, the Cornell researchers use a tiny single-crystal microcantilever less than a millimeter long and only a few thousands of atoms thick.

Brought vertically downwards toward a surface, and set in motion, the cantilever will slow down in proportion to the friction it feels from the surface beneath. Surprisingly, the friction force between the cantilever and sample depends on the chemistry of the sample.

By studying this dependence of non-contact friction on the chemistry of the sample the Cornell scientists have made the first direct, mechanical detection of non-contact friction arising from the weak electric fields caused by motions of molecules in the samples.

The samples included various polymer materials.

This work is motivated by recent efforts towards single-molecule MRI, which require the detection of very small forces -- forces that have been hindered by non-contact friction. ([Physical Review Letters, 21 April 2006])

Physics News Update

Black Hole Paradox Solved By NASA's Chandra
It is estimated that up to a quarter of the total radiation emitted since the Big Bang comes from material falling towards supermassive black holes. For decades, scientists have struggled to understand how black holes, the darkest objects in the Universe, can be responsible for such prodigious amounts of radiation.

New X-ray data from Chandra give the first clear explanation for what drives this process: magnetic fields. Chandra
observed a black hole system in our galaxy, known as GRO J1655-40 where a black hole was pulling material from a companion star into a disk.

Gravity alone is not enough to cause gas in a disk around a black hole to lose energy and fall onto the black hole at the rates required by observations. The gas must lose some of its orbital angular momentum, either through friction or a wind, before it can spiral inward. Otherwise matter could remain in orbit around a black hole for a very long time.

Scientists have long thought that magnetic turbulence could generate friction in a gaseous disk and drive a wind from the disk that carries angular momentum outward allowing the gas to fall inward.

Using Chandra, Miller and his team provided crucial evidence for the role of magnetic forces in the black hole accretion process. The X-ray spectrum showed that the speed and density of the wind from J1655's disk corresponded to computer simulation predictions for magnetically-driven winds. The spectral fingerprint also ruled out the two other major competing theories to winds driven by magnetic fields.

NASA/Chandra media release

NASA-Funded Study Says Saturn's Moon Enceladus Rolled Over

Saturn's moon Enceladus - an active, icy world with an unusually warm south pole - may have performed an unusual trick for a planetary body. New research shows Enceladus rolled over, literally, explaining why the moon's hottest spot is at the south pole.

Enceladus recently grabbed scientists' attention when the Cassini spacecraft observed icy jets and plumes indicating active geysers spewing from the tiny moon's south polar region.

"The mystery we set out to explain was how the hot spot could end up at the pole if it didn't start there," said Francis Nimmo, assistant professor of Earth sciences, University of California, Santa Cruz.

The researchers propose the reorientation of the moon was driven by warm, low-density material rising to the surface from within Enceladus. A similar process may have happened on Uranus' moon Miranda, they said. Their findings are reported in Nature.

NASA media release

A New Kind of Acoustic Laser

Sound amplification by stimulated emission of radiation, or SASER, is the acoustic analog of a laser. Instead of a feedback-built potnet wave of electromagnetic radiation, a saser would deliver a potent ultrasound wave.

The concept has been around for years and several labs have implemented models with differing features. In a new version, undertaken by scientists from the University of Nottingham in the U.K. and the Lashkarev Institute of Semiconductor Physics in Ukraine, the gain medium -- that is, the medium where the amplification takes place -- consists of stacks (or a superlattice) of thin layers of semiconductors which together form "quantum wells."

In these wells, really just carefully confined planar regions, electrons can be excited by parcels of ultrasound, which typically possess millielectronvolts of energy, equivalent to a frequency of 0.1-1 terahertz. And just as coherent light can build up in a laser by the concerted, stimulated emission of light from a lot of atoms, so in a saser coherent sound can build up by the concerted emission of phonons from a lot of quantum wells in the superlattice.

In lasers the light buildup is maintained...
Samplings

by a reflective optical cavity. In the U.K.-Ukraine saser, the acoustic buildup is maintained by an artful spacing of the lattice layer thicknesses in such a way that the layers act as an acoustic mirror.

Eventually the sound wave emerges from the device at a narrow angular range, as do laser pulses. The monoenergetic nature of the acoustic emission, however, has not yet been fully probed. The researchers believe their saser is the first to reach the terahertz frequency range while using also modest electrical power input. Terahertz coherent sound is itself a relatively new field of research. Essentially ultrasound with wavelengths measured in nanometers, terahertz acoustical devices might be used in modulating light waves in optoelectronic devices.

Physics News Update

Haleakala Telescope Finds Planet

An international team of astronomers has used a small, automated telescope located on Haleakala to discover a planet orbiting a Sun-like star 600 light-years from Earth.

The team, led by Peter McCullough of the Space Telescope Science Institute in Baltimore, includes UH astronomer James Heasley. They used a relatively inexpensive telescope made from off-the-shelf components to scan the skies for extrasolar planets. Called the XO telescope, it consists of two 200-mm telephoto camera lenses and looks like a pair of binoculars.

The team found the planet, dubbed XO-1b, by noticing two percent dips in the star’s light output when the planet passed in front of the star. The observation also revealed that XO-1b is in a tight four-day orbit around its parent star, which is in the constellation Corona Borealis.

Heasley stated, “In the future, we can use small telescopes such as XO to find out where planets around stars may be, and larger telescopes such as those on Mauna Kea to confirm such discoveries.” The team confirmed XO-1b’s existence by using the Harlan J. Smith Telescope and the Hobby-Eberly Telescope at the University of Texas’s McDonald Observatory to measure the slight wobble induced by the planet on its parent star. This so-called radial-velocity method allowed the team to calculate a precise mass for the planet, which is slightly less than that of Jupiter (about 0.9 Jupiter masses).

University of Hawaii staff members on Maui who made operation of the XO telescope possible include Bill Giebink, Les Hieda, Jake Kamibayashi, Daniel O’Gara, and Joey Perreira.

University of Hawaii media release,
PhysicsWeb

LEDs target tumours

Scientists in the US have developed the first hand-held optical scanner that can be used for the early detection of breast cancer. The device, made by Britton Chance of the University of Pennsylvania and colleagues, is intended to be a complement to traditional breast screening methods, such as mammograms, and could be commercially available within the next few years [Rev. Sci. Instrum. 77 064301].

It’s thought that 1 in 10 women will develop breast cancer. Although highly efficient scanning techniques such as mammography exist, these can be uncomfortable and not everyone has access to them. A portable device that both patients and doctors could use would overcome these problems and provide women at high risk of contracting the disease with a way of regularly examining themselves.

The device consists of a plastic box measuring about 10 cm by 10 cm with a circuit containing two light-emitting diodes (LEDs) and one diode, amplifiers and a microchip. The LEDs emit light in the near-infrared region of the spectrum between about 650 and 900 nanometres. Since water and fat do not absorb light at these wavelengths very much, the light is able to penetrate as deep as 5 cm into the tissue.

The device is then scanned over the breast and can detect a growing tumour by changes to the absorbed signal; when the scanner passes over the tumour, more light is absorbed because there are more blood vessels in growing tumours than in surrounding healthy tissue. So the idea is that the device monitors a fall in intensity in tumour regions. The scanner can also be connected to an audio device so that it emits a loud beeping noise when it reaches a tumour and a quieter one when it passes over healthy tissue.

This information can be saved on the microchip for a doctor to analyse later.

The device has already performed well in a small pre-clinical trial on 100 women, correctly detecting cancer in 92% of the patients. This is comparable to MRI and better than mammograms say the researchers.

However, unlike mammography, and other such techniques that detect anatomical changes, the scanner detects physiological changes that occur in the earliest stages of breast cancer. Detecting breast cancer early is crucial so that it can be treated before it has time to spread to other parts of the body. The device is also suitable for women under 40 who have denser tissue that is difficult to penetrate using conventional techniques. The team is now working on securing funding to develop a clinical prototype and hopes to commercialise the device within three years.

PhysicsWeb
Laser Longevity Benefits Holography Display at Questacon

John Elsom, Questacon National Science and Technology Centre, Canberra, Australia, Nick Osborne, Coherent, Inc., Santa Clara, California, and Teresa Rosenzweig, Coherent Scientific, Adelaide, Australia, email: teresa.rosenzweig@coherent.com.au

A solid-state 532 nm laser is, literally, behind the spectacular display of Paula Dawson’s *Eidola Suite* triptych at the Questacon Science and Technology Centre.

**Introduction**

One of the most impressive and unique exhibits at Questacon – The National Science and Technology Centre in Canberra – is the *Eidola Suite*, consisting of three large-scale hologram panels by world-renowned holographic artist Paula Dawson. Created in 1985, these artworks enable the viewer to experience a location transformed from raw bushland into a typical family home. Displaying metres of apparent depth in each panel, these holograms pushed existing ion laser technology to its very limit in terms of coherence and stability when first created. But in a remarkable contrast reflecting the dramatic evolution of laser technology, the current exhibit is displayed using a turnkey diode-pumped Nd:YVO₄ laser that delivers several watts of single-mode, hands-free output. Moreover, this all-solid-state laser has now passed the 55,000-hour mark without requiring any significant maintenance or diode replacement.

**Transmission Holograms**

The story of these holograms starts in 1984, when Paula Dawson won a commission from the Australian Government to create an artistic hologram display for the Australian exhibit at the Science Exposition ’85 in Tsukuba, Japan. She then donated the holograms to Questacon, which opened in 1988.

Ms. Dawson was already a well-known holographer who had honed her skills at the world-famous Laboratoire d’Optique de l’Université de Franche-Comté, in Besançon, France. Her ambitious plan was to create a triptych of three related scenes using panel sizes and a depth of scene that far exceeded anything previously produced in Australia. To get this huge scale of representation, she selected simple transmission holograms designed for playback with a laser.

Figure 1 shows simplified, schematic optical layouts for both recording and playback of this type of transmission hologram. Basically, the scene or object is illuminated with spherical wavefronts from a divergent laser beam. Light reflected from this so-called object beam is combined with light from a reference beam. This reference beam follows the same overall path length as the object beam, but passes only through spherical optics so it has none of the phase and amplitude distortions of the object beam. The resultant interference fringes are captured on a photographic plate. When this plate is re-illuminated by a reference beam having the same direction, incidence angle and divergence as the original beam, the scene is re-created in transmission as a virtual image. To successfully record holograms using this method requires a TEM₀₀ laser beam with a coherence length that is twice the largest object/scene dimension. The phase and amplitude of the beam also must be stable throughout the exposure time.

**Working with Ion Lasers in 1985**

For each of the *Eidola* scenes, the recording medium was a large (0.95 x 1.5 metre) glass plate, coated with a silver halide emulsion housing an intermediate grain size, and chosen to deliver the optimum combination...
Laser Longevity Benefits Holography Display at Questacon

of recording speed and image quality. [These plates were hand-produced in a very limited edition by Agfa.] In order to achieve realistic (a few minutes or less) exposure times for such large plates required several watts of visible laser light, which in 1985, could only be obtained from a water-cooled ion laser. Ms. Dawson chose a first-generation Innovar argon ion laser from Coherent, which delivered up to 8 Watts of single-frequency output power at a wavelength of 514.5 nm.

Recording these holograms presented significant practical challenges in terms of illumination, laser stability and opto-mechanical setups. Ms. Dawson explains, "I wanted the scene lighting to appear as natural as possible in order to draw the viewer's consciousness seamlessly into the scene, rather than just give the impression of viewing an interesting hologram. In the real world, particularly outdoors, we're used to overhead illumination so that's what I set out to create. Moreover, we're also used to seeing objects illuminated from ambient reflections from a range of angles, and I set out to match that experience, as well, by using multiple object beams."

The first problems were laser coherence and stability. The holograms have an effective optical depth of up to 10 metres, requiring a coherence length of 20 metres or more. So the laser had to be operated with an internal etalon in order to achieve a single longitudinal mode. But in 1985, many of the automated feedback controls had not yet been incorporated in ion lasers, so keeping this mode stable for over a minute was challenging. In fact, even something as minor as a bubble in the water-cooling system could disturb the stability of the laser head and cause a mode-hop. So the laser was cooled with a closed-circuit cooling system and bubble-free spring water.

Then there was the issue of stability for the beam delivery optics, which required extraordinary vibration-isolation measures. In order to maintain a stable phase relationship, each of the six object beams and the reference beams must have path lengths that are stable at the sub-micron scale over the minute-plus exposure time. Most problematic was the reference beam, delivered from a mirror mounted on a long overhead cantilever. In fact, Ms. Dawson used a seismograph to study the vibration characteristics of her workspace. Not surprisingly, the most vibration-free time window was between 3 and 4 in the morning. Nonetheless, the first attempt taken during this time interval produced a blurred image – due to a vehicle driving on the nearby Burwood highway. Because this was a government-sponsored project, arrangements were made with the local police for subsequent exposures. Ms. Dawson would telephone them immediately prior to shooting a hologram and they would temporarily close the highway!

