Australian PHYSICS

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A Publication of the Australian Institute of Physics

Promoting the role of physics in research, education, industry and the community

The Role of the National Measurement Institute

Women in Physics Lecture Tour

Plasma Propulsion

Monte Carlo simulations

A Year 12 study tour of Russia

Australian Science Media Centre

Australian Physics
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Cover Image:
The above image is of a pure monoisotopic silicon boule cylinder from which the 1-kg polished sphere on the cover was created. It is being held and photographed by Mr Walter Giardini, Avogadro project co-ordinator here at NMI. Read more about the role of the NMI on page 190.

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

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

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President's Column

Is physics a dirty word?

Why does the science education professor at Flinders University, Professor Westwell say, *"the only place where people studied or practiced biology, physics and chemistry was in universities"*?[1] Why is it that when you ask most people to draw a physicist, they will likely draw an Albert Einstein-like figure?[2] And when people ask what you do and you tell them you are a physicist, either they are not sure what to say next, say they never understood physics, change the subject, or retreat[3].

Yet physics has contributed to nearly every aspect of our livelihoods leading to such inventions as alternating current and hydroelectric power to television, holography and the World Wide Web. By studying fundamental principles, such as quantum mechanics, new devices, such as the transistor now used in all electronics, were invented. Physics comprises the fundamental building blocks upon which our entire modern society is constructed. Physics is practised and exists all around us. Not just in universities! It is as though physics is the subject that "should not be named"[4]. So is "physics" a dirty word?

The Institute of Physics (IOP) has recently published several reports on "Physics and the UK Economy" prepared by the Centre for Economics and Business Research Ltd[5]. This report found that only 2% of all registered businesses in the UK relied on physics, yet were more productive on average and made up 6.4% of the gross value added to the UK economy. There is also an indirect multiplier effect as physics-based industries support an additional 5% of the economic activity.

The AIP wants the impact of physics on the Australian economy to be recognized

Although the Australian industry base is different to that of the UK, it cannot be ignored that physics is very important for any modern society and provides the innovation and opportunities to make business efficient, effective and profitable. It is recognised, and there is an expectation in Australian government circles, that innovation will be a major contributor to assisting industry to move out of the current economic crisis, providing the needed opportunities, particularly manufacturing.

In Australia, there are about 2 500 professional physicists[6] with about another 20 000 people in the work force who have undertaken an undergraduate degree in physics but do not work in a laboratory. The IOP "Physicist: Think" campaign identified that "today's physicists are employed across a broad spectrum of careers because their education and training can be applied to any number of situations, from academia and industry, to consultancy and financial services."

This is all evidence that physics is important, that it is the basis for most of the technologies on which modern society is dependent and that physicists are working in all aspects of society. And yet there is a tendency to fear and hide physics and physicists. Why?

The development of a National Science Curriculum has started to bring out these issues. Westwell[1] claims, *"If you ask a professional scientist what their specialty is, they don't identify as a physicist, biologist or chemist but as a neuroscientist or other"*. In fact many school students up to year 10 do not realize they are studying physics when they learn the topics of energy, levers, simple electronics circuits and space. It is only in when they choose their subjects for the final senior school years that physics is clearly identified and students choose senior physics, often with little idea of what it is. Nevertheless in NSW in 2007 26% of the boys and 8% of the girls (total 16.7%) in year 11 choose physics, dropping to 22% of the boys and 6.5% of the girls (total 13.7%) in year 12[7], with physics usually chosen to boost the students' university admission scores. However, this also means that the 83.3% of students, who did not take physics in senior years, never really find out what physics is and so the mystery of it continues. Once undertaken, the senior physics subject appears to be redily enjoyed by many of the students.[8] Why is physics hidden or nameless in these early years? Would more students consider doing physics in senior years and even undertake a BSc majoring in physics if students were more exposed earlier on?

Many new discoveries appear to be at the interface of different scientific disciplines creating reasons to remove the discipline silos and teach science with a multidisciplinary approach in both the school and university education. The argument is that being a generalist does not automatically produce mediocrity, just as specialization does not always equate with excellence. It has been said that there is "plenty of insipid research out there that matters only to small communities of like-minded specialists and will never see the light of day. And many of history's brightest minds have belonged to generalists, not specialists."[9]

There is a major flaw in these arguments: regardless of the research, multidisciplinary or not, the physical principles are still the basis of understanding. The basic physics that was discovered by Newton, Kepler, Maxwell and Einstein is still required in the multidisciplinary project. Bringing together the molecular-biologist who can make DNA strands to any sequence design and the solid state physicist who can take the DNA and measure its electrical conductivity and model its properties, for example, requires the specific depth of the discipline which each specialist brings to create a true synergy. A scientist trained in a multi-disciplinary curriculum does not achieve that depth, but does this limit the ability for innovation and discovery? Are they able to see

continued on page 185

Editorial

If I were to look over the grades from all of the students I have taught, particularly those in the top 5 – 10%, without a doubt in my mind there would be a (virtually) perfect correlation between the percentages of male to female students overall compared with males to females in the top 5 – 10%. In other words, over my career female students have performed as well in senior physics, grades 11 and 12, as my male students have.

On the other hand, whereas I would need both hands to count the number of male students who have chosen to pursue studies in physics directly out of secondary school, I would not need a single finger to count the number of female students who chose to study physics. Granted this is an anecdotal observation, but one that I would hazard to guess most physics teachers would share, sadly.

To be clear, the issue is not that female students do not choose to pursue physics as an academic and/or career choice, obviously they do; it is that the number of female students who choose to pursue a career in physics is terribly disproportionate to the number of male students who make that choice given that both prove themselves to be on par intellectually and academically. So why do female secondary students avoid studying physics at university?

A number of organisations and institutions, like L'Oreal's Women in Science series, make great effort promoting the abilities and achievements of women once they have entered tertiary physics. In addition, look at Tanya Monro, not only was she AIP's candidate for the Women in Physics Lecture Tour 2008 (see The Joy of Physics page 194), but received this year's Malcolm MacIntosh Prize for Physical Scientist of the Year 2008. Next year's AIP WIP Lecturer is the equally deserving Christine Charles (pages 195 – 198). If that were not enough you can read about Penny Sackett's appointment as Australia's Chief Scientist (page 187) or Sophie Vitesnik's budding interest in physics (page 204); and let us not forget the new CSIRO Chief Executive Dr Megan Clark and our own AIP President Cathy Foley.

But a physics life is not always a breeze for them. Tanya Monro writes about the struggles confronting the need for women physicists to engage the public, and therefore be a visible role model for young women: *"For women in physics, these barriers to engagement can be even greater, especially when we try to juggle family with the excitement (and demands!) of a career in physics. This only compounds the issues for increasing the participation of women in physics at all levels."*

But surely these same problems afflict women in biology, chemistry, medicine and engineering. Can female students and academics in those disciplines be any less encumbered by their gender or family roles than women in physics? Are they any less devoted to their families or careers than female physicists? Obviously not, so again, why do female secondary students avoid studying physics at university?

Could it be simply that there are more female biology and chemistry teachers compared to the number teaching physics? Was it really my (female) students' unfortunate circumstance that I was their physics teacher and that is why none of them pursued physics? I am going to find out in what amounts to a most unscientific questionnaire by asking former female students that "…if I had been a female teacher, with all of the same teaching characteristics, style and personality (as much as that is possible), would you have considered a career in physics any more or less than you did?"

I'll get back to you with the results.

John Daicopoulos

Submission deadline for the January/February 2009 issue is 19 December 2008
Submission deadline for the March/April 2009 issue is 13 February 2009

President's column – continued from page 183

connections between disciplines missed by the specialists? Richard Feynman, one of the great physics teachers and physicists, pointed out the importance of deep physical understanding before being able to take multidisciplinary research to new heights.[10] Maybe there is room for both the generalist and the specialist; they are bringing different skills to a project team.

Futhermore, those physicists that are located in universities and government research labs need to see that the effectiveness and impact of their research is mostly achieved by the industrial and industry-based physicists who play a very important role in the transition of physics from laboratory to application; an aspect often disconnected from the academic researchers.

We need to remember that traditional measures of research by scholarly benchmarks, such as science metrics associated with high performance and excellence in academia, are not required in other environments that need solutions to real-world problems.

The AIP wants the impact of physics on the Australian economy to be recognized; that the role of the industrial and industry-based physicist be recognized as the crucial part of taking fundamental discoveries to the point of application; and that future generations will always need to have basic physical principles understood and learnt before they can take the steps to creating any new knowledge whether it is in fundamental physics, application and industrial physics or multidisciplinary research at the boundaries of the different science disciplines.

Finally, we need the wider community to recognize that physics touches them everyday, that physicists work in many places other than labs, that people who work in physics are as diverse as any other profession and that a degree in physics is a good general education opening many possible career paths. It is up to us to reach out and expose physics as being accessible, relevant and not a "dirty" word to be hidden!

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Letter

I note your highlighting (Australian Physics October, p165) that "It wasn't that long ago that we didn't even know that atoms existed". I should have thought Lucretius ("On the Nature of Things" ~ 59BC) would be considered "that long ago".

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Branch News

Victoria

The 2008 Nobel Prize for Physics was celebrated at the October meeting of the Victorian Branch. This year's prize was awarded in equal parts to Yoichiro Nambu (USA) and to Makoto Kobayashi and Toshihide Maskawa (Japan) for their discoveries on spontaneous symmetry breaking and CP violation.

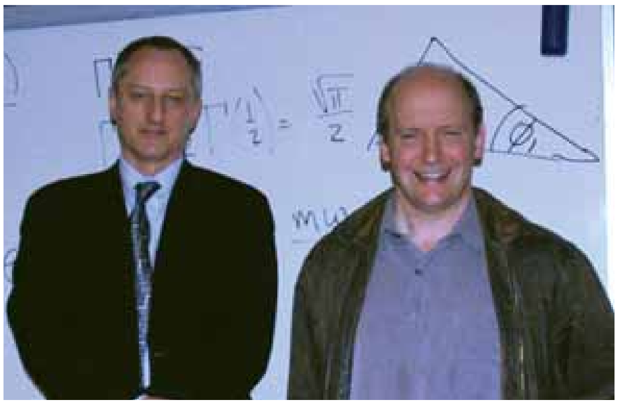
The 2008 Nobel Lecture was a joint presentation by Professor Ray Volkas and Associate Professor Martin Sevior from the University of Melbourne.

Ray is a theoretical particle physicist working in a number of areas of early universe cosmology and high-energy astrophysics. Martin is an experimental particle physicist working at the Belle experiment in Japan and the ATLAS experiment at CERN, investigating CP-violation and rare decays in B-mesons.

Both Ray and Martin describe their work as 'the search for physics beyond the Standard Model'.

Ray presented a theoretical perspective on the prize. Symmetries underpin conservation laws such as momentum, energy, angular momentum and electric charge. Through the gauge principle, they are also used to explain how particles couple through the strong, weak and electromagnetic interactions. But some symmetries occur in spontaneously broken form, and this accounts for why W and Z bosons are massive, whereas photons are massless.

Nambu's great achievement was to realise that the idea of spontaneous symmetry breaking could be imported from condensed matter physics into particle physics.



Nobel Prize Lecture: Ray Volkas and Martin Sevior [courtesy Nicoleta Dragomir]

Another important symmetry is CP invariance, which is almost, but not quite, conserved in the Standard Model. The model by Kobayashi and Maskawa for this subtle violation earned their half share of the prize.

Martin presented an experimental perspective on the prize. The theory developed by Kobayashi and Maskawa, published in 1973, to explain the CP-violation observed in the decay of neutral K-mesons was remarkably prescient. It required the existence of three new quarks in nature, as well as requiring complex mixing between the different generations of quarks.

These new quarks - charm, bottom and top - were subsequently discovered in 1974, 1976 and 1995, respectively. The existence of complex mixing was verified by the discovery in 2001 of CP-violation in neutral B-mesons by the Belle experiment in Japan and the BaBar experiment in the USA. Complex mixing has since become a high precision measurement and a baseline from which to search for physics beyond the Standard Model.

September meeting news

Wednesday December 10, 6.30pm, Elizabeth Murdoch Theatre, Melbourne University (Drinks and food available from 6pm)

Talk by Alain Aspect and awarding of the Undergraduate Practical Award Professor Alain Aspect will present on Bell's Inequalities and Quantum Information. Professor Aspect is the Research Director of the Centre National de la Recherche Scientifique (CNRS), France.

