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COVER: This month's front cover shows a three-dimensional AFM nanolithography image, courtesy of NT-MDT and Coherent Scientific. For more information see page 157.

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PRESIDENT’S COLUMN

It is now old news that the Coalition is back in power and that other issues swamped the news at the time of the election campaign. Despite this competing news, education did get some attention from both parties and it gained considerable relevance from Rupert Murdoch’s pronouncements as well as the senior people who supported his views.

On top of all of that, there was significant editorial comment in the lead up to the election which supports our view on the support of education and research.

Internationally the game is afoot as well. I have seen a number of publications from the UK and the USA on these and related matters. Recently a German colleague drew my attention to a full year campaign in Germany focussing on the plight of education and science with liberal lashings of effective science communication.

So what do we do now? Accept that there will be no change till the next election or later? I don’t think so - as we cannot wait that long. The AIP executive, as well as FASTS, will be maintaining the pressure on the government and you can help. You have the material on our web site so continue to use it (www.aip.org.au/initiative2001). It is valid data and it cries out for an answer. Make sure that your local member is sick of a stream of scientists knocking on their door asking why nothing is being done on this issue.

Utilise the persistence that you rely on to achieve any of the personal goals you have in life. This is important for Australia’s future so make sure that something is done about it.

On an issue closer to the core of the AIP, the executive have been working on updating our database, our image, our procedures and soon we will announce proposed changes to the constitution of the AIP. The goal is to change the constitution to reflect more modern perspectives and to simplify our membership structure. I will provide more detailed commentary in a future Physicist as I want all members to be aware of the changes and the reasons for them. If you have any suggestions on possible changes to the constitution please let me know.

Finally, many of you will have been inundated with Congress emails from me in November. My apologies for this. The long list of email addresses was an oversight on my part and the numerous copies was a fault of my email program. My apologies for any inconvenience.

I hope you have enjoyed a good break and are looking forward to a great new year. I wish you all a prosperous 2002!

John O'Connor

AUSTRALIAN INSTITUTE OF PHYSICS — AGM 2002

The 39th Annual General Meeting of the AIP will be held at 6 pm on Thursday February 14th 2002 at 1/21 Vale St, North Melbourne, VIC 3051.

AGENDA:
1. Apologies, recording of proxies
2. Minutes of 38th Annual General Meeting
3. Business arising from the minutes
4. President's report
5. Treasurer’s report (including appointment of auditors)
6. Any other business.

Moira Welch, Hon Secretary

AUSTRALIAN INSTITUTE OF PHYSICS 2002 COUNCIL MEETING

The Council meeting for 2002 will be held at 1/21 Vale St, North Melbourne on Thursday February 14th and Friday February 15th. A/Professor John O’Connor, AIP President, will be the chairman.

Those invited to the Council meeting, in addition to the National Executive and the Chairs of State Branches, include the Convenors of AIP topical groups, the National Science Policy convenor, the Editor of the Physicist, the National Education Convenor, and the Presidents of the AIP’s six cognate societies: the Australian Optical Society, the Astronomical Society of Australia, the Australian Acoustical Society, the Vacuum Society of Australia, the Australasian College of Physical Scientists & Engineers in Medicine, and the Australian Society for General Relativity and Gravitation.

A report on the Council meeting will be published in the March/April 2002 issue of the Physicist.

Moira Welch, Hon Secretary
EDITORIAL

Roll On, the Global Village

The Afghan conflict provided an awe-inspiring display of U.S. military technology, a war being fought almost by remote control, like something out of a science fiction novel. Satellites orbiting overhead could virtually read the numberplates on Taliban vehicles, while Stealth bombers and B-52s rained godlike destruction from the skies. Cruise missiles can sweep down the main street of a town, turn on a sixpence and home in on an individual window of a target building. Pilotless aircraft are making their appearance on the scene, and can even distinguish individual faces, apparently. Boeing is designing new pilotless aeroplanes that will make manned fighters and bombers redundant within a few years. Thus the Taliban found themselves fighting a futile struggle against remorseless and invulnerable machines, and soon gave up. Once again the U.S. showed its might as the "global policeman", and the only remaining superpower.

With such great power comes great responsibility, however. The U.S. should be all the more careful how it uses this awesome superiority, lest we all find ourselves lost in a "Brave New World". Even a highly-principled nation like the U.S. can misuse its power, as it did against Allende in Chile, or the Sandinistas in Nicaragua. Ideally, this sort of unfeathered power should not be exercised by any single nation, but should only be used under the aegis of an organization of collective security, with the consent of the community of nations.

Yet the United Nations is not ready to exercise this sort of responsibility either. Its decision-making can be frozen by a veto in the Security Council. It has no democratic or proportional representation mechanisms. The U.S. and other great powers have little faith in the organization, and only use it when convenient. And finally, its resources are far too weak. An attractive possibility is that NATO could be refocused to act as an organization of common security for the community of democracies, and to exercise their external peacemaking and peace-enforcing responsibilities. It has already played this role once in Bosnia, with mixed success it is true, but it got the job done in the end. The UN authorized the intervention, and NATO carried it out: providing an excellent procedural model for other such actions which may become necessary in the future.

It would not be a huge extension of its role to give NATO a similar function world-wide, perhaps folding in the OECD as well to handle issues of economic development. Japan, Australia and New Zealand are already members of the OECD, and could easily be accommodated as new members of NATO; and other stable democracies could be admitted over time. Russia, for instance, has already suggested that it should be admitted.

NATO already has a Council to determine questions of policy, an Assembly where issues can be debated in a democratic fashion, and only needs a Court to settle disputes on the basis of international law. It could form the nucleus for an eventual democratic world federation, built up over many years in the same way that the European Union has built up from its starting point in the European Coal and Steel Community. Such an organization could effectively tackle many global problems, not only peace and security, but also the environment, hunger and poverty, disease and underdevelopment.

This last year has marked the centenary of Australian federation, and fifty years since the start of European unification. It was also the start of a new millennium. It would be wonderful if it could mark the start of a new era of common security worldwide as well, and a start towards an eventual world federation. Physicists, who already form a closely-knit worldwide community, should find such ideas very natural.

On another note: some members did not receive their copies of the May/June issue of the Physicist: a bunch of copies must have been lost in the mail. We have replaced as many as possible, but have now run out. Our sincere apologies to those who missed out.

Let me wish a Happy New Year to all our readers.

Chris Hamer
C.Hamer@unsw.edu.au

The Physicist Volume 38, Number 6, November/December 2001
AROUND THE TRAPS

Nobel Prize 2001

This year's Nobel Prize in physics has been awarded to Carl Weiman and Eric Cornell of the JILA laboratory in Colorado, and Wolfgang Ketterle at MIT for their creation of the first atomic Bose-Einstein condensates (BEC) in 1995. The condensates, in which many atoms condense into the same quantum ground state, can be used to demonstrate many fascinating phenomena, such as atom lasers, atom optics and superfluidity (see Peter Hannaford's article on this issue).

The Colorado team used laser cooling and then evaporative cooling to lower a gas of rubidium atoms to an incredible 20 nK above absolute zero; while the MIT team used a gas of sodium atoms.

[Peter Rodgers, 'Physics World', November 2001, p. 5]

Big Plans at Monash

Monash University has recently announced some ambitious new spending plans to reinforce its commitment to science. As well as $157 million for the new synchrotron, they plan to spend another $300 million to create a technology park called the STRIP (Science Technology Research and Innovation Precinct) on the western side of the Clayton campus.

"As research-based companies develop, they will be able to expand into adjacent university land, so a cluster of emerging industries linked to Monash innovative research will progressively develop in and around the university", says Alison Crook, Monash deputy vice-chancellor (Resources). "We see the STRIP becoming a significant engine of Australia's creative economy." Some industries will especially link with the synchrotron facilities, such as scientific computing, bioinformatics, data mining, biotechnology, nanotechnology and environment.

[MONASH magazine, Spring/Summer 2001]

More Grand Plans

Astronomers are drawing up plans for new, gigantic ground-based telescopes the size of a football field. The Californians have proposed a 30m California Extremely Large Telescope (CEL T), while the Europeans, not to be outdone, have an even more ambitious plan for the 100m 'Overwhelmingly Large Telescope' (OWL). The aim is to perform spectroscopic measurements on sources identified by the 8m Next Generation Space Telescope, in order to study the formation of planets and galaxies. New segmented mirror technologies have made these designs possible. The projected cost would be $300m - $1 billion, and a facility could be up and running by 2012.


Federation Fellowships

Of the first 15 Federation Fellowships awarded, three went to physicists. The recipients are: Prof. Mike Dapaht of the Research School of Astronomy and Astrophysics at the ANU, for his work on galaxy formation; Prof. Bob Clark of the University of NSW, for work on quantum computing; and Prof. Keith Nugent of the University of Melbourne for work in optics. Each Fellowship is worth $225K per annum for five years.

Molecular Transistors

A team of scientists at Bell Labs, have made a transistor from a single molecule. The team, consisting of physicists Hendrik Schon and chemists Zhenan Bao and Hong Meng, used "conjugated molecules" of carbon, hydrogen and sulphur, poured onto gold electrodes, which self-assemble into miniature transistors. The invention threatens to make Moore's Law obsolete, but will need to be tested and improved for several years.

[Sydney Morning Herald]

Planes Found

Eight new planets orbiting nearby stars have been found, bringing the total of known extrasolar planets to 74. Three of the new planets have nearly circular orbits, rather than elongated elliptical ones. The first of the three was found orbiting the star Epsilon Reticuli in the southern constellation of the Net. "These discoveries suggest we could find a true counterpart of our solar system in only a few years", said Chris Tinney of the AAO, the Australian member of the team (see also the article by Bridie West in this issue). One of the new planets was found at the Anglo-Australian Telescope in Siding Springs, and the other two by the Keck telescope in Hawaii.

[Sydney Morning Herald, 17th November]

Budget Troubles

Two huge projects have run into budget difficulties recently. At CERN in Geneva, the construction program for the Large Hadron Collider (LHC) is running 30% over budget estimates, amounting to a deficit around AS1 billion. The laboratory director, Luciano Maiani, is in hot water because he failed to inform the member states earlier; and a budget cut of 10% is being implemented across all divisions of CERN. The first operation of the LHC may be delayed beyond 2006. Meanwhile, the International Space Station project is facing a US$5 billion funding shortfall. Changes are being considered that would reduce the crew from six or seven to three, effectively ending the station's usefulness as a scientific laboratory.

New CSIRO Head

Catherine Livingstone, former managing director of the hearing-implant company Cochlear, has been appointed chair of the CSIRO. The government's hope is that she will help to gain more industrial funding for the organization. External funding currently accounts for one-third of the CSIRO budget of $870 million. The CSIRO has shed around 900 staff since 1990, including many of its research staff in basic physics, as government support for its programmes has declined.

http://www.csiro.au

Support for Kyoto

Japan is leading the way towards ratification of the Kyoto protocol on climate change. The Koizumi administration has declared its willingness to ratify the protocol some time next year. The European Commission has also asked its 15 member states to ratify by 14 June 2002, before the World Summit on Sustainable Development in Johannesburg in September. The protocol, requiring industrialized nations to cut greenhouse gas emissions by an average 5.2% within the next decade, must be ratified by signatories representing 55% of such emissions in order to come into force.

The Bush administration has withdrawn from the Kyoto process, and Australia has declared it will not ratify without the participation of the US, despite generous concessions offered during the negotiations.

[Sydney Morning Herald, 5th November]

Sydney staff moves

Due to cuts in its operating budget, the School of Physics at Sydney now can support less than half the staff it had in the mid-1980s. Voluntary retrenchment was recently offered to all the general staff, whereupon effectively all the administrative staff immediately left. A rebuilding process is under way.

Meanwhile, a few new academic appointments have been made possible from outside funds. Marcel Bilek was appointed Professor of Applied Physics, and Bernard Pailthorpe was appointed as Professor and Director of VisLab. A new lecturership in Computational Physics has been advertised.

[Don Melrose, 'Alumni News']
Honours
Robert May, the Australian eco-physicist who recently stepped down as Chief Scientist in the UK, and is now President of the Royal Society, has been created a Lord. Lord May of Newtown?

Carbon Magnets
Tatiana Makarova and co-workers at the Ioffe Physico-Technical Institute in St. Petersburg have discovered ferromagnetism in polymerized carbon-60. The two-dimensional "hombordial" phase of this material, forming highly-oriented layers like graphite, retains its magnetization until 500 K, well above room temperature. The discovery could lead to lightweight and cheap metal-free magnets.

["Physics World", November 2001, p. 3]

Report Card on Australia's Scientific Research
A major new study presents a detailed analysis of the current state of Australian scientific research. Monitoring Australia's Scientific Research was written by Linda Butler from the Research Evaluation and Policy Project at the Australian National University.

Using data from the Institute for Scientific Information (ISI), Butler highlights a number of notable trends in Australia's presence in the literature:

- Australia's share of the major scientific journals indexed by ISI increased significantly in the 1990s from 2.2% to nearly 2.8%. While publication output is increasing at a greater rate than for many comparable countries, Australia's relative citation performance is falling behind.
- In 1988 Australia was ranked sixth on relative citation impact among the major publishing nations, but by 1999 had dropped to eleventh position. The increase in Australian publication output has been at the expense of impact.
- There are strong indications that Australia's relative citation impact is being adversely affected by the push in the university sector to evaluate research on the basis of publication counts, with little reference to the quality of that output. Academics are increasing their publication count, but this is occurring in journals with few international profiles.

Copies of the publication can be obtained from: Australian Academy of Science, GPO Box 783, Canberra ACT 2601 Fax: (02) 6257 4620; email: nas@science.org.au

Fred Hoyle
The famous astrophysicist Fred Hoyle has died, aged 76. His most important work concerned the nucleosynthesis of chemical elements in stars. In order for this process to occur successfully, he postulated that a resonance must exist some 7 MeV above the ground state of carbon 12: a prediction that was triumphantly confirmed in an experiment at Caltech. Many people felt that Hoyle should have shared the Nobel Prize in this area with Willy Fowler.

Fred Hoyle was also famous for his maverick adherence to ideas such as his 'steady-state' cosmological model of the Universe; and for his best-selling science fiction novel, "The Black Cloud". He was a colourful and controversial figure in the physics community.
2001 PHYSICS NOBEL PRIZE GOES TO BOSE-EINSTEIN CONDENSATION

Based on a lecture to the Victorian Branch of the AIP on 25 October 2001

PETER HANNAFORD and WAYNE ROWLANDS

Centre for Atom Optics and Ultrafast Spectroscopy, BSEE, Swinburne University of Technology, Hawthorn, Victoria 3122

The Royal Swedish Academy of Sciences has awarded the 2001 Nobel Prize in Physics jointly to Eric Cornell (JILA and NIST, Boulder, USA), Wolfgang Ketterle (MIT, Cambridge, USA) and Carl Wieman (JILA and University of Colorado, Boulder, USA) "for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates".