Eidola – A Time-Window Concept

As shown in Figure 2, the holograms represent an interesting time-window concept on life, using subjects and details that viewers of all ages can appreciate. Paula explains, "I wanted to create three vignettes spaced in time showing the life cycle of a piece of bushland on which an average family home is built and then inhabited."

The views were all created in a studio in Wantirna [near Melbourne]. The first panel [Figure 2a] is a view of the site in a natural state, following a bush fire. Notable features are the grass trees that were painted black to appear charred. The background is sculpted out of white sand with styrofoam "rocks." The contrast of the black trees on the white sand make a stark and bold artistic statement, while also producing for a very dramatic hologram because of the grayscale contrast. According to Paula, this panel represents the moment just before life sprouts forth, with the trees conveying an allegorical "time zero" message, because, as with many bushland plant species, their seeds can only germinate after the intense heat of a fire.

The second panel [Figure 2b] shows a house frame sitting on the sand; the bare skeleton of the house that is not yet a home for living in. This panel also incorporates a novel dramatic effect. The viewer can actually see the other two holograms as windows in the house frame, showing the past and future of the house.

The third image [Figure 2c] presents the viewer with a finished home, now inhabited by a typical family. The hologram is a window, with the viewer inside the home looking out into the garden. The scene includes details, such as the carport, a car, a child's tricycle and – thanks to the extreme viewing angles [nearly 180°] supported by these holograms – even a hose pipe mounted on the house wall. But from a technical viewpoint, the most challenging aspect is that the viewer can see into another part of the house through a window. Here a dressing table mirror shows a complete and accurate reflection of the outside scene from a different angle.

The Display at Questacon

At Questacon, the Eidola panels are now displayed in a room with low ambient light. They are mounted in the walls of this room, which physically isolates them from the rear-laser illumination setup located in a separate room, accessible only to safety-qualified technical personnel.

In stark contrast to the struggle to record these holograms using 1985 technology, the simplicity and reliability of the opto-mechanical setup in this room is
Laser Longevity Benefits Holography Display at Questacon

514.5 nm recording wavelength, it is close enough to prevent noticeable size/shape distortions in the images.

Unlike other diode-pumped solid-state (DPSS) lasers, the Verdi operates in a single longitudinal mode. The resulting long coherence length makes the Verdi an ideal source for playback of these high-depth holograms. In addition to the inherent stability of an all-solid-state laser, compared to a gas laser, the factory-sealed Verdi also incorporates both passive and active cavity stabilization technology to keep the laser locked on the same cavity mode. This technology includes active cavity length stabilization, and a proprietary solder-bonded optics technique, [PermAlign™], instead of adjustable mounts that could drift over time. And thanks to its use of de-rated pump diodes, the Verdi has been powering this exhibit for 55,000 hours without maintenance downtime or diode replacement.

In a beam delivery setup designed by Dr. John Close of the National University’s Physics Department, the output of this Verdi laser is split into three equal parts on an optical bench, as follows: The initially polarized output beam is split 66/33 using a half-wave plate and a beamsplitter. The stronger beam is then split with a 50/50 beamsplitter that is angle-tuned. The three equal intensity beams are then coupled into a single-mode fibre with a 2-micron core, using a commercial objective lens and a 3-axis flexure nanopositioning stage. The fibre was custom made by the Photonics CRC at Technology Park. The original idea was that the NA (numerical aperture) would be large enough to avoid the need for lenses on the output. Finally, however, it was decided to use a cylindrical lens to optimally fill each panel. As with original reference recording beam the playback beam is positioned above (at a height of 4.2 metres) and behind the hologram, making the same 33° angle of incidence at the upper edge of the holographic plate.

Conclusion

The Eidola Suite by Paula Dawson remains one of Australia’s finest holographic achievements and continues to “wow” viewers of all ages at Questacon – The National Science and Technology Centre. The ambitious scope of these remarkable pieces and the limitations of the technology available at the time made them challenging to produce. However, advances in technology now enable them to be displayed with a single laser illumination source that requires essentially no routine maintenance.

Figure 2. Photo of three of Eidola holograms. (a) The site in its natural state after a bushfire, (b) the framework of the house and (c) the finished home.

a testament to the advances in laser technology and fibre-optic delivery over the past 20 years. In 1998, at Ms. Dawson’s suggestion, Questacon acquired a Coherent Verdi laser rated at 5 watts. The Verdi is an all-solid-state laser based on a diode-pumped Nd:YVO₄, rod and intracavity doubled to deliver 532 nm. Although this is not a perfect match for the original
NOMINATIONS FOR POSITIONS ON THE AIP EXECUTIVE

Nominations are now called for the following positions on the National Executive of the AIP

Vice President
Honorary Secretary
Honorary Treasurer
Honorary Registrar

Those elected will take office in February 2007, after the AIP Annual General Meeting. Members are urged to take advantage of this opportunity to be involved in the election of the new officers of the AIP.

All positions are held for two years. The Honorary Treasurer, Honorary Registrar and Honorary Secretary may seek renomination at the end of their two-year term of office. The Vice President, after serving two years, takes office as President for two years.

Nominations of AIP members for these positions, proposed and seconded by AIP members, must be in writing and must include the consent of the person being nominated.

All nominations should reach the Honorary Secretary by December 30th 2006, either by email [secretary@aip.org.au] or by normal mail addressed to the Honorary Secretary at the address below.

Ian Bailey, Honorary Secretary
Australian Institute of Physics
Phone 08 9332 1513
Mailing Address: P. O. Box 16, Willetton WA 6955

Fusion Research: Australian Connections, Past and Future

Whilst the national nuclear energy debate discusses the merits of yesterday's fission technology, the rest of the world is moving on. A consortium of over 30 of the world's most developed nations, and representing over half its population, is on the brink of building the next step fusion energy experiment, ITER. Coincidentally, the very week the Prime Minister launched a review into nuclear energy, the ITER partners initiated the ITER implementing agreement, which is set to bring the world's largest science experiment to life. Once ratified by the host governments (scheduled for Dec. 2006), construction will commence in Cadarache, in the South of France.

Australia does not yet have any formal connection to the world's largest truly international scientific project, which is surprising in view of the long and distinguished history of Australian contributions to fusion research, starting with the discovery of nuclear fusion, and the 'triton' by Sir Mark Oliphant and Lord Rutherford. More recently, the National Plasma Fusion Research Facility was established jointly by the Commonwealth and the ANU, based on the 'heliac' concept, which was first demonstrated in Australia.

A group of over one hundred scientists and engineers have formed the Australian ITER Forum, which aims to develop the case for an Australian role in the ITER project, both by participation, and the formation of an International Centre of Research Excellence in Fusion Related Research. With Federal Government support, the Australian ITER Forum has scheduled a workshop for October 12-13, "Towards an Australian involvement in ITER" www.ainse.edu.au/fusion. It will bring together the research community, industry, government, and the ITER partners to discuss a possible role for Australia, building on its past accomplishments, to participate in the pioneering demonstration of the ultimate clean, sustainable base load energy source. A full article will appear in the September/October issue of Australian Physics.

Prior to this, from July 27 to August 18, Dr Barry Green, a senior ex-pat fusion scientist in the international fusion program, will tour Australia. His tour will span eight cities, and cover the fusion process and its advantages as a source of energy, and outline ITER as the next, logical step on the path to developing a fusion power-producing reactor. www.ainse.edu.au/fusion/bgreen.html.

Boyd Blackwell
News

New Centre opens to study antimatter
Australia will be positioned to take a world-leading role in the area of antimatter, with the establishment of the Australian Research Council Centre of Excellence for AntiMatter-Matter Studies (CAMMS), which was launched recently by ARC Chief Executive Professor Peter Høj.

The new Centre will focus on the positron, the positively charged 'antiparticle' of the negatively charged electron. When the electron and positron come together, they eventually annihilate one another and produce two gamma rays.

The Centre for AntiMatter-Matter Studies is a joint venture between The Australian National University, the Australian Nuclear Science and Technology Organisation, Flinders University, Griffith University, Murdoch University and the University of Western Australia.

Professor Høj said the ARC Centre of Excellence for AntiMatter-Matter Studies would ensure that Australia was at the leading edge of the field, and that it would work alongside collaborative partners from eight overseas institutions around the world including Europe, Japan and the US.

Positron interactions have broad application in fields such as materials science and medical technology. They can be used to characterise the size and nature of free volume in materials at the nano-scale and are also widely used as a diagnostic tool in Positron Emission Tomography (PET) scans to detect cancers.

ANU media release

OPAL Reactor Operating Licence Granted

On 14th July ANSTO was granted a licence by its regulator, ARPANSA, to operate its new nuclear research reactor, OPAL.

"The granting of the licence takes us one step closer to the start of a new era in Australian science," said ANSTO Executive Director, Dr Ian Smith. "Not only will OPAL increase ANSTO's capacity to supply Australia and the region with critically important radioisotopes, it will provide world-leading capability for our scientists to apply nuclear research to such areas as biotechnology, food and molecular biology, nanotechnology, health, environmental management processes and engineering. "This research will result in tangible social and economic benefits for Australia," concluded Dr Smith.

The license was granted following an exhaustive examination of all the evidence presented by ANSTO, including cold commissioning tests. ARPANSA were also advised by overseas consultants, including an IAEA review team - all experts in the field of nuclear reactor engineering. OPAL has met the highest possible standards imposed upon the nuclear industry.

This will now allow ANSTO to load nuclear fuel and begin its second commissioning phase, where further testing will take place to ensure OPAL's performance meets expectations. When this is complete the current ANSTO reactor, HIFAR, will shut down. This will occur early in 2007.

ANSTO media release

Earth Scientist elected new President of Science Academy

Professor Kurt Lambeck, Professor of Geophysics, Australian National University (ANU), has been elected to lead Australia's senior organisation of research scientists and technologists, the Australian Academy of Science. He succeeds Dr Jim Peacock who completed his four-year term at the end of the Academy's scientific meeting at the Shine Dome on Friday 5 May.

Kurt Lambeck, 64, was elected to the Academy in 1984. He has been at the ANU since 1977, including 10 years as Director of the Research School of Earth Sciences. His principal research areas have included climate and environmental sciences, geophysics and space science. His current research focuses on the interactions between ice sheets, oceans and the solid Earth, as well as the rise and fall of sea levels and their effect on human civilisations.

His research has been recognised in Australia and overseas. He is a Fellow of the Royal Society of London and a Foreign Member of the Netherlands Academy, the Norwegian Academy, Academia Europaea and the Académie des Sciences, Institut de France. He is the recipient of many prestigious international awards.

He has extensive links with the international scientific community having held research positions in Europe and the United States. For many years he has represented Australia on numerous International Committees including the Intergovernmental Panel on Climate Change and the Antarctic Science Advisory Committee. He was Foreign Secretary for the Academy from 2000-04.

ANU media release

Recognition for optical fibre innovation

Breakthrough research into optical fibre technology has won a Sydney student a prestigious DuPont Australia and New Zealand Innovation Award.

Alex Argyros, University medallist in physics and doctoral candidate, won the Tertiary Student prize as part of the biannual DuPont awards. He has developed a hollow-core polymer fibre that could revolutionise the optical fibre industry.

"Polymer optical fibres - made of a single material that transmits light even at wavelengths where the polymer is not transparent - offer a cost effective alternative for hollow wavelengths in many applications," he said.

The DuPont Innovation Awards Program is an Australian and New Zealand independently judged competition and recognises innovation and advances in industry, science and agriculture.

Sydney University media release

Science Circus celebrates 21st birthday with an eye to the future

The Shell Questacon Science Circus will celebrate its 21st birthday with an eye to the future after Shell Companies in Australia and The Australian National University confirmed their continued support for Australia's largest and longest running educational outreach programme.

The unique and enduring partnership at the heart of the Science Circus has allowed it to expose countless students in rural and remote Australia to the joy of science.

The Science Circus was the brainchild of Professor Mike Gore, Questacon's founding Director. When Questacon was established, under the auspices of ANU, as Australia's national science and technology centre, he recognised that it "should not simply be another building but that it must develop programmes that will reach out to all Australians - both in our cities and in the remote rural areas".

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This ongoing support from the partners will mean that the Science Circus will continue to engage more than 100,000 people and 150 communities around Australia each year.

**ANU media release**

**Sunspot cycles a key to drought prediction**

New discoveries linking rainfall patterns on Earth with the periodic twisting of the magnetic field within the Sun could provide a powerful tool in the prediction of drought.

Associate Professor Robert Baker from The University of New England outlined the results of his research at the Regional Congress of the International Geographical Union in Brisbane on 5th July. He said his model could be used - in conjunction with other indicators such as the Southern Oscillation Index (SOI) - as a significant decision-making tool in agriculture and natural resource management. The paper he presented to the Congress was titled "Predicting drought in south-east Australia using solar cycles".

Dr Baker has correlated sunspot patterns - which have been recorded since 1745 - with historical rainfall records in south-eastern Australia. The correlation shows that periods of high rainfall are associated with periods of increased sunspot activity.