New South Wales

Einstein Lecture News

Each year the NSW Branch nominates a distinguished speaker whose work has covered a wide range of topics with an emphasis on Einstein's ideas and their consequences for physics and technology today.

This year the Einstein Lecture was held at the Powerhouse Museum on 25 August and featured Dr Joe Khachan from the University of Sydney on the topic of "Einstein and the dream of Plasma Fusion Energy". Einstein's most famous equation, $E = mc^2$, provides a solution to our energy problems. It tells us that a small amount of mass (m) can be converted to a great deal of energy (E). Sadly, it does not tell us how.

Dr Joe Khachan live demonstrations with the audience.

Dr Khachan presented live experiments and demonstrations detailing discoveries since Einstein's work 103 years ago with particular focus on the science of energy. In his lecture, the science of plasma physics and how it can be used to produce energy was presented through a series of demonstrations of achieving the plasma state with ordinary household objects. The public audience that attended the talk enjoyed the practical plasma demonstrations and left the lecture with a simple device that gives them a unique viewing window on all that is made from the plasma around us.

The talk was very well received and geared to scientists and members of the public alike with many discussions continuing later after the lecture. The Australian Institute of Physics thanks the Powerhouse Museum for hosting the event and Dr Joe Khachan for delivering an outstanding 2008 Einstein Lecture!

Branch news continues on page 209

News

Professor Penny Sackett Australia's New Chief Scientist

The Minister for Innovation, Industry, Science and Research, Senator Kim Carr, announced the appointment of Professor Penny Sackett as Australia's new, full-time, Chief Scientist.

"Professor Sackett will provide high-level advice to Government, foster relationships with science organisations and industry groups and stimulate community thinking on the big scientific issues of our time.

"Boosting the role from part-time to full-time demonstrates the store the Rudd Government places in high-calibre, independent, scientific advice.

"Professor Sackett comes to the position with a long list of professional achievements and credibility in the innovation, science, engineering and technology communities."

Professor Sackett was Director of the ANU Research School of Astronomy and Astrophysics and Mount Stromlo and Siding Spring Observatories (2002 – 2007) and remains a Professor in the School. She is a member of the Australian and American Astronomical Societies, the International Astronomical Union and the Association for Women in Science.

She is an Elected International Fellow of the Royal Astronomical Society and is involved in governance of the Gemini Observatory and the Hubble Space Telescope Science Institute. She is also currently a director of the Giant Magellan Telescope, a project to build the world's most powerful optical telescope.

"Professor Sackett will have a vital role in raising awareness of emerging issues in science, engineering and innovation. She will encourage young Australians to see science as an exciting career option," Senator Carr said.


Seator Kim Carr (left) and Professor Penny Sackett (right)

"Professor Sackett is an outstanding scientist. I congratulate her on her appointment and look forward to working with her.

"I would also like to acknowledge our outgoing Chief Scientist, Dr Jim Peacock, and thank him for his contribution over the past two and a half years," he said.

Minister for Innovation, Industry, Science and Research, Senator Kim Carr

2008 Walter Boas Medal in Physics awarded to Professor Peter Drummond

The AIP Boas Medal Selection Panel has unanimously recommended the award of the 2008 Walter Boas medal to Professor Peter Drummond, Australian Research Council Centre of Excellence for Quantum-Atom Optics, and Centre for Atom Optics and Ultrafast Spectroscopy, Swinburne University of Technology.

The Australian Institute of Physics grants the Walter Boas award for original research making, in the opinion of the examiners, the most important contribution to physics. This is judged in papers published during the four years immediately preceding the date on which entries for the award close.

Professor Drummond's research dealing with many-body problems, particularly in relation to ultra-cold atoms and in quantum optics, has led to the development of new theoretical calculations in both fields.

This theoretical work has been characterised by testable predictions and consequently Professor Drummond's work has been adopted by a range of experimental groups.

In papers published in the 4 years preceding the date on which entries for the award close Professor Drummond has produced an exceptional body of work including:

• development of evidence for universality in strongly interacting Fermi gases, where the state of the system can be described by a single parameter;

• development of methods of treating the stochastic equations in quantum many-body calculations, including by use of Gaussian representations, which has attracted widespread attention as a possible route towards explaining high-Tc superconductivity;

• application of the phase-space methods of dealing with many-body systems towards quantum dynamical problems, which are the only known first principles methods for calculating the time-evolution of many-body quantum systems in any number of dimensions; and

• discoveries in fundamental quantum theory leading to the first continuous variable Bell inequality for correlations, giving the possibility of high efficiency, loophole-free demonstrations of the failure of local realism in quantum mechanics.

The importance of Professor Drummond's work is evidenced by exceptional citation rates, even within the relevant field of research, indicating a high degree of visibility for the theoretical work. In addition the high level of adoption by experimentalists of the published results as well as use of the developed theoretical results to explain existing experimental results indicates a significant impact of the work on the community. Finally, this assessment has been endorsed by the selection of Professor Drummond's papers for editors' awards and collections.
Australian Institute of Physics

Nobel Prizes awarded

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2008 with one half to Yoichiro Nambu Enrico Fermi Institute, University of Chicago, IL, USA "for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics" and the other half jointly to Makoto Kobayashi, High Energy Accelerator Research Organization (KEK), Tsukuba, Japan and Toshihide Maskawa, Yukawa Institute for Theoretical Physics (YITP), Kyoto University, and Kyoto Sangyo University, Japan "for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

The fact that our world does not behave perfectly symmetrically is due to deviations from symmetry at the microscopic level.

As early as 1960, Yoichiro Nambu formulated his mathematical description of spontaneous broken symmetry in elementary particle physics. Spontaneous broken symmetry conceals nature's order under an apparently jumbled surface. It has proved to be extremely useful, and Nambu's theories permeate the Standard Model of elementary particle physics. The Model unifies the smallest building blocks of all matter and three of nature's four forces in one single theory.

The spontaneous broken symmetries that Nambu studied, differ from the broken symmetries described by Makoto Kobayashi and Toshihide Maskawa. These spontaneous occurrences seem to have existed in nature since the very beginning of the universe and came as a complete surprise when they first appeared in particle experiments in 1964. It is only in recent years that scientists have come to fully confirm the explanations that Kobayashi and Maskawa made in 1972. It is for this work that they are now awarded the Nobel Prize in Physics. They explained broken symmetry within the framework of the Standard Model, but required that the Model be extended to three families of quarks. These predicted, hypothetical new quarks have recently appeared in physics experiments.

As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier.

A hitherto unexplained broken symmetry of the same kind lies behind the very origin of the cosmos in the Big Bang some 14 billion years ago. If equal amounts of matter and antimatter were created, they ought to have annihilated each other. But this did not happen, there was a tiny deviation of one extra particle of matter for every 10 billion antimatter particles. It is this broken symmetry that seems to have caused our cosmos to survive. The question of how this exactly happened still remains unanswered. Perhaps the new particle accelerator LHC at CERN in Geneva will unravel some of the mysteries that continue to puzzle us.

Nobel Committee

Makoto Kobayashi (top)
Toshihide Maskawa (middle) and
Yoichiro Nambu (bottom)

Joint Australian Academy of Science National Committee for Physics and Australian Institute of Physics announcement

The National Committee for Physics within the Australian Academy of Science is joining with the Australian Institute of Physics to oversee an open consultation with the physics community in Australia.

The aim is to create a report that highlights the key issues for Physics in Australia and to provide both a snapshot of where physics currently stands and the opportunities available to the discipline over the coming decade. The document will be useful to advise governments and raise the profile of this important underpinning science.

This process includes:

- An up-to-date examination of the physics discipline in Australia. It has been over 15 years since the last survey of the discipline of Physics in Australia was conducted back in 1993.
- An evaluation of the opportunities available for future growth of the discipline. With the enormous growth and rapid changes in the discipline internationally, it is important to determine how to strategically plan for Australian research across all sub disciplines.
- An investigation of Australian investment in physics research and development - A key factor to understanding the health of the physical sciences discipline is to determine the trends of current government and business investment and the impact this will have for the physical sciences.
- Identification of challenges for physics within schools, business, government and academia - with declining student populations in fundamental science, fewer teachers trained in the discipline, top-heavy faculty demographics, expensive infrastructure costs and rapidly changing fields, many important decisions need to be made to determine the future health of the discipline.

The National Committee for Physics will oversee the consultation process and form an Executive Working Group in charge of collation, integration of the data and production of the final report.

A trial of this process was conducted within the Australian Optical Society in 2008. It is planned to use the lessons learned, in the consultation with the wider Physics community.

A forum will be held at the AIP Congress in 2008 to launch this exercise, start the consultation process, call for nominations for Chairs of the various sub-disciplines. The input from the sub-disciplines will be collected and merged into the final report, which will be completed in late 2010.

It is vital, not just for the success of this endeavour but also for the health of the discipline that you as a physicist participate in this exercise and have your say. All perspectives on this issue are relevant and welcome.
Australian Institute of Physics

FASTS comment on VenturousAustralia

FASTS, the Federation of Australian Science and Technological Societies, is pleased to have the opportunity to provide comments on VenturousAustralia: the report of the review committee of the National Innovation System, available at: *www.innovation.gov.au/innovationreview/Documents/NIS_review_Web3.pdf*

FASTS agrees with the key finding of the review that Australia's innovation performance and investment in key knowledge indicators has been slipping since the mid-1990s and share their acute concern that Australia has become 'complacent' about investing in science and innovation (p. ix).

FASTS strongly supports the general direction of the review and its core themes of:
• the necessity for a comprehensive re-invigoration of funding and policy;
• the urgent need for substantial increases in public and private investment;
• the critical importance of developing human capital;
• greater emphasis on open collaboration;
• the need for international engagement; and
• a more strategic marshalling and co-ordination of resources.

FASTS is concerned that the current global financial travails should not result in stepping back from significant reform including enhanced funding measures. Long term productivity should not be compromised;
the imperative to commit to key recommendations is even more urgent and compelling in the current world financial crisis.

FASTS recognises it is not feasible for the Government to introduce all 72 recommendations in this or indeed the next few budget cycles. Therefore, we believe the three key initiatives that are absolutely necessary are:
• Implementation of the principle of funding the full costs of research
• Implementation of the tax credit for R&D
• Implementation of a comprehensive suite of integrated programs to support innovation in firms.

However, there are important recommendations covering industry, universities, PFRAs, innovation in Government, governance, coordination and priority setting that will have high impact and their implementation is also urgent.

These include:
• Increasing the stipends and funding periods for PhD students (6.11);
• Increase investment in public sector research agencies (6.3, 6.4);
• Stronger focus on international engagement (7.6);
• Extend NCRIS (6.14);
• Address the problems facing national collections (7.11); and
• Implement CRC review recommendations.

FASTS notes, however, that there are key elements missing from the report that do need to be taken up in either the White Paper or cognate policy and funding announcements; notably:
• Preparedness R&D;
• Better risk-aware research programs; and
• Knowledge transfer and 3rd stream funding mechanisms.
Federation of Australian Science and Technological Societies

UNSW astronomers honoured by new stamp

UNSW's pioneering role in showing the unrealised potential of ground-based astronomy in Antarctica has been celebrated on a new postage stamp.

In the foreground the stamp depicts a telescope in Antarctica - together with an infrared image of organic molecules in space that it obtained - with background detail taken from a photograph of a UNSW field station at the Concordia base, high up on the Antarctic plateau.

The photograph was taken in 2003 by Tony Travouillon, a PhD student with the School of Physics, and also shows the UNSW flag flying on the observatory. The flag, however, is barely distinguishable to the naked eye - it is, after all, a postage stamp.

Australia Post has featured research in astronomy as part of its new Australian Antarctic Territory stamp series for the International Polar Year of 2007-08. The series contains four stamps featuring science programs where Australia is playing an international leadership role in Antarctica. These are in astronomy, glaciology, marine biology and oceanography.

"We're very proud to have our achievements recognised in this way," says Professor Michael Burton, a member of the UNSW team and lead author of the scientific paper that presented the astronomical image depicted on the stamp.