The Recipients

Eric Cornell (pictured with Carl Wieman in Fig. 1a) obtained a B.S. from Stanford University and a Ph.D. from Massachusetts Institute of Technology (MIT) in 1990. At MIT he worked with David Pritchard on ultrahigh precision mass spectroscopy of ions. In 1990 he joined Carl Wieman as a postdoc at the Joint Institute for Laboratory Astrophysics (JILA) in Boulder where they set about searching for Bose-Einstein condensation in alkali vapours. In 1992 he became a Senior Scientist at the National Institute of Standards and Technology (NIST) in Boulder. Cornell visited Australia in July 1996 to participate in an Atom Optics workshop in Palm Cove, Queensland and the International Quantum Electronics Conference (IQEC) in Sydney.

Wolfgang Ketterle (pictured in Fig. 1b) obtained his Diplomphysik from the Technical University of Munich, and a Ph.D. from the Ludwig-Maximilians University in Munich and the Max-Planck-Institut-für-Quantenoptik in Garching in 1986. In 1990 he went to work as a postdoc with David Pritchard at MIT, where he developed the so-called dark SPOT atom trap, which turned out to be crucial for the observation of Bose-Einstein condensation. Pritchard apparently thought so highly of his younger colleague that he handed over his entire laser-cooling lab to Ketterle, who assumed responsibility for the Bose-Einstein condensation project in 1993. He became a full professor at MIT in 1997. Ketterle also visited Australia in July 1996 to participate in the IQEC meeting in Sydney.

Carl Wieman received a B.S. from MIT and a Ph.D. from Stanford University in 1977 - just the reverse to Cornell. At Stanford he worked with Ted Hänsch and Art Schawlow (1981 Physics Nobel Prize) pioneering Doppler-free laser polarization spectroscopy and two-photon spectroscopy of atomic hydrogen. He then took a position at the University of Michigan, before moving to the University of Colorado and JILA in Boulder in 1984. At Boulder he introduced two major advances to laser cooling and trapping which greatly reduced the complexity: the first, in 1985, was the use of inexpensive diode lasers to cool the atoms, and the second, in 1989, was the use of a simple glass vapour cell to trap and cool the atoms directly from a vapour instead of from a laser-slowed atomic beam. These advances opened the field of laser cooling and trapping to numerous laboratories around the world and prompted an article on Laser Cooling and Trapping for the Masses [1]. Wieman's prime motivation for developing and simplifying laser-cooling methods was for studies of parity

Fig. 1 (a) Carl Wieman and Eric Cornell on the JILA tower. Courtesy the University of Colorado at Boulder/Photo by Ken Abbot

Fig. 1 (b) Wolfgang Ketterle. Courtesy the Massachusetts Institute of Technology
non-conservation in caesium and, later, for the search for Bose-Einstein condensation. Wieman visited Australia in December 1998 as the Australian Academy of Science Frew Fellow, and lectured on Bose-Einstein condensation here in the Hercus Theatre.

It is noteworthy that the average age of the three recipients is only 44, or 38 when they first realised Bose-Einstein condensation in 1995. It is also significant that all three recipients, including Wieman, had a connection at some stage with either Daniel Kleppner or David Pritchard at MIT, where programs had been initiated to search for Bose-Einstein condensation in atomic gases.

**A Brief History of BEC**

The story begins in 1924 when a young, unknown Bengali physicist, Satyendra Nath Bose from Dacca University in India, derived Planck's distribution law treating the photons purely statistically as a gas of identical particles. After his paper had been rejected by Philosophical Magazine Bose sent it to Albert Einstein, who realised the importance of the work, translated the paper into German, and submitted it for publication in Zeitschrift für Physik [2]. Einstein then generalised the problem to an ideal gas of identical particles - Bose-Einstein statistics [3]. The following year Einstein published a second paper, in which he noted that as the temperature of the ensemble of identical ‘Bose’ particles is lowered or the number of particles is raised, the particles should undergo a quantum mechanical phase transition, with all the particles condensing into the lowest quantum state where they accumulate with zero velocity [3] - Bose-Einstein condensation (BEC). Apparently, Einstein thought little of his prediction: “The theory is pretty, but is there also some truth in it?” he wrote to Paul Ehrenfest, and turned his back on the problem forever [4].

Bose-Einstein condensation had the reputation of “having only a purely imaginary character” until 1938 [5] when Fritz London in Paris proposed that the He I-He II phase transition (at the lambda point 2.19 K), which had been discovered by Willem Keeson in 1928, could be a manifestation of Bose-Einstein condensation. In 1941 Lev Landau (1962 Physics Nobel Prize) in Moscow developed a phenomenological theory of superfluidity in liquid-He for strong intermolecular interactions, though Bose-Einstein condensation was apparently never mentioned in his Institute [6]. In the 1950s Oliver Penrose and Lars Onsager demonstrated that only about 8% of liquid-He below the transition temperature actually participates in the condensate, owing to the strong intermolecular forces in the liquid. In 1957 John Bardeen, Leon Cooper and John Schrieffer (1972 Physics Nobel Prize) interpreted superconductivity in terms of bosonic “Cooper pairs” of electrons, a phenomenon closely related to the frictionless flow of a superfluid. In 1972 David Lee, Douglas Osheroff and Robert Richardson (1996 Physics Nobel Prize) realised superfluidity in 3He at temperatures below 3 mK, where the fermonic 3He atoms form bosonic Cooper pairs which enter a condensed state.

**Quest for BEC in Atomic Gases**

During the 1970s there was growing speculation about the possibility of achieving BEC in a dilute atomic gas. The experimental conditions required, however, seemed formidable. The temperature of the gas needed to be low enough and the density (n) high enough for the de Broglie waves of the individual atoms (of wavelength $\lambda_d h/mv$) to overlap to permit the quantum statistics to become significant. For example, for a gas at 300 K and $10^{15}$ Torr the phase space density ($\lambda_d n$) required to achieve a BEC is still too low by about twenty orders of magnitude!

The search for BEC in atomic gases began around 1980 when Daniel Kleppner and Tom Greytak at MIT and Isaac Silvera and Joop Walraven in Amsterdam initiated experiments based on spin-polarised atomic hydrogen. The hydrogen atoms were first refrigerated with liquid-helium and trapped in a magnetic trap where they were further cooled by evaporative cooling, allowing the hotter atoms to escape and leaving the colder ones behind. The hydrogen atoms were spin-polarized to prevent molecular formation and the formation of liquid hydrogen below 20 K.

During the same period major break-throughs were being made in laser cooling and trapping of atoms by Steve Chu, Claude Cohen-Tannoudji and Bill Phillips (1997 Physics Nobel Prize) and others. In 1990 Carl Wieman at JILA in Boulder initiated a program to combine the techniques of laser cooling of alkali atoms, in particular $^{87}$Rb and $^{133}$Cs, with the techniques of evaporative cooling that were being used for atomic hydrogen at MIT, and he hired Cornell as a postdoc to work on this. Around the same time, David Pritchard and Wolfgang Ketterle at MIT initiated work on $^{23}$Na, and later Steve Chu and Mark Kasevich at Stanford joined in the search using $^{87}$Cs, while Randy Hulet and co-workers at Rice University in Houston started work on $^3$Li.

It is fascinating to recall the events leading up to the realisation of BEC [7, 8]. Cornell, Ensher and Wieman write [7]:

In 1992, it was reassuring to move ahead on efforts to evaporate with the knowledge that, while we were essentially proceeding in the dark, there were not as many monsters in the dark as we had originally imagined. Of course, even given successful evaporative cooling, there was still the question of the sign of the scattering length [of the interacting atoms], which must be positive to ensure the stability of a large condensate. The JILA group had sufficient laser equipment, however, to trap either $^{87}$Rb, $^{85}$Rb, or $^{133}$Cs. Given the ‘modulo’ arithmetic that goes into determining a scattering length, it seemed fair to treat the scattering lengths as statistically independent events, and the chances then of nature conspiring to make all three negative were too small to worry about.

After the May 1994 International Quantum Electronics Conference in Anaheim, Science reported [9]:

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During the 1970s there was growing speculation about the possibility of achieving BEC in a dilute atomic gas. The experimental conditions required, however, seemed formidable. The temperature of the gas needed to be low enough and the density (n) high enough for the de Broglie waves of the individual atoms (of wavelength $\lambda_d h/mv$) to overlap to permit the quantum statistics to become significant. For example, for a gas at 300 K and $10^{15}$ Torr the phase space density ($\lambda_d n$) required to achieve a BEC is still too low by about twenty orders of magnitude!
Both Ketterle's group at MIT and the Cornell/Wieman group at Boulder reported that they had managed to combine dark SPOT traps with evaporative cooling. Reaching the threshold for BEC, however, will require an improvement of another 3-4 orders of magnitude in density and temperature. 'The big excitement now' says Ketterle 'is that we saw the first step of cooling, and people expect this will carry us down by several more orders of magnitude.' Cornell isn't so upbeat; he notes that the results so far are 'not even in the ballpark' for BEC. But when he was told that Ketterle was optimistic, he said: 'Well, I'm plenty optimistic. I'd just hate to open Science magazine and read myself saying that 3-4 orders of magnitude is close.' As Wieman explains 'the whole business of laser-cooled atoms for Bose condensation is at an early enough stage that the kinds of problems encountered by people doing hydrogen have not yet shown up.' As for Chu, he takes the view that the past is prologue; 'I'm betting on nature to hide Bose condensation from us. The last 15 years she's been doing a pretty good job.'

The following year, at the May 1995 Division of Atomic, Molecular and Optical Physics (DAMOP) meeting in Toronto, Cornell reported achieving an atom temperature of 200 nK by evaporative cooling, which prompted a headline in the Times: "Scientists create record -273°C cold." Cornell, Ensher and Wieman [7] go on to say that:

The number of groups with clear evidence of evaporative cooling had increased to four. The Rice, JILA and MIT alkali groups were all seeing significant increases in phase space density. The JILA alkali group returned from Toronto with a shared impression that 'there is no time left to tiddle around.'

One month later, in mid-June 1995, we (PH and WJR) attended the Twelfth International Conference on Laser Spectroscopy on the Isle of Capri. The first session on the Monday morning was devoted to "Progress towards Bose-Einstein Condensation". The opening talk was a theoretical one by Jean Dalibard from Paris. The second, by Wolfgang Ketterle, was advertised as "Evaporative cooling of sodium atoms", but the speaker did not appear. After the anticlimax of a thirty-minute break in the program, the Chairman Emnio Arimondo announced the third talk, by Eric Cornell, as "Progress towards BEC in magnetically trapped heavy alkali atoms." Cornell was relatively new on the laser spectroscopy scene and we were curious to see and hear him for the first time. He put up the first overhead, but the title had changed to "Evidence for BEC...". He then proceeded to describe with overheads sketched in the roughest, thickest black handwriting (apparently prepared on the plane crossing the Atlantic) how during the week before the conference the JILA group had succeeded in realising BEC in $^8$Rb (Figs. 2a and 2b), though he was careful to point out that the results were still preliminary and yet to be confirmed. The JILA group had kept the observation of BEC a tight secret, and by the end of the talk the audience appeared to be in a state of shock. We proceeded to morning tea and one of us happened to be standing next to Claude Cohen-Tannoudji, and asked him whether he believed it. He gave a nod of approval, and that seemed good enough for us. Upon arrival back in Melbourne, some of our colleagues were more than sceptical. By the time the paper appeared in 14 July 1995 issue of Science [10] the title had changed again, this time to "Observation of BEC...".

**Observation of BEC**

Science [11] relates the events just after the initial observation of BEC on Monday 5 June:

Eric Cornell says that for the first few days after he and his colleagues introduced a new state of matter to this planet, their achievement didn't really sink in. 'I really felt kind of numb. It wasn't until the third night afterward that I didn't sleep all night thinking 'Oh my god, this really happened''

The first observation of BEC had been so dramatic and spectacular: literally textbook material, which is very rare for an initial observation of a new phenomenon in physics.

![Graph](image_url)

**Fig. 2** (a) Peak density at the centre of the $^8$Rb atom cloud as a function of frequency $\nu_{\text{evap}}$ of the "r.f. scalpel" used to determine the final depth of the evaporative cooling cut, and hence the temperature of the cloud of atoms. (The r.f. transitions flip the spins of the hottest atoms into untrapped states, thereby releasing them from the magnetic trap.) The discontinuity near 4.25 MHz (180 nK) indicates the first appearance of the high-density condensate fraction as the cloud undergoes a phase transition. When $\nu_{\text{evap}}=4.1$ MHz, nearly all the remaining atoms are in the condensate fraction. Below 4.1 MHz, the r.f. scalpel begins to cut into the condensate itself [10].

(b) Horizontal sections taken through the velocity distribution at progressively lower values of $\nu_{\text{evap}}$ showing the appearance of the condensate [10].

Reprinted with permission from Science 269, 198 (1995). Copyright American Association for the Advancement of Science.
Bose-Einstein condensation is a beautiful manifestation of a macroscopic quantum phenomenon, with about one million atoms all occupying the same (lowest) quantum state of a simple potential well and described by a single macroscopic wave function, rather like the photons released by stimulated emission in a single-mode laser. BEC has been described as a "superatom", "like a troop of soldiers marching in lock-step", or in the words of Cornell "really quite an amazing juice". In the world of phase transitions BEC is unique in that it is the only purely quantum mechanical phase transition; that is, the only phase transition that would still occur without any interaction between the particles.

About four months later, Wolfgang Ketterle and his group at MIT reported the observation of BEC in atomic $^2\text{Na}$ [12]. In 1997 Randy Hulet and colleagues at Rice University reported a BEC of about one thousand atoms in $^7\text{Li}$ [13]. Lithium is an especially interesting case since the scattering length for $^7\text{Li}$ is actually negative, which severely limits the number of atoms in a stable condensate, and it has a second isotope, $^6\text{Li}$, which is fermionic.

Figure 3 shows the progress in evaporative cooling of the various groups with different alkali atoms up to 1996 [8] (from which one should have been able to predict the observation of BEC almost to the month!).

In 1998 Tom Greytak, Daniel Kleppner and colleagues at MIT finally succeeded, after an eighteen-year struggle, in realising BEC in spin-polarised $^4\text{He}$ [14]. Hydrogen, being the closest of any of the atomic gases to an ideal Bose gas of noninteracting particles, paradoxically turned out to be extremely elusive for BEC because evaporative cooling is very inefficient and also because the lifetime of the atomic gas is limited by dipole relaxation and the condensate is difficult to detect optically. In early 2001, Alain Aspect, Chris Westbrook and colleagues at Orsay [15] and Michelle Leduc, Claude Cohen-Tannoudji and colleagues in Paris [16] succeeded in achieving BEC in a gas of spin-polarised metastable $^3\text{He}^*$ atoms. At the present time BEC in $^{133}\text{Cs}$ still remains elusive, largely because of losses from strong inelastic collisions between the ultra-cold caesium atoms, but there is still hope, for example, by utilising different magnetic states together with so-called Feshbach resonances to tune the sign and magnitude of the scattering length of the atoms.