The most well-known sunspot cycle is the 11-year cycle, which comprises alternating five- and six-year periods of relatively high and low sunspot activity. Once every 11 years, too, there is a sudden reversal of the polarity of the Sun's magnetic field, so that there is a complete magnetic cycle (the "Hale cycle" or "double sunspot cycle") every 22 years. The 11-year sunspot cycle, however, is part of a more complex pattern that includes cycles of 900 and 1,500 years. [Some of the climatic effects of these longer cycles can be deduced from ice-core data and historical records.]

Dr Baker's model, which incorporates all these factors, indicates that south-eastern Australia - much of it currently drought-affected - could be heading for a period of even lower rainfall. This is because of an imminent coincidence of several of the solar cycles. The sunspot minimum in the 11-year cycle due in August this year coincides with that phase of the Hale cycle in which the magnetic field lines emerge from the Sun's south pole. Dr Baker said historical records showed that this coincidence was associated with reduced sunspot minima, and more severe droughts in eastern Australia. On top of this coincidence - and contributing to the potential for drought conditions - the Sun is entering a longer, 500-year period of reduced sunspot activity.

**UNE media release**

**ANU astronomer receives prestigious international prize**

ANU astronomer and Federation Fellow Professor Brian Schmidt has been awarded the prestigious Shaw Prize for Astronomy 2006 jointly with US colleagues.

The US$1 million Shaw Prize is awarded in three categories - Astronomy, Life Science and Medicine, and Mathematical Sciences - to individuals whose work has resulted in a positive and profound impact on mankind.

Professor Schmidt, with Saul Perlmutter from the University of California Berkeley and Adam Riess from the Space Telescope Science Institute, were commended for discovering the rate of the expansion of the universe is accelerating. Their result requires the existence of a previously unknown 'force' connected to the fabric of space-time - known as 'dark energy' - that opposes gravity, driving the acceleration.

Professor Schmidt led an international team, including Riess, called the High-Z Supernovae Search that found the expansion of the universe was speeding up, not slowing down (the commonly held view), by studying a class of exploding stars called Type Ia supernovae. Professor Perlmutter led a second team, which reached similar conclusions.

**ANU media release**

**Technology heralds the greening of nuclear energy**

Dr Hashemi-Nazhad is the sole Australian scientist working as part of an international collaboration on Accelerator Driven Systems (ADS), a type of sub-critical fission reactor which harnesses the high energy ion beam generation of an accelerator and the plentiful, radioactive metal, thorium to generate power.

Originally proposed by Italian Nobel physics laureate Carlo Rubbia, the system uses thorium as a fuel and requires a particle beam to keep it running. One advantages of thorium over plutonium or uranium is that it cannot undergo nuclear fission by itself, and cannot sustain a nuclear chain reaction. If the particle beam is switched off, it is impossible for the fuel to enter a chain reaction and cause a meltdown, like that at Chernobyl," said Dr Hashemi-Nazhad.

A recently released report by CERN European Organisation for Nuclear Research detailed the financial viability of the ADS system and found that it will be at least three times cheaper than coal and 4.8 times cheaper than natural gas, due to the long life of the reactor.

With around 25 per cent of the world's thorium deposits found in Australia, Dr Hashemi-Nazhad argues it is essential that we take the lead in this new technology. The Australian government must make a significant investment in this work. It is also essential for American universities to support the training of young scientists in the field of nuclear technology, at present there is an obvious shortage of applied nuclear science skills in Australia," he said.

University of Sydney media release

[See the article by Dr Hashemi-Nazhad in this issue - page 89]

**World-first NASA/Macquarie University science education project launched online**

One of humankind's biggest questions - How did life begin on Earth? - will be tackled by budding scientists the world over as a science education project developed by NASA and Macquarie University over the last two years.

Released on May 24th, the NASA/Macquarie University Pillbara Education Project is designed to give students and the public a taste of "real science" in action. It uses a suite of high-tech NASA Learning Technologies to take users on a virtual field trip of the Pilbara region of Western Australia to find evidence of the oldest known life on Earth; allows them to study these fossils using virtual laboratory tools; and compare the environments - in the Pilbara and on Mars - in which life may have begun.

Assistant Director [Management and
Soaring temperatures and declining rainfall could potentially wipe a billion dollars a year off Australia's economy in the next 30 years, according to Queensland University of Technology research. QUT's professor of Global Change, Professor Peter Grace, has examined five major grain-growing areas around Australia.

He found that while levels of the greenhouse gas carbon dioxide were increasing, increasing temperatures and lower rainfall would offset its effect of boosting productivity.

"In Australia over the next 30 to 50 years, atmospheric CO2 levels are predicted to increase significantly, with temperatures rising up to three degrees and rainfall falling by around 20% or more in some areas," he said.

Of the five grain-growing areas examined, most affected by global warming were the South Australian regions of the Southern Mallee (24% decline in production) and the northern Eyre Peninsula (19%). Next were the Riverina district in New South Wales (12%), central eastern Western Australia (10%) and the Darling Downs in Queensland (5%).

"Whilst these are preliminary predictions, under the new climatic conditions, farmers can expect shorter growing periods and new pests and diseases," Professor Grace said. "In the longer term, as rainfall decreases, the scarcity of water resources across the continent could mean their diversion from farming to more pressing needs related to human consumption and sanitation. This will put pressure on domestic food production and our export markets."

Professor Grace said there was an urgent need to fully explore farming practices that are designed to save water with the introduction and development of drought-tolerant varieties a high priority.

QUT media release

**Synchrotron sparks up**

The first electrons have spun around the storage ring of the Australian Synchrotron – an important step towards "first light".

The storage ring was completed at the end of March and the final components of the vacuum system baked and bolted into place at the end of May. The official end of installation, and the transition from construction to commissioning, was celebrated on 2 June. And in the following week, the Accelerator Physics team achieved the first turns of a full-design-strength 3GeV electron beam in the storage ring.

The Australian Synchrotron is due to open in April 2007.

**Lighting device wins first place for physics students in international competition**

Two physics school students have just returned from the 2006 Intel International Science and Engineering Fair in Indianapolis with First Place for Technical Communication for their portable photometric device.

The device allows vision impaired people to differentiate between stairways, handrails, signage and door handles in public areas. It works by determining the luminance contrast between two adjacent surfaces.

Ian Cannon and Rickystan Savaiko, Year 12 students from Redeemer Baptist College in Sydney competed with 1,500 students from 47 countries. Their work was showcased to eminent judges and Nobel Laureates in the world’s biggest pre-university scientific research competition.

They walked away with First Place from the Society for Technical Communication and Fourth Place in the Engineering category of the Grand Awards.

Their prototype is a triluminate colorimeter using red, green and blue LEDs for illumination with 45/0 degree geometry measuring diffuse reflectance. It divides the RGB palette into 729 divisions with a universally recognized colour assigned to each division. An LCD display and auditory output report RGB, CMYK, hue, saturation and luminosity values.

The device is inexpensive and has a likely future with organisations employing building codes which specify particular luminance contrast values for stairways, handrails, signage and door handles in public areas to assist the vision impaired.

The device has drawn the interest of the International Standards Organisation which has invited Ian and Rickystan...
News

to advise on the best algorithm to use in the determination of luminance contrast.

Ian and Rickstan won entry to ISEF as two of the four Young Scientist team members that represented Australia this year. The Young Scientist Awards Scheme is organised by the Science Teachers' Association of New South Wales. Students conduct an original scientific investigation in a creative manner. Teachers assess students’ work and send the best for state judging.


FASTS

FASTS Forums
FASTS are planning two forums in the second half of the year.
Internationalisation of S&T – Tuesday September 12th, Shine Dome, Canberra
This will focus on:
• geopolitical dimensions of internationalisation of S&T [i.e., S&T diplomacy, R&D is not just for commercial benefit];
• enabling conditions – what is required to leverage international science? [e.g., role of professional societies in developing linkages and networks to enable ‘last follower’ adoption/adoption of global R&D]

What is the role of Public Sector Research Agencies? – Monday 13th of November, Ridges Lakeside Hotel, Canberra
In the past 25 years PFRAs’ share of Govt support for R&D has declined from 51% to 26%. This raises important questions as to what are the expectations of different institutions and modes of R&D.

FASTS Elections
At the Annual General Meeting of FASTS to be held on Monday 20th of November, 2006, in Canberra, elections for the following office holders on Executive will be conducted:
• President-elect (1 year as President-elect followed by 2 years as President);
• Secretary (2 year term);
• Chair – Policy Committee (2 year term);
• Early career scientist (1 year term).
I would urge all societies to consider whether any of your members might be candidates for these positions.

Executive meets roughly once a month by phone hook up and its members also attend Board meetings [3 meetings per annum, including AGM, for 2 days each]. All positions are honorary and the President is a full member of PMSEIC.

Topics - Science meets Parliament 2007
As previously advised, Science meets Parliament 2007 will be conducted in March 2007. The exact dates, however, cannot be advised until November when the Government announces the 2007 sitting schedule.

It is intended that Parliamentarians will again be offered approximately 18 – 20 topics. However, this time we will try something different with the topics to try and leverage SmP a bit more effectively. In previous iterations of SmP we have identified 2 – 3 general or even ‘meta-science’ issues and sought to promote a consistent message on general issues such as more funding or position on intelligent design. However, FASTS have not sought to arrive at a common position for each scientific topic to coordinate lobbying or media.

Accordingly, it is proposed that for SmP 2007 we will:
• select the topics (balancing need for some generality to include all participants and necessity for focus to attract political interest); and
• build an informal network of experts from relevant societies to develop a position on each topic including 3 – 4 key policy statements/positions which will become the basis for presenting a coherent message to Parliamentarians and media on each topic.

ALP Innovation Blueprint
Labor’s innovation blueprint is a constructive contribution to revitalizing Australia’s innovation policy.

The President of FASTS, Professor Tom Spurling said Labor’s blueprint will challenge some long-standing assumptions and was a welcome contribution to the innovation debate.

“Labor has correctly recognised that innovation policy needs to focus more clearly on the ‘demand-side’ by building capacity in business to harness and leverage research.”

“They have proposed establishing up to 10 Enterprise connect centres to give firms better and smarter access to expertise and facilities in universities, research agencies and TAFEs”.

“The policy intent is to develop stronger ‘clusters’ and linkages between the ‘demand’ and ‘supply’ side.

“However, to be effective, such linkages need to be based on real strong personal relations and trust. Perhaps a more effective model is a larger number of smaller, agile and focused centres.”

“Attaching such centres to the existing, under-resourced industry ‘action agendas’ may provide a stronger strategic focus to a weak element in the current system.”

“Getting the incentives right to enhance business investment in R&D is crucial.”

“Scraping the R&D tax concession in favour of grants and loans may do more damage than good, however reassessing the balance between concessions and grants and the policy intent of such support is overdue.”

“There is a growing sense that Australia is frittering away the opportunity to invest in future productivity delivered by the current commodities boom. The ALP innovation blueprint is a timely reminder that a strong national commitment to innovation is fundamental to our future prosperity”, concluded Professor Spurling.
Peter Hannaford has had a remarkable career from country boy in the 1940s to head of Swinburne's Centre for Atom Optics and Ultrafast Spectroscopy. It's all the more remarkable because he was educated at some of Australia's lesser-known rural schools rather than one of Melbourne's more exclusive and influential private schools. During his early years, "We stayed typically one to three years in any one place, which meant that we would make friends and then move on. On the other hand, I enjoyed this as a challenge, just moving from school to school."

The reason for this life-style was his father's employment. According to Hannaford, "My father was born in England and he emigrated to Australia in the mid-1920s. After returning from the First World War he studied classics at Sidney Sussex College, Cambridge and trained to be an Anglican priest. He was recruited by the Bishop of Rockhampton to come out to North Queensland and his first postings were Mount Morgan and the outback towns of Winton and Longreach."

It was in Mount Morgan, near Rockhampton, that he met Hannaford's mother. "She was a dressmaker before she married and she was a keen pianist." It was only natural that the young Hannaford was brought up in a very religious home with "perhaps a narrow upbringing." While his family was not financially well off, they were, however, "rich" in things cultural. "We were encouraged very much to read books and there were always many books available." There was a strong emphasis on education in his home. "I'm very grateful to my parents for ensuring that I had a good education."

As he grew up his views on religion changed and he began questioning some of the foundations of religion. "I practised religion until about thirteen. I think I've been disillusioned by religious wars."

**Meccano and crystal sets**

His father's many postings landed the family in the Riverina district in New South Wales in the 1930s and it was in Cobram, just over the Murray River, that Hannaford was born. As a young boy he showed great interest in things mechanical and was always experimenting in one way or another. "I was very keen on meccano sets. Playing with magnets, especially electromagnets and magnetizing things I found absolutely fascinating. A few years later I built a crystal set. Australia was playing England in a cricket test at the time and this was a way of staying up all night at boarding school to listen to the cricket being played in England without anybody knowing." This early experimentation and fascination with things mechanical was to serve him well in his later career as a scientist.

**Schooling**

For his secondary education he went to Ballarat Grammar School, "It was a tiny boarding school and very hard up for funds in those days. They couldn't afford many good teachers."