The stamp features the SPIREX infrared telescope, which was operated at the South Pole in collaboration with scientists from the USA, and the UNSW AASTINO site testing laboratory at Dome C in collaboration with French and Italian scientists.
UNSW

The Role of the National Measurement Institute

by Laurie Besley
Chief Executive and Chief Metrologist
National Measurement Institute

Why NMI Exists

The reason for having a national metrology institute like Australia's National Measurement Institute (NMI) is very simple: it is to provide the nation with a facility that if accessed appropriately can ensure that quantitative measurements made in Australia are fit for their purpose. This means that these measurements deliver results that are as accurate as they need to be, can be compared with each other with reliability and assurance, and can also be used with confidence by groups outside Australia with the knowledge that the measurement results are supported by an infrastructure guaranteeing their quality.

This has always been important, as recognised by the nations that signed the original Treaty of the Metre in 1875 to ensure that the world had a common set of units on which to base their measurements. Today, in our modern global economy it is absolutely vital. The intimate linkage of operations in many different parts of the world to produce an integrated product such as a motor vehicle would not be possible unless such companies can be confident that the metre is the same length in Japan as in Australia, that the second is the same interval of time, that the ampere is the same level of electrical current.

In physics such a system has been in place for some time and perhaps we sometimes take it for granted. But results for quantitative chemistry, where a true reference system is still in its infancy and far from widespread in its application, reveal the danger of not having such infrastructure in place, or of allowing it to deteriorate, or of not using it effectively. For example, looking at the data in Figure 1, reported[1] only relatively recently (2002), illustrates the degree of difference in the results produced by some 100 plus laboratories all trying to make an identical measurement on an identical sample. In this case, measurements of the level of lead in wine, fitness for purpose can be interpreted as meaning that accuracies of perhaps 15% relative are appropriate. But the results in Figure 1 show that differences of 50% relative are common. Moreover, the uncertainty attributed to each result, as indicated by the error bars in the diagram, reveal that in many cases the operators' confidence in their results is grossly overstated. One of the reasons for such a horrifying result is perhaps that these laboratories do not have appropriate linkages to a common point of reference. Having in place a metrology system accessed by all of the measurement laboratories involved, a system of traceability, greatly diminishes the chance of such a result.

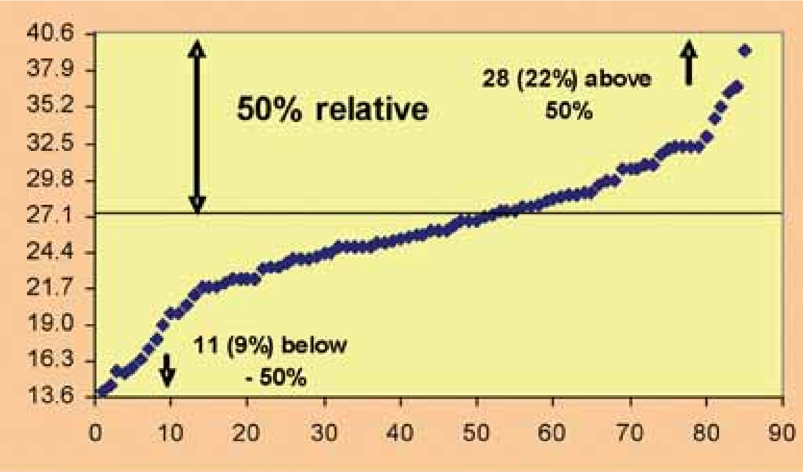


Figure 1: The spread of results relative to the reference value in a comparison reported in the year 2002 for about 160 laboratories of measurements of lead in wine.

An easily understood example of such a traceability system is in mass measurement. At NMI we maintain a mass standard, a platinum-rhodium artefact whose mass is defined in terms of the world's standard kilogram maintained at the International Bureau of Weights and Measures in Paris. Secondary mass standards are calibrated by NMI against this primary standard; these secondary standards are then used to calibrate working standards sent to NMI by Australia's industrial calibration laboratories, usually accredited by the National Association of Testing Authorities, NATA. Those working standards are used to calibrate field standards in the Australian community, to ensure such devices as weighing scales in supermarkets, weighbridges and pharmaceutical dispensing scales are all delivering the correct results. A critical part of this quality assurance system is that these results have a traceability chain right back to Australia's primary standard of mass.

So NMI's role is not only to provide such an infrastructure in all of the fields of measurement for Australia, but also to maintain it in appropriately robust condition, to extend its scope and quality as required, to link it effectively into global systems and to disseminate it effectively into the Australian scientific, industrial and regulatory community.

NMI's Present Profile

NMI is an arm of the Commonwealth Government, administratively being a division of the Department of Innovation, Industry, Research and Science. It is the Australian body created to address the requirements of the National Measurement Act wherein it is charged with the responsibility of developing, maintaining and disseminating the fundamental units of measurement for the nation.

NMI currently has five laboratory sites: two in Sydney (at Lindfield and Pymble), two in Melbourne (at Port Melbourne and Clayton) and one in Perth (at Kensington), as well as a liaison office in Canberra. It employs some 360 staff, of whom about 250 have tertiary

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qualifications, with about 60 of those being qualified in physics or engineering. It therefore represents a very significant Australian resource for expertise in these disciplines.

Of NMI's annual operating budget of about sixty million dollars it receives only about half directly as appropriation funding from the government. The other half it earns through the sale of its services and products to the Australian community and to overseas organisations. This gives NMI a unique flavour with a balance between public good activity and quasi-commercial operations.

NMI is organised into five operating branches. One of those provides the internal business services to the organisation, such as human resources, IT, finance, communications, knowledge management, training services and marketing. There are two branches whose work is in chemistry or biology, the first delivering fundamental capabilities in metrology in those areas, and the second (the largest branch in NMI) delivering analytical services in them. Then there is one branch responsible for both metrology and services in physics and one branch that deals with legal metrology. In addition there are two groups reporting directly to the Chief Executive – one is responsible for international relations, and the other, the Canberra office, which facilitates the relationship between NMI and its parent department on the one hand and other Commonwealth government agencies on the other.

Scientific metrology is only one aspect of the standards and conformance system of any nation and NMI works intensively with the other components of that system – Standards Australia which produces documentary standards, the National Association of Testing Authorities (NATA) which offers technical accreditation programs, and the Joint Accreditation System of Australia and New Zealand (JAS-ANZ) which offers certification of conformity assessment bodies.

How NMI Got To Where It Is

NMI was formed in July, 2004 from three other organisations, each of which had significant long histories of their own. Its formation was accompanied by a change in federal legislation which formally established the legal authority of NMI and extended its responsibilities from physical measurements to those of chemistry and biology.

The Australian Government Analytical Laboratories (AGAL) was the oldest and largest of those constituent bodies. Its background was in the pre-federation customs laboratories operated by the various Australian colonies, later to become the states of federated Australia. After federation, AGAL arose out of the Commonwealth's Customs Department and in a somewhat turbulent history grew under various Commonwealth government departments to become the Australian Government's principal resource for the provision of expertise, services and advice in quantitative chemistry.

The National Standards Commission (NSC) was the youngest and smallest of the three constituent bodies. Originally the Commission was an advisory body formed to address the requirements of the Weights and Measures (National Standards) Act of 1948. After the replacement of that act by a revised version in 1960, NSC morphed in 1964 into a corporate body having a variety of legal responsibilities including the power to approve the design of instruments for domestic trade.

The third body was the National Measurement Laboratory, which was part of CSIRO. In the form of the National Standards Laboratory it came into being in 1938 with the specific responsibility of providing the physical standards of measurement for the country. Originally sited in the grounds of Sydney University, in 1978 it moved to what is now the NMI's headquarters on the CSIRO site in Lindfield, a northern Sydney suburb.

What Does NMI Do?

As described above NMI's primary function is to deliver Australia's standards of measurement to the community. In practice, however, the expertise that activity generates means that NMI can offer a whole range of associated services, and it does just that. These services include:

- Calibration and measurement services in a wide range of physical measurement areas, including mass, force, pressure, flow, humidity, length, volume, density, temperature, electrical current, electrical voltage, electrical impedance and resistance, time, frequency, photometry and radiometry, ultrasonics, acoustics and vibration.
- Applied research capability in all of these areas;
- Pattern approval of legal measuring instruments;
- Test and measurement capability in a wide variety of chemical and biological fields, including organic, inorganic and microbiological, but specialising in measurements for the food, environment and resources sectors;
- Analytical method development and research capability in all of these areas;
- Specialist laboratories in sports drug detection and analysis (the only laboratory in Australia accredited by the World Anti-Doping Agency (WADA), forensic drug analysis and ultra-trace (ppb and lower) analysis;
- Production of certified reference materials and reference gas mixtures for chemical analysis, including maintenance of the COMAR global reference materials database.
- Conduct of proficiency testing schemes in chemistry;
- Delivery of technical training in measurement techniques in both physics and chemistry (NMI is now an accredited training organisation);
- Maintenance of the collection of patent-related biological materials under the Budapest Treaty;
- Policy advice to all arms of government on measurement issues.

Scientific metrology is only one aspect of the standards and conformance system of any nation...

Figure 2 Silicon spheres used in the Avogadro Project at NMI.

Much metrological research is of such complexity that partnerships with other research organisations are advisable to get maximum leverage from the activity.

Several books have chronicled the history of Australia's measurement system and may be of interest to readers. A history of Australia's standards laboratory has been written by Jack Wright[2] and another, of wider scope, was produced more recently by Jan Todd[3].

What Constitutes NMI's International Activity?

NMI has an important role to ensure that Australia's standards of measurement are consistent with those maintained elsewhere in the world and to ensure that they are accepted as valid by those other national jurisdictions. This is an important facilitating mechanism for international trade in our global marketplace.

As part of an international mutual acceptance agreement we make formal comparisons of our measurement standards with those of other national metrology institutes through a program operated by the International Bureau of Weights and Measures (BIPM). Results that express the degree of equivalence of the national standards of many countries in many different fields can now be found on the BIPM's website.

NMI also represents Australia in a number of international forums to do with measurement, including the International Committee of Weights and Measures (CIPM), the Asia-Pacific Metrology Programme (APMP) – our regional metrology body, and the reference materials group of the International Organisation for Standardisation (ISO). We also have a role with the Codex Alimentarius, the world's regulatory body for food issues.

Much metrological research is of such complexity that partnerships with other research organisations are advisable to get maximum leverage from the activity. For this purpose NMI has collaborative research agreements with a number of other overseas institutes, including our counterpart bodies in Japan, Korea and Germany.

One major project that we are involved in over the past decade is the so-called Avogadro Project, which aims to produce a new determination of Avogadro's Number in order for this to act as the foundation for a new atomic-based definition of the fundamental unit of mass, the kilogram. NMI has worked with the optical workshop of CSIRO Materials Science and Engineering to produce and measure the dimensions of the world's most spherical objects, 1-kg spheres that have been manufactured from high-purity, mono-isotopic, single-crystal silicon [Fig 2]. Our Australian facility is the only such source of such objects and the international collaborators are relying on Australia to provide them to the project. The aim here is to relate the number of atoms in these beautiful balls to their mass. Other measurements such as chemical and isotopic purity, lattice constant determinations and the mass measurements themselves are being made by other members of the international consortium of laboratories involved in this project. The accuracy required when all of these measurements are combined is a part in 10^8, a fiendishly difficult task for such objects.

What Will the Future NMI Look Like?

The future NMI will offer services over a greater range of activities. NMI is forever expanding its scope, as it must as new measurement needs emerge in the Australian community in response to the adoption of new technologies. Currently the new areas on which NMI is concentrating are those of nanotechnology and biotechnology.

Nanotechnology is being increasingly used in fields as diverse as novel structural materials, coatings and powders, pharmaceuticals and foods. To control industrial processes and study the health and environmental impacts of such particles we must be able to measure their dimensions reliably. In response to this need, NMI is developing primary standards for the dimensional characterisation of particles of nanometre sizes and establishing a particle sizing laboratory service for nanoparticles.

In biotechnology the measurement needs are even more diverse. Here our program is currently concentrating on characterising genetic material such as DNA and studying the replication processes that form the basis of most qualitative and quantitative measurement in this area. Within Australia we are working with industry and

groups such as the Commonwealth's main regulatory body in this field, the Office of the Gene Technology Regulator, and the Dept of Agriculture, Forests and Fisheries. Outside Australia we are working collaboratively with other national metrology institutes tackling different aspects of the same sort of tasks as ourselves.

However, it is probably not possible, or cost-effective, for NMI to attempt to address all of Australia's needs for new measurement standards from within its own resources. Already NMI delegates the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to maintain the nation's standards for ionising radiation because it was not appropriate for NMI to have its own nuclear reactor. It may be appropriate for other delegations to be considered for the future to take maximum advantage of the measurement capability already in existence in other Australian agencies. This may be particularly relevant as NMI attempts to buttress measurement activity in a wide variety of biological fields.