**How to get a BEC?**

It is useful at this stage to summarise some of the the conditions required to achieve a BEC in a dilute gas of atoms such as $^{85}\text{Rb}$.

First, the atoms need to be bosons, i.e., they must have integral total angular momentum, such as $^{85}\text{Rb}$ ($J=2$) or $^\text{40}\text{He}^* (J=1)$, which is the case for all but a few weakly abundant isotopes such as $^\text{7}\text{Li}$, $^\text{39}\text{K}$ and $^\text{4}\text{He}$. The atoms also should have a positive (repulsive) scattering length to ensure stability of a large condensate, and the scattering length should be moderately large to allow efficient elastic scattering and hence efficient evaporative cooling.

In a typical experiment (on $^{85}\text{Rb}$) about $10^4$ atoms at about $10^{-6}$ Torr are trapped and laser-cooled in a magneto-optical trap to $T = 20 \mu\text{K}$ ($\text{AdB} = 40 \text{ nm}$) and $n = 10^{10}$ atoms cm$^{-2}$. This leaves about six orders of magnitude to go in phase space density $\lambda_{\text{cm}}$. The cold atoms are then optically pumped into a low field-seeking magnetic state and loaded into a pure magnetic trap with an approximate harmonic potential and tight confinement (typically 100-200 gauss cm$^{-2}$). The atoms are then further cooled by forced evaporative cooling, selectively removing the hotter atoms and rethermalising the remaining atoms by elastic collisions, until $T = 200 \text{ nK}$ ($\text{AdB} = 400 \text{ nm}$) and $n = 10^5$ atoms cm$^{-2}$, where the phase space density $\lambda_{\text{cm}}$ approaches unity. At this point the atomic de Broglie waves begin to overlap allowing the formation of a BEC.

The past six months has seen some dramatic advances in schemes for simplifying the production of a BEC. Jakob Reichel, Ted H"ansch and colleagues in Munich [17] and Claus Zimmermann and colleagues in T"ubingen [18] have succeeded in realising BEC in a magnetic microtrap fabricated lithographically on a substrate ('atom chip'). Because of the small dimensions of the microtrap, the magnetic fields required to produce a BEC scale down accordingly. This also means that the atoms can be much more tightly confined in the trap, thereby reducing the time for evaporative cooling from about a minute to a few seconds, and that only a modest vacuum ($=10^{-8}$ Torr) is required to allow formation of a BEC. This has greatly reduced the complexity and cost of the experiment, bringing BEC within reach of "the masses".

**Why all the Fuss?**

It is often asked why all the fuss when BEC in liquid-$^4\text{He}$ was achieved more than seventy years ago? What is different about BEC in a dilute atomic gas?

First, a dilute atomic gas is close to an ideal Bose gas of non-interacting particles where the quantum nature of the phase transition is not obscured by the complications of strong intermolecular interactions. Second, a dilute atomic gas well below...
the transition temperature can be close to an 100% pure condensate. By contrast, only about 8% of liquid 4He actually participates in the condensate, even though all of the liquid may appear to be in a superfluid state. Third, a BEC in an atomic gas can be manipulated and outcoupled from the harmonic potential well for applications, for example, as a coherent beam of atomic de Broglie waves for atom interferometry, for atomic clocks, or for atom lithography. Finally, a BEC in an atomic gas is applicable to many species, including 208Rb, 209Rb, 23Na, 6Li, 3H and gaseous 4He* to date. Other candidates in the future include 40K, 133Cs, 87Sr, and species such as molecules which could be condensed by ‘sympathetic cooling’ in an atomic BEC.

### Initial Experiments with Condensates

The citation for the 2001 Prize indicates that the award was not only for the achievement of BEC, but also for ‘early fundamental studies’ of condensates. This recognises the impressive range of experiments that the recipients undertook immediately after the already spectacular and difficult work of realising a condensate. This section gives an overview of some of these early experiments.

One of the first investigations concerned the collective excitations of the trapped condensate, and was pursued independently by the JILA and MIT groups. In essence, this involved ‘kicking’ the condensate in some controlled manner, and then observing the dynamical response. Various techniques for exciting the condensate were employed, including modulating the trapping magnetic fields [19, 20] and using far-off resonant laser beams to perturb the trapping potential [21]. The lowest energy mode is simply the ‘sloshing’ motion of the entire condensate in the trap, and reveals no information about the internal interactions. The frequencies of higher energy modes, however, are sensitive to the mean field of the condensate. Both groups observed dynamical behaviour of the BEC that was consistent with theoretical expectations.

An important property of a BEC is that it is described by a single macroscopic wavefunction, and therefore possesses a well-defined phase: the condensate is a ‘coherent’ ensemble of atoms. For many people, the demonstration of this internal coherence was crucial in confirming that high-density atom clouds were indeed described by Bose-Einstein condensation. The JILA and MIT groups again took different approaches to examining the coherence properties of BEC, both relying on the overlap of two condensates. Ketterle produced two condensates (by ‘cutting’ a single condensate in half using a far-off resonant laser beam), and then allowed them to expand freely [22]. In the region where they overlapped, the two condensates interfered, showing an absorption fringe pattern (Fig. 4). The experiments of Cornell and Wieman created a two-component BEC by using r.f. and microwave transitions to transfer a fraction of the original condensate into a different spin state. The coherence of the condensates was then used using a time-domain version of separated oscillatory field interferometry [23]. The interference demonstrated in both of these approaches indicated long-range correlations, a measure of first-order coherence. Analysis of

![Fig. 4 Interference patterns from two expanding and overlapping condensates [22]. The two figures are for different initial separations of the two condensates. The fields of view are 1.1 mm (horizontal) by 0.5 mm (vertical). Reprinted with permission from Science 275, 637 (1997). Copyright American Association for the Advancement of Science.](image)

The coherence properties of a BEC naturally lead to many analogies with the laser, and the notion of an “atom laser” has generated much discussion. In this context, an output coupler is required to extract atoms from the condensate in a controlled manner. The first such output coupler was demonstrated by Ketterle’s group, and used a series of short r.f. pulses to spin-flip some of the atoms into untrapped states [25]. The untrapped atoms then fell under gravity out of the condensate, producing a train of matter-wave pulses (Fig. 5). Applying such an output coupling scheme to a split BEC showed interference fringes between the output pulses, indicating that the outcoupling process preserves the coherence of the BEC [26].

### Further Experimental Investigations

Following the initial excitement of achieving BEC, and the first sets of experiments discussed in the previous section, many other groups around the world successfully set up BEC laboratories. In the explosion of activity that ensued, the MIT and JILA groups continued to produce some of the most interesting and beautiful results.

Continuing with the analogy between BEC and lasers, two of the main components for an “atom laser” existed: a resonant cavity (the magnetic trap, or, in later work, an optical trap) and an output coupler. The third component required was a gain mechanism, to give coherent amplification of the matter waves. In a sense the condensation process itself is a gain...
mechanism, where atoms from the non-condensed thermal cloud have an enhanced probability of scattering into the condensed state due to "bosonic stimulation". Ketterle was able to manipulate various pieces of a BEC to demonstrate phase-coherent matter-wave amplification in a controlled manner [27]. This work coupled a small cloud of atoms out from the BEC, and "injected" them into the original BEC. In the presence of appropriate "pumping" laser light, atoms scattered out of the original BEC and into the input matter wave, which emerged "amplified" (i.e., with about 30 times as many atoms as it began with). This matter-wave amplification was also shown to be phase-coherent by observing interference fringes when the amplified cloud was overlapped with an additional out-coupled pulse from the BEC.

As mentioned above, one of the more dramatic consequences of Bose-Einstein condensation is the phenomenon of superfluidity. A fundamental property of a superfluid is that bulk circulation of the fluid is quantised, forming persistent vortices. In a pattern quite familiar by now, the JILA and MIT groups used different techniques to successfully produce and study vortex motion in BECs. At JILA, their previous work on two-component condensates was extended to allow the production of a toroidal condensate with a precisely engineered phase variation around the hollow centre [28]. This procedure imparts angular momentum to the BEC, producing a single vortex. At MIT, a conceptually simpler approach was employed: they "stirred" their BEC with a pair of off-resonant laser beams [29]. The resultant rotating BEC was observed to form regular arrays of vortices, as shown in Fig. 6.

Although the scope of this article does not permit a detailed discussion of many of the novel and fascinating BEC experiments that have been reported, or are in progress, it is worth listing at least some of them to allow some appreciation for the current status of the field.

- **Feshbach resonances**: An important parameter that governs the properties of a BEC is the atomic scattering length. Magnetic fields have been used to tune condensates close to Feshbach resonances, allowing manipulation of both the magnitude and the sign of the scattering length of atoms in a BEC. This changes the mean field of the condensate, and can lead to a controlled collapse and explosion of the BEC (a phenomenon described whimsically by Cornell as a "bosonova").

- **Output couplers**: In addition to the Ketterle r.f. spin-flip method described in section 7 above, other groups have demonstrated output couplers for BEC. These have included continuous (i.e., non-pulsed) r.f. output coupling, self-pulsed ('mode-locked') output from multiple BECs tunnelling out of an optical lattice, and optical Raman processes that propell atoms from the BEC, thus not relying on gravity.

- **Non-linear atom optics**: The (weak) interactions between atoms in a BEC leads to a non-linearity in the matter-wave equation. This allowed the realisation of the atomic equivalent of optical four-wave mixing, where three distinct momentum populations were established from a single BEC and their non-linear interaction created a fourth momentum population. In this process the conservation of momentum is equivalent to the phase-matching condition in the usual optical case.

- **Spinor condensates** (spin-ordered states, ferromagnetic structures); Molecular BEC (photoassociation of atoms in a condensate); Optically-confined BEC; All-optical BEC (i.e. no magnetic trapping); Reversible formation of BEC; Superradiant scattering, Degenerate Fermi gas; and Squeezed condensates.

References and further information for the work listed above can be found on the world wide web at http://amo.phy.gasou.edu/bec.html/
Concluding Remarks

Even the large number of BEC experiments mentioned above and discussed in the preceding sections does not give a true picture of how rapidly this field has expanded, and continues to expand. Indeed a simple on-line database search for the keywords “Bose-Einstein condensation” reveals some interesting statistics. In the five-year period preceding the initial JILA and MIT observations, roughly 60 BEC-related papers were published, while in the five years following the number of papers is closer to 750. The level of activity, both experimental and theoretical, is showing no signs of slowing: the number of BEC-related publications for the years 2000-2001 is, at the time of writing, already close to 500.

It is clear that Bose-Einstein condensation in dilute atomic vapours, first realised and studied by Eric Cornell, Wolfgang Ketterle and Carl Wieman, has provided us with a major new branch of physics, which has many exciting years ahead to look forward to.

We thank Wolfgang Ketterle for permission to reproduce Figures 1(b), 3, 4, 5 and 6; and Carl Wieman for permission to reproduce Figures 1(a) and 2.

References


The Harrie Massey Medal

The Australian Institute of Physics, on behalf of the Institute of Physics, UK, seeks nominations for the 2002 Harrie Massey Medal, to be presented by the President of the IOP at the AIP Congress in Sydney in July 2002.

Background: The Massey Medal was proposed at the AIP Congress in 1988 and established in 1990 as a gift of the Institute of Physics, UK, to mark the 25th anniversary of the founding of the AIP as a separate institution in 1963.
Sir Harrie Massey, born near Melbourne in 1908, had a distinguished career in the UK and in 1931, with Edward Bullard, published the first experimental evidence for electron diffraction in gases. He saw the potential of using direct rocket probes of the atmosphere layers and eventually, as Chairman of the British National Committee for Space Research, he guided the entire UK space research programme. From 1960-64 he was President of the European Preparatory Commission for Space research. He was knighted in 1960.

Conditions: The prize is awarded every two years for contributions to physics or its applications made by an Australian physicist working anywhere in the world, or by a non Australian resident in, and for work carried out in, Australia. A lecture on the work for which the Medal is awarded is presented at Congress in the year of the award, and an article published in the Physicist. The recipient must be a member of the Australian Institute of Physics or of the Institute of Physics, UK. Previous winners have been:

1990 Professor R Dallitz
1994 Professor R Baxter, ANU
1996 Professor A Snyder, ANU
1998 Professor D Melrose, University of Sydney

1992 Professor D H Briggs
1995 Professor A D Buckingham, University of Cambridge
1997 Professor D Pegge, Griffith University
2000 Professor A Thomas, University of Adelaide

Nominations, preferably as a Word file email attachment, must reach Moira Welch, Honorary Secretary of the Institute (m.welch@uws.edu.au), no later than February 22nd 2002, accompanied by the following:
• A citation of not more than 300 words, written for a scientifically literate lay person (the citation is a crucial factor in the selection of the recipient);
• A short curriculum vitae for the Nominee: a full publication list is not required, 10 of the Nominee’s most significant papers should be listed;
• A list, with dates, of the Nominee’s most significant contributions to their chosen field;
• Names and contact details of 3 referees.

Further details may be obtained from the Secretary, Ph 02 4578 4328, or email as above.

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REPORT ON UNIVERSITIES WELCOMED

FASTS welcomed the report “Universities in Crisis” by the Senate Employment, Workplace Relations, Small Business and Education References Committee. The report paints a grim picture of the university sector, a position that has been reached after a decade of inaction and under-investment by successive governments.

Professor Peter Cullen, President of the FASTS, said that Australia needed a constructive debate on the role and future of our 39 universities. "It will involve clear thinking and hard decisions," he said. "We need to balance the sometimes conflicting factors of our size, our small population and our role in the region. What resources should we bring to bear on this sector as an advanced nation with a mid-sized economy? This is a debate we have to have - the sector cannot be left to wallow indeliberately any longer. Research and higher education may have been swept from the front pages by the dramatic events both in Australia and overseas of the past month, but these issues are long-term and we ignore them at our peril."

Professor Cullen said it would take time to digest the 471 pages and 39 recommendations of the Report, but at first glance, the report highlighted many of the issues of concern to the sector. One thing is clear: Australia needs to increase its national investment in research and higher education.

"We can argue what the level of that investment should be, and the appropriate balance between government, private and industry sources."

Professor Cullen said the science community welcomed a number of the recommendations, including proposals to double the number of research fellowships, to increase in the level of Block Grants, and to make the office of Chief Scientist a full-time position. "Now we would like to see a wider canvassing of views, to maximise support from all sections of the community," he said.

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ACADEMY OF SCIENCE BACKS NEED FOR RESEARCH REACTOR

The Australian Academy of Science has restated its strong support for the decision to build a new research reactor to replace the one at Lucas Heights. Professor Michael Barber, Secretary, Science Policy said, on hearing the news of the Labor Party's intent to review yet again the proposal to build an up-to-date research reactor "There have been many reviews over the past ten years and all the issues have been well documented. There is no need for yet a further review. Knowledge Nation is important to Australia. High standing in nuclear science and technology is a critical component of knowledge."

Barber went on to say "A state-of-the-art research reactor is critical to the national interest, in developing a radiopharmaceutical industry in health care and in maintaining the excellence of Australian research. Simply put, "Knowledge Nation" offers many positives for wealth generation, but a knowledge nation is scarcely possible without a research reactor."