But it taught him how to learn for himself from text books. He was fortunate in Year 12 to have had as a teacher Kostas Rindzevicius, a refugee from Lithuania. "He entered Australia and started doing labouring work on a farm. Then he decided to become a teacher. He'd actually been a mathematics lecturer at Kaunas University in Lithuania and he came and taught mathematics and physics. When he arrived I was the only student in his Year 12 mathematics class and he promised to teach me mathematics if I taught him English. He was a very inspiring person. We formed a close relationship and he did encourage me to go on to university."

**At Melbourne University**

After secondary school he enrolled to do a science degree at the University of Melbourne and took up residence at Trinity College. "At Trinity about 40% of the intake was from Melbourne Grammar, 40% from Geelong Grammar and the rest from other schools and the country. I was from the country. I was confronted with people from quite rich families, which I did not find easy at the time."

"In the second year, I was exposed to organic chemistry and I didn't like organic chemistry, mainly because there was a lot of memory work involved and I couldn't see the reason for having to learn all this stuff. That really put me off chemistry and was
The reason I swung to physics.

Sir Leslie Martin\textsuperscript{2,3} was the head of the School of Physics at that time. David Caro\textsuperscript{3} taught first year physics and according to Hannaford, “he was an excellent lecturer and very meticulous. He was proud of his lectures. After that I wasn’t turned on by physics. At that stage I had no idea I was going to do research.”

Turning point

Things changed after the third year. He was looking for a vacation job and had found an advertisement placed by the CSIRO’s Division of Physical Chemistry at Fishermen’s Bend. When he enquired about the job he was told that the position was no longer available but that there might be one in the Division of Chemical Physics. So, not knowing the difference between Physical Chemistry and Chemical Physics, he went in search of this job. “I was interviewed by Dr Lloyd Rees\textsuperscript{4}, the Chief of the Division. I recall talking about the Mössbauer effect, which was a very new and exciting effect that opened up the opportunity of doing spectroscopy with unprecedented resolution and of looking for extremely small effects”, said Hannaford. Rudolf Mössbauer had discovered the Mössbauer effect in 1957, one year before he received his doctorate from the Technical University in Munich, and he had just been awarded the 1961 Nobel Prize in Physics for this discovery\textsuperscript{5}. At the CSIRO Clive Coogan was just starting up some work on the Mössbauer effect and Rees “allowed me to go and work with him. That was the turning point in terms of a scientific career”.

He found the environment at the CSIRO Division of Chemical Physics extremely exciting and stimulating. According to Hannaford, “I was plunged into this atmosphere of arguably the leading physical science laboratory in the country and just sitting down at morning and afternoon tea with all these famous scientists around me was very inspiring.” At the end of the three months, he had decided that he would “like to do research in physics. Not only would I like to do research in physics, I’d like to do research on the Mössbauer effect.” He applied to do an MSc at the University of Melbourne. Bill Wignall “became my supervisor to do some work on the Mössbauer effect. We were just starting from scratch. He knew a little about it, I knew almost nothing, so we learnt together, which I think was a wonderful experience, being able to learn a new field together with your supervisor.” For his PhD he studied the Mössbauer effect for tin-119 atoms that had recoiled into abnormal crystal lattice sites as a result of the thermal neutron capture reaction $\text{Sn}^{118}(\gamma, \gamma')\text{Sn}^{119m}$. According to Hannaford, his PhD work was “the first observation of irradiation induced defects using the Mössbauer effect”.

During his undergraduate years he had also met Kay Berriman, who later became a primary school teacher. They married and she became a close companion and a constant source of support and encouragement throughout his scientific life. They have three children, Linda, Julienne and Andrew, and five grandchildren.

Cathode sputtering process

After his PhD he was offered a permanent position back at the CSIRO Division of Chemical Physics. He remained at the CSIRO for over thirty years. “I applied for a job which was advertised in the spectroscopy section to work in the group of Alan Walsh\textsuperscript{6,7}. At that stage I hadn’t heard much about the work he was doing. In fact, Walsh was already famous for his invention of the atomic absorption spectrophotometer which was to revolutionise chemical analysis. A few years later Walsh became a Fellow of the Royal Society of London and a Knight Bachelor. My professor at the University of Melbourne, John Cowley\textsuperscript{8}, who had earlier worked at the CSIRO Division of Chemical Physics, advised me to take the position in preference to an overseas postdoctoral position,” Hannaford said the new CSIRO position “didn’t amount to such a big change in direction, just a shift in energy scale from the resonance absorption of gamma rays by nuclei to the resonance absorption of light by atoms”.

When Hannaford arrived at the CSIRO, he found “the laboratory was full of people coming from industry wanting to use this new technique of atomic absorption and find out more about it. So the group was working very closely with industry at that stage, producing prototype instruments.” Walsh had a project in mind for Hannaford when he arrived at the laboratory. According to Hannaford, “Normally in atomic absorption the sample is dissolved into solution and sprayed into a flame. The flame vaporizes the sample and produces atomic vapour. The amount of absorption of resonant light from a source such as a hollow-cathode lamp determines the concentration of that element present in the sample. What he wanted me to do was to look into the possibility of doing away with the flame. The flame wasn’t a perfect device, by a long way, for sampling elements. In particular, you couldn’t vaporize solid samples directly that way; the sample first had to be dissolved and then sprayed into the flame. Walsh had already done some preliminary work on a method of vaporizing solids directly, and that was based on the process of cathodic sputtering in a rare gas discharge.” Hannaford, together with a colleague David Gough, spent several years developing a suitable cathodic sputtering apparatus and showed that it could be used for analyzing solid samples directly\textsuperscript{9}. “The only problem was that there was little interest commercially because
everybody seemed to be happy with the flame. They patented the device anyway.

Coherence spectroscopy

Several years after Hannaford had been at the CSIRO, Walsh arranged for him to spend a year at the University of Reading to work with George Series, a pioneer of coherence spectroscopy and a Fellow of the Royal Society of London. According to Hannaford, "The technique that Series had been working on was called optical radio frequency double resonance. This is a magnetic resonance technique in which polarised resonant light is used to inject polarisation into atoms, and a magnetic field is applied to split the excited levels in the presence of a radio frequency field which is tuned to resonance with the Zeeman splitting. In this way, it is possible to measure extremely small splittings such as hyperfine structure in the absence of Doppler broadening. Now, Doppler broadening, which arises from the random thermal motion of the atoms in the vapour, normally tends to smear out the hyperfine structure. But this was a method that could give you essentially natural line-width resolution."

Hannaford, together with Series and John Deech, worked on a time-resolved level-crossing experiment, which is similar to an optical radio frequency double resonance experiment but which allowed them to achieve resolution below the natural line-width by preferentially selecting the radiation emitted by atoms having lifetimes longer than the mean lifetime. This introduced him to coherence spectroscopy.

When he returned to Australia, in 1973, he thought, "Okay, let's see if we can use the cathodic sputtering method which we had developed for atomic absorption to do these coherence spectroscopy experiments." The reaction he received was that "the sputtering discharge is a very hostile sort of environment" and that would destroy the coherence induced by the light. "So the first thing I did when I got back was to try a very simple coherence experiment. It's called the Hanle effect and it was discovered by Wilhelm Hanle in 1923. But it's a very powerful technique in which an atomic vapour is excited with polarised resonant light and the intensity of the polarised fluorescence is measured in a specific direction as an applied magnetic field is swept through zero. You see a narrow peak or dip, depending on the geometry."

"We were able to see beautiful Hanle resonances with essentially natural line-width resolution and 100% contrast in atomic vapours produced by sputtering in a rare-gas discharge. I think this really convinced me that cathodic sputtering was potentially a very powerful technique for producing atomic vapours of essentially any element in the periodic table to do this highly precise sort of work."

Tunable dye lasers

During his time at the University of Reading (1972-1973), dye lasers were just coming on the scene, and it was clear that these tunable light sources were about to revolutionise spectroscopy. Series had arranged to have a flash-lamp pumped pulsed dye laser delivered on trial from a small company in Belfast. Hannaford recalls how one of his most memorable moments was seeing for the first time the sodium D-line doublet in the fluorescence from a vapour cell as the dye laser was tuned shot by shot through the resonance.

Upon returning to the CSIRO he immediately submitted a proposal to purchase a pulsed nitrogen-laser pumped dye laser and began looking into the possibility of using cathodic sputtering to vaporize elements for laser spectroscopy. The first experiment we tried was to excite the atomic vapour generated by cathodic sputtering with sharp resonant laser pulses and to record the atomic fluorescence as a function of time. This was a very simple experiment that gave the lifetime of the excited atoms. Now, there's a lot of interest in atomic lifetimes because they are related to the transition probability or strength of the atomic transition. That information is important in a number of applications. One is atomic absorption itself. It determines the magnitude of an atomic absorption signal. Another important application is in the determination of the abundance of elements in the Sun from the Fraunhofer absorption lines. Astrophysicists need to know the transition probabilities precisely and they need to know them for a wide range of elements and transitions."

He started this work on zirconium which is "a good example of an element which is very difficult to vaporize by thermal means." He and a colleague, Martin Lowe, spent the next three years sorting out a large discrepancy with previously published lifetime values for zirconium before they were sufficiently confident of the reliability of their results and this enabled them to eliminate essentially all sources of systematic error along the way so that we could then really quote our atomic lifetime values down to about the 2 per cent level."

At that stage he remembered asking "What element should we do next?" With the cathodic sputtering technique he knew that they could do "almost any level of any element in the periodic table and we could do them very quickly using the sputtering method." But when he examined the National Bureau of Standards tables of atomic transition probabilities to see what had already been done "there was
almost a complete blank for all the 'refractory' elements that were difficult to vaporize thermally."

"Yet it turned out these were the very elements astrophysicists were wanting transition probabilities for in order to work out the abundances of elements in the Sun and stars. He had read about the solar abundance work of Nicolas Grevesse, an astrophysicist at the University of Liege in Belgium, and wrote to him. Meanwhile Grevesse had just heard about the CSIRO atomic lifetimes work and he wrote to Hannaford. Their letters crossed in the mail.

According to Hannaford, they provided the data from the solar spectrum taken at the Jungfraujoch Observatory in the Swiss Alps, and we measured the atomic lifetimes for the systems which they told us they wanted. By obtaining data for a large sample of transitions for each element we were able to make definitive measurements of the abundances for a large number of elements in the Sun and also in a few stars. This collaboration, with Grevesse and Emile Biemont from the University of Liege, continued for about fifteen years.

From this research he and Martin Lowe moved on to doing "time resolved coherence spectroscopy in a sputtered vapour, a bit like the atomic lifetimes work mentioned previously," he said, but now they used polarised laser pulses and applied a magnetic field, like in the Hanle effect. "In this case we could look for the beating of the fluorescence from pairs of Zeeman split levels coherently excited by the sharp laser pulses. The beat frequency is related to the Zeeman splitting of the levels. We were able to see beat signals with close to 100% visibility in atomic vapours produced by cathodic sputtering."

In 1981, he went back to work with Series at the University of Reading. He did some laser spectroscopy experiments on the 'optogalvanic effect', in which an atomic resonance is detected by observing changes in the impedance of an electrical discharge when an incident laser beam is tuned to resonance with the transition. He and Series realised that what had never been done was "to use the optogalvanic detection technique to do coherence spectroscopy." They were able to use the optogalvanic effect in a sputtering discharge of the kind developed at the CSIRO to detect nonlinear Hanle and level-crossing resonances in refractory metal atoms such as zirconium and yttrium produced by cathodic sputtering in the discharge."

Saturated Absorption Spectroscopy

Back in 1981, the CSIRO had purchased a narrow-bandwidth continuous-wave ring dye laser and he began tackling a different type of experiment together with David Gough. "This was to do Doppler-free saturated absorption spectroscopy in a sputtered vapour. The reason for wanting to do this was that in sputtered vapours you can do essentially any element in the periodic table. They were able to observe high-resolution saturated absorption spectra in a sputtering discharge. So quite a long term program was established and we were able to make very precise measurements of small hyperfine splittings and isotope shifts in a wide range of elements. There was a spin-off here. It's possible to use this technique as a method for determining isotopic abundances in elements, by measuring the intensities of the various isotope components in the Doppler-free spectrum. We developed this technique and showed it was feasible. It was patented as a method for isotope analysis but was never commercialised."

Laser cooling of atoms

On his next visit to England, in 1989, he worked in the Clarendon Laboratory in Oxford and was fascinated by experiments being conducted by Christopher Foot on laser cooling of atoms. "The thing that particularly attracted my attention was that he was using miniature semi-conductor diode lasers to do the laser cooling and this greatly reduced the complexity and cost of the equipment and made it virtually accessible to many groups."