Another major change that NMI will undergo in the next two years relates to its new responsibility for a national trade measurement system. Currently the legislation that ensures that Australian consumers get a fair deal in any trade involving measurement is in the domain of the Australian States and Territories who control such matters as the dispensing of petrol through service stations, the use of weighbridges to weigh commercial products, the weighing of products at supermarket checkouts, and the dispensing of liquor in hotels. This has the consequence that companies operating Australia-wide in such areas, or across State boundaries, have to contend with different sets of laws and procedures in each State or Territory, with consequent heightening of their business costs.

In May 2007, the Council of Australian Governments (COAG) decided to reduce the regulatory cost for domestic trade by Australian businesses by amalgamating the multiple existing trade measurement regulatory systems of the States and Territories into a single new national system under the control of the Commonwealth. It also decided that NMI would have responsibility both for the introduction of this new system by July 1, 2010 and its operation thereafter. For NMI this means that our staff numbers will increase by approximately another 140 people, who will transfer from employment by the States and Territories to employment by the Commonwealth, and that we will have to operate a much more geographically-dispersed business than we are currently doing.

A little more than one year into the transition period, things are going well. Appropriate Commonwealth legislation has been drafted and introduced to Parliament and is likely to be passed in the next few months. Negotiations with the States and Territories about the transfer of staff and assets are proceeding satisfactorily. However, there is still a major challenge ahead for NMI to produce an improved national trade measurement system for the country and to get it operating efficiently.

Conclusion

Despite its somewhat pedestrian name, NMI is a vibrant, exciting place to work. Measurement extends into all parts of human activity, so the scope for our services is almost infinite and variety is certainly the name of the game. We aim to be a whole-of-government resource providing services to a wide range of other departments, as well as to a list of some 10,000 private-sector clients. You can read more about us on our website at *www.measurement.gov.au*.

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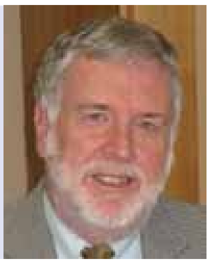
Dr Laurie Besley is the Chief Executive and Chief Metrologist in the National Measurement Institute, Australia. He is a member of the Executive Committee of the Asia-Pacific Metrology Programme, and is on the editorial boards of the journals "Metrologia", "IET Science Measurement & Technology", and "Accreditation and Quality Assurance".



The joy of physics

An Australian tour through the eyes of a female physicist

by Tanya Monro

For me, one of the most wonderful things about being a physicist is the joy of those moments when I get to reach out and share my passion for physics with those around me. To have a shot at inspiring the next generation of potential scientists and making an impact on researchers outside my own field.

It is all too easy to fall into a pattern where you circulate in a world inhabited only by those who speak your particular dialect of physics. We are all so busy – trying to get that next paper in, to go to all the key conferences, the grants submitted, helping our students, writing reports and giving lectures, that it sometimes takes something extraordinary to drag us out of our usual world to really engage with the community about physics.

For women in physics, these barriers to engagement can be even greater, especially when we try to juggle family with the excitement (and demands!) of a career in physics. This only compounds the issues for increasing the participation of women in physics at all levels.

The AIP Women in Physics Lecturer scheme is a wonderful mechanism for getting female physicists "out there". It shows school kids that women can have a blast doing physics, that physics is a really tangible way of making a difference to their world. It also helps to dispel the "men in white coats" vision of the scientist that still seems to pervade society.

It is also a wonderful way of celebrating our successful women – as you can see when you look through previous recipients of this award. I feel honoured to be counted amongst them. Despite many studies and good intentions, we are still very much working in a world where physicists are predominantly male, particularly at senior levels. This undoubtedly affects our research culture, and the opportunities available for the talents of women to contribute to the future of physics in our country. While I have been lucky enough in my career never to have encountered any serious discrimination-related roadblocks, I would be lying if I said that I never felt my gender has influenced some people's perceptions of my research capabilities.

We have to work to create a culture, both within society in general, and in our research institutions, to create an open environment that recognises and is receptive to innovation and talent, regardless of its gender or background.

It was only July last year that Chris Deller emailed to tell me that I had been selected the AIP Women in Physics Lecturer for 2007, but it has been such an extraordinary year for me in so many ways that it feels like much longer ago. When Olivia Samardzic first approached me to ask if I would consider being nominated I have to admit that my first reaction was *in what spare time*? With 3 pre-school aged boys (James, Alex & Ben) and a growing research group of 20-odd I felt stretched to my limits. However, one of the great things about this tour is that I was given the flexibility to do it in a way that worked for me, which was to do each city as a separate trip to avoid being away from home more than necessary.

The AIP Women in Physics tour has given me the chance to engage with people I would not run into in the ordinary course of events – school kids from around Australia, as well as interested students, fellow physicists and members of the public from across the country. It has been a wonderful adventure.

Some parts of the tour will stick in my memory for a very long time. Highlights of the school visits ranged from visiting my old school, SCEGGS Darlinghurst in Sydney, and noticing halfway through my talk my Yr 10 biology teacher, Miss Mara, sitting in the back row smiling at me. Or giving a talk at the Australian Museum in Sydney, with a glorious view of the city from the window, and a really keen and curious audience who really made me think with some of their questions. Driving through the wonderful scenery of Tasmania. Or the honour of giving the Claire Corani Memorial Lecture in Adelaide after celebrating awards from the AIP-SA Branch to two women physicists, Barbara Possingham and Barbara Potts, in recognition for reaching over 50 years since they were awarded their PhD in Physics.

Lowlights of the school visits also stick in mind, with one school (which shall remain nameless) yielding questions of the quality: "how much do you earn?" and "how old are you?" All I can hope is that my answers might have shaken up their preconceived ideas about scientists!

I have given public lectures, professional lectures and talks to schools, in Adelaide, Sydney, Tasmania, Melbourne (2 trips) and Brisbane. As I write this, I am gearing up to do the last leg of this wonderful tour, in ACT. It has been a long journey, one that has given me a lot back.

To the women out there – I strongly encourage you not to put this opportunity in the "later" basket, even if it might be tempting. Being the AIP Women in Physics Lecturer has been a wonderful and enriching experience for me.

The tour has given me a fabulous chance to talk to physicists all around the country about the opportunities and challenges we face, as well as discussing recent breakthroughs in research. The AIP is a critical vehicle for bringing us together, and we need to work to find more effective ways to pool our experiences to create a bright and forward-looking vision of the future of physics in Australia.

I have to admit I catch myself dreaming that the year ahead might be one in which I travel a little less. I have deliberately not kept track of all of my travels because, between the AIP tour, my travels around Australia for the Defence White Paper, numerous conferences and other miscellaneous work trips, it has been more unusual for me to have a whole week in Adelaide than not. I would not have changed it for the world though – it has been a year that has taught me much, and if I have given even a part of this back through this tour, then I am well satisfied.

There are many to thank. To Olivia, for nominating me, and to Chris Deller for your efforts in organising all the logistics for this rather extended tour. To all the wonderful hosts from the AIP Branches who generously gave of their time to escort me, and to ensure that the tour ran smoothly. To Heike, and all the other wonderful researchers, staff and students within the Centre of Expertise in Photonics at the University of Adelaide for coping with my erratic appearances (thank God for email!) and to David, my husband, for his patience with my frequent travels.

I hope to see many of you at the upcoming 18th National AIP Congress in Nov/Dec in Adelaide. It promises to be a great event! As well as the rich offerings of the conference itself, there will be opportunities to visit the optical fibre laboratories of the Centre of Expertise in Photonics, and I look forward to continuing many of the conversations that begun during my tour then. With this I pass the baton onto the next AIP Women in Physics Lecturer…

Tanya Monro awarded Malcolm MacIntosh Prize for Physical Scientist of the Year

Optical fibres are the backbone of the internet, carrying vast amounts of data across cities, countries and oceans. Without them global communication would be more expensive and much slower.

Tanya Monro's research has contributed to their performance. But she thinks that optical fibres can do much, much more for humanity. She's dreaming of aircraft that know when they're getting metal fatigue; water plants that react within seconds of cryptosporidium entering the water supply; tractors that know how much fertiliser every metre of the field needs; and wearable sensors that detect certain proteins or viruses.

Tanya leads a team of over 20 researchers at the Centre of Expertise in Photonics at the University of Adelaide. She and her colleagues have created a new class of optical fibre using soft glass. These holey optical fibres have thousands of potential applications in industry, health, agriculture and defence.

For her leadership in photonics Tanya Monro receives the 2008 Malcolm McIntosh Prize for Physical Scientist of the Year.
More information: *https://grants.innovation.gov.au/SciencePrize*

The AIP Women in Physics Group is pleased to announce Associate Professor Christine Charles has been awarded the AIP Women in Physics Lectureship for 2009.

The Australian Institute of Physics Women in Physics Lecture Tour celebrates the contribution of women to advances in physics. Under this scheme, a woman who has made a significant contribution in a field of physics will give a series of public lectures around Australia.

Christine Charles is an Associate Professor in the Space, Power and Propulsion group in the Research School of Physical Sciences and Engineering at the Australian National University. She has been coordinating a French-Australian collaborative research program since the early 1990s. This has expanded to include institutions from England, Germany, The Netherlands, Liechtenstein, the USA, Korea, and Japan.

Her main research interest has been the investigation of the fundamental processes leading to ion acceleration in plasma systems, both in the laboratory and in astrophysics, along with numerous associated applications. These include plasma thrusters and interplanetary space travel, nano-structure materials for hydrogen fuel cells, nano-arrays for screening new pharmaceuticals, and hydrogen-free optical waveguides for photonics. She is the inventor the "The Helicon Double Layer Plasma Thruster", a novel space plasma engine for interplanetary travel and attitude control of earth orbit satellites. She has demonstrated this thruster concept both at NASA and ESA (the European Space Agency) and more recently at EADS-ASTRIUM, the company which runs the Ariane and Airbus 380 programs.

Christine also holds a Bachelor of Music in Jazz composition.

Associate Professor Charles will visit each of the six Australian State capital cities and present lectures to varied audiences: professionals, school students and the general public. This will include at least one public lecture arranged by each participating AIP Branch. She may also visit universities and other scientific centres throughout Australia, to give research colloquia. AIP members will be notified when details of the lectures, their times and venues are finalized.

For further information: *http://www.aip.org.au/*
Or please contact Dr Chris Deller
AIP WIP Lecture Tour National Coordinator
CiSRA (Canon Information Systems Research Australia)
christine.deller@cisra.canon.com.au

Plasma Propulsion

by Christine Charles
Space Plasma, Power and Propulsion group, Research School of Physical Sciences and Engineering, The Australian National University

Jules Verne's story "From the Earth to the Moon" published in 1868 is a classic example of our fascination with safe manned space travel. This French author pioneered the science fiction genre and there has been over a century of concocted tales of interstellar voyages with people imagining the adventures that would ensue if only scientists could unlock the secrets of faster space travel. Although Neil Armstrong set foot on the moon and robots are presently zooming around on the surface of Mars, the technology has not yet lived up to that big dream.

The principle of a rocket is to emit particles via an open exhaust or nozzle thereby creating a force (called the thrust) in the opposite direction. Conventional rockets are based on combustion of propellant in the nozzle and are fundamentally limited on both chemical and thermal bases by the amount of energy that can be stored in the chemical bonds of the fuel and by the maximum temperature the walls of the combustion chamber can withstand. While chemical rockets are well suited to high thrust, low specific impulse (high propellant usage) missions like a shuttle launch, an alternative is needed for interplanetary missions that require high specific impulse (low propellant usage) but necessitate only low thrust because they occur in microgravity [1]. The field of electric propulsion is dedicated to developing the higher specific impulse technologies necessary for such missions.

Plasma propulsion is a branch of electric propulsion that uses the properties of plasma to overcome the basic barriers that limit conventional rockets. A *plasma* is a hot ionised gas containing atoms, ions, and electrons that emits photons. Because plasma propulsion uses its propellant more efficiently, it can be used on missions that require greater changes in velocity once in space. Examples of successful missions based on plasma propulsion are DEEP SPACE 1 and SMART 1. DEEP SPACE 1 was a NASA spacecraft [2] launched in 1998 with the primary goal of testing new technologies such as the electrostatic ion thruster, also defined as an ion gridded thruster (Figure 1). SMART 1 was a satellite [3] launched by the European Space Agency (ESA) in 2003 that travelled and orbited around the Moon with its main propulsion system consisting of a Hall effect thruster, another type of ion engine.