It is easy to justify this investment in a research reactor on the grounds of:

- national interest,
- the continuation of internationally recognized Australian basic and strategic research, and
- strengthening strategic industry-research links to promote technological development.

Federation Fellowships

The Australian Academy of Science welcomed the announcement of the first recipients of the Federal Government's Federation Fellowships. The Academy's President, Professor Brian Anderson, said he is delighted that eight Academy Fellows have been named among the fifteen recipients.

An initiative of the Federal Government's Backing Australia's Ability innovation action plan, the Federation Fellowships are designed to attract and retain researchers of the highest international standing in key positions in Australia. Funded through the Australian Research Council, each Fellowship recipient will receive a salary of $225,000 each year for five years.

Professor Anderson said: "The Academy has a proud history of supporting and promoting science in Australia and it is very pleasing that Fellows of the Academy have been honoured in this way."

Professor Anderson went on to say that the Federation Fellowships recognised the people behind the science. "Australia needs good people in order to do good science. Increasingly, Government in Australia is acknowledging the importance of science and technology to Australia's future. The Federation Fellowships are part of this ongoing commitment from Government."

Three of the recipients, Professor Robert Clark from The University of New South Wales, Professor Max Colthart from Macquarie University and Professor Yi-Wing Ma, from The University of Sydney, were admitted as Fellows to the Academy this year. "It has certainly been a great year for them and the Academy is delighted that they are receiving the recognition they deserve," Professor Anderson said.

Other Academy Fellows to receive the Fellowships are:

Professor Michael Delpita, Australian National University
Professor Graham Goodwin, The University of Newcastle
Professor Martin Green, The University of New South Wales
Professor Keith Nugent, The University of Melbourne
Professor Mandymam Srivastava, Australian National University.

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ACADEMY LISTS PRIORITIES FOR THE NEXT AUSTRALIAN GOVERNMENT

The President of the Australian Academy of Science, Professor Brian Anderson, said 'This year, political parties and business and community groups have come to a remarkable degree of agreement on the need to promote science and education in Australia, for the economic and social benefits that they bring. Indeed, many of us in the science community see that education, health and scientific development must be universal if humankind is to prosper."

'With jitters in the global economy and security questions around the world, Australia needs to invest in something it can be confident will build a better nation. Education means jobs for young people in knowledge-based industries. Science means innovation for those industries. We hope that politicians from all parties will adopt our priorities."

'For example, there are disturbing signs that
the supply of science and mathematics teachers will not meet future demand. At the moment, aspiring teachers studying science pay higher HECS fees than those in the humanities. This deters students from becoming science teachers. In a new booklet, the Australian Academy of Science recommends HECS-exempt scholarships for students commencing science and maths teacher education.

'Enthusiastic, well-trained science and maths teachers are the essential link between bright young people and science-related careers,' said the President of the Academy, Professor Brian Anderson, today. 'They encourage students to take up the enabling sciences at school and continue at university. This measure could attract more able young people to science and maths teaching and help reverse the decline in science enrolments.'

The HECS proposal is one of 12 recommendations in a booklet, *Priorities in research and innovation for the next Australian Government*, published by the Academy of Science. The booklet has been circulated to all federal parliamentarians and it is also available on the Academy's website at www.science.org.au.

The booklet makes suggestions on:
- building a knowledge economy
- the higher education system
- science and mathematics education and awareness
- private investment in research and development
- major national research facilities
- government research agencies, especially CSIRO
- Cooperative Research Centres
- the roles of state and Commonwealth governments national research priorities.

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**Eureka Prizes**

The Australian Museum has announced the launch of the 2002 Australian Museum Eureka Prizes - Australia's pre-eminent and most comprehensive national science awards. The 2002 series is the biggest ever - an extraordinary 16 prizes worth almost $160,000.

Three new prizes are launched in 2002: the $10,000 Australian Catholic University Eureka Prize for Research in Ethics; the $10,000 Institution of Engineers Australia Eureka Prize for Engineering Journalism; and the $10,000 Pfizer Eureka Prize for Health and Medical Research Journalism. In addition, Brian Sherman will sponsor the long-running prize for environmental research.

These join established prizes for environmental and science journalism; environmental education programs; industry commitment to science; critical thinking; promotion of science; secondary school biological and earth sciences; engineering innovation; biodiversity and scientific research; and science book authorship.

In an exciting and newsworthy development, the 2002 Australian Museum prize for industry will bring not only prestige and distinction to the winner but also permanent recognition, as the winning company will have a new species named after them through the Australian Museum's Immortals Program.

Information on the full range of prizes on offer in 2002 and entry/nomination forms is available from the Australian Museum's webpage at http://www.amonline.net.au/eureka. Entries in most prizes close on Friday 17 May 2002, with winners to be announced in August 2002 at a gala award ceremony during National Science Week.

*Roger Muller*

*Australian Museum*
SMENA Scanning Probe Microscope from NT-MDT

Alberto Cimmino from the University of Melbourne with the recently installed SMENA Scanning Probe Microscope from NT-MDT.

The Russian word SMENA means ‘innovative design’ and is a name well deserved by the compact, versatile and portable design of the atomic force microscope seen in photo. At Melbourne University, the SMENA will be used for educational purposes in the third year Physics Laboratories, as well as a tool for their research into the development of quantum computers.

NT-MDT is a Russian company specialising in the manufacture of Scanning Probe Microscopes and related equipment. Coherent Scientific has recently been appointed as their exclusive distributor for Australia and New Zealand.

For more information please contact either Jen Weeks (jen.weeks@coherent.com.au) or Gerri Stewart (gerri.stewart@coherent.com.au). Coherent Scientific Pty Ltd 116 Sir Donald Bradman Dr, Hilton SA 5033 Phone: +61 8 8150 5200 or Fax: +61 8 8352 2020 Email: sales@coherent.com.au URL: http://www.coherent.com.au/

NIST-Traceable Calibration Verification Standards Offer Quality Assurance for UV/VIS Spectrometers

Now available from Ocean Optics are NIST- (National Institute of Science and Technology)traceable absorbance standards for both ultraviolet and visible calibration verification. These standards can be used to verify calibration for any spectrophotometer system configuration and to check the system’s performance and accuracy. The UV and VIS absorbance standards are available in two separate kits.

The two calibration standards kits (STAN-ABS-UV for ultraviolet and STAN-ABS-VIS for visible wavelength ranges) each contain a background reference for low, medium and high absorbance standards, which should read within +/- 5% of the absorbance data provided. The absorbance standards are ready-to-use; preparation time and potential dilution errors are eliminated. All standards are non-toxic, non-carcinogenic and have a one-year shelf life.

The STAN-ABS-UV kit is certified from 200-450 nm while the STAN-ABS-VIS kit is certified from 400-900 nm. NIST-traceable certificates, user instructions and data charts are provided in each kit.

These polymer-based standards are sub-micron, non-surface-charged, solid spheres in matrices of ultrapure water. Their small bead size, coupled with Brownian motion, ensures that the polymer spheres stay in a homogenous suspension.

Optical instrumentation should be calibrated with reliable standards to ensure accurate measurements. The regular use of absorbance standards ensures careful assessment of clarity, particle counts, sizes and colours. The precision and ease of use for these absorbance standards make the standards attractive to many industries.

For further information please contact: Lastek Pty Ltd, 10 Reid St, Thebarton SA 5031 Tel: (08) 8443 8668. Fax: (08) 8443 8427 Email: sales@lastek.com.au www.lastek.com.au

Spectra-Physics Introduces First Compact, "One-Box" Ion Laser

The new Solano from Spectra-Physics is the first air-cooled ion laser system to integrate both laser head and power supply into a single, compact package. In particular, the entire laser measures only 14.6" x 5.9" x 6.4" (370 mm x 133 mm x 163 mm), making it nearly half the size of competitive products. These dimensions conform to the same standard footprint traditionally used for the laser head alone in biomedical and other applications. System builders can therefore eliminate or reassign the space normally required for the power supply.

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For further information please contact: Lastek Pty Ltd, 10 Reid St, Thebarton SA 5031 Tel: (08) 8443 8668. Fax: (08) 8443 8427 Email: sales@lastek.com.au www.lastek.com.au

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Further information is available from Warsaw Scientific Pty Ltd at (02) 9319 0122 or fax (02) 9318 2192 or at sales@warssach.com.au

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Warsaw Scientific is pleased to announce that it has been appointed the exclusive distributor for Wavelenght Electronics Inc. for Australia & New Zealand. Wavelenght Electronics specialises in the design and manufacture of high quality compact laser diode driver and temperature controller components for the Photonics/Telecommunications industry.

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Further details on these and other components from Wavelenght Electronics are available from WARSASH Scientific on (02) 9319 0122 or at sales@warssach.com.au
THE ANGLO-AUSTRAILIAN PLANET SEARCH

BRIDIE WEST

Planet hunters have witnessed a period of rapid progress since the first extrasolar planet was discovered in 1995; just six years later over sixty have been found. Although extrasolar planets appear to be fairly common, the planets which have been discovered are very different from every object in our own solar system. This has fuelled debate about how solar systems form and whether a habitable planet like Earth is rare or even unique.

Last year an extrasolar planet was discovered from Australia for the first time. By the end of 2000 the Anglo-Australian Observatory (AAO) Planet Search Team, who were responsible for that discovery, had found three further planets including one unusual one: the first extrasolar planet in an Earth-like orbit. I met Australian Astronomer Chris Tinney, head of the AAO Planet Search Team, to discuss the team’s research. On another occasion I spoke to team-member Greg Henry (based in Tennessee) by telephone.

CHRIS TINNEY AND THE AAO

Chris Tinney is involved in two main areas of astronomy which he calls ‘understanding brown dwarf stars and searching for extrasolar planets’. He explains that ‘the two fields are closely related - brown dwarfs and extrasolar planets form by different mechanisms but the mass ranges overlap’.

Tinney became interested in brown dwarfs as a graduate student in 1988 – several years before the first brown dwarf and the first extrasolar planet were discovered (1994 and 1995 respectively). Almost ten years later, driven by his connections with successful American planet hunters, Geoff Marcy and Paul Butler, Tinney became involved in the search for extrasolar planets. Tinney says, ‘I first met Geoff Marcy in 1994 and a few years later Paul Butler applied to the AAO to set up a planet search in Australia - which is how I got involved’.

The AAO planet search team has two bases. Their laboratory is located within the grounds of the CSIRO Radiophysics laboratory in Epping, a fairly sleepy suburb of Sydney (where Chris Tinney). This is where data are analysed and equipment is improved. For observing, the team use the 4 metre Anglo-Australian Telescope (AAT) located 500 kilometres north west of Sydney at Siding Spring Mountain, Coonabarabran. The AAO planet search team targets the 200 closest Sun-like stars visible from the Southern Hemisphere.

RESULTS

Given the number of planets that have been discovered since 1995 it is understandable that not every discovery is exciting to everyone. Tinney feels ‘two of the planets we found are not too significant’. He is unenthusiastic because two extrasolar planetary classes have been established during the past few years and the AAO have simply found a further planet of each type. He says ‘Both of those classes of planet are nothing like our own solar system and they were not predicted before 1995’.

One class of extrasolar planet, referred to by Tinney as a ‘short period hot Jupiter’, is approximately as massive as Jupiter and has a small, nearly circular orbit and an orbital radius of less than 0.05AU (5% of the Earth-Sun distance). The first planet found by the AAO team matches this class of planet exactly. It orbits its star, HD179949, in just 3.1 days and has an orbital radius of just 0.045AU; its orbit has an eccentricity of 0.05 (almost circular) and it is at least 84% as massive as Jupiter.

The second class of extrasolar planet is also approximately as massive as Jupiter but has a highly elliptical orbit. The second planet found by the AAO team orbits µ Ara. It is at least 1.86 times as massive as Jupiter and its orbit has an eccentricity of 0.62 (quite elliptical).

Tinney explains that the most significant of the AAO’s discoveries is the third planet. Like all the other known extrasolar planets it is a gas giant (a massive planet like Jupiter without a solid surface), but ‘the third planet, which orbits Reticulum, was the first extrasolar planet to be found in a circular orbit outside the 0.05AU radius’ says Tinney. He explains that ‘the interesting thing about the third planet is that it is in an orbit, just larger than the orbit of the Earth. It would be in a habitable zone if it orbited a star like the Sun but it orbits a much bigger star so the luminosity and the radius of the star are much greater’. The planet has an eccentricity of 0.02 (almost circular), an orbital period of 426 days and an orbital radius of 1.1AU.

Bridie West is a physics graduate of the University of York, UK. She is currently taking a year out to travel around Australia, watch her partner participate in triathlons, learn how to run and write about astronomy. She is very grateful to Chris Tinney and Greg Henry for taking the time to discuss their research with her.
Although the third planet does not lie within the habitable zone (the region round a star where the temperature is right for liquid water to exist), Tinney says that the discovery of a planet in a circular orbit at 1 AU means that planets like our own are probably out there. A second planet in an Earth-like orbit was found earlier this year by planet hunters in the Northern Hemisphere. The planet which orbits star HD28185 is in an almost circular orbit with an orbital period of 385 days.

**TECHNIQUES & TECHNOLOGIES**

The AAO team uses the radial velocity technique. If a planet orbits a star, the planet's gravity will affect the motion of the star, causing the star to 'wobble'. The planet and the star will attract each other, and revolve around their common centre of mass in complimentary orbits. When the planet is moving away from Earth, the star has a maximum velocity towards Earth. When the planet is moving towards Earth, the star has maximum velocity away from Earth. This change in the star's velocity causes a detectable Doppler shift in the spectrum of the light emitted by the star. If a star speeds up and slows down in a regular pattern (wobbles) this could be due to a planet.

Using the radial velocity technique, it is easier to detect a more massive planet because the planet's gravity has a stronger effect on the star. Similarly it is easier to detect a planet in a tighter orbit. This may explain why astronomers have been detecting massive gas giants and not small rocky terrestrial planets. When it is possible to detect smaller planets in larger orbits, astronomers may find that the planets which were discovered between 1995 and 2001 are not common examples. This seems more probable when you consider that research groups which use less accurate techniques tend to discover only the most massive planets in the tighter orbits. Tinney says 'The first person to find an extrasolar planet was Michel Mayor. He targets large numbers of stars but he uses smaller telescopes and lower precision techniques so his hit rate has been lower and he has found easier targets'.

The AAO are able to measure a change in velocity as small as 3 m/s using techniques which were developed by Butler and Marcy. Tinney says 'their technique works well due to the use of iodine cells in observing, and their software. Using an iodine cell, calibrated with white light, to measure the spectrum of the starlight increases the accuracy of the experiment. Without this technique, our equipment could only be used to measure velocity changes greater than 200 m/s'. He explains that 'what we are measuring is much smaller than the resolution of the spectograph will measure. We need to worry about the shape of unresolved lines because a small mismatch can make us detect a spurious velocity shift. The iodine cell eliminates systematic inaccuracies.'