So what is involved in laser cooling of atoms? According to Hannaford, "If you take a cloud of atoms and shine on laser light which is tuned just below the frequency at which the atoms normally absorb, then in order to make up for the difference in frequency so that the atoms can absorb the laser light the atoms have to be moving towards the laser beam. So by tuning the laser light to the low frequency side you can select out those atoms which are moving towards the laser beam and only those atoms will absorb photons. If they absorb enough photons it's possible to slow the atoms down. Now, to slow an atom from room temperature down to very, very low temperatures requires something like one-hundred thousand photon absorptions. If you now apply, say, six similar laser beams -- three pairs of counter-propagating beams in mutually orthogonal directions -- then no matter which direction an atom is moving, it's always going to be slowed by laser light. Using these techniques, it's possible to cool a cloud of atoms down to within a few micro Kelvin of absolute zero and to confine them in a 'magneto optical trap'." The development of these methods to cool and trap atoms with laser light led to the award of the 1997 Nobel Prize in Physics to Steven Chu, Bill Phillips and Claude Cohen-Tannoudji."

Atom optics

When he returned from Oxford in 1990 he had discussions with Geoffrey Opat and Tony Klein..."
in the School of Physics at the University of Melbourne. They were well known for their pioneering work on neutron optics and neutron interferometry. According to Hannaford, "At that stage Geoff was looking for something perhaps a little different, perhaps better than neutron interferometry. We started talking about using laser-cooled atoms instead of neutrons to do matter-wave interferometry." A collaboration started which turned out to be extremely fruitful and led to a number of novel experiments and proposals. A large part of the experimentation was done by a student, Wayne Rowlands. They were joined by a research fellow from Moscow, Andrei Sidorov, and later by a CSIRO colleague, Russell McLean. But what was the reason for wanting to produce an interferometer based on cold atoms? Hannaford, replied, "Such an interferometer would be extremely sensitive to interactions such as gravitational interactions. In a light interferometer, for example, the light beam is split and then recombined to give interference fringes and the light travels at three-hundred million metres per second across the interferometer. In a cold-atom interferometer the atoms might be travelling at, say, one-tenth of a metre per second; so the atoms sample interactions for a relatively long period while there're traversing the interferometer. In addition, atoms such as caesium are very heavy compared with, say, neutrons in a neutron interferometer; the particle fluxes are many orders of magnitude higher; and of course you do not need a nuclear reactor." "So", he continued, "there's great interest in producing an atom interferometer for fundamental experiments on gravity fields and also for commercial work. The mining industry is very interested in detecting gravitational anomalies associated with large ore bodies hidden deep beneath the surface of the Earth." There is also interest by defence agencies for inertial navigation, especially for submarines.

**Centre for Atom Optics and Ultrafast Spectroscopy**

In 1997 Hannaford was appointed a Professorial Fellow at the Swinburne University of Technology, initially on a part-time secondment from the CSIRO. What was his motivation for joining Swinburne University? According to Hannaford, "I guess that about every seven years or so I have moved on to a slightly different topic" and "Swinburne University was wanting to raise its research profile and initiate some new research in specific areas, and one of these areas was optics and lasers. The Pro Vice-Chancellor [Research], Kerry Pratt, approached me and I agreed to start up a new femtosecond laser laboratory." He was joined by Martin Lowe on a part-time secondment from CSIRO.

He had his reasons for working with femtosecond lasers. According to Hannaford, "The duration of the laser pulses (less than about 10⁻¹³ seconds) is the sort of time scale atoms take to approach each other in a gas and interact to form molecules, or the time scale required for molecules to vibrate. It's also the time scale required for molecules to dissociate and for chemical reactions to occur. So it's possible to use these very short laser pulses to study in real time chemical reactions as they actually occur, molecules as they actually vibrate, molecules forming and dissociating, and so on. The idea is to have two pulses, usually in a pump-probe arrangement. The first pulse, the 'pump', effectively opens a shutter and the second pulse, the 'probe', closes the shutter. So you can effectively do high speed photography on what's going on." A state of the art two-colour femtosecond laser system was purchased and a new laboratory was built in a car park in the basement of the Applied Sciences building. The laboratory was opened in February 1999 by Ahmed Zewail, who later that year was awarded the Nobel Prize in Chemistry for this sort of work - *femtochemistry* he called it. In 2001 the group was joined by Lap van Dao from the University of New South Wales. The laboratory is currently involved in studies of ultrafast processes in biological molecules such as myoglobin, haemoglobin and light harvesting carotenoids; semiconductor materials such as gallium nitride and gallium indium nitride; and semiconductor quantum dots and quantum wells.

Back in his laboratory at CSIRO support for basic research was declining and in 2001 Hannaford arranged for his atom optics group of Andrei Sidorov, Russell McLean and David Gough, and also Tien Kieu from the micromanufacturing group, to move full time to Swinburne University to form the Centre for Atom Optics and Ultrafast Spectroscopy (CAOUS). The Centre has expanded rapidly in recent years and now has groups working in the areas of atom optics, ultracold molecules, ultrafast spectroscopy and applied optics, as well as a theory group. It is also now part of the ARC Centre of Excellence for Quantum-Atom Optics (ACAO) and the recently established ARC Centre of Excellence for Coherent X-Ray Science (CXS). CAOUS currently has 16 research staff, 16 postgraduate students and 6 Honours students.

In 2005 the atom optics group of Andrei Sidorov, Brenton Hall, Shannon Whitlock and Hannaford succeeded in creating a Bose-Einstein condensate (BEC) of rubidium-87 atoms on an 'atom chip' comprised of magnetic microstructures on a permanent magnetic thin film, suitable for device applications. A Bose-Einstein condensate is a new state of matter, predicted by...
Albert Einstein in 1925, in which bosonic atoms, such as rubidium-87, confined in a trap are chilled below a critical temperature so that all the atoms collapse into the lowest quantum state of the trap. The realization of a BEC in a dilute gas led to the award of the 2001 Nobel Prize in Physics to Eric Cornell, Wolfgang Ketterle and Carl Wieman.

Apart from being the Director of CAOUS Hannaford has and continues to supervise a number of postgraduate students.

Achievement

Hannaford has come a long way from tinkering with meccano and crystal sets to working with ultracold atoms and state of the art femtosecond lasers. So what does he consider his major achievement in research to date? “I've been fortunate to have chosen research areas which have later turned out to be frontier areas and usually these areas have been recognized a few years after we've started. There's an element of luck there. So I think a major achievement is just to be able to contribute to these new very exciting areas. I suppose if I had to single out one achievement then it would probably be the development of the cathodic sputtering technique as a universal method of producing atomic vapours for the very exciting field of laser spectroscopy.”

References

1. All quotations are from tape number ORAL TRC 4789 held in the Oral History Collection of the National Library of Australia. The interview was conducted by Dr Ragbir Bhathal for the National Project on Australian Physicists.


Conferences

2006

July 17-21
ICOOPMA2006: First International Conference on the Optical and Optoelectronic Properties of Materials and Applications
Darwin, NT

July 22 - 26
International Symposium on Gas Kinetics
Orleans, France
www.gk2006.org

July 30 - August 4
International Conference on Nanoscience and Technology ICN&T 2006
Basel, Switzerland
www.icn2006.ch

August 12 - 20
National Science Week
National
www.scienceweek.info.au

Aug 28 - Sep 1
9th International Conference on Nucleus-Nucleus Collisions
Rio de Janeiro, Brazil
www.nn2006.com.br/

Sep 8
Nanotechnology Conference
Sydney, NSW
www.hkc22.com/nanotechnology.html

September 10 - 14
Megagauss XI - Ultra high magnetic fields: their science, technology and application
London, UK
http://conferences.iee.org/MG-XI

Sep 25 - 29
5th Symposium on Turbulence, Heat and Mass Transfer
Dubrovnik, Croatia
130.83.243.201/thmt-06/announce.html

2008

June 15 - 19
17th World Hydrogen Energy Conference
Brisbane Convention and Exhibition Centre
www.whec2008.com

November 21 - 23
15th AINSE Nuclear and Complementary Techniques of Analysis
Melbourne University, Melbourne, Australia

2007

July 8 - 12
World Conference on Science and Technology Education
Perth, WA
www.WorldSTE2007.asn.au

October 8 - 12
Advanced Infrared Technology and Applications 2007 Giorgio Ronchi 9th International Workshop [AITA 2007]
CIO, Leon, Guanajuato, Mexico
ronchi.iei.pi.cnr.it/AITA2007
Moving towards a national system for assessing research quality

Australia is moving towards a national Research Quality Framework (RQF) following the announcement of $3 million funding in the 2006-07 Budget. The RQF was announced by the Prime Minister in May 2004 and seeks to measure the quality and impact of research in universities and publicly funded research agencies.

The Minister for Education, Science and Training, the Hon Julie Bishop MP, said that once developed, the RQF would more readily identify and reward the highest quality research undertaken in Australia's publicly funded research sector.

"It will also recognise research that provides significant broader impact to Australia, whether economic, social, environmental or cultural. The RQF will be the first research assessment exercise carried out internationally that considers research impact," Minister Bishop said.

"The RQF will bring Australia in line with other research-led economies and will fill the gap that currently exists where there is no system-wide or expert-based way to measure the quality and impact of Australian research."

"The funding announced in this Budget will allow further development of the model and the next phase of the process. The recently appointed RQF Development Advisory Group will advise the Government on how the RQF model, if adopted by the Government, could be most effectively implemented," Minister Bishop said.

Questacon to receive a facelift

Questacon, Australia's national science and technology centre, will receive $15.3 million over the next four years to undertake essential upgrades, the Minister for Education, Science and Training, the Hon Julie Bishop MP, announced on 9th May.

The additional funding, announced as part of the 2006-07 Budget, will ensure that the national icon in Canberra continues to provide a unique experience for the 400,000 visitors it receives each year.

"This funding will be used to implement Questacon's 30 year asset renewal plan which identifies key upgrades required to enhance the life of the 18-year-old facility and maintain its status as an important national institution located within the Parliamentary Zone," Minister Bishop said.

"Questacon, with its hands-on approach, encourages younger people to learn and understand the importance of science."

Australia invests $41.5 million to secure world-class researchers

On 11th May, the Minister for Education, Science and Training, the Hon Julie Bishop MP, awarded Australian Research Council (ARC) Federation Fellowships to 25 world-class researchers to retain 18 of our best home-grown researchers, bring five Australian research leaders back home and attract two foreign nationals to continue their cutting edge research in this country.

"This $41.5 million investment over five years will enable Australia to maintain and build its international reputation as a leading research nation," Minister Bishop said.

"Our support for the innovative work of these researchers, in diverse fields including biomedicine, engineering, justice and law enforcement, environmental sciences, architecture, the physical sciences and history will help to ensure a brighter future for all Australians."

"The Australian researchers returning to this country have most recently held positions with Harvard University, the University of Minnesota, the University of Oklahoma and Yale University in the USA, and the University of Oxford in the UK. The foreign nationals will come to Australian universities from the National Institute on Drug Abuse and Brown University in the USA."

Research to be undertaken under the Federation Fellowships announced today includes:

- developing new drugs to combat mental illnesses;
- identifying the reasons for the success or failure of peace building in the Pacific and Asia;
- developing a new generation of silicon solar cells that will reduce the costs of generating electricity from sunlight;
- improving our understanding of Islam and terrorism in Southeast Asia;
- developing new methods of detecting explosives and identifying types of explosives - technology which has relevance for counter-terrorism, medical sciences, forensics, energy generation, monitoring the environment, and quality control in the food industry;
- improving our understanding of Australian climate variability and our ability to respond to predicted impacts; and
- developing polymers (plastic-like materials) that respond to electrical signals which can improve the quality of life for people with heart implants, neuromuscular disorders and spinal cord injuries.

Federation Fellowships are funded under the ARC's National Competitive Grants Program, as part of the Government's 10-year $8.3 billion commitment to innovation-Back Australia's Ability.

For further information go to www.arc.gov.au/

Innovation Report reveals strengths in science and innovation

On 18th May, the Minister for Education Science and Training, the Hon Julie Bishop MP, released the Australian Government's Innovation Report 2005-06.

The Innovation Report provides a comprehensive overview of the Australian Government's policies and programmes in science and innovation, focussing on the three key themes of: 

- Backing Australia's Ability: strengthening Australia's ability to undertake research, accelerating the commercial application of ideas and developing and retaining Australian skills.

A significant aspect of the Report is advice on the progress that departments and agencies have made in the last year in the implementation of the National Research Priorities.

The report identifies Australian businesses as the largest performers of R&D, noting that business expenditure on R&D is at the highest recorded level. A record number of small and medium sized firms obtained support through the R&D Tax Offset which helps small companies undertake innovative research and development.

Small innovative firms are also being assisted through a range of programs overseen by the Industry Research and Development Board including the COMET initiative, where private sector business experts help firms to commercialise new ideas. Both large and small firms get assistance through the new Industry Cooperative Innovation Program where groups of companies work together on strategic innovation projects.

Increasing research efforts and inter-agency collaboration in key areas is enabling considerable long-term benefits to Australia; for example, the Australian Research Council and the National Health and Medical Research Council have finalised arrangements for a new funding initiative called Thinking Systems, which will support research across sectors, institutions and research disciplines.