Ion gridded thrusters and Hall effect thrusters both eject ions initially created in a plasma and both need a second device called a neutraliser to emit a sufficient number of electrons to neutralise the high velocity emitted ion beam. One or two neutralisers are usually placed just beside the thruster and oriented towards the exit of the thruster: the accelerated ions and the electrons from the neutraliser make the exhaust plasma plume (Figure 1). Neutralisation is necessary to prevent space charge effect on your spacecraft; this results when the ions come back towards the rocket creating damage and no net thrust. Ion engines such as ion gridded thrusters and Hall effect thrusters are in fact plasma engines with specific ion extraction and acceleration systems. Ion acceleration using potentials applied on the grids or at an anode means that these thrusters usually achieve high specific impulse (typically 3000~s) and provide good thrust (typically 100~mN for 1 kWatt). The drawback of this efficiency is detrimental grid or wall erosion. Scalability and stability of the plasma plume at very high power (>5 kW) is a challenge. Japan's JAXA solar electric propulsion mission, HAYABUSA [4], was launched in 2003 and uses a microwave ion engine (a microwave generated plasma, grids for ion extraction and a neutraliser). HAYABUSA is currently on a stable return path to Earth and is due to land in Australia mid 2010 [5].

For more ambitious interplanetary missions where safety and reliability are important, magneto-plasma thrusters are of interest as a neutral plasma (no need of a neutraliser) is emitted where the source of thrust is essentially from the ions. These thrusters have yet to be tested in space. Australia's recent involvement in electric propulsion has been marked by the invention and development of three distinct thrusters, the Dual Stage Four Grid ion thruster [6] at the Australian National University (ANU), the fast neutral thruster [7] (Sydney University) and the Helicon Double Layer Thruster [6] (ANU).

The story of the Australian Helicon Double Layer Thruster is on-going and has already been the subject of TV documentaries (ABC CATALYST [2004 & 2007] and DISCOVERY CHANNEL CANADA 2008). The Helicon Double Layer Thruster (HDLT) concept (Figure 2) is based on the discovery of a current-free electric double layer in an expanding magnetised plasma, where the electric double layers are similar to cliffs of potential (like a river waterfall) that can energise charged particles falling through them. They exist in the plasma environment of the earth and stars and can cause phenomena as diverse as aurorae, luminous

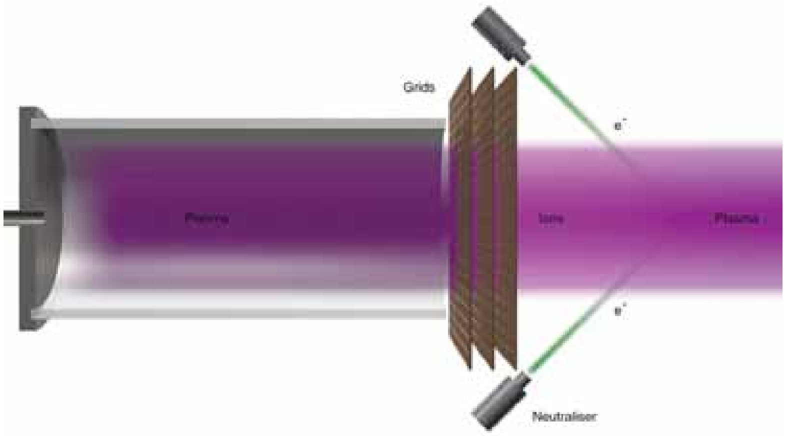


Figure 1: Schematic of an ion gridded engine (courtesy of Rhys Hawkins, VizLab, ANU Supercomputing Facility).

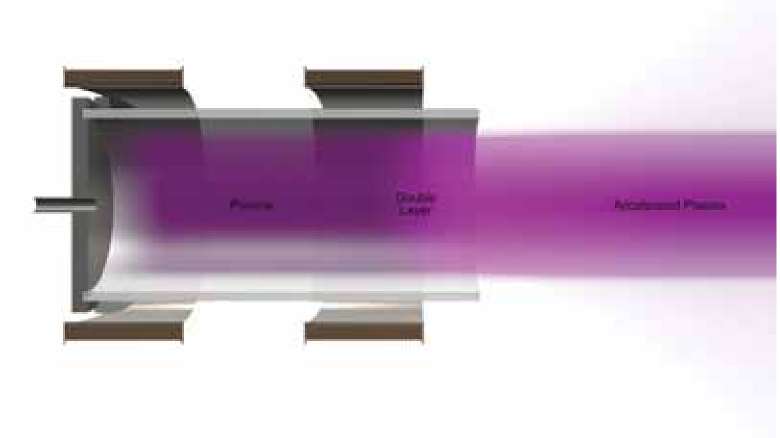


Figure 2: Schematic of the Helicon Double Layer Thruster; the radiofrequency antenna surrounding the tube is not shown for clarity (courtesy of Rhys Hawkins, VizLab, ANU Supercomputing Facility).

draperies in the polar sky, and electromagnetic radiation from rotating neutron stars called pulsars. Such a double layer was discovered in 1999 in a Space Plasma, Power and Propulsion laboratory system in Canberra and the energy of the highly supersonic ions it accelerates has been measured for an extended range of propellants including argon, xenon, hydrogen, and oxygen. Here, the double layer is not triggered by forcing two plasmas to interact (independently generated by grids with separate potentials, much like a man-made dam), but self generates under certain parameters, much like the riverbed suddenly falling away to create a waterfall. Optimisation of this effect to create a very efficient thruster for an interplanetary spacecraft has been under thorough investigation since 2002 [8, 9, 10].

The first HDLT prototype was designed and completed by April 2005 in Australia in collaboration with AUSPACE, a small Canberra based company, and the Cooperative Research Center for satellite systems [11]. The thruster prototype was subsequently tested in a space simulation chamber at ESTEC, the European Space Agency's development center in The Netherlands (Figure 3). Following the testing campaign, an independent study aiming at validating the HDLT concept was subsequently carried out by ESA's Ariadna program. The HDLT prototype was brought back to Australia in June 2005 and further testing is being carried out at the Australian National University in IRUKANDJI, a new space simulation chamber. Since late 2006 the Space Plasma, Power and Propulsion group at ANU has been working under contracts with EADS-ASTRIUM [12] the largest aerospace company in the world. This success has led to the most recent Australian Research Council linkage grant (mid 2008 to mid 2010) which will lead to the development and testing of a new HDLT prototype.

A schematic of the HDLT (Figure 2) shows that the HDLT consists of a pyrex tube, a rf copper antenna surrounding the tube and connected to a radiofrequency (13.56 MHz) generator, two solenoids (connected to a current power supply) creating a divergent magnetic field and a gas feed (connected to a gas tank) positioned on the 'closed' end of the thruster. There are no moving parts and no electrodes or grids immersed into the plasma. In a general sense, gas or plasma expansion leads to acceleration (i.e., the Solar Wind expanding from the Sun's surface into the Universe). In the HDLT a divergent magnetic field is added to the geometric expansion and there is a pressure range over which the plasma spontaneously sets up a 'cliff' in its potential (called the double layer) over a narrow distance (typically 1 cm) near the exit of the thruster (Figure 2). This non-linear structure is called a double layer as it consists of two adjacent layers of charge (a thin positively charged layer on the thruster side and a thin negatively charged layer on the exhaust side) such that electroneutrality is violated within the double layer. Ions created in the pyrex tube (upstream of the double layer) accelerate in the electric field of the double layer and are expelled out of the HDLT in the form of a low-divergence (<10 degrees) large area high velocity (typical exhaust velocity of 17 cm/s in argon) ion beam. The beam ions are not magnetised, do not follow the divergent magnetic field lines, and detach from the thruster and magnetic field at about 10 cm downstream of the double layer.

Plasma propulsion is a branch of electric propulsion that uses the properties of plasma to overcome the basic barriers that limit conventional rockets.

A sufficient number of electrons overcome the potential barrier of the double layer so that the beam is neutral: hence there is no need for a hollow cathode neutraliser mounted externally to supply electrons to the emitted ion beam. The ion beam has been measured for a variety of propellants [10] such as argon, hydrogen, oxygen and xenon (the latter being the commonly used electric propulsion propellant) making it very flexible in terms of propulsive performance and allowing the possibility of using in-situ propellants for reduced spacecraft launch mass. A recent collaboration with EADS-ASTRIUM has shown successful operation with alternative propellants such as methane, nitrogen, nitrous oxide and ammonia, suggesting that the HDLT could also operate with hydrazine [13]. For example, on a telecommunication satellite the station keeping is provided by chemical bi-propellant systems that stop operating when one of the two components runs out and large bubbles of gas are injected in the propulsion motors. At this point the pressure in the tanks is around 3 bars and there are some 15 to 20 kg of unused liquid and gas. Using such mass of residual fluid in an HDLT engine could equate to an additional year of useful operations and safe placement in the graveyard orbit. The most recent finding is the successful operation of the HDLT with carbon dioxide, showing that refuelling in space can now be envisaged since the main constituent of Mars and Venus is carbon dioxide [14].

Understanding the physics behind the thruster remains a great challenge that very closely relates to other astrophysical phenomena (acceleration of the Solar wind, the Earth's aurora, neutron stars, extragalactic jets…). The double layer at the heart of the HDLT is current-free which distinguishes it from most double layer laboratory devices investigated

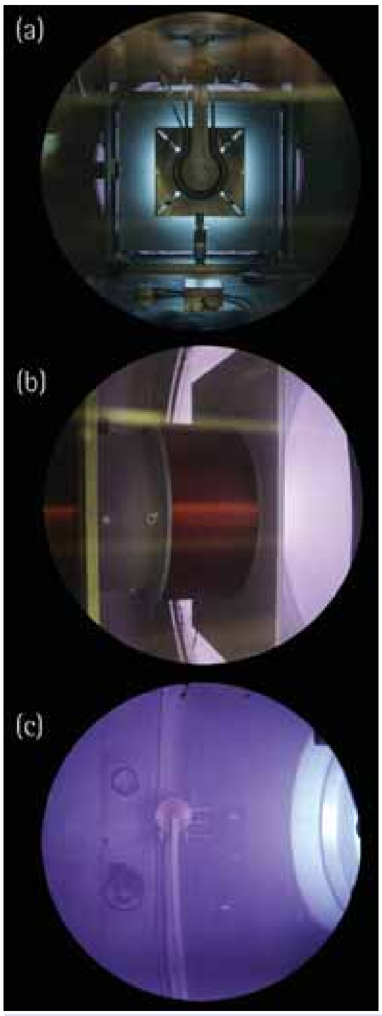


Figure 3: Testing of the first Helicon Double Layer Thruster prototype in the Hatch/Corona space simulation chamber at the European Space Agency in 2005 [from Ref 16]: three photos taken from viewing ports placed at the back of the Hatch (a), on the side of the Hatch (b), and on the side of the main Corona chamber (c) with the HDLT prototype operating in a high density xenon mode (original photos by C. Charles).

over the past few decades [10]. It appears as a very attractive candidate for acceleration of the Solar wind in coronal funnels [15]. Analytical models, particle simulations and a number of experimental devices are being developed at the Australian National University with the aim of elucidating the role of the magnetic field on the current-free double layer formation. Since the discovery of the current-free double layer, the Space Plasma, Power and Propulsion group has published over 30 refereed publications in renown international journals, many in collaboration with universities or space agencies worldwide [6, 10].

In summary the Helicon Double Layer Thruster is a new type of magneto-plasma thruster that combines the helicon technology for an efficient coupling of the electrical power to the plasma and a current-free double layer (formed spontaneously in the physical and magnetic nozzle of the thruster) for an optimised acceleration of the plasma ions. A large area, low divergence high velocity ion beam (the source of thrust) is measured in the nozzle for various propellants. In addition to the scalability in geometry and electrical power, the simplicity and the absence of any moving parts, electrodes, or neutraliser give the HDLT an extended lifetime. Recent tests suggest that optimisation of the physical and magnetic nozzle of the prototype will greatly improve its performances.