The smallest velocity change which the AAO planet search team can measure is tiny (3 m/s equates to a slow jog). However, it is not small enough to enable them to detect a planet of Earth's mass in an Earth-like orbit. Tinney says, 'Over twelve years, using 3 m/s precision, we can detect the motion of a star produced by a planet of Jupiter size in a Jupiter-like orbit'. This means that in 12 years time they could have detected one planet in a twin of our own solar system.

The transit method is a second detection technique which is available. This method involves detecting a diminution of the light reaching Earth from a distant star. The brightness of a star appears to decrease if a planet passes between the star and the Earth. The inclination of the planet's orbit determines whether a transit can be detected. The planet must also be massive and in a tight orbit to be able to measurably reduce the amount of starlight which reaches Earth. Therefore, the transit method can only be used to detect a small percentage of the planets which have been detected using the radial velocity technique.

The transit method has only been used successfully on one occasion. In 1999 American astronomer Greg Henry, who later joined the AAO, was able to use the transit method to confirm that a shift in the spectrum of light emitted by a star was due to the presence of an extrasolar planet. Henry says that the first successful detection of a planet using the transit method 'showed that these planets really are there' and that 'radial velocity technique results are not due to pulsations within stars themselves' (which had been suggested by David Grey). Henry already had the equipment to detect transits because his research involved detecting brightness changes in Sun-like stars in an attempt to better understand the sunspot cycle.

Although the transit method can help astronomers to learn more about extrasolar planets, it is not used to detect planets initially. Tinney says 'transits tell us interesting physics about the planet such as the orbital plane and the size of the planet but only when we already know that the planet is there'. If the orbital plane of a planet is known, astronomers can determine the mass of the planet; the radial velocity technique only reveals a minimum mass. Henry explains that 'If you don't know the orbital plane of the planet, you don't know if a velocity change is due to a real heavy planet making a minimal contribution or a real light planet making a maximum contribution. You can only tell the minimum mass of the planet. When you see a transit you can calculate the true mass of the planet'.

If a planet is in a tight orbit there is a greater chance that the planet can be detected using the transit method. Tinney says 'Greg is happy to make his telescope available to us and Paul [Butler] already knew him. We first contacted him in September 2000 about the short period planet we had found'. For a planet as big as Jupiter within 0.05 AU of a star, Henry says there is 'about a 1 ten-thousand probability of seeing a transit' and explains that 'for planets within the habitable zone the orbits are longer and the probabilities of finding transits are much less'. Unfortunately the orbital plane of the short period planet found by the AAO in 2000 did not allow a transit of that planet to be detected.

The Holy Grail for planet hunters is to detect a habitable planet. The only example of a habitable planet that is known is Earth, so astronomers are looking for Earth-like planets. Even if the AAO improve their equipment, they will never be able to find an Earth-like planet using the radial velocity technique. Tinney explains that 'The limit of the radial velocity technique is a star's stability. Stars are not much more velocity stable than 3 m/s. A small spot on the surface of a star - similar to a sunspot - can cause a change in the light emitted by the star which can make you think the velocity has changed. Hence an artificial velocity shift has been created.' The transit method is
only suitable for detecting a planet when a transit is predicted from radial velocity data.

Although the techniques and equipment used by Tinney’s planet search team are already of optimum precision, there is more the research group can achieve. They have not been active long enough to detect a Jupiter and Tinney feels that they should also improve ‘efficiency’. He says ‘we need to do some instrument improvements and target more stars’.

The future for the AAO

By targeting more stars, astronomers should find more planets and may be able to learn more about the formation of solar systems. The two main classes of planets which have been found, ‘short period hot Jupiters’ and planets in highly elliptical orbits, were not predicted by the standard theory of solar system formation. The theory was based on the two main types of planets which exist in our solar systems: gas giants in long, circular orbits and small rocky planets in shorter circular orbits.

According to standard theory, gas giants should not be able to form close to stars. Tinney says ‘We can only make [using current computer models] gas giants if they are far enough away from a star for water to exist as ice. Planets need to accrete ices and dust to get a rapid build up of material in order to get big enough to become gas giants’; either gas giants form away from stars and migrate towards them or the theory is incorrect.

Standard theory is that planets form in almost circular orbits. If a gas giant is already orbiting a star in a highly elliptical orbit it will destabilise any other planets within its major and minor axis. If a system ejects a massive planet, that could cause another planet within the system to fall into an elliptical orbit – the eccentricity of the orbit would depend on the masses of the ejected planet and the remaining planet. In both situations, either a highly elliptical orbit or the ejection of a massive planet has to come first and there is no theory to explain how one of these could happen before the other. Consequently, while astronomers have some understanding of elliptical orbits, they cannot explain exactly why most of the known extrasolar planets are in orbits with high eccentricities. Tinney admits that ‘it is not clear how highly elliptical orbits are formed’.

More planets, slightly smaller planets and planets in slightly larger orbits will probably be discovered by the AAO over the next decade – providing that the planets are there to be found. Tinney expects ‘the AAO to find two or three new planets a year – but I do not know what exactly we will find. I’m pragmatic – I wait and see what happens.’ If planetary systems like our own solar system are common, then it is possible that the AAO will find the largest planets in similar systems within the next decade. It is hoped that planet hunters will also eventually be able to better explain solar system formation.

How to detect an Earth-like planet

Astronomers must use a method other than the radial velocity technique if they are to find small, rocky planets in habitable zones. If other Earth-like planets exist, the method which is most likely to find them involves directly photographing them. Tinney says ‘Internationally, the trick being followed is adaptive optics systems. They use bendy mirrors to take out distorting effects of the earth’s atmosphere and detect light from extrasolar planets.’ These programs will target young Sun-like stars. As stars age they dim by a factor of approximately two but as planets age they dim by many orders of magnitude. This means that in a young planetary system the planet will be relatively brighter than an identical planet in an older system.

Within the next 20 years direct imaging of Earth-like planets orbiting young Sun-like stars should be possible but even if such systems exist, this method will not necessarily find inhabited planets; young planetary systems may not have existed long enough for life to have developed.

Since 1995 planet hunters have found that planets are fairly common, that there are other systems with more than one planet and that there are other classes of planet than rocky ones in short circular orbits and gas giants in long circular orbits. If the Earth and the Sun are a common example of a star-planet system then it is likely that a twin system will be found within the next two decades. The ability to detect evidence of life on an extrasolar planet will probably take much longer. Nonetheless, it seems likely that the rapid progress of the planet hunters has only just started. The ability to detect planets which are hundreds of light years away will almost certainly bring more surprises and, if they exist, it may bring us the closest we have come to meeting our extraterrestrial neighbours.

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DEMAND FOR MATHS AND SCIENCE TEACHERS HOTTING UP

Aggressive recruiting by principals of rural schools and teaching agencies from the UK are bringing the market for science and mathematics teachers to the boil. Shortages in these key subjects are hitting hard at country schools and schools in disadvantaged areas, such as the western suburbs of Sydney and Melbourne. The problem is hurting schools across the board.

Ms Jan Thomas, Vice-President of FASTS, said that shortages were forcing schools to use an increasing number of under-qualified teachers in these key subject areas. "School principals from remote areas have been making special trips to teacher training institutions to recruit next year's staff," she said. "We haven't seen that before. Things are only going to get worse - we're bracing ourselves for the time when the Americans enter the recruiting market in pursuit of science and mathematics teachers. American salaries and conditions look pretty attractive to Australians."

Ms Thomas said that forty per cent of teachers taking mathematics in junior high school classes are under-qualified. She said some schools had reached the stage where they are dropping the more challenging levels of mathematics and science. "There are two sides to the problem: the lack of any organised program to update the knowledge of existing teachers (especially those teaching out of field); and a shortage of young people entering science and mathematics teaching," she said.

The solution calls for action by both Federal and State governments. The Federal Government needs to provide extra places at universities for teacher training and retraining. "We also need additional funding to allow student teachers to undertake practice teaching in country schools," she said. "New teachers are not going to choose country schools if they don't know what they're like, and we can't afford to send them there for practice sessions." The State governments need to provide study leave for existing mathematics and science teachers. Half a day a week over a year would allow teachers to improve their discipline knowledge and absorb the latest information about their subjects.

"Unless Australia tackles the issue in a determined way, this country will go backwards," Ms Thomas said. "A modern economy demands a properly educated population. Recent statements by the Business Council of Australia and Rupert Murdoch underline the widespread concern of the community about our national investment in education."

Ms Thomas said the Federal Government had talked a lot about the need for literacy and numeracy, but the education system were still waiting for follow-up action and funding. "As far as the ALP is concerned, the recent announcements for HECS-free scholarships and re-training are a promising start; but the problem requires action on a grander scale," she said.

Toss Gascoigne

[The following report was contributed by a Physics Olympiad student, Sophie Dowling, who was invited to attend a meeting in Russia, and was given some financial support from the AIP to help finance the trip.]

The Russian Experience

Our trip essentially consisted of an in depth tour of Moscow and St Petersburg, with a large majority of our tour conducted in Moscow. Prior to the Russian segment of the tour there was a brief three day interval in London. While in London, thanks largely to Rod, we took in the sights of Buckingham Palace, Hampton Court Palace, St Paul's Cathedral, and Madame Tussaud's Wax Museum, while essentially covering all points of interest of the "Monopoly board." Simultaneously we embraced the Monument, Tower Bridge, The Globe Theatre and The Royal Observatory.

The first week of the tour began with a trip to Red Square, and the communist hallmark, Lenin's Mausoleum. Located on the fringes of Red Square was St Basil's Cathedral, which was also a significant point of focus to the tour. Within this central region of the city stands the Kremlin, possibly Moscow's most renowned political and historical landmark. The group made two visits to the Kremlin. On the initial visit we surveyed the region from the streets surrounding. On our second visit we entered the microcosm city and conducted a tour guided by our hosts. Within this experience stood out many architectural and historical points of interest, including the world's largest cannon and bell accompanied by Russia's oldest Cathedral.

Among many cultural highlights of Russia, we were also taken to the Church of Christ the Saviour, otherwise referred to as "Christchurch." A large portion of the program that was dedicated to the culture of Russia was spent in many other Churches and Cathedrals. These locations were common throughout both St Petersburg and the Moscow city region. Included in this segment of the trip was a traditional Russian Orthodox Church, where we viewed a live ceremonial service; a Catholic Church, which is one of only three still existing in Moscow today, the Kazan Cathedral; and the Cathedral-Museum known as "The Saviour of the Spilt Blood," and St Isaac's Church.

Evidently a fair portion of the program was dedicated to a cultural and environmental integration. Our tour maintained a cul-
natural focus as we were taken to visit and scout locations such as the food and clothes markets in Gorki Park, Old Arbai Street, a Russian Jazz festival in synchrony with the "White Night's Festival," a cruise on the Moscow river, the Moscow zoo, Neveki Prospect and the "Great Moscow Circus."

Our schedule also had us enlisted to visit many museums and other scientific landmarks of Russian history. The group visited a military museum, which was accompanied by an open air display of tanks, aircraft and other various arsenals used in Russia's wars. Our guides took us to several space museums dedicated to Russia's success in the field of Space Exploration. Standout features also include a visit to the "Planetarium" in Moscow city, where the group examined the Sun through a telescope and listened to a lecture from a leading scientist of the "Soyuz" organisation. Also in our program of Russian space history was a visit to the Cosmonaut training facility "Star City," at which stands the monument of Yuri Gagarin, and a private meeting set up by the "Soyuz" organisation with two Russian cosmonauts, Alexander Serebrov and Sergei Avdeev. Also visited was a memorial dedicated to the "Great Patriotic War," "The Hermitage," a Russian art museum dedicated to the history of Russian art, politics and literary culture and the "Summer Gardens" at one of the Tsar's Summer Palaces. The tour also visited the memorial ground where the Russian army successfully forced the German army to ceasefire.

The program extended us the time to view a performance of the ballet "Giselle" at the Bolshoi theatre in the heart of Moscow. While residing in the countryside we were given the opportunity to capitalise further on Russian history and tradition, with a visit to Russia's most famous monastery and gardens in which there was an allotment of land that had a traditional cottage erected. The trip was concluded with a celebration in the heartlands of Moscow's countryside.

Samira Afrastabi, Sophie Dowling, Andrew Lines, Emily Mitchell, Toby Moysa and Evan Williams

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This month's front cover shows a three-dimensional AFM nanolithography image, courtesy of NT-MDT and Coherent Scientific. The 2.0um x 3.0um portrait image was created by electrical local probe oxidation on film and the topography image obtained in resonant mode using a NT-MDT Scanning Probe Microscope (SPM) for both techniques. The portrait is of Albert Szent-Gyorgyi Von Nagyrapolt who was a 1937 Nobel Laureate in medicine.

Please see the back page and the Coherent Scientific website (www.coherent.com.au) for more details on NT-MDT and 'How many Nobel prize winners can you fit on a pin head?'. The Product News on page 152 includes details of a recently installed SPM at the University of Melbourne.
NEW SOUTH WALES PHYSICS INDUSTRY DAY, 2001

Some 65 innovators gathered on Wednesday the 26th September at the Penrith campus of The University of Western of Western Sydney (UWS) to partake in Physics Industry Day, 2001. This was the third Physics Industry Day held by the NSW Branch of the Australian Institute of Physics (AIP) and was a joint meeting with the Innovative Technology Network (ITN) of UWS. This year’s Industry Day was particularly successful because it attracted about 25 participants from private industry and provided plenty of opportunity for them to interact with some 35 researchers from all University Physics Departments in NSW, CSIRO and ANSTO. Twelve talks on a wide variety of R & D projects were presented during this day with time in between talks for proactive discussion and viewing a variety of posters and innovative products. Ph.D students representing all Physics Departments in NSW presented posters on their respective applied/industrial research projects and took part in a competition, with a $1000 first prize, for the research work judged to be the most innovative. For entry into the student competition the project undertaken was required to be applied physics research with possibility of commercial development.

The morning was divided into two sessions the first of which began with a presentation entitled “Physics at ANSTO: supporting Australian Industry” by Brian Spies, Head of the Physics Division of ANSTO, in which he discussed use of ion beam analysis and neutron scattering in current research and industrial projects. Brian outlined the proposal for the Replacement Nuclear Reactor with its associated instrumentation and discussed possibilities for future use by industry. The morning sessions continued with the following 15 minute presentations:

- “Innovation in an Ancient Industry”, Jim Walsh (R.J. Walsh & Son) discussed development of the Hiittite Special racing sulky
- “Uses of Plastics & Rubber in Rehabilitation Equipment”, Robert Bossard (Bosshard Medical) talked about development of plastic and rubber wheelchair components
- “Production of Hard Tool Coatings using Plasma Immersion Ion Implantation” and “Modification of Surfaces of Prosthetic Materials to improve Biocompatibility”, Marcela Bilek & David McKenzie (Dept Applied Physics, The University of Sydney)
- “Lasers for High Precision Manufacturing & Diagnostic Therapeutic Medicine” Jim Piper (Centre for Lasers & Applications, Macquarie University) discussed laser machining of plastics and the Sydney 2000 Olympic torch burners as well as joining nerves and blood vessels.