Report on nuclear power released

Minister for Education, Science and Training the Hon Julie Bishop MP today released the full report Introducing Nuclear Power to Australia: An Economic Comparison on 6th June.

Commissioned by the Australian Nuclear Science and Technology Organisation (ANSTO), the report provides an analysis of the costs of generating electricity from nuclear power compared to coal and gas power stations.

Minister Bishop said she welcomed the report as a constructive addition to the current debate about a potential nuclear power industry in this country.

The report can be downloaded from www.ansto.gov.au
Accelerator driven sub-critical nuclear reactors

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Introduction
Recent experimental observations and theoretical calculations indicate that a dangerous climate change is becoming increasingly likely. The record-breaking heat wave that affected much of Europe in the summer of 2003 took place 50 years earlier than expected from calculations based on previous global warming predictions.

These climate changes are related to the increase in the concentration of carbon dioxide in the Earth’s atmosphere resulting from the massive consumption of fossil fuels all over the world, dominated, at present, by the industrial countries, including Australia.

Besides the greenhouse effect, it is now well established that within the first half of the current century there will be a shortage of fossil fuel (mainly oil and natural gas). Such a fossil fuel shortage will be accelerated because of improvement in the living standards of the so-called ‘third world’ countries and the heavy industrialization of ‘emerging countries’ such as China, India and some Latin American countries.

Due to the greenhouse induced global warming and the exhaustion of fossil fuel, nuclear energy provides an attractive and logical solution for the world energy problem. However worldwide public concerns about the safety of nuclear power plants impose a precondition on any decision on the nuclear energy production. In other words the new generation of nuclear power stations must be safe and environmentally friendly.

For many years, there have been investigations into the possibility of obtaining nuclear energy using a different method from that of the conventional nuclear reactors and which is safer and less expensive.

A New Method of Nuclear Energy Production
The conventional nuclear reactors operate at critical condition. The criticality of a nuclear assembly is determined by the effective neutron multiplication coefficient $k_{en}$ which is defined as:

$$k_{en} = \frac{\text{Number of fissions in any one generation}}{\text{Number of fissions in immediately preceding generation}} \quad [1]$$

When $k_{en}$ = 1, the number of fissions in each succeeding generation is a constant and the chain fission reaction initiated in the system will continue at a constant rate. Such a system is said to be at a critical condition. If $k_{en} > 1$, the number of fissions in the system increases with each succeeding generation; the corresponding condition is referred to as supercritical. On the other hand, if $k_{en} < 1$, the chain reaction will eventually die out and the system is called subcritical. Since the number of fissions is proportional to the number of neutrons absorbed in the system, in equation 1 the number of the absorbed neutrons can replace the number of fissions.

Conventional nuclear reactors operate in a very narrow range of the neutron multiplication coefficient ($0.994 < k_{en} < 1.006$). Outside this range, either the reactor fades out or becomes supercritical and overheats.

In a subcritical reactor, the number of neutrons originating from fission is not sufficient to overcome the neutron losses (due to leaks and absorption of neutrons by materials within the reactor). Therefore, under

![Figure 1: Pictorial representation of high-energy proton interaction with target nucleus. In the first stage the incident particle interacts with individual nucleons (intranuclear cascade (INC) phase). This is followed by intermediate stage (pre-equilibrium). In both of these stages light high-energy particles (dominated by neutrons) are emitted which then interact with other nuclei in the extended target (intranuclear cascade). In the second stage the residual nucleus either undergoes evaporation releasing neutrons and light ions (with energies around 1 MeV) or fission. In the final stage the residual nucleus (or nuclei) de-excite via gamma emission.](image)

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with radius \( r \) of a cylindrical lead-target, for three different incident proton energies (as calculated using MCNPX 2.5e Monte Carlo code). The neutron multiplicity increases with increasing target radius and reaches a plateau value which is proton energy dependent.

Figure 3 shows the energy spectra of neutrons emanating from a cylindrical lead target of length equal to the range of protons (range long) and diameter 20 cm irradiated along its axis with protons of different energies. It can be seen that, although the upper energy limit of the spallation neutrons varies with the incident proton energy, the overall shape of the neutron spectrum does not change noticeably with the proton energy.

The original idea of constructing a subcritical nuclear reactor \( k_{\text{eff}} < 1 \) and introducing externally produced neutrons into the subcritical assembly in order to maintain a chain reaction is some times attributed to Tostevin, Joint Institute for Nuclear Research, JINR, Dubna, Russia, 1989\(^b\), although his works were published only as JINR preprints. Bowman et al.\(^10\), Los Alamos National Laboratory, LANL, USA, 1992, suggested using neutrons produced in the interaction of high energy protons with a lead target to transmute long-lived radioactive waste nuclei into short-lived or stable isotopes. Carlo Rubbia\(^11\) (CERN, 1993), the joint winner of the 1984 Nobel Prize introduced this idea more openly into the public forum in scientific publications and public lectures.

A nuclear reactor operating under subcritical conditions and driven by an accelerator is generally referred to as an Accelerator Driven System (ADS). The CERN group uses the term Energy Amplifier (EA) for this type of reactor.

In an Accelerator Driven System, this external source consists of neutrons created by the spallation process when a medium energy proton beam reacts with a heavy target. The supply of neutrons is proportional to the proton beam intensity.

As already mentioned the proposal to use a particle accelerator as a neutron supplier for a subcritical nuclear reactor is few decades old but it has become a realistic option due to recent massive progress in accelerator and computer technologies. After about seventy years of experience in accelerator technology the energy efficiency and reliability of these machines have reached an industrial level. Increases in computing power and the development of simulation programs have allowed detailed simulations of the behavior of the Accelerator Driven Systems under different realistic conditions. These simulations can look at particle and radiation production in nuclear
interactions and their transport in complex systems, material behavior under different and extreme conditions, thermodynamics of the complex thermal systems and nuclear material burn up and production in the system.

Problems associated with conventional critical thermal nuclear reactors

There are four major problems associated with the current conventional thermal nuclear reactors such as pressurized water reactors [PWR] or light water reactors [LWR]:

1. Inefficient use of the nuclear fuel in the current thermal reactors. The main fuel of these reactors, $^{239}$U, is only about 0.7% of mined uranium. The remaining 99.3% of the mined uranium is not used in the fuel cycle.

2. Production of long lived [on a geological scale] nuclear waste.

3. Safety issues and possibilities of nuclear accidents, however remote.

4. Unavoidable production of fissile material [$^{239}$Pu], which can be diverted to military applications.

The new generation of nuclear power plants must have solutions for all of these problems and accelerator driven subcritical reactors provide such solutions.

Solutions of the problems

1. Solution to the inefficient use of the nuclear fuel

The fuel of an accelerator driven subcritical reactor is bred from natural thorium or uranium [$^{232}$U] via the

$$^{232}\text{Th} + n ightarrow ^{233}\text{Th} ightarrow ^{233}\text{Pa} ightarrow ^{233}\text{U} \quad (2) \quad \text{and} \quad ^{235}\text{U} + n ightarrow ^{236}\text{U} ightarrow ^{236}\text{Np} ightarrow ^{237}\text{Pu} \quad (3)$$

following reactions:

The end product of both reactions is fissile material that can be used as fuel in ADS. Both of these elements are abundantly available in Australia (Australia has the world's largest thorium reserves - 300,000 tons) $^{17}$.

In both of the above fuel breeding processes almost 100% of mined uranium or thorium can be converted to fissile material and burnt in the reactor.

Due to the massive amount of $^{239}$Pu produced in reaction 3, the uranium option must be carried under strict observation, supervision and control of the IAEA.

The $^{232}$Th option is preferred to $^{235}$U because thorium is more abundant than uranium in the earth's crust by a factor of 3-4, and because of other reasons given in the following text.

2. Solution to the nuclear waste problem

a) By using the more abundant fuel [thorium] very long-lived [geological scale] plutonium and minor actinide radioactive waste will not be produced. It must be noted that in a uranium-burning reactor most of the radiotoxicity of the spent fuel is a result of plutonium isotopes.

b) As ADS operates in sub-critical conditions, a very large excess of neutrons is available in the system. The excess neutrons can be used to transmute long-lived radioactive wastes [such as the fission products] to short-lived or even stable isotope $^{99}$Tc ($T_{1/2} = 2.11 \times 10^5$ years) + $n \rightarrow ^{100}$Tc $\rightarrow ^{100}$Ru (stable)

$^{129}$I ($T_{1/2} = 1.57 \times 10^7$ years) + $n \rightarrow ^{130}$I $\rightarrow ^{130}$Xe (stable)

species via a neutron capture process $^{13,14}$. For example

This method of nuclear waste transmutation is not available in conventional reactors as these reactors operate in critical conditions and there are no excess neutrons available to be used for waste incineration.

The excess neutrons in the ADS also will be used for fuel production from $^{232}$Th via reaction (2) as already mentioned.

The excess neutrons in suitably designed ADS also can be used to transmute the stockpile of the nuclear waste that has been accumulated over the last 60 years operation of the conventional critical nuclear reactors $^{15}$. The final nuclear waste of the ADS requires only about 500 years of storage time [which is manageable with today's technology] to bring its activity to the level of coal ash $^{16}$. This must be compared with the geological scale storage time required for the nuclear waste of the current nuclear reactors.

The long-lived nuclear waste isotopes of conventional reactors such as $^{241}$Am, Cm isotopes and $^{239}$Pu can be incinerated by the fission process. In such cases not only the nuclear waste isotopes are destroyed but also a significant amount of energy is produced $^{13,14,17}$.

In other words, an ADS produces its own fuel and incinerates its own long-lived nuclear wastes as well as the waste from existing conventional critical reactors.

It must be mentioned that 1 kg of thorium if converted to fissile material and burnt in ADS can produce $8.3 \times 10^{11}$ joules of thermal energy. This will result in much less than 1 kg of nuclear waste to be stored for ~500 years. If the same amount of energy is produced by coal it will result in $2.3 \times 10^9$ kg of CO$_2$.
Accelerator driven sub-critical nuclear reactors

3. Solution to the nuclear safety issue

An ADS will operate under sub-critical conditions (e.g., $k_{\text{eff}} = 0.95-0.98$) and the operation of the reactor is directly linked to the operation of the attached accelerator that provides a high energy ion beam to produce spallation neutrons. These neutrons keep the ADS operational, i.e., the system remains operational as long as the accelerator functions. The proton beam plays the role of the control bars in the current reactor with the difference that, if it fails, the fission reaction in the system dies out and it can never lead to overheating and critical power excursion.

There are many ways to shutdown an accelerator [an electric device] or divert its beam away from the sub-critical reactor core.

Two major nuclear accidents (Three Mile Island and Chernobyl) were both caused by critical power excursions.

Moreover an ADS fuelled with thorium does not contain $^{238}\text{U}$ and therefore will not breed $^{239}\text{Pu}$ which can be diverted to military applications. In a thorium fuelled ADS the approximate uranium isotope mixture in the subcritical core after an integrated neutron exposure of $3 \times 10^{20}$ cm$^{-2}$ will be $^{232}\text{U}$ ($44\%$), $^{234}\text{U}$ ($30\%$), $^{235}\text{U}$ ($4\%$), $^{238}\text{U}$ ($22\%$) and $^{239}\text{U}$ (negligible). A very difficult and extremely intensive isotope separation is required to separate 'weapon grade' $^{233}\text{U}$ from this type of mixture.

**Overall cost of electricity production via ADS**

Although the cost of energy production by means of uranium burning conventional reactors is lower than that of the coal powered power stations, it would be better if these costs were further reduced. The cost of energy production by ADS using thorium will be less than that of the current nuclear reactors because;

1) Thorium is much more abundant than uranium in the Earth's crust and therefore cheaper. The current price of 1 kg of ThO$_2$ (99.9% pure) and UO$_2$ is US$82.50 and US$100.30 (see www.ucs.com/review/ucx_prices.html) respectively. Taking into account the thorium and uranium contents of these compounds, 1 kg of pure Th and U will cost US$93.90 and US$118.50 respectively.

2) Th is almost all of the $^{232}\text{Th}$ can be converted to ADS fuel.

3) No fuel enrichment and associated cost is required.

4) The control system of the ADS will be much less sophisticated than that of the current reactors and therefore less expensive.

Detailed analyses have shown that the cost of the energy production by ADS would be ~ 2c per kWh.

**Accelerator requirements**

Fig. 4 shows the variation of the neutron multiplicity with energy of the incident proton for a range long lead target of diameter $20\,\text{cm}$ as calculated using the MCNPX 2.5e code. The energy gain of an ADS is defined as $G = \frac{P_{\text{out}}}{P_{\text{in}}}$ where $P_{\text{out}}$ and $P_{\text{in}}$ are output and input thermal powers respectively. The $G$ is directly proportional to the energy cost of the neutron production $\frac{\text{np}}{E_p}$, where np is the number of the spallation neutrons per proton of energy $E_p$ on the target. From Figure 4, it can be seen that $\frac{\text{np}}{E_p}$ and neutron yield per unit energy of the incident proton $\frac{\text{np}}{E_p}$ as a function of incident proton energy. The energy gain of an ADS is directly proportional to $\frac{\text{np}}{E_p}$. Calculations were performed using MCNPX code.