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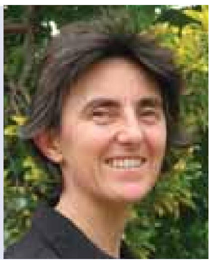
Christine Charles is Associate Professor at the Australian National University. Along with an Engineering degree in applied physics, a Masters in materials science, a PhD in plasma physics, she is the inventor of the Helicon Double Layer Thruster, a new electrode-less magneto-plasma thruster.



Wagga Wagga

WW

2009

Final Notice - Registrations close soon!

33rd Annual Condensed Matter and Materials Meeting

Charles Sturt University, Wagga Wagga, NSW

3 - 6 February, 2009

Wagga 2009 will be held at the Convention Centre, Charles Sturt University, Wagga Wagga, NSW. Arrival formalities will commence from 4.00 p.m. on Tuesday, 3 February, 2009 with scientific sessions commencing 8.50 a.m. Wednesday, 4 and concluding with lunch on Friday, 6 February, 2009. Accommodation will be available on the University Campus near the Convention Centre. This meeting is an opportunity for all condensed matter and materials scientists to meet in an informal atmosphere to discuss their current research, future direction and other matters of importance in the field. The traditional informal Wagga format will apply, with emphasis on contributed poster papers, selected contributed oral papers plus a number of invited plenary papers presenting areas in fields of current topical interest, e.g., the status of quantum computing, Bose-Einstein condensation in light-atom assemblies, the Avogadro project, “soft” condensed matter, nuclear power and waste, etc. Students are particularly encouraged to submit oral presentations. Depending on submitted papers, the program will comprise some focussed sessions such as soft-matter science, studies of surfaces and interfaces, photonics, etc. If you have never been to a “Wagga”, now is the time. If you are an old hand, welcome back.

Wagga 2009 registration can be completed on-line at: *http://www.acpo.csiro.au/wagga09*

Payment in full, either by cheque or electronic bank transfer should accompany the registration. A receipt will be issued on arrival at the conference. The cost for the full three days attendance is A$310. This consists of A$100 for registration (including conference dinner and trivia night) and A$70 per day for accommodation. The latter covers dinner, room, breakfast and lunch. Reduced fees are available for retirees and students, as indicated on the registration form. Students incurring significant travel costs are invited to apply to the Organising Committee for assistance with travel costs.

Abstracts: Contributed papers are requested in all areas of condensed matter and materials research. Abstracts should be typed on a single A4 page using the abstract template which can be downloaded from the conference website. Abstracts may be submitted by mail or email to the address below and should have an accompanying note detailing the address of the communicating author and preference for oral or poster presentation.

Conference Proceedings: Participants are invited to submit a manuscript for publication in the conference proceedings which will be peer-reviewed and published electronically on the website of the Australian Institute of Physics. A template for the preparation of manuscripts is also available at the conference website and manuscripts should be presented upon arrival at the conference.

Dates:	Abstract and Registration deadline (with payment):	28th November 2008
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Is Simulation Better than Reality in Radiation Transport?

by Zdenka Kuncic

The previous edition of Australian Physics (September/ October 2008) featured the article "Molecular Dynamics – A Third Way for Physics" (p. 160) written by this author's colleague Nigel Marks. His article highlighted the rapidly growing importance of computational physics over the last half-century and the emergence in the twenty-first century of its rightful place as a third, independent approach to physics, complementing and even enhancing the traditional theoretical and experimental approaches. The present article extends this further with the example of radiation transport. Modelling the passage of particles (both neutral and charged) through different media is a complex, multidimensional problem that naturally lends itself, somewhat remarkably, to the numerical technique known as Monte Carlo (MC), which relies on random sampling.

The namesake of this well-known technique is the famous gambling city of Monaco, where one can find an exceedingly simple yet effective random number generator: the roulette wheel. This article describes the salient features of MC radiation transport models and presents an overview of how this deceptively simple, yet powerful and versatile numerical method has infiltrated into areas of modern physics research ranging from astrophysics to medical physics. Indeed, in medical physics, MC is widely regarded as the "gold standard" when it comes to calculating key physical quantities such as absorbed radiation dose; experimental measurements are often benchmarked against MC calculations. This is what has prompted the author to pose the question: is simulation better than reality?

> The true logic of this world is in the calculus of probabilities

The development of modern MC methods is credited to von Neumann and his colleagues Ulam, Fermi, Metropolis and others who worked together at the Los Alamos National Laboratory (LANL) during the Manhattan project era. Von Neumann's remarkable insight into the unique compatibility between statistical methods and digital computing was recorded in a famous letter he wrote in 1947 to the then Theoretical Division Leader at LANL. In that letter, he outlined a novel approach to calculate neutron diffusion from fission devices. What he outlined was effectively the first modern MC computational algorithm.

The Boltzmann transport equation

MC uses stochastic methods to calculate the most probable outcome of the system being simulated. As James Clerk Maxwell put it: *The true logic of this world is in the calculus of probabilities.* In other words, MC methods simulate the way many complex systems in nature actually operate. In radiation transport simulations, the physics of particle propagation and particle interactions in a medium is modelled from first-principles using the Boltzmann transport equation:

$$\left[\frac{\partial}{\partial s}+\Omega\bullet\nabla\right]\Phi(\boldsymbol{x},\Omega,s)=-\Sigma(E)\Phi(\boldsymbol{x},\Omega,s)+\int\Sigma(\Omega\bullet\Omega',E)\Phi(\boldsymbol{x},\Omega',s)\,d\Omega'$$

The left hand side of this equation describes intrinsic time and spatial variations in the flux density Φ of particles at position x propagating in direction Ω along a path length .

$$s=\int v\,dt$$

The terms on the right hand side describe sinks and sources in the medium through which the particles are propagating. The first term on the right hand side describes removal (i.e. attenuation) of particles from state $(\boldsymbol{x},\Omega,s,E)$, where Σ(E) is the interaction cross-section per unit length of incident particles with energy E interacting (via absorption and scattering) with target particles in the medium (i.e. orbital electrons and atomic nuclei). The second term on the right hand side of this equation describes the creation of particles in state $(\boldsymbol{x},\Omega,s,E)$ from particles in state $(\boldsymbol{x},\Omega',s,E)$, where $\Sigma(\Omega\bullet\Omega',E)$ is the differential scattering cross-section per unit length. The probability for such interactions is measured by

$$\Sigma^{-1}d\Sigma/d\Omega'=\Sigma^{-1}\Sigma(\Omega\bullet\Omega')$$

MC randomly samples this probability density function (PDF) to evaluate the integral in the Boltzmann equation. It also randomly samples the PDF for particle transport, which depends on the mean-free-path between interactions, λ. In the case of photons, for instance, their exponential attenuation through a medium gives the following relation between the path length s and random number R: $s=-\lambda\ln R$.

The Boltzmann transport equation represents a multi-dimensional integration problem which, when applied to model real-world systems, becomes intractable to solve analytically by any means or even with conventional numerical integration techniques, except with extremely non-ideal assumptions (e.g. single particle species, no scattering, simple geometries, homogeneous medium, restricted particle energies and interaction processes). The main source of mathematical complexity is that scattering processes (e.g. Compton scattering for photons, Møller scattering for electrons) progressively change both the energies and trajectories of particles. This makes the solution to the transport problem highly dependent upon its boundary conditions. MC is the only method that offers a rigorous solution to the general problem under realistic conditions.

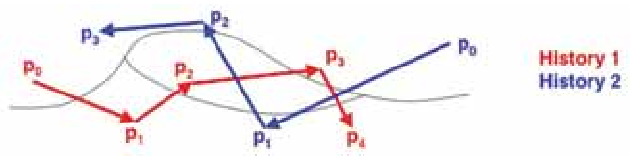

Figure 1: Monte Carlo radiation transport models simulate large numbers of randomly selected particle histories, pi, each of which includes the trajectories of the primary particle and of all the secondaries (not shown) produced as a result of interactions in the medium. Thus, a history tracks a sequence of states pij. A statistical estimate of quantities of interest is then obtained from the expectation value averaged over all simulated histories. Data from *http://mcnp-green.lanl.gov/publication/pdf/LA-UR-05-4983_Monte_Carlo_Lectures.pdf*

Simulating radiation transport the Monte Carlo way

The MC method draws on the elements of probability, statistics and random sampling to obtain the most probable solution to the integral form of the Boltzmann transport equation. In essence, this requires simulating large numbers of particle histories (families of tracks) selected randomly using machine-generated (pseudo) random numbers. Each history consists of a sequence of states of a primary particle as it propagates through a medium, plus the sequence of states of all its progeny resulting from various interaction events in the medium (Figure 1). The process is intrinsically a Markovian one in that the next event depends only on the current state, not on the sequence of previous events. Events are tallied within specified regions in order to calculate macroscopic quantities of interest from statistical averages. For example, the distribution of energy deposit in the medium (which is a key quantity of interest for radiation dosimetry applications) is readily obtained by tallying the local energy transfer from particles to the medium for all events that occur in each of the simulated histories, and then calculating the average. Thus, the error in MC computed quantities is limited only by statistical accuracy, $\sigma/\sqrt{N}$, where σ is the variance and N is the number of simulated histories.

The efficiency of a MC simulation depends on the variance as well as the computation time. Various "variance reduction" algorithms have been developed to minimise σ (e.g. photon splitting techniques). Similarly, "condensed history" techniques are routinely applied for electron transport schemes to reduce processing time, since the very large cross sections for electrons results in an extremely large number of interactions. An event-by-event simulation is possible, in principle, but the cpu time required to achieve an acceptable level of statistical uncertainty is prohibitive. Condensed history reduces cpu time by grouping minor "soft" collisions together and analytically calculating averaged segments of electron tracks between major "hard" collisions (Figure 2), such as Coulomb interactions with atomic nuclei resulting in secondary photon production (bremsstrahlung emission). Electron interactions are condensed using multiple scattering theory for elastic angular deviations and stopping power for energy losses. For a review on this subject, see Nahum, Radiat. Environ, Biophys. 38, 163 (1999).

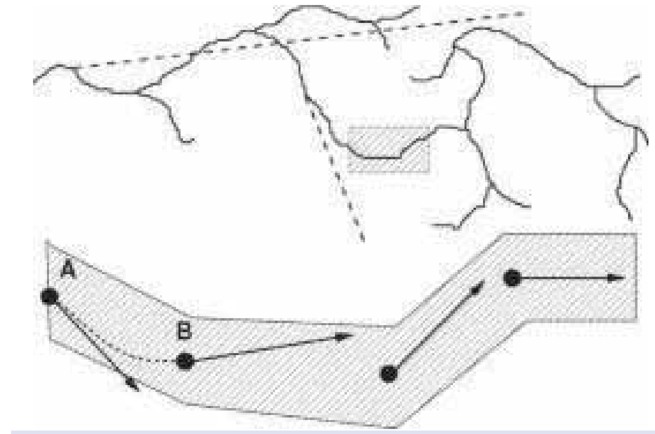

Figure 2: The upper part of this figure shows a schematic electron track including secondary electron branches and photons (dashed lines, interactions not shown). The lower part shows a zoom-in of the shaded portion of the track, illustrating the condensed history technique employed to minimise computation time for electron transport simulations. This technique involves estimating local averages of grouped multiple minor events and only modelling discrete events that result in substantial energy losses. The filled circles and arrows show the electron position and direction at each discrete event. The surrounding shaded area indicates the region where energy is actually deposited. From Chetty et al., Med. Phys. 34(12), 4818 (2007).

Physics applications

MC is used to model radiation transport in a wide range of physics problems (Figure 3). In nuclear physics, it is used to model neutron and photon diffusion from nuclear reactors. In astrophysics, it is used to model photon transport in cosmic X-ray sources in order to deduce key physical parameters that would otherwise be impossible to measure. For a novel example of this kind of application, see McNamara et al., Mon. Not. R. Astron. Soc., 386, 2167 (2008). MC simulations are also used to test and calibrate X-ray detectors on orbiting satellite science payloads such as ESA's XMM Newton telescope and NASA's Chandra observatory. Similarly, in high-energy physics, MC simulations are used to validate particle detectors, such as the ATLAS detector in the Large Hadron Collider experiment.

Figure 3: Examples of physics applications of Monte Carlo radiation transport - the XMM Newton X-ray telescope (top); the ATLAS detector in the Large Hadron Collider (centre); medical linear accelerators for external beam radiation therapy (bottom).