A panel discussion chaired by Ross Pearce (leader of ITN Group at UWS) was held at the end of the morning talks from 12:15 to 1:15pm with presentations by Tony Pensabene from The Australian Industry Group (AIG), Terry Freund from AusIndustry and John Colless from the Europe Australia Cooperative Centre. Tony Pensabene reported on latest developments relating to tax incentives and funding for R & D as a result of the Innovation Summit held last year; Terry Freund itemised the various funding schemes available from AusIndustry for R & D; John Colless described the collaboration amongst UWS, University of Melbourne and various European Universities to obtain research funds for local R & D projects.

After lunch, during which student project judging took place, were four presentations:

- “Industrial R & D at CSIRO Division of Telecommunications & Industrial Physics (TIP)”, Cathy Foley discussed various collaborative projects with industry.
- “Pigtailed in Fibre Optics?”, Sue Law (Australian Photonics Co-operative Research Centre) suggested how this might be done robotically to make it cost effective: venture capital is required.
- “Cochlear Ltd. from Laboratory Prototype to Global Company”, Jim Patrick (Cochlear) discussed how the Cochlear Implant was developed to suit the anatomy of the human ear as well as the history and current commercial status of Cochlear Ltd.

The presentations were all excellent and stimulating and initiated much discussion, particularly with respect to the need to take out or not take out patent protection depending on the type of innovative product developed. All of the oral presentations as well as most of the poster displays described applications of physics to industrial processes and/or manufacture of particular products.

At the conclusion of afternoon tea Pal Fekete, Chairman of the NSW Branch of the AIP presented a cheque of $1,000 to student competition first prizewinner Carl Masens from the Department of Applied Physics at UTS for his research project “Design & Control of Self Assembled Monolayers for use in Nanodevice Technology”. Second prize of $500 was awarded to Ben Lough from the Department of Engineering Physics at the University of Wollongong for his project “Numerical Calculation of the Thermionic Cooling Efficiency of Semiconductor Heterostructures”; third prize was awarded to Joshua Simons, Centre for Lasers &...
Applications, Macquarie University for his project "A Novel Solid-state 598 nm Laser Source". Student projects were judged on presentation, physics content and "commercialisability" as perceived by the judging panel. Thank you to John Lowke and George Collins for assisting me with the judging.

The NSW Branch wishes to maintain Physics Industry Day as an annual event where innovators from industry, government research laboratories and University departments get together for useful discussion. Next year Physics Industry Day will be bigger and part of the Biennial AIP congress to be held at Darling Harbour from the 8th to the 11th of July and we are now seeking an increased presence from private industry at this conference. A special part of next year's congress will be a two hour forum in which four physicists will discuss innovative products they have each developed and the difficulties they have experienced in setting up a company to commercialise their innovations. The theme for AIP Congress 2002 is "Physics & Industry Working Together".

Ken Doolan
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VICTORIA

September Meeting

Focus on Careers in Physics

The Victorian branch of the AIP recently held an "undergraduate careers night" at the Royal Society of Victoria. The evening was aimed at providing information about careers in industry available to students after completing a degree in physics. Speakers were invited from the areas of photonics, teaching and medical physics to come and talk about their experiences and the job prospects in their respective fields.

Executive Director of Redstart Pty. Ltd., Terry Polkinghorn, discussed the prospects of a career in photonics. He said that given the enormous growth in photonics, the need for undergraduate and TAFE trained photonics specialists was going to grow exponentially over the next decade.

Colin Hopkins, a Senior Physics teacher at Balaclava High School, discussed the pros and cons of science teaching in today's schools. Colin reiterated the common opinion that there will be a large shortage of science teachers within the next decade and discussed the improved pay and working conditions enjoyed by teachers recently.

Representing the Australasian College of Physical Scientists and Engineers in Medicine, Trevor Ackerly, spoke about the opportunities available working in the area of medical physics. On a daily basis Trevor is involved in the maintenance and operation of a variety of medical diagnostic and treatment equipment. This field is continuing to grow as the number and complexity of these machines increases and the need for people with training in physics becomes more and more important.

Overall, the night provided a good chance for students to hear about prospective careers in these fields and discuss the various opportunities available to physics graduates.

Jared Cole

TASMANIA

Dr Roland Warner (Antarctic CRC & Australian Antarctic Division) presented an interesting public lecture entitled "Antarctica and Global Warming - Estimating the Long-term Response" on Tuesday, 2nd October, to an audience of about 50 people. This was a joint AIP Tasmanian Branch and Australian Meteorological and Oceanographic Society sponsored lecture.

After outlining his talk, Dr Warner introduced us to some Antarctic numbers. The Antarctic ice sheet amounts to approximately 26 million cubic km of ice and annual accumulation averages approximately 15 cm per year spread over an area of approximately 14 million square km. Presently, the accumulation rate is known only to an accuracy of order 15%.

Accumulation appears to be in approximate balance with loss which proceeds as an outflow of the continental ice mass. The ice moves essentially as a block flow steered by the ice surface slope, with a region of shear near the base. It was left as a simple exercise for the audience to check that the gravitational potential energy of ice deposited on the high, cold Antarctic plateau does correspond to the warming of the ice by the time it is discharged at the coast. At the edge of the continent ice is lost via melting and calving of icebergs.

An interesting aside was that year 2000 was a bumper year for 'monster icebergs', which are of general fascination to the public. The largest of these was designated 'B15', which when separated from the Ross ice sheet was 295 km long, 37 km wide and about 250 m thick. Another large iceberg 'A43-A' split off from the Ronne Ice shelf on the other side of Antarctica just a few months later. The combined loss of ice from just these two monsters accounted for more than two years of total Antarctic accumulation, emphasising the variable nature of the ice loss process from year to year. There is no evidence that the number of large icebergs is changing, although detailed satellite observations have been possible for only a few decades.

Another newsworthy topic has been the effect of warming of the Antarctic Peninsula region. While the temperature data are noisy, the best estimate is that this region has warmed by about 2.5°C in the last 50 years, significantly in excess of average global warming. Accompanying this warming there has been extensive decay of floating ice shelves that have existed in the region for centuries. A recent idea that may account for this rapid ice loss is that enhanced melt water accumulating in crevasses may result in increased fracturing, weakening the floating ice shelves, which then disperse into myriads of smaller icebergs.

Dr Warner reported on research at the Antarctic CRC with Professor Bill Budd on the future of the Antarctic ice sheet under the influences of an expected enhanced greenhouse gas climate change scenario. The ice sheet model has been developed over the past thirty years from initial pioneering work by Professor Budd and co-workers. The scenario includes assumed "middle of the road" projections of increasing concentrations of greenhouse gases, levelling out at 3 times pre-industrial levels by the end of the 21st century. This leads to an increase in Antarctic accumulation of approximately 50% (greater up-take and transport of moisture from the Southern Ocean) and a summer temperature increase of around 3 K. The major factor influencing the future of the West Antarctic ice sheet is the increased melting of floating ice shelves by warmer sub-ice shelf water temperature which are predicted to increase by 2 K. In their simulation, this leads to the collapse of the West Antarctic ice sheet which they predict will largely disappear by the end of the millennium. Today it largely consists of a thick ice shelf grounded on the sea-floor.

Dr Warner made the point that even if we manage to limit our increase in global greenhouse gases to around three times "pre-industrial" levels by the end of the 21st century, significant consequences of our modification of the climate will continue to be played out in the coming millennium.

The audience thanked Dr Warner warmly for his interesting presentation of one of the significant predicted outcomes of the atmospheric experiment humanity is undertaking, and for insight into the atmosphere-ocean-ice interaction processes that lead to this prediction.

Gary Burns

The AGM of the Tasmanian Branch was held on Thursday 15 November. General business of the meeting included all the usual matters of report and budget and the election of the new committee. The committee for the next 12 months comprises: Elizabeth Chancellor (Chair), Bob Delbourgo (Vice-Chair), Stephen Newbery (Treasurer), Gary Burns (Secretary), Marc Duldig, Raymond Haynes, John Humble and Ian Newman. After the meeting a small dinner was held and then a well attended public lecture on Astronomy in the 21st Century was delivered by the well-
known radio astronomer Prof Richard Wielebinski. Prof Wielebinski is an ex-Tasmanian who graduated in electrical engineering and science from the University of Tasmania before heading to Cambridge where he gained his PhD in 1963. He returned to the University of Sydney as a lecturer and after a few years was appointed director at the Max Planck Institute for Radioastronomy in Bonn, a position he has held ever since.

In his public lecture Prof Wielebinski opened with a very brief history of astronomy. He showed how optical astronomy was an old science commencing at least 5000 years ago. He then discussed the advances of the last 50 years. The major change in astronomy over that time has been the opening of the full electromagnetic spectrum to observations. This was initially with the development of radio astronomy, firstly with large single dishes and more recently large arrays of dishes such as the Very Large Array. The move to shorter radio wavelengths allowed observations of cold dust in the universe and the move to infra-red with high altitude ground-based systems, aircraft and satellites allowed observations of hot gaseous regions of star formation. At the same time very long baseline interferometry (VLBI) was being developed in radio astronomy giving unprecedented angular resolution. Also developed in parallel with these techniques were the UV, X-ray and gamma ray satellite telescope systems that probed some of the most violent regions in the universe.

Prof Wielebinski listed a number of the big achievements of the last 50 years. The realisation that the universe is not static but highly dynamic was perhaps the greatest change. The discovery of galactic jets, pulsars and supernova remnants, compact stellar objects and the lumpsiness in the microwave background were all important steps. The ever increasing number of galaxies seen with deeper viewing as in the Hubble deep field and the observation of gravitational lensing are more recent but equally important advances. In the future there are a number of exciting projects under construction or being planned. The Square Kilometre Array radio telescope proposals, space based VLBI and large arrays for mm wave astronomy are examples. Others include the Stratospheric Observatory for Infra-red Astronomy, various new large satellite experiments and some very large ground based optical instruments. He discussed the possible European Overwhelmingly Large optical telescope (OWL) which is being promoted and would have a 100m diameter mirror with deployment sometime after 2010. Prof Wielebinski also mentioned the possibility of deep sea neutrino telescopes located 5000 m below the surface and opening up a new astronomical window.

Prof Wielebinski noted that these very large facilities and satellites were daunting because their scale was now such that the people designing and building them may well complete their working lives before the instrument becomes operational. This was not an encouraging or motivating force for most scientists who want to see results from their labours. However, he noted that the large scale instruments were cost effective, producing published journal papers at a cost of $90,000 - $270,000 each. He pointed out that there was still a substantial role for smaller facilities in both quality research and as the training ground for future scientists. Prof Wielebinski concluded with a prediction that the new directions for astronomy would be in the total spectral study of black holes, particularly the galactic centre black hole, and the further development of cosmology from both observational evidence and theoretical understanding.

Marc Duldig

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Fax (03) 9326 2670, email aip@racv.org.au, website http://www.aip.org.au
A.L.FRANKLIN PTY LTD: SCIENTIFIC INSTRUMENT MAKERS TO AUSTRALIA

M.KEENTOK

Department of Mechanical and Mechatronic Engineering University of Sydney

A.L.Franklin Pty Ltd was a manufacturer of scientific instruments in Sydney between 1919 and 1999. Readers may well remember the company, its products and its founder, Arthur Louis Franklin, who was a member of the Australian Institute of Physics and who regularly participated in Sydney branch meetings until his death in 1972. Other than his obituary notice, little recognition has been given to his contribution to scientific instrument making, to industry and to the war effort (World War 2).

Besides manufacturing instruments, A.L.Franklin and his son Ray were engaged in continuous improvement of their instruments and in research and development of inventions, in their pursuit of accuracy and excellence. A.L.Franklin and Ray both showed a commitment to innovation and despite the small size of their company, they produced a large number of inventions and patents. A few of these inventions will be showcased in this article. Scientific instrument making draws heavily on a thorough knowledge of physics, materials science and engineering design. This work is dedicated to Prof H.C.Bolton who died recently.

INTRODUCTION

The scientific instrument industry is of some importance to the Australian economy, providing approximately $1,000M worth of exports in 1989 according to Dr Clive Coogan (Kimpton, 1989; Coogan, 1989). More recent statistics suggest this may have been an overestimate, but the scientific instrument industry is certainly now producing more than $1,000M per year. Growth in the scientific instrument industry is above the average for Australian manufacturing industry.

Of course the scientific instrument industry is of importance to physics and to academic organizations - as a provider of instruments and also as a partner in innovation - i.e. there is a synergy. Scientific instrument making as such is based on physics and engineering.

The story of A.L.Franklin Pty Ltd (ALF) is a story of innovation and will include several of the ALF instruments as case studies. However the story of ALF is mainly the story of Arthur Franklin, the founder.

A.L.Franklin the man

Arthur Franklin was born in Shrewsbury, England, in 1892 into a family with a manufacturing background. He had a passion for science and as soon as he could read he was studying physics and chemistry. As a child Arthur suffered the usual childhood illnesses and also diptheria, whooping cough and scarlet fever. These left his health in a weakened state and he was later advised to move to a warmer climate.

Because of family circumstances he was forced to leave school at 16, before matriculation, and he found employment as an instrument maker at Birmingham University. He worked for Prof J.H. Pointing, an eminent physicist of the time, who was a Fellow of the Royal Society and who is remembered for the Pointing vector and the Pointing theorem, as well as work on gravitation. Arthur made instruments for Pointing's laboratory and also worked as a lecture assistant; this period of apprenticeship taught Arthur all the physics that was to be fundamental to his later working life (Keentok, 2000).

In 1912, at the age of 20, Arthur left England and moved to Sydney. In the years 1912-1919, Arthur worked as a scientific instrument maker for Andrew Thom Pty Ltd and Prouds. Work repairing scientific instruments was plentiful and occupied him after hours in his home workshop. A major Education department contract for scientific equipment provided the stimulus for Arthur Franklin to go into business for himself in 1919. That year was also significant personally for Arthur - he married Gladys LeFreeman, his life-long partner and later company director of ALF (and office manager). In this period Arthur also became involved in the scouting movement and was Scout Master of the Mosman Group until 1932.

The work at Prouds introduced Arthur to clock making and this was a major activity of the company in its first three decades (mainly town hall clocks). Arthur Franklin was also involved in the setting up of Townsend and Mercer (Australia) in 1929 and was subsequently on the board of directors of the company until his death in 1972.

Arthur Franklin was elected to an Associateship of the Australian Institute of Physics (now MAIP) in 1965, after being a subscriber (and participant) from about 1950 (Anon, 1972). In 1966, the NSW branch of AIP organised a scientific instrument exhibition at the University of NSW in Sydney and Arthur Franklin presented a paper 'Pioneering in Scientific Manufacturing' (Franklin, 1966) at the formal conference program. In this paper Arthur talked of instrument makers he had known in Sydney during the early days of the twentieth century and provided some insight into activities at ALF.