Therefore the $G$ reaches a plateau at energies $E_p > 1$ GeV.

Figure 4 suggests that a 1 GeV proton accelerator will be adequate to achieve about the maximum gain. With the neutron multiplicity of 24.5 neutrons per 1 GeV proton [Fig. 4] a subcritical assembly with $k_{\text{eff}} = 0.95$ or $k_{\text{eff}} = 0.98$ (extremely safe operational level) coupled with an accelerator which provides a proton beam with integrated proton current of 10 mA [beam power of 10 MW] will have a thermal energy gain $= 37$ and 96 respectively. Such an ADS may produce 370 MW at $k_{\text{eff}} = 0.95$ and 960 MW at $k_{\text{eff}} = 0.98$. Obviously higher powers will be produced at higher beam currents.

A certain fraction of the ADS electric output power must be fed back to run the coupled accelerator. The electric power required to obtain a proton thermal beam power of $P_{\text{th}}$ is $P_{\text{in}}\xi$ where $\xi$ is the electric to beam power conversion efficiency of the accelerator. For modern accelerators $\xi$ is about 0.5. Also there is a heat loss in conversion of the thermal to electric power, efficiency of which is $\eta = 0.42$. Therefore fraction of the output power required for accelerator operation will be $f = \frac{P_{\text{th}}}{P_{\text{in}}\eta} = \frac{1}{G\xi\eta}$.

![Figure 4. Variations of the neutron multiplicity np, and neutron yield per unit energy of the incident proton (np/Ep) as a function of incident proton energy. The energy gain of an ADS is directly proportional to np/Ep. Calculations were performed using MCNPX code.](image-url)
Accelerator driven sub-critical nuclear reactors

Thus for $k_{eff} = 0.95$ and $k_{eff} = 0.98$, $f$ will be 13% and 5% respectively.

**Basic principles of the ADS operation**

The basic principles of the operation of an ADS are shown in Fig. 5. When this representation of the ADS is compared with that of the conventional thermal reactors it becomes obvious that the design of a subcritical nuclear reactor will not dramatically differ from that of the conventional reactor. This by itself is an advantage because over 60 years of experience with nuclear reactors can, and will, be an asset and foundation in the design and operation of this new generation of reactors. However a major effort must be put to the design of accelerator, beam window, spallation target and fuel rods. Also the type of material that can be used in an ADS must be radiation resistant and be able to handle large exposure to high-energy nuclear particles.

Like any other reactor, an ADS has a core, which in this case has fuel elements made of pellets composed of mixed oxides (MOX) of $^{233}$ThO$_2$ and $^{232}$UO$_2$ enclosed in an appropriate cladding. The initial amount of the $^{232}$U in the rods is for startup purposes. During the ADS operation the consumed $^{232}$U will be replaced by $^{233}$U bred from $^{232}$Th according to reaction (2). The core and ADS as a whole would be designed so that $k_{eff} < 1$. The spallation target is positioned between the fuel rods in the core. The beam of protons from a high-power accelerator is directed towards the spallation target (e.g. lead) to produce spallation neutrons and thus sustain the chain reaction in the system. The reactor core and target are embedded within an environment that acts as neutron and heat storage medium as well as neutron moderator. We will refer to this medium as M-medium. The type of the material that can be used for M-medium depends on the type of the ADS - whether it is a fast or thermal ADS - and it must be compatible with the type of the material used for cladding. For fast ADS it is proposed to use the lead as both target and M-medium in such a case the M-medium will be molten lead.

If material of the M-medium is different from that of the target then the target must be enclosed in a leak proof container made of a corrosive resistant substance that has high thermal conductivity and a high melting point. Tungsten can be a good candidate for this purpose. As most of the energy deposition by the beam happens within the first 20 cm of the target length and considering a beam power of more than 10 MW, such a target-system must rapidly dissipate the absorbed heat to the surrounding medium.
Accelerator driven sub-critical nuclear reactors

The ADS control unit can be equipped with temperature, neutron and other sensors, which will send electronic signals to the accelerator if reading level[s] exceed a desired limit, triggering beam abort away from the core. Extra redundant safety units such as those used in conventional reactors can also be added for further safety.

The heat produced by the fission of the material in the core is stored in the M-medium from which it is transferred to the heat exchangers and electricity generating units in a conventional manner.

Inside the reactor vessel and in the vicinity of the core we have placed a fission product transmutation container (FPTC). This is used to consume the available excess neutrons in the system for transmutation of long-lived fission product isotopes such as $^{129}$I and $^{99}$Tc. The FPTC is accessible from outside of the main reactor vessel for loading and discharging the waste in liquid phase.

To exploit all the capabilities of the ADS, its fuel must follow a closed cycle. That is the spent fuel must be processed and partitioned according to the best available methods and technologies. Figure 6 shows different stages of the closed ADS fuel cycles. After the initial cooling stage of the spent fuel, the fissile materials and unused thorium in the spent fuel are separated and used in new fuel rod fabrication. The long-lived and transmutable fission products are separated for injection into the FPTC. The final untransmutable wastes are sent to an appropriate waste storage facility where they will be kept for a period of about 500 years. Today's technology allows us to be confident that such a waste storage will be safe and environmentally harmless.

Obviously the nuclear waste that can be used as fuel and transmutation material is not limited to the waste produced by the ADS itself. In the fabrication of the ADS fuel rods the waste from the conventional critical reactors can be and will be used as well. This provides the long awaited solution to public concern about the stockpiles of nuclear waste produced over the last 60 years of operation of nuclear reactors.

Some predictions for future electricity generation in Australia

The electricity generation from fossil fuels, especially coal, will continue for many years, although in an improved and more environmentally friendly manner. Due to the massive world demand for energy, the export of coal and natural gas will not be reduced as a result of installations of nuclear power plants in Australia and other parts of the world for several decades to come.

In addition, R&D into renewable resources and production of energy from them will continue and may even accelerate.

For immediate economic, environmental and geopolitical reasons it is not difficult to predict that Australia's initial involvement in the field of nuclear energy will be in terms of conventional generation three thermal nuclear reactors. Alongside of which uranium enrichment and fuel processing plants will be established. However it will not be possible to avoid ADS technology because of the fact that this type of nuclear system provides the only known and logical method for handling, managing and eliminating the dangerous and environmentally harmful nuclear waste. Australia's future nuclear power plants, beyond those

Figure 6. A closed fuel cycle for ADS. The MOX fuel refers to the one that is made of mixed oxides of the fissile materials.
Accelerator driven sub-critical nuclear reactors

that may be installed after the conclusion of the current nuclear debate, will use ADS technology because of the massive thorium resources of Australia, the safety of these reactors and the cleanliness of energy production by the ADS method.

It must be mentioned that involvement in ADS research and development and eventually installations of thorium based Accelerator Driven Systems in Australia will not affect uranium exports. This is because the number of existing commercial uranium burning nuclear reactors in world (441) and those that are under construction (~15) and those that will be constructed in the future (including those in Australia). The demand for uranium in the world market not only will not decrease but is expected to increase as fossil fuels become scarcer and willingness for their massive use diminishes.

The impact of the ADS technology to the Australian economy is enormous. Calculations show that if the known thorium resources of Australia (300,000 tonnes) are burnt in accelerator driven sub-critical reactors, it will provide an energy equivalent of $4.3 \times 10^{19}$ barrels of oil. This amount is equivalent to 5800 years of oil export at a rate of 2 million barrels per day (similar to that of a major oil producing country in the Persian Gulf) or an income of ~ A$US$70x10^8 [US$52x10^8] per year for 5800 years at today's oil price.

Accelerator driven subcritical nuclear reactors besides producing clean and cheap energy, provide a unique solution for the elimination of plutonium, minor actinides and long-lived fission products in conventional nuclear reactor waste as well as the plutonium from warheads: one of mankind's unnecessary, unwise, self-destructive, cruel and crude technical achievements, for a peaceful and environmentally clean Earth.

References

Upcoming Physics events and activities

**Movie stunts and the physicist**
2 August, Cook and Phillip Park, NSW

Stunt people are trained to jump, fall, roll, and take a few bumps. This student workshop will show how physics makes stunts more about science and less about blind courage. Students will work out how to guarantee a safe landing. Their mission is to ensure the safety of the stunt people while keeping the thrills.

For more details: Kellie Harris, (03) 9320 6389, Scion @ Ausmus.gov.au, www.scienceinthecity.net

**Science talent search competitions in states**
August to October in SA, WA and Vic

School science projects are being presented, exhibited and judged across the country over the next three months.

In Victoria, the Science Talent Search public judging day is on 12 August with an exhibition day on 30 October.

South Australia's Oliphant Science Awards (nominated for nuclear physicist and state governor Sir Mark Oliphant) will have their public open day on 20 August.

And in Western Australia, the Science Talent Search presentation day is on 16 September, with entries on public display for two weeks following. Presentations and public displays of entries for the Inventor of the Year competition, School's category will be held in October.

For more details: Science Teachers Association of Victoria (03) 9385 3999, South Australian Science Teachers Association (08) 8224 0871, Science Teachers Association of Western Australia (08) 9244 1987.

**Young Inventors Festival**
8 September, Drage Airworld, Wanneroo

See over 150 inventions, models and posters on display, talk with young inventors and vote for the People's Choice award at the Young Inventors Festival in Wanneroo in September.

For the third year in a row, hundreds of young inventors will develop and turn ideas into inventions.

For more details: Brendan O'Brien (03) 5761 2131, obrien.broo@edumail.vic.gov.au, www.myrrheeps.vic.edu.au/YoungInventorsTrial/peopleschoice.htm

**Science Drama finals performance & awards night**
9 September, Darebin, Vic

Dancing molecular reactions, Einstein's theories enacted and physics in poetry. Watch school teams sing, dance and perform science in a textbook-free environment as they compete in the Science Drama awards.

For more details: Science Teachers Association of Victoria (03) 9385 3999, info@stav.vic.edu.au

**SILLIAC's 50th anniversary celebrations**
12-13 September, University of Sydney

SILLIAC, the first computer built in an Australian university, will be 50 in September 2006 with a special two-day event focusing on the past, present and future of information and communications technology — ICT Pioneers and Leaders.

For more details: Alison Thorn, (02) 9356 5914, a.thorn@physics.usyd.edu.au


**Physics at Adventureworld Day**
28 September, Bibra Lakes, WA

School students experience the physics of theme park rides and measure the thrills.

For more details: Science Teachers Association of Western Australia (08) 92441987, info@stawa.asn.au

**Electric Vehicle Challenge**
28 October, Perth

Teams will race electric vehicles that they’ve designed and built.

For more details: Science Teachers Association of Western Australia (08) 92441987, info@stawa.asn.au

**Physics in Science Week: Saturday 12 August to Sunday 20 August.**

A host of physics events are happening across the country as part of Science Week. Here is a selection.

More information at www.scienceweek.info.au

**SCINEMA, various locations nationwide**

SCINEMA - Festival of Science Film - is showcasing short films and documentaries. Themes include: wildlife at risk, environment, sustainable health, state of the planet, inventions & discoveries, and maths, physics & astronomy.

**Arnhem Land - a space science & astronomy history, Nhulunbuy, NT**

A presentation unifying space & astronomy science of yesterday, today & tomorrow in NE Arnhem Land. Includes Aboriginal (Yolngu) mythology, space science missions & local modern-day astronomy.

**Outback inventors, Alice Springs, NT**

Clever ideas from open spaces - bush ingenuity and technology on display.

**Coffee and Science Show, Hawker, ACT**

See a science show performed by members of the University of Queensland Physics Demo Troupe that goes off with a bang and invites audiences to participate in hands on challenges.

**Hawker hosts hot science moments: free public lecture, Hawker, ACT**

What would it be like to travel in a black hole? Could we reach other universes without spaghettification? Climate change - what does it all mean? Come along and find out!

**Bones, rocks and stars: the science of when things happened, Civic, ACT**

Focusing on famous dating controversies - from ice ages to the age of the Earth - and drawing on experiences such as the celebrated Hobbit fossil of Indonesia, Chris Turney explains how scientists 'tell the time'.

**Understanding climate change, Kent Town, SA**

What exactly is the Greenhouse effect and how will it affect our planet? What is being done to address climate change and what can you do? We will also give you a tour of the Weather Bureau.

**Tutankhamen, Howard and Marvin, Adelaide, SA**

A rich and diverse range of features exploring the ancient world, ancient Egypt and space travel. The oldest and newest of things will be represented. Tutankhamen, Howard Carter and Marvin, the world's first artificial moon. The night sky and the human eye.
participants will witness a demonstration of "Marvin" the computerised mat cutter, who has revolutionised the preparation of archival mounts for the preservation and display of photographs and art on paper.