Detector response simulations also play a vital role in medical physics, where a variety of radiation detectors are used in imaging and dosimetry equipment. In nuclear medicine, MC simulations are used to develop image correction techniques that correct for target movement. In radiation therapy and diagnostic imaging, radiation protection is a critical issue and MC is an essential tool for obtaining accurate measurements of absorbed radiation dose and for developing best-practice strategies and protocols for minimising exposure to unwanted ionising radiation. MC simulations are used extensively in radiotherapy to validate beam quality and to improve radiation delivery techniques in external beam therapy, and also to determine radiation dose distributions from radionuclides used for internal radiation therapy. Indeed, one of the most exciting developments in radiotherapy physics is the prospect of implementing MC in clinical treatment planning systems, which currently rely on approximate radiation transport algorithms. In most cases, the performance of these algorithms for radiation treatment planning is adequate, but the approximations break down for treatments involving heterogeneous tissue (e.g. air cavities, lungs) and at the boundary between different

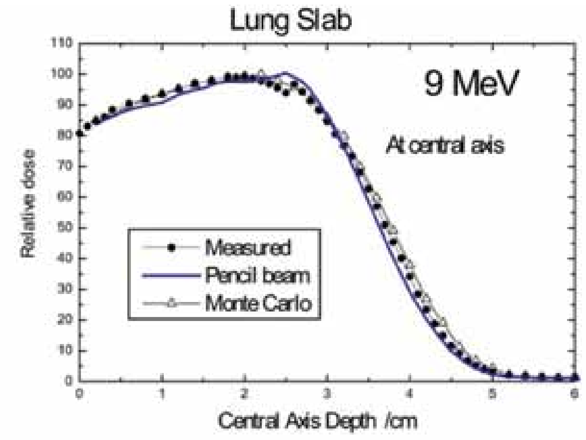

Figure 4: Normalised radiation dose versus depth along the central axis of a lung slab irradiated by a 9 MeV clinical electron beam. The measured values are experimental, while the pencil beam values are calculated by a commercial treatment planning system. Data from Ding et al., Int. J. Rad. Oncol. Biol. Phys. 63(2), 622 (2005).

tissues. This results in clinically significant inaccuracies in dose calculations (Figure 4) and an increased risk of adverse radiation-induced health effects.

This sample of MC applications is no doubt incomplete and arguably somewhat selective. Nevertheless, it does demonstrate the intra- and multi-disciplinary capacity of MC radiation transport simulations. Indeed, perhaps one of the best examples of cross-fertilisation facilitated by MC simulations is that of space radiation dosimetry. This involves the calculation of radiation dosage absorbed by astronauts exposed to galactic cosmic rays and solar energetic particles, and is receiving renewed attention from NASA and ESA, both of which are planning long-duration manned space missions (e.g. to the Moon and Mars).

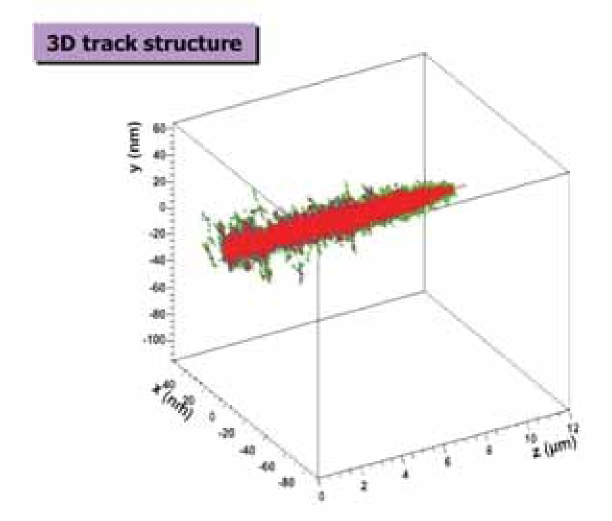

Figure 5: 3D track structure of a primary 2.37 MeV He+ particle delivered to a nanometric volume of liquid water, simulating cellular irradiation. Data provided by S. Incerti and S. Guatelli, from the Geant4-DNA collaboration (http://cern.ch/geant4).

Space radiation is a particularly challenging problem because it consists of particles, such as protons, alphas and heavier ions, which can cause potentially lethal biological damage to humans. Importantly, the extent of damage to human DNA by such particles has not yet been quantified because human cell structures are especially radiosensitive to particles at energies below a few kiloelectron volts (keV), where the wave properties of particles and the dielectric response of media cannot be neglected. At these relatively low energies, the cross-sections for particle interactions, particularly with biological structures on sub-cell scales (i.e. nanometres), are poorly known experimentally or theoretically. This is a major challenge in current radiation dosimetry research.

The Geant4 multinational collaboration (*geant4.web.cern.ch*), which has developed one of the most sophisticated open-source codes for MC radiation transport, has recently released their next-generation code Geant4-DNA. To date this remains a framework; considerable work is yet to be done to simulate the additional physical, chemical and biological processes involved in radiation interactions on DNA scales (Figure 5). [See Chauvie et al., Rad. Res., 166(4), 652 (2006).]

Final remarks

Monte Carlo is an exceptionally powerful, yet deceptively simple, numerical integration technique that is uniquely suited to modelling complex, real-world systems. It is an extremely useful and versatile tool for modelling radiation transport in particular in a variety of different contexts. But is simulation really better than reality? The answer is that it is only as good as the physics the user puts into it; and the more physics there is to simulate, the longer the computation time. So there will always be a trade-off between accuracy and speed. In the end, our ability to simulate reality will be limited not so much by Moore's law or by the development of cleverer algorithms, but by conceding that just when we think we have included all the physics, there is still more to model.

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Scientific Study Tour of Russia 2008

by Sophie Vitesnik
Year 12 student at Braemar College in Woodend Vic

In February this year, on my 17th birthday, I was offered the opportunity of travelling with five other National Youth Science Forum students to Western Australia, Moscow and St Petersburg. Upon my immediate acceptance life became considerably busy with time management theory becoming practice with paperwork, endless lists, passport, visas, letters, speeches, newspaper articles, VCE mid year exams and finally packing!

Our journey began with professional leadership training in a specially designed expedition to the Kimberley region of Western Australia. A Cessna flight to Kununurra from Darwin revealed the outback landscape of our country that took my breath away.

Our five-day bushwalk through the Kimberley wilderness area was amazing. I am most grateful for the opportunity to witness and experience the beauty of this pristine and unique part of our country as industrial and agricultural development increasingly affects the area, and climate change begins to take its toll.

Dawul Primary School

On our last day out in the bush we visited the Dawul Primary School in Doon Doon. The children's smiles and laughter were extremely contagious and they listened attentively and were enthralled with our science presentations. We made paper cups to hold water, used springs to make cardboard frogs jump and as we pierced a water bomb with a needle without making it pop their eyes filled with wonder! I could have easily stayed longer with these keen, energetic budding young 'scientists'. Before departing the Doon Doon Aboriginal Community the Woolah people held a traditional smoking ceremony to allow the spirits of the land to recognise us and give us safe passage.

The next leg of the journey saw us touching down in Moscow Domodedovo! My first day in Russia will always be remembered as we were warmly welcomed to Rossiya by the past Director of the All-Russian Youth Aerospace Society (Soyuz), Alexander Gorshkov or better known as Sasha. We were to become extended members of his family sharing their city apartment, family meals, their passion and love for their country and even felt their utter devastation and pain when Russia lost to Spain in the Soccer!

Our education in Russian history and culture began immediately with the Kremlin and Red Square being our first stops. No book or photo could prepare us for the breathtaking sight of the vast flat space within the red walls of the Kremlin and the magnificent St Basil's Cathedral towering over Lenin's Tomb. Our main transport around Moscow was typical for Moscovites – walking and the metro. Moscow has a well developed and efficient underground metro system where trains are so frequent a timetable is not necessary for the 7 million daily passengers!

Mendeleev Station

The 176 stations are a succession of art galleries where chandeliers, intricate mosaics, gilded paintings, stained glass windows and bronze sculptures of historical images give a fascinating insight into the Soviet era. My favourite station was Mendeleev Station dedicated to Dmitri Ivanovich Mendeleev, the Russian chemist and inventor credited with being the creator of the earliest version of the periodic table of elements. The station walls are segments of the periodic table and the lights are based on the structures of molecules.

Over the next week we were immersed in the rich Russian culture, language, and history but also day-to-day living. We were beginning to feel at home and even the Cyrillic alphabet was becoming less daunting. Just when I thought no city could surpass Москва for beauty and historical sites we arrived in St Petersburg! Our four short days in St Petersburg were spent in a continuous state of marvel and awe, especially when visiting the Peterhof, the Hermitage Museum and, for me in particular, attending the Ballet performance of Tchaikovsky's Swan Lake by the Russian Classical Ballet Palace Theatre.

"Once you have seen the world from space, borders between countries no longer exist" - Yuri Gagarin

Returning to Moscow we eagerly anticipated our visit to Star City, the Yuri Gagarin Russian State Science Research Cosmonauts Training Centre (RSSRCTC). Star City (also known as Zvenzdny Gorodok meaning "little town of stars") is a two-hour drive from Moscow in a Secret Zone of Russia and we were privileged to have as our guide the retired Lt. Col. Alexander Belyav, an engineer and experienced member of the cosmonaut training and preparation team. He had permission to accompany us to view and experience some exclusive areas of the 64-hectare training centre.

When accepted into the Gagarin Cosmonaut Training Centre, members undertake three years of schooling, studying subjects such as astronomy, physics, and mathematics,

and undergo continuous rigorous fitness programs with numerous biomedical and psychological testing. The medical centre in Star City contains the world's largest indoor centrifuge (Centrifuge TSF18).

Former Director, Lt. Col. Belyav proudly took us to view the 18-metre long centrifuge arm in action, which rotates inside a specially constructed room to simulate the forces experienced during space flight. Inside this spinning machine a cosmonaut must be able to function, both physically and cognitively, under extreme forces – reaching up to 8g's (g-force) and travelling at 270 kph for 40 seconds, by comparison formula one drivers experience 2g's while accelerating and 5g's while braking. The TSF18 took 9 years to design and build, and weighs 305 tonnes. It is capable of forces as high as 30g's and tests both the ability of cosmonauts and equipment. With Lt. Col Belyav eager to teach us more we visited the hydro lab, which simulates micro gravity. It is situated in a four-storey building containing 5000 tonnes of water!

A 6-hour underwater training session simulates conditions outside the International Space Station, and the pressures exerted on the body result in a 3kg weight loss.

Everyone who travels to the International Space Station must first spend time at Star City, including American astronauts. We are six of the sixteen people in the whole of Australia to actually observe cosmonauts training for space walks in the high tech training pool. We were also able to sit in the simulator pods where cosmonauts, before a mission, have to undertake 100-200 hours of training. The simulators duplicate the movement and conditions in space. We were given the opportunity to step inside and experience a life-size model of the space station MIR.


Sitting within a simulator pod

The Yuri A. Gagarin Museum honours the work of the thousands who have been part of the space program and displays over 2000 artefacts and historic spacecraft donated by cosmonauts. Included in the collection is the space suit of Soviet cosmonaut Valentina Tereshkova (the first woman in space), the last picture taken of Yuri Gagarin and the 4th Hero of the Soviet Union Medal ever to be awarded. Yuri Gagarin is a great Russian hero, and many customs and traditions have arisen from his space journeys and his life. At the Yuri Gagarin Monument, which is a larger than life bronze statue, crews lay wreaths before they journey into space.

Our last stop was an amazing visit to Korolev, the Russian Space Industry's Mission Control Centre that has the primary responsibility over the largest and most ambitious experiment in human spaceflight – the International Space Station (ISS) - we were able to witness the tracking of the Station in real time!


The Rocket Club

The Centre controls the Soyuz during the launch, flight and docking stages. There are two mission controls in the world and as the Russians are very proud to explain to us, the Korolev has a more complete logistical control of space flight operations than its counterpart, the U.S. Johnson Control.

Eager to meet Russians and experience their science and technology we visited a Rocket Club situated just out of Moscow. Here we built a rocket parachute from scratch and learnt how to build a model rocket. The launch, with the assistance of our young Russian friends, was extremely successful. The school is thriving, travelling abroad to compete in rocket competitions and gaining impressive results whilst earning a strong reputation. Even after our late departure there was six young boys who apparently stayed at the club until after 7.30pm! The instructor explained, "They enjoy it so much that they never want to leave".

Unfortunately, in this great journey came a time for departures. We farewelled Sasha and attempted to convey the extent of our gratitude and our promise to return.