A SHORT COMPANY HISTORY

ALF started in 1919 when Arthur Franklin received a sub-contract to make science apparatus for the Education Department. In the early years, this was balanced with other manufacturing activities which helped pay the way. The company occupied several premises in the Sydney City area before 1939, moved out to Artarmon during the war and in 1946 finally moved to Brookvale, where the company remained till its closure in 1999. It is not well-known that ALF made scientific instruments for use in the RAAF and RAN during the Second World War (Keentok, 2000), a contribution which has not been recognised in official histories such as that of Mellor (1958). Scientific instrument making became the sole manufacturing activity after the Second World War. The company participated in the post-war manufacturing boom and the business showed considerable growth during this period.

After the death of his father in 1972, Ray Franklin became Managing Director. In 1985, Ray sold the company, which continued as a manufacturer of scientific instruments until it eventually became insolvent and closed in September 1999. A more detailed company history has been compiled (Keentok, 2000) and this will hopefully be published in a specialist journal.

INNOVATIONS

During its 80 year life time, ALF manufactured many types of scientific instruments. The full list is extensive (Keentok, 2000) and the better known items were barometers, manometers, rolling parallel rules, laboratory masses, penetrometers, balances and chondrometers. Perhaps some of the more unusual items were the 56 lb portable balance for the Victorian government, the gasmeter calibration equipment for the NSW Department of Local Government and water level followers for the hydraulics laboratory. During the war, ALF made air speed indicator calibrators and altimeter calibrators for the RAAF, and Kew barometers for the RAN. However ALF were more than manufacturers, as both Arthur Franklin and his son Ray were constantly improving designs and creating new inventions in their home workshops. These inventions included a fire alarm system, a fire extinguisher, injecting devices, viscometers, a measuring balance and a drying chamber. A hypodermic needle lapping machine was developed in collaboration with CSIRO. Some inventions were not patented, however despite this, Arthur was responsible for 24 patents (listed in Keentok, 2000).

What makes this story different from other stories of innovation is that nearly all the inventions were developed in-house and without input from the universities and CSIRO - with only one (or two) exceptions. Kannegiesser (1996) details stories of innovation relating to the scientific instrument industry and some of these originate entirely from academia (university or CSIRO). A selection of ALF designs will now be showcased: the barometers, the grain chondrometer, the IR moisture balance and water level surface follower.

Barometers were a well-known specialty of ALF and their catalogue lists at least five types. Considerable expertise is required in the manufacture and filling of mercurial barometers and making of the scale - details are given in Franklin's lecture (Franklin, 1966). A major improvement by ALF to the design of the Fortin mercurial barometer was the introduction of a cleaning device in the bowl (Franklin, 1966). ALF also had unique laboratory testing equipment, including a pressure tank for testing mercurial barometers. David Lain CSIRO NML writes that 'Franklin barometers are quality instruments, they have a unique (I think patented) design for removing the contamination on the surface of the mercury in the cistern. The device for removing the contamination in the cistern is a disc (I think ceramic) which is the same internal diameter as the cistern and suspended above the mercury. To remove contamination from the surface of the mercury, the mercury level in the cistern is lowered so that the mercury is forced through a 10 mm diameter hole in the centre of the disc, then by raising the mercury surface in the cistern the contaminating floating of the surface of the mercury are thus trapped on the lower surface of the disc. This contamination in other barometers affects greatly the readability (and thus accuracy) of the instrument.'

The grain chondrometer is a device for measuring the density of granular materials such as wheat, oats and barley. The chondrometer has been used for decades in the wheat industry, both in NSW and overseas, as a quick and simple method for determining wheat quality. The original NSW chondrometer was inaccurate and was improved by ALF over a long period of time until it gave reproducible readings. Ray Franklin writes of giving a demonstration to officials in which he was able to obtain high, low or average readings, at will, simply by 'cheating'. The ALF Mark 2 chondrometer (and later models) was less susceptible to this problem.

The infra-red moisture content balance uses the change in weight of a sample after drying by infra-red radiation to determine volatiles and water content. This technique is still widely used in such applications as determining the water content of cereals, paper, sand, textiles, tobacco and foodstuffs. The ALF IR moisture content balance gave a read-out of % moisture up to 30% without any calculation, to an accuracy of 0.25% (ALF, 1984). Make-up weights could be added to the sample as it dried, to make determinations up to 100%. The drying chamber and associated chimney was a Franklin design.

The water surface level follower is an instrument for measuring the surface level of a body of water in a hydraulic model, such as a harbour or river mouth. ALF developed a water surface level follower to satisfy the exacting performance requirements of the hydraulics research laboratory. In this device, the water level is detected electronically by make and break switching at the water surface. The switching activates or de-activates a DC motor which moves a vertical screw to force the sensing probe in contact with the water surface. A mechanical readout is provided at the machine and electronically at a central control station.
CONCLUSION

Arthur Franklin made significant contributions to scientific instrument-making and to the scientific instrument industry. A case study of innovation and invention has been presented, listing many examples.

A commitment to innovation is seen very strongly in the story of ALF, in the time and effort put into research and development, and in the number of patents produced. Innovation can be seen in small firms (ALF did not employ more than 11 staff at any time) and large multi-national corporations are not necessary for innovation (Keentok, 2000). This may have implications for future government industry policy.

Arthur Franklin the man was one of the quiet achievers of his generation. He did not lack in tenacity, hard work as well as inspiration. He maintained arduous work well past his retirement age. He championed the local manufacture of scientific instruments, particularly during the Second World War. Industrial preparedness for manufacture of defence equipment was a government policy of the 1930s.

Any reader who has information on ALF the company, the man or the instruments, is welcome to provide information to the author, for inclusion in a more substantial history to be published in a specialist journal (email: mattik@mech.Eng.usyd.edu.au). Information on other scientific instrument makers of the time would also be appreciated.

ACKNOWLEDGEMENTS

The assistance of Ray Franklin, Julian Holland and the librarians at the State Library of NSW in the research for this article is gratefully acknowledged.

In view of his contribution to the history of science and his personal encouragement to the author, this article is dedicated to Prof H.C.(Bert) Bolton.

REFERENCES

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Prompt Critical

A Most Accomplished Physicist

A recent article in our sister journal "Physics World" sees the history of our discipline falling in arrears through insufficient attention to preserving what historians see as records rather than bald journal publications. The latter almost always fail to reveal the human actions and interactions that made discoveries happen.

Historians and scientists alike will be pleased with a splendid biography of an important physicist not widely known in Australia, perhaps due to his South African origin. Brian Austin's "Schoenland - Scientist and Soldier" traces in captivating detail the life and times of the late Sir Basil Schoenland, justly acclaimed as the greatest South African scientist of the twentieth century.

A brilliant student at Rhodes University, in Grahamstown, Schoenland won a scholarship to study at Cambridge, where he wanted to go rather than Oxford. Completing his mathematics tripos in 1915 he joined the army and carried out important work in signals, rising to the rank of Captain. Returning to Cambridge he studied at the Cavendish under Rutherford and formed the friendships that later shaped his career.

Between the wars he studied lightning, elucidating many of its mysteries and earning him a Fellowship of the Royal Society. War again intervened, leading him to initiate important work on radar. He rose in rank to Brigadier, becoming General Montgomery's science adviser in Europe.

After the war he helped reorganise South African science, advising General Smuts until the Nationalists came to power. Schoenland was chosen on the recommendation of his friend Mark Oliphant to be the second Vice-Chancellor of the Australian National University, but his appointment was vetoed by higher authority.

Another Cavendish friend, Sir John Cockcroft, begged Schoenland to become his deputy at Harwell. He eventually accepted and later succeeded Cockcroft as Director, playing a vital stabilising role in the evolution of Britain's nuclear energy establishments.

Space constraints limit what I can reveal about this remarkable physicist. "Schoenland - Scientist and Soldier" is a first-class, entrancing biography published in handsome format by Institute of Physics Publishing in hardcovers at £49 UK for over 600 pages. It has the ISBN 0-7503-0501-0. This gem of a book should be held in every library of quality in Australia, even at the cost of a budget overrun.

Cofin Keye
Reviews Editor

Plasma Astrophysics and Space Science

J. Buchner, et al (eds)
Kluwer Academic Publishers,
Dordrecht 1999
xx + 754 pp. + CD, US$315 (hardcover)
ISBN 0-7923-6002-8

Most of the non-dark matter of the universe is in the plasma state and this book represents a tour of some of the dominant themes that come into play in trying to understand astrophysical observations from a basic plasma physics point of view. The book, a conference proceedings, contains papers divided into sections on Magnetic Reconnection, Coronal Heating and Solar Wind Generation, Jets and Winds, Multi-Ion and Dusty Plasmas, Nonlinear Dynamics, Dynamo, Plasma Turbulence, Nonthermal Radiation, Cosmic Ray and Particle Acceleration. There are some famous names in the author list, including Australia's own Don Melrose. For instance, in the field of magnetic reconnection there are, inter alia, papers by the pioneers, Parker and Petschek, and a review paper by Priest. This in itself would make it an interesting collection, but there is also modern material on observations from new satellites like SOHO as well as 3-D visualisations of computer simulations provided in an accompanying CD. The quality of the printing is high, but the proof reading of the camera-ready copy could have been more rigorous in spots, e.g. there is a reference to "non-linear impudence" on p. 378 in the Colgate and Li article!

There is no doubt that this is valuable collection of papers by leading practitioners in the field, but at over AS$600 only the richest libraries would be able to afford it. Also, most of the papers are reprinted from Astrophysics and Space Science, Vol. 264, so libraries subscribing to this journal would be paying twice.

Robert L. Dewar
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Reviews

Number: From Ahmes to Cantor

Midhat Gazale
Princeton University Press, Princeton 1999
xvi + 297 pp., US$29.95 (hardcover)

This book is one of many that have appeared in recent years aimed at popularising mathematics. As its title suggests, it is a book about numbers, and it is aimed at an audience such as physicists or engineers who have some (perhaps considerable) experience using mathematics already. It is written by an engineer who regretted that in his technical education he felt never really learned what numbers were. So he tackles important fundamental questions. What are irrational numbers? How did the decimal system come about? Are there other useful ways to represent numbers than the positional systems like decimal and binary? What are transcendent numbers?

The author begins with a historical description of the development of our number system. None of this is new, and readers would be better served reading Tobias Danzig's "Number: the Language of Science" for this material. He then moves on to basic properties of the integers and rationals, and actually crams in a lot of elementary number theory. The author's main original contribution to the above questions is his notion of "cleavages", a geometric way of understanding the real numbers, which I found quite interesting.

Unfortunately, the pace is too uneven; some parts are easy reading, others difficult plodding. There are far too many errors; mathematical, historical and typographical. Some topics he labours, others he drops before you find out why he introduced them.

If you have time to read a book of this kind, I would recommend you begin with Tobias Danzig.

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Nuclear Data for Neutron and Proton Radiotherapy and for Radiation Protection.
Report 63, ICRU Publications 2000 x + 261 pp., AS190 (paperback)

Proton and fast neutron therapy are modern radiation oncology modalities. Success of radiation treatment depends on accuracy of treatment planning of radiation doses to target and beam optimization. The treatment planning computer codes, which are based on radiation transport Monte Carlo simulations, require knowledge of neutron-induced nuclear reactions, kerma coefficients and proton-induced kerma coefficients for wide spectrum of biological element.

This report describes nuclear data that are available for fast neutron up to 150 MeV and proton up to 250 MeV. The nuclear cross sections are evaluated using a combination of measured data and nuclear model calculations. Up until now, not much experimental data for high energy neutron and proton have been available for biologically important elements. The report also describes typical neutron and proton spectra sources used in radiotherapy as well as methods of beam production. It is important to have this for accurate simulations of absorbed doses in neutron and proton therapy.

The evaluated cross sections and kerma coefficients are tabulated for wide spectrum of isotopes included in tissue composition. Additionally, the book is supplemented by a CD with extensive and detailed data that can be used for simulation of absorbed and equivalent biological doses, microdosimetry, simulations of dosimeter response, transport codes for simulations of radiation shielding on accelerators and nuclear reactors. This book will be useful for medical physicists and engineers involved in a proton or neutron therapy, nuclear physicists, medical and health physics students.

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Radiation Safety and ALARA Considerations for the 21st Century
Health Physics Society
Medical Physics Publishing, Madison WI 2001 vii + 281 pp., US$33.95 (softcover)
ISBN 1-930524-62-1

The Midyear Topical Meeting of the Health Physics Society in the US this year was held jointly with the First International ALARA Symposium of the 21st Century. Lead roles in organizing the ALARA symposium were played by the Nuclear Energy Agency (NEA) of the OECD and the International Atomic Energy Agency (IAEA). This symposium featured the work of the Informed System on Occupational Exposure (ISO), which was sponsored by the IAEA and the NEA.

ALARA itself is the acronym for the recommendation of the International Commission on Radiological Protection (ICRP) that radiation exposures from any particular source should be "as low as reasonably achievable," economic and social factors being taken into account. As the papers in the symposium show, the pursuit of ALARA can involve techniques ranging from sophisticated cost-benefit analysis down (or up, depending on your point of view) to the application of simple common sense. As the title of one of the papers aptly puts it, ALARA might be seen as a "great philosophy but too subjective for regulation."

The crux of the problem of taking "economic and social factors" objectively into account is outlined on page 8, under the sub-heading "The Fly in the Ointment." Essentially, any procedure for balancing the cost of measures to control radiation exposure against the resulting benefit to society tends to involve placing a dollar value on human life, or on some formulation of population exposure. It is not easy to determine such values objectively.

Nevertheless, ALARA has been the cornerstone of the radiation protection system since at least 1977, although not necessarily in the form of a rigid cost-benefit framework. Also, help is on the way: the ICRP is reconsidering the whole question of ALARA optimisation in the context of new recommendations that it aims to publish around 2004-5.

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An Introduction to Nuclear Physics
W N Cottingham and DA Greenwood
Cambridge University Press, Cambridge 2001 xvi + 271 pp., US$29.95 (paperback)
ISBN 0-521-65733-4

Nuclear Physics, Principles and Applications
John Lilley John Wiley and Sons, Chichester xvi + 393 pp., AS84.95 (paperback)
ISBN 0-471-97936-8

Nuclear Physics plays an important part in the undergraduate physics curriculum, exploring systems involving three of the four fundamental interactions and providing an example of an isolated quantum system with tractable degrees of complexity. The search for a suitable text for second or third year level has never been easier as the sub-discipline now covers far more topics that can be comfortably dealt with in a standard physics program.

These two texts, published this year, provide interesting and good books aimed at this level. Both come from courses presented in the UK, with Cottingham and Greenwood's book from Bristol and Lilley's from Manchester and as such are perhaps better suited to the Australian context than comparable American texts.

As to be expected the books reflect the background and biases of the authors with Cottingham and Greenwood's including perhaps more weak-interaction physics than in Lilley's. While one could argue that this is an integral part of the behaviour of the nucleus it comes at a cost of other material in a relatively short book. Further, while this material is often found in texts on particle physics there is not enough here to make the book appropriate as a prescribed text for a nuclear and particle physics course. Cottingham and Greenwood's strength is their clear logical development of physical principles.