Rocking our universe, Melbourne, Vic
Brian Cox might be better known in Australia as the boyish keyboard player in bands such as DARE and for the hit song with D:REAM - 'Things can only get better'. But BBC viewers in Britain also know him as an enthusiastic science presenter. Armed with a PhD in High Energy Particle Physics from the DESY Laboratory in Hamburg, he is now working at CERN in Switzerland, and is more turned on by the prospect of what will be discovered about our universe when the particle accelerator starts up there in 2007.

Stop poverty with technology - appropriate technology for development workshop, Brunswick, Vic
Get your hands dirty and have a go at designing and building appropriate technologies, which can be used to improve quality of life in developing communities.

Cafe Scientific presents 'The biggest questions in the universe' with Brian Cox, Sydney, NSW
Panel discussion including Bernie Hobbs (ABC TV New Inventors), Paul Willis (ABC TV Catalyst), UK physicist Brian Cox and local astronomers, discussing dark matter, multiple universes, extra-terrestrial life, and what really went on before the Big Bang.

World Robot Olympiad, Australian Museum, NSW
The World Robot Olympiad brings together young people all over the world to develop their creativity and problem solving skills through challenging and educational robot competitions. Includes the finals of the NSW Roboathlete competition.

The physics air show, Australian Museum, NSW
Watch barrels being crushed and see brains expand, to find out the amazing physics of air. This entertaining and interactive science show demonstrates all the cool things about air that you didn't know.

Sailing into the final frontier: The Giant Magellan Telescope, Darling Harbour, NSW
Australian scientists have just embarked on an international partnership to build the most powerful extension to the human eye yet known: The Giant Magellan Telescope. Penny Sackett from ANU will discuss this exciting project.

'Master matter blaster and the beginning of time: what makes up the universe?' Ultimo, NSW
UK's popular science communicator Brian Cox contrasts the size of the universe today with what we think it looked like less than a billionth of a second after the big bang. Some of this new science will be coming out of CERN, the world's largest particle accelerator in Europe, which has a giant new machine starting up in 2007.

Go-kart go! Fremantle, WA
Be thrilled by this exhibition and demonstration of Willetton Senior High School's entry vehicle into the Panasonic World Solar Challenge, the solar car driven in competition from Darwin to Adelaide.

Nuclear energy - lecture and forum, Gingin, WA
What is nuclear power and how does it work? What are the bi-products of nuclear power and what challenges do they present? A lecture and forum with panel of experts.

Alternative energy fun day and "Energy for the future" art competition, Gingin, WA
Partake of a pancake cooked on the solar oven and discover other forms of energy. School classes/groups can join in the inaugural 'Energy for the Future Art Competition' and win a telescope for their school.

For more information about all these Science Week events visit www.scienceweek.info.au

J. L. William Senior Lecturer, Experimental Physics

School of Physics, Faculty of Science
Monash University, Melbourne, Australia
Outstanding physicists are invited to apply for the inaugural tenured J. L. William Senior Lectureship in experimental physics. Applicants will hold a PhD in physics and have a proven record of excellence in their field of research, including publications in the highest impact physics journals. Successful applicants will be expected to establish and lead a vigorous independent research group, supervise research students and contribute to undergraduate teaching.

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Hollywood Physics – Daredevil Stunts

One of the most popular series of movies is certainly the twenty films featuring the celebrated secret agent 007 – James Bond – released over a period of 40 years, making the name and number household words in many countries. From Dr No in 1962 to Die Another Day in 2002 they provided fans with a feast of breathtaking escapes and daredevil stunts. Physics professor Barry Parker examines the underlying science involved in the lake crashes and improbable armaments of superspies, weird flying machines and submersibles employed by Bond and the villains opposing him.

Parker has written a book titled *The Fantastic Physics of Film’s Most Celebrated Secret Agent* which, I must say, is a patchy presentation. Its scientific analyses are roughly at senior high school level, extending to single-line equations and some simple line-diagrams. The kinematics and elementary dynamics are fair enough, but there is an almost total lack of consideration of the energy requirements of death rays and gadgets.

Explanations are poor and inaccurate for topics such as radar, rocketry, radioactivity and nuclear weapons. For example, plutonium is not less radioactive than uranium (p.188).

The diagram of a bomb employing liquid hydrogen is ludicrous. In discussing radar Parker gets the Doppler frequency shift wrong (p.89). A serious flaw for non-American readers is the use of imperial units of measurement. When will Americans join the rest of the world?

The *Fantastic Physics of Film’s Most Celebrated Secret Agent* runs to 229 pages and is published by the Johns Hopkins University Press. In hardcovers it costs US$25 and bears the ISBN 0-8018-9268-6. I enjoyed many parts of it but cannot recommend it except to James Bond fans who will lap it up. School teachers might get a few good ideas from it.

Colin Keay
Reviews Editor

The encyclopedia therefore serves in part to achieve both the alphabetic and thematic presentations in a unified manner. Cross-referencing between sections is reasonably well done, and strong reference is made to texts, foundational journal articles and other appropriate references. The index is extensive (some 180 pages) and well catalogued, and relatively straightforward. The editors have maintained a consistent and clear format for all entries, allowing experts or users to dip in and recover valuable information quickly.

Just from this short summary, it can be seen that the *Encyclopedia of Condensed Matter Physics* has reviews of fields and details that an individual is not likely to be familiar with. This is especially so because the very field crosses many boundaries – physics, chemistry, metallurgy, engineering, nanotechnology, and bioengineering to name a few. There are some 322 entries by my count, each of which is scholarly and in-depth. The editors have chosen a dictionary-style alphabetical ordering of major topics, rather than a thematic presentation like a textbook or a handbook. Nonetheless, the ordering follows key themes, so that many issues relating to ‘semiconductors’ are listed under ‘s’ for example, with numerous subheadings.

The major themes by this arrangement are Alloys, Biological Structures, Catalysts, Ceramics, Composites, Crystals, Disorder, Electronic Properties, Electronic Structure, Excitons, Group Theory, Insulators, Ion Transport, Lattice Dynamics, Liquids, Magnetic Effects, Mechanical Properties, Metals, Molecular Modelling, Nanostructures, Nonlinear Dynamics, Nuclear Models, Optical Properties, Phonons, Polymers, Proteins, Quantum Mechanics, Quasicrystals, Scattering, Semiconductors, Statistical Mechanics, Superconductivity, and X-ray Techniques. There is also a separate subject classification (reprinted at the beginning of each volume for ease of reference) making explicit linkages between themes and providing cross-references for topics such as: Biophysics, Electrical Properties, Historical Reviews, Instruments, Magnetic Properties, Materials, Mathematics, Microscopy, Spectroscopy and Structures which may cross several disciplinary boundaries. There are 39 major headings in this thematic content list. There are also many individual entries on other specific topics.

The article on Specific Heats gives a
Reviews

detailed and well-informed overview of applicability and failings of Debye and Einstein models, and of the separability of contributions from phonon, conduction electron, magnetic and hyperfine contributions. Each figure has direct references to research papers, including very recent (2004) work. Many articles such as this one have a separated section at the end of the article defining nomenclature used in a clear manner.

The articles on Statistical Mechanics give scholarly reviews of key principles at the level of a typical third year undergraduate course and lead on to other related articles such as superconductors at a more advanced level. Articles on Sum Rules and Surfaces were particularly lucid and insightful in summarising several key issues in each case.

From this brief discussion I hope it is clear that the foundations in physics of Condensed Matter Physics are well-presented in this encyclopedia.

My greatest appreciation probably relates to some areas of least expertise, including extensive and authoritative monograph reviews of numerous alloy types, ceramics, composites and catalysts. The detail of some of the complex phase diagrams for binary or ternary alloys are intriguing and are presented clearly. Summaries of mechanical and electrical properties and engineering-based alloy designations for example are entertainingly surveyed and summarised with clear illustrations, many reprinted with permission from original research papers.

I can highly recommend this encyclopedia for the reference collection of many libraries in different disciplines and, for example, nodes of Centres or research groups who may want to address issues in a more holistic manner. The encyclopedia could be recommended also to assist with lecture preparation at the third year, fourth year or graduate levels, as many of the reviews are concise and provide a quick grounding in key concepts.

Chris Chanter
School of Physics
University of Melbourne

Princeton Series on Astrophysics
Electromagnetic Processes
Robert J Gould
X + 271 pp, US$45 (paperback)
This book is part of the

Fundamentals of Atmospheric Radiation
Craig F. Boheren and Eugene E. Clothiaux
WILEY-VCH, Weinheim 2006
xviii + 472 pp., EUR 89.00 (softcover)
ISBN 10 3-527-40503-8

This book is advertised as a physics textbook. Atmospheric radiation is a specialised part of physics although it employs standard optical and radiative theories and formulae. The book is appropriate to undergraduate students in meteorology or atmospheric science, but there is some useful material in physical optics. There are few textbooks at this level. The book is quite long and wordy in places but it is written in a lively, sometimes folksy, style with examples of phenomena observed from everyday life. There are four hundred problems but many require estimates or discussion and there is no list of solutions. The book covers most of the essential features of atmospheric radiation. Emission and absorption of photons by atmospheric molecules and particles leads to scattering by atmospheric particles. There is a good section on absorption by atmospheric molecules and one on black body concepts and radiometry. There are comprehensive discussions on multiple scattering covering two chapters, a core subject in atmospheric radiative transfer. Starting with scattering by a pile of plates the discussion leads through two-stream theories to multiple scattering at higher orders. The Monte Carlo method of scattering is then covered, giving an insight into the effects of orders of scattering and the mean free path of photons. Finally there is a chapter on optical phenomena, mainly due to clouds. An omission is any discussion on radiative balance and transfer through a typical atmosphere, a central subject in atmospheric radiation theory.

C M R Platt
CSIRO Atmospheric Research
This book covers the traditional territory of mathematical methods in physics and engineering. It is intended to be a teaching tool for courses aimed at the junior undergraduate level, as given in the School of Applied and Engineering Physics at Cornell University. The material covered includes topics in linear algebra, tensors, curvilinear coordinate systems, complex variables, Fourier series, Fourier and Laplace transforms, Dirac delta-functions, differential equations and solutions to Laplace's equation. A number of more advanced topics are included such as closed-valued complex functions and group theory. The authors have an engaging and pedagogic style.

Readers of this column will no doubt have their own favourite books in this area. I grew up with "Mathematical Methods of Physics" by Mathews and Walker and "Mathematical Methods for Physicists" by Arfken, now in its sixth edition. These more advanced books are predominately aimed at the graduate level. One of the first things I look for in any book on mathematical methods is the way in which the authors tackle the topic of branch cuts. Any lecturer on mathematical methods is also looking for worked examples and numerous exercises. This book passed these tests admirably. Indeed, I used a number of the problems in my own course this past semester. In summary, a welcome addition to the good books in this area.

Murray Batchelor
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Having set that scene, Barlow moves on to address some of the more general debates that exist in Australian science circles about priorities, large team research etc. In these he presents very good arguments that some of the hype and direction at present is not supported by evidence. He is not aligned with any camp and is not following a "party line" but instead he is following a very valid "evidence based" approach.

The purpose of this book is to first set the current science and research scene properly on an evidence based footing and then move on to developing a workable and sustainable research and development strategy which can work for the Australian community.

I recommend to all of you that you read this book. You won't agree with all of it but much of it will strike a chord, even with sceptics. I am sure that even if you disagree with some aspects, you will still be provided with some great material to ponder, some ammunition for your next discussion on this issue and some strategies which will work nonetheless.

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Mathematical Physics (Second Edition)
Applied Mathematics for Scientists and Engineers
Bruce R Kusse and Erik A Westwig
Wiley-VCH, Weinheim 2006
xi + 678 pp., EUR 69.00 (softcover)
ISBN 3-527-40672-7

The Australian Miracle
An Innovative Nation Revisited
Thomas Barlow
Picador, Australia 2006
ix + 262 pp., $A 25 (paperback)
ISBN 10 0 330 42232 4

Most physicists, and many members of the public, have clear ideas on what is wrong about the Australian economy. Too much reliance on primary produce, inventions are lost overseas, industry does not invest enough in research and development, scientists are not valued highly enough, ... and the list goes on. Some of these issues make the news from time to time but only if there is a good negative spin that can be applied to it. In fact, the author of this book has identified no less than TEN such issues, but he has taken a different perspective in that he refers to them as "Ten Myths About Australian Science" (Chapter 1). Normally I would switch off at this point with strong negative perceptions of the author unless they had some real credibility. Thomas Barlow, as an Australian PhD graduate, work experience here and overseas, as well as a recent stint as the Science Advisor to Minister Brendan Nelson certainly has the credentials to warrant reading further.

In this very readable and provocative book Thomas looks to each of the myths and presents a strong case for overturning well held views. He presents new material that I have not encountered before. He also recounts anecdotes from politicians and senior scientists he has met in the course of his work which give interesting insights to the depth and breadth of misconceptions.

He gives a knowledgeable account of the inventions and developments which propelled Australia into the twentieth century at the top of the world in GDP per capita, with low death rates and high literacy rates. He discusses a range of inventions, developments and enhancements that gave Australia an edge over more developed economies.
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