The Russian Scientific Study Tour was an amazing experience. The Russian people, their rich history, architecture, culture and melodic language were all so contrasting to that of my country. I am left in awe of the human spirit, the pure enormity and the achievements of the Science and Technology behind the space program of a major world player.


The Korolev Mission Control Centre

It was an honour to represent the National Youth Science Forum, my community, state and country and I am further inspired, as a young woman, to make a difference through my study of science. I sincerely thank the Australian Institute of Physics (Victoria) for their encouragement and support. I sincerely appreciate The Australian Institute of Physic's support of the International Program of the National Youth Science Forum. As a Year 12 student pursuing an exciting career in the field of science, it was inspiring to experience their recognition and encouragement.

Australian Science Media Centre

by Nigel Kerby

The world is being dramatically transformed. The rapid pace of change has presented us with some unprecedented scientific challenges. Climate change, increasing competition for fewer resources, the threat of a global pandemic and loss of biodiversity are just a few. These are big issues that need bold solutions from a public empowered by knowledge. At the same time the media is undergoing its own revolution. The traditional hardcopy sources of information are giving way to a myriad of online resources that anyone can access and everyone can shape. It is within this turbulent landscape that the Australian Science Media Centre (AusSMC) opened for business in November 2005.

Our philosophy

The AusSMC believes that scientists can make a big impact on the way issues are covered in the media. By building bridges that help the scientific community to engage with journalists, the AusSMC supports scientists to take more initiative and play a leading role in informing public debate.

The AusSMC is a non-profit, national organisation that represents no particular faction in science. Its agenda is simply to make evidence-based science more easily available to journalists and give scientists a bigger voice on important issues of the day. The Centre was inspired by renowned UK neuroscientist Baroness Professor Susan Greenfield during her period as an Adelaide Thinker in Residence in 2004. She was behind the world's first Science Media Centre in London.

The Australian centre operates from Adelaide with five full time staff headed by CEO Dr Susannah Eliott. Funded by Australian business, industry and media organisations, the centre guarantees its independence by capping all contributions at 10% of its operating costs. It is governed by a Board of Management and advised by a panel of eminent scientists from across Australia.

How the AusSMC operates

Rapid Reaction

Flu outbreaks, plane crashes, cancer clusters, earthquakes. When science is in the news AusSMC staff round up comments from relevant experts for immediate distribution to media outlets around the nation. These quotes are used either directly by journalists in their stories, for follow up interviews or as a barometer of where individual scientists stand on an issue.

National media briefings

When issues emerge or stories need more depth, the AusSMC runs national briefings for journalists in cities around Australia or online. Experts are targeted to give short presentations and answer media questions with time set aside for one-on-one interviews. All physical briefings are also streamed live over the internet making them easily accessible to journalists throughout the country.

Media enquiries

Assisting journalists in finding a suitable expert for their story is all part of a normal day for the AusSMC. The Centre maintains a growing network of contacts that helps locate the right expert quickly.

Website

The AusSMC website (www.aussmc.org) has become an important resource and is updated constantly. There is an archive of information and quotes on recent hot topics and briefings, nutshells, science blogs and more.

Nutshells

From bird flu and stem cells, to genetics and geosequestration, these easy to read backgrounders are compiled for general reporters that need to grasp the facts quickly. Nutshells are overseen by scientists widely acknowledged for their work in those fields.

We need your help

The AusSMC is always on the lookout for Australian scientists who are willing to engage more with the media.

The Centre will keep your details on hand for when your field of expertise is in the news. Similarly, media officers are encouraged to make contact as the AusSMC is always happy to receive recommendations.

You can also contact the Centre if you wish to put your views on a scientific topic into the public domain via the AusSMC's Science Blog web page.

For more information about the AusSMC visit their website: *www.aussmc.org* or contact the Adelaide-based centre on 08 8207 7415 or email *info@aussmc.org* .

The AusSMC IS

- Independent – With a broad range of sponsors and by capping individual contributions to 10% of total operating costs, the AusSMC is able to provide an independent service and a spectrum of opinion from the scientific community without fear or favour.
- Media driven – While most issues we cover are driven by the level of media interest, the AusSMC also plays a role in providing journalists with heads-up on emerging issues.
- Proactive – The AusSMC is constantly 'horizon scanning' looking for situations where science can help clarify an issue.
- Collaborative – When scientists from different institutions are involved with the same media story, the AusSMC can provide an independent platform, enabling coordinated distribution of the message to the media.

The AusSMC IS NOT

- A distribution service for institutional media releases;
- Responsible for increasing the profile of specific concepts or areas of science in the media;
- A PR agency for institutions that do not have access to a media office;
- Set up to take general enquiries directly from the public or non-media institutions.

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Reviews

Engineering a High-Tech Business. Entrepreneurial Experiences and Insights
José Miguel López-Higuera and Brian Culshaw eds.
SPIE Press, Bellingham WA, 2008
xii&276pp., $47USD (softbound)
ISBN: 978-0-8018-8809-0

Moving into a start-up company, particularly in its very early stages, either as a founder or as an early employee can be a uniquely rewarding experience. Whilst there are many books about creating and growing start-ups (particularly in the US) this book is the first one, to my limited knowledge, that focuses on the start-up phenomenon in the photonics space. The book does not try to provide a linear story of the growth of companies in the photonics space but rather provides some excellent snap-shots and first-person case studies of how the start-up process can occur.

The book is based on contributions from authors (the majority of them entrepreneurs themselves) and this provides a breadth of views although the disparity of styles, together with the light hand of the editors, often leaves something to be desired in terms of continuity. However, this approach does allow the personalities of the individual authors (many of them known personally by the reviewer) to shine through.

The book is divided into four sections, the first of which, entitled Reflections, Motives and Money, aims to provide an overview of the process. The first chapter, however, provides a reasonably incomprehensible economist's take on the process of innovation which could be enough to put many readers off pursuing the rest of the book. However, be not deterred, dear reader, as the both the content and readability of the book increases significantly once past this very dry beginning.

The second section, devoted to various case studies written by the entrepreneurs themselves provides, to me, the real meat of the book, both in terms of the space devoted to it (over half the book) and in terms of the stories that are told. Whilst some of the chapters tend to be a bit formulaic in presentation (with a first we did this, then we did that approach) others really capture the trials and tribulations, highs and lows of creating and building a photonics company from scratch.

The eclectic choice of contributors from a range of countries (not just the US) provide a broad range of raisons d'etre and business models which provide food for thought for anyone contemplating taking the plunge into a start-up. As a minor gripe, I would have liked to have seen a couple of failures (eg from the photonics bubble of 1998-2001) but maybe the people concerned (and their lawyers) did not want to get involved. (For a good article on the downside, see the Wall Street Journal article from August 2002 on Latus Lightwave, which can be found at *http://www.happinessonline.org/InfectiousGreed/p26.htm*)

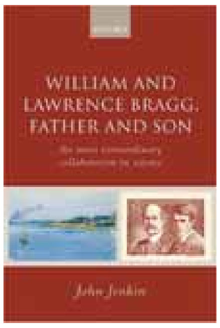
The third section, Supporting the Entrepreneur, could be valuable to someone just setting out on the road towards a start-up although I found the chapter on IP strategy rather abstract and surprisingly US-centric, with little discussion of the various options for IP protection outside of the 'traditional' US patent.

The final section focusing briefly on the role of universities seems very much an afterthought and does not link well into the main body of the book. The two examples discussed are far too country-specific (Spain and the US) but at the same time too general to be of any real value.

Overall, the editors have done a good job of capturing some of the flavour of being involved in a start-up in the photonics space and the book is recommended to provide an insight into some of the strategies and war stories of those who have succeeded in this space.

Recommended follow-up reading:
"City of Light" by Jeff Hecht - an extremely well-written view of the development of fibre optics up to 1995
"Telecosm" by George Gilder - a fascinating read of one-man's hyping of the photonics bubble
"The Innovator's Dilemma" by Clayton M Christianson - a seminal, must-read book for anyone contemplating a technology start-up

Simon Poole
Finisar Australia



William and Lawrence Bragg, Father and Son
John Jenkin
Oxford University Press, New York, 2008
xiv&458pp., (hardbound)
ISBN: 978-0-19-923520-9

The author must have put his heart and soul into writing this book. He has done an incredible amount of historical research into the family and entourage, not to mention the original physics sources. This is evident from the detailed archival material and the numerous footnotes and references, plus reported conversations with family members. The result is a scholarly volume that not only traces the history of the Braggs, but places their work within the social and political setting of the times. Although he mainly covers the period 1860-1920 and especially the years leading to the First World War (so as to cover the period of their wonderful collaboration into X-ray crystallography) Dr Jenkin does try to round off the book by a synopsis of their later years and achievements.

The elder Bragg (whom I shall refer to as William, although that was also Lawrence's first name) was born in Cumbria but did his schooling under his uncle's sponsorship in Market Harborough and later on the Isle of Man, before going to Cambridge; he distinguished himself by becoming Wrangler in Part III of the Tripos Examinations, which included mathematics and physics. He was then offered an opportunity to move to Adelaide University on the recommendation of Horace Lamb, who had recently resigned from the Chair there. William was glad to avail himself of the chance to stand on his own two feet and made a remarkable impact on the life of that city during his

period there (1886-1910). He worked extremely hard (20 hours lecturing per week!) and chaired numerous scientific bodies as well as carrying a heavy administrative load at the university. He married (Gwendoline) the daughter of Sir Charles Todd who oversaw the establishment of the inland telegraph from south to north and who was a notable man in his own right. The birth of two sons (Lawrence, Robert) and a daughter occurred while still resident in Australia. He managed to find time to engage on ground-breaking research on the transmission and ionization properties of alpha-particles through different materials and this gained him world-wide recognition by fellowship of the Royal Society of London.

This was to prove a launch pad for a return to England with his family and William was appointed to a chair at Leeds on the recommendation of Rutherford. By then, his academically precocious son had gained an Honours (BA) degree from Adelaide, which was to be a starting point for more advanced studies at Cambridge, his father's alma mater.

It was at that point that they both began their momentous collaboration on X-ray diffraction off various crystals; apparently it is to Lawrence that we owe the famous "Bragg law" of reflection off crystal planes. They uncovered the crystal arrangements of alkali halides and of diamond, underlining the fundamental atomic structure of matter.

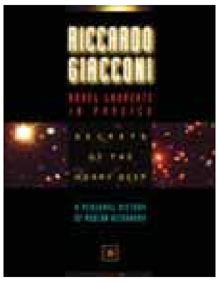
Their research was interrupted by WW1 and I was interested to learn that both father and son contributed substantially to the British war effort: Lawrence by devising his sound-ranging method of pinpointing enemy gun emplacements, William by using hydrophones to locate German U-boats, which were proving to be such a menace at the time. It was during one of the 1918 campaigns at the front that Lawrence received news that he had been awarded the Nobel prize jointly with his fathe; which must have cheered him no end, amongst all the surrounding misery. He was one if its youngest recipients. Unfortunately his brother, Robert, was killed during the Dardanelles campaign -- a very severe blow to the entire family.

After the war, the crystallographic collaboration largely came to an end and father and son went their separate ways: Lawrence to take up Rutherford's old chair at Manchester and William to University College, London. It is perhaps surprising that neither of them returned to Australia (despite William's tremendous impact there) except for one brief visit by Lawrence in the early 60s.

William ended his career by heading the Royal Institution and Lawrence at that time became head of the Cavendish Laboratory in Cambridge. There he nurtured a famous school of X-ray crystallographers many of whom went on to win Nobel prizes like him, by uncovering the structure of organic molecules.

I learnt much from this book and I am sure it will be invaluable to scientific historians by the wealth of references. Read and enjoy. You too will learn much about trying to maintain a significant research profile in faraway places.

R. Delbourgo,
University of Tasmania



Secrets of the Hoary Deep
Riccardo Giacconi
Johns Hopkins University Press, Baltimore MD, 2008
xiii&411pp., $45USD (hardbound)
ISBN: 978-0-8018-8809-0

Astronomers who are old enough to remember the trade before 8-m telescopes will have heard of Riccardo Giacconi. The rumbles of his explosive personality spread out from the epicentre of the seismic shifts of the past two decades, the success of the Hubble Space Telescope and the rise to power of Europe as an astronomical force of the first rank. In both of these, Giacconi was prominent. In the Hubble, as the exponent of the science-management synthesis he learned as one of the inventors