On the negative side is their rather poor use of figures and diagrams, for example the Segre chart is presented with the proton number on the x-axis. Although this fits better on the page almost all other presentations show it the other way around! Similarly a plot of the energy levels in potential wells would have been more appropriate than a table which appears to be upside down! At the end of the day the main problem with the text may be the length, it is perhaps just too close to the lecture notes to provide enough material for students to read around issues and they are not helped by a rather too short Further Reading list.

On the other hand Lilley's book is approximately half as long again as Cottingham and Greenwood's, but probably has twice as much. It. For example Lilley's book discusses the biological effects of radiation in 22 pages compared to 6 in Cottingham and Greenwood's and, reflecting the different emphasis, Lilley's book also has a separate chapter on Nuclear Medicine. Lilley's book has about twice the number of problems and both books are to be complimented on providing excellent solutions to all problems. Lilley's book covers material at much the same level as Krane's book Introductory Nuclear Physics (Wiley 1987).

I was a little disappointed to see that Lilley makes no mention of the Nilson model and to find 15 year old spectrum of a superdeformed band in a book published this year! A current text might also have seen fit to include a number of web sites pointing students to a wide range of resources now available. In many respects Lilley's book is more readable than Krane's, with better sections on applications and power, but in the same way that Lilley's book probably would be a better choice for students than Cottingham and Greenwood's, the extra length of Krane's book (845 pp in paperback) probably makes it the more valuable resource.
book. On balance both books are ideal for undergraduate students and I will certainly be putting them on my recommended reading lists!

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Fundamentals of Cosmology
James Rich
Springer-Verlag, Berlin 2001
viii + 302 pp., DM 99.90 (hardcover)
ISBN 3-540-41350-2

Cosmology is the study of the large scale structure and history of the universe, and extraordinary discoveries continue to flow from this exciting field. While many will be acquainted with the past developments such as the discovery of the big-bang expansion and its associated cosmic background radiation, as well as the synthesis of the low mass baryons, cosmology is now entering a dramatic new era which could be called 'precision cosmology'. One recent discovery has been that of the acoustic anisotropy in the cosmic background radiation, implying that the universe is nearly at its so called critical energy density. As well that the universe is accelerating, based on fluxes from high red shift supernovae, suggests that the expansion process is dominated by what is called 'vacuum energy' or in older terminology, a 'cosmological constant'.

Other observations have led to the suggestion that as well the universe contains 'dark matter', though this could be a manifestation of a 'modified gravity' law at cosmological scales. All these exciting developments are laid out in a very accessible form in this textbook especially written for senior undergraduates or graduates from various backgrounds. It deals in a very nice and explicit form with the basic ideas of cosmology and general relativity (without excessive tensors) and assumes homogeneity and isotropy to keep the analysis simple. In keeping with its textbook design it contains nearly 100 diagrams, numerous problems, some with solutions. This is a fine textbook and would be very enjoyable for private study.

R T Cahill
School of Physics
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The Atomic Nature of Crystal Growth
B Tutuashvift
Springer-Verlag, Berlin 2001
xii + 370 pp., DM 179 (hardcover)
ISBN 3-540-66496-3

This is a book for readers who wish to have a theoretical understanding of the factors and phenomena that influence and determine the growth of crystals at the atomic or molecular level. The major areas of fundamental physics/chemistry drawn upon for the treatment of the title-topic are classical & statistical thermodynamics, surface tension, diffusion, and interphase relationships. The overall structure of the presentation provides a review of classical & statistical thermodynamics and a series of appendices outlining the major mathematical techniques used in the text, which help prepare the reader prior to delving into the main substance of the book; an extensive reference section for further reading is also included, if required. The core material of the book considers equilibrium between different phases of materials, the process of nucleation that is the trigger to crystal growth and crystal growth itself, with consideration of idealized crystal face features. The author has produced a clear, detailed, and extensive presentation of the many matters that are of theoretical interest, and need to be considered, for an understanding of crystal growth processes. It is an academic work of good quality and substance. Perhaps one could ask the question, though: Will this book aid, in a practical way, the "crystal growth industry" to achieve purer, better quality, larger, etc., crystal specimens? The answer is, probably yes, although the connectivity will require considerable further work. Finally, it is a specific, reference book, rather than a "must read" for the well informed, non-specialist physicist or chemist.

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Applied Radiobiology and Bioeffect Planning
David R Wigg
Medical Physics Publishing, Madison WI 2001
xx + 489 pp., US$180.00 (hardcover)
ISBN 1-936524-05-6

Recent advances in Radiobiology allow complex 3D modeling and treatment of patients with finely judged variations in radiation dose. Current treatment modelling (planning) is based on physical dose only, however biological effect is usually not directly proportional to dose. Radiobiology is the science of mathematically modelling the effect of radiation on complex and interrelated biological systems. Bioeffect planning is the translation of physical dose plans into units, which express radiobiological effect.

Dr David Wigg, an Australian Radiation Oncologist, is a pioneer in the development of bioeffect planning. He has taken to heart the following quote: “All models are wrong, but some are useful” (Box, 1984), and has provided details of the more useful best-estimate parameters and models while maintaining a healthy caution of such models.

The earlier chapters discuss Linear-Quadratic radiobiological models, and parameters such as radiosensitivity, time, cell repopulation, dose rate, fractionation, and volume effects. A specific application of the parameters to stereotactic treatments of AVMs is included, and the issue of biological effects of chemotherapy, particularly on late reacting normal tissues, is addressed, despite limited available data.

Of particular interest are the tables of “plausible parameter values” of radio-sensitivity, volume effect and doubling times, which comprise a very useful summary of radiobiological data for application to bioeffect planning. Several useful predictive models of tumour control probability and late tissue effects are detailed. Clinical applications of these models are used to display the potential advantages of bioeffect planning in differentiating between dose and fractionation schemes, between subtly different treatments and therefore for optimizing complex treatment plans.

This book is recommended for Radiotherapy Physicists interested in the application of Radiobiology to planning.

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The Wizard of Quarks
Robert Gilmore
Copernicus Books, New York 2001
xii + 202 pp., US$ 24 (hardcover)
ISBN 0-387-95071-0

This book is subtitled "A Fantasy of Particle Physics". It describes the Standard Model of Particle Physics by parodying the classic "Wizard of Oz". It is the zaniest popular book on science that I have ever encountered, and it defies classification. The author has long experience as an experimental Particle Physicist, and he knows the subject matter intimately. A list of a few of the chapter headings will help to set the scene: "The Witch of Mass", "The Kingdom of Cern", "A Weak Old Woman" and "The Higgs of the Maskvilles". (OK, I know the last one is a pun on Sherlock Holmes, but a book like this is allowed a little poetic licence.) In some ways it is a poetic work, the text is littered with pieces of verse, or perhaps doggerel. How about: "Hey ho, hey ho, it's after quarks we go"? So "Snow White and the seven vertically-challenged persons" gets a mention too. There are many fine sketches by the author who is clearly a talented artist. We meet the Witch of Charge, the Weak Witch, and the Witch of Colour. New discoveries are relayed to Dorothy and her friends by the CERN Information Centre, as in CERN Information Centre. Luckily not all the jokes are that awful.
Advances in Network and Acoustic Echo Cancellation

J Benesty, T Gansler, D R Morgan, M Sondhi and S L Gay
Springer-Verlag, Berlin 2001
dvi + 222 pp., DM 213.89 (hardcover)
ISBN 3-540-41721-4

Adaptive filtering is now part and parcel of wide range of research, development and production systems. Despite this, it is not unreasonable to make the following generalizations:

- Published algorithms are most often backed up by extensive mathematics and computer simulation, which is a long way off practical implementation.
- Practical tricks are usually not worthy of publication unto themselves, and so the average punter does not implement particularly robust, efficient or economical systems.
- People working in field x are often not aware of adaptive filtering developments in field y that may offer them significant improvements.

With these thoughts in mind, here is one of the more useful and usable publications the reviewer has read. Many advanced topics in network and acoustic echo cancellation are presented in a unified fashion, with a balanced level of mathematics and consideration of many practical implementation issues. The simpler problem of network echo cancellation is presented ahead of more complicated single- and multi-channel acoustic echo cancellation. The book is principally developed in the time domain, with frequency domain equivalents presented in two latter chapters. The authors assume a readership with some background knowledge in adaptive signal processing, seeking to condense the “basics” into a single introductory chapter. There is an extensive reference list, current to 2000. All-in-all, reading the book would be a worthwhile activity for anyone actively working with adaptive signal processing, and not just researchers in the network and acoustic echo cancellation.

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Organic Electronic Materials

R. Farchioni, et al (eds)
Springer-Verlag, Berlin 2001
xviii + 448 pp., DM 192.49 (hardcover)
ISBN 3-540-66721-0

This book is a collection of reviews on the basic phenomena relevant to the electronic and optical properties of organic materials. It is divided into two parts: the first focusses upon the properties of conjugated polymers whereas the second part discusses the nature of low molecular weight organic solids.

This division accurately reflects the two main material groupings that exist within the area of organic electronic device research—amorphous/semi-crystalline polymers and semi-crystalline/crystalline organic solids. In general, the review topics have been well-chosen and cover a broad area of research, both experimental and theoretical. Some chapters particularly stand out as exemplary treatments of complex topics. For example, chapter 4 on the Photophysics of Conducting Polymers by E M Conwell is one of the most complete and clearly written papers, the potential excitations that can be stimulated in organic electronic materials, that the reviewer has read.

The chapter on the application of photoelectron spectroscopy to the study of these materials by Fahlin and Salanneck also deserves mention. Overall, this is an excellent book that will be a useful resource to expert researchers and to non-experts who wish to learn more about this fascinating, and rapidly developing, research area.

Although not as extensive as the competing “Handbook of Conducting Polymers” edited by Skottheim, this volume is a less expensive resource for final year undergraduate and graduate courses in a variety of disciplines that wish to discuss many aspects of organic materials as electronic devices.

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University of Newcastle
"Physics and Industry Working Together"

The 15th Biennial Congress of the AIP
- incorporating ACOFT and AOS

Monday 8th to Thursday 11th July 2002
Darling Harbour Convention Centre

Call for Abstracts

Abstracts may now be submitted for congress 2002. Abstracts can be submitted on the web at www.aip.org.au/Congress2002. The deadline for abstract submissions is the 15th of February, 2002. Abstracts can be submitted either as word documents or in LaTeX format. The Call for Papers (enclosed in this issue of the Physicist) has more information on how to submit abstracts, or check the website. For organisational purpose all abstracts should be submitted under one of the 'group' labels. This is not intended to discourage submissions from any area of physics. If you have difficulty identifying a suitable interest group stream for the research field of your abstract please contact the organisers.

For the first time ever, Congress 2002 will have a refereed proceedings and authors who would like to submit a full paper for consideration will be able to do so. This is the first time a full proceedings of an AIP congress will be published, and we are pleased to be able to offer the option of submitting an abstract only or an abstract and full paper to congress participants. Details of how to submit full papers will be available soon, so keep an eye on the website.

Invited Speakers

The congress programmes committee has been busy organising the invited speakers, and several prominent physicists, and non-physicists have accepted invitations to speak at the congress. Just a few of the outstanding invited speakers at the congress are listed below. A more complete list is contained in the Call for Papers.

Barry Barish, professor of physics at Caltech is director of the Laser Interferometer Gravitational Wave Observatory lab.

Philip Burke of Queen's University , Belfast, is the father of computational collision theory, which has a multitude of applications in both fundamental science and in industry.

Richard Maughan played played a major role in establishing the fast neutron therapy accelerator at the Karmanos Cancer Institute and is currently working on developing a proton therapy facility at the University of Pennsylvania.

Sheila Tobias from Arizona, of "They're Not Dumb, They're Different" fame, is looking at why able students choose not to study physics, and is working on professionalising the science master's degree.

There are many other distinguished speakers from industry and academia, so make sure you check out the full list on the call for papers.

Please contact Pat (p.lekete@physics.usyd.edu.au) if you have any suggestions, queries or contributions, and don't forget to keep an eye on the website at www.aip.org.au/Congress2002.

David Thorncroft, the new sponsorship coordinator, is now seeking both sponsorships and companies interested in trade displays. If you have ideas or suggestions, please contact David: david.thorncroft@aebishop.com.

This is shaping up to be a spectacular congress, and we look forward to seeing you all there at Darling Harbour in July!

Kate Wilson
Publicity Officer,
Congress 2002 and NSW AIP
**CONFERENCES & MEETINGS**

**2002**

**Jan 21 - Feb 1**

‘DynamicSummer’
15th Annual Summer School of the Centre for Theoretical Physics, ANU, Canberra
*Contact:* Dr Rowena Ball, Rowena.Ball@anu.edu.au
http://www.anu.edu.au/dynamicsummer/  

**Jan 30 - Feb 1**

26th Annual ANZIP Condensed Matter Meeting (Wagga2002)
Charles Sturt University, Wagga Wagga
*Contact:* http://www.ph.adfa.edu.au/wagga
*Email:* wagga@ph.adfa.edu.au

**July 8 - 11**

FIFTEENTH BIENNIAL CONGRESS OF THE AUSTRALIAN INSTITUTE OF PHYSICS,
Darling Harbour Convention Centre, Sydney.
*Contacts:* Pal Fekete (02) 8303 9730 Email: p.fekete@physics.usyd.edu.au  
or
David Neilson Tel (02) 9385-4564, Email: D.Neilson@unsw.edu.au

**July 9 - 12**

Western Pacific Geophysics Meeting
Wellington, New Zealand

**July 15 - 19**

11th INTERNATIONAL CONGRESS ON PLASMA PHYSICS
Incorporating the 6th Asia Pacific Plasma Theory Conference, and the 24th AINSE Plasma Science & Technology Conference
E-mail: icpp@icmsaust.com.au
Telephone: (+61-2) 9241-1478 Fax: (61-2) 9251-3552

**July 21 - 26**

8th International Conference on New Diamond Science & Technology (ICNDST-8)
University of Melbourne
Contact: Bronwen Hewitt, Tel: +61-3-8344-6389; Fax: +61-3-8344-6122.
Email: icndst-8@unimelb.edu.au
www.conferences.unimelb.edu.au/icndst-8

**July 22 - 26**

7th International Conference on the Structure of Surfaces.
City Hall, Newcastle.
*Contact:* John O’Connor (02) 49215439 or john.oconnor@newcastle.edu.au

**July 22 - 26**

EXCON ’02, Excitonic Processes in Condensed Matter,
Darwin
*Contact:* Jai Singh, Tel: (08) 89 466 811, Fax: (08) 89 466 667
Email: jai.singh@ntu.edu.au

**2003**

**August 19 - 21**

Workshop on Recent Advances in Absorbed Dose Standards
ARPANSA, Melbourne
*Contact:* Mr. Robert Huntley, ARPANSA, Lower Plenty Rd., Yallambie, VIC 3085, Ph: +61 3 9433 2224, FAX: +61 3 9432 1835
*Email:* robert.huntley@health.gov.au
http://www.arpansa.gov.au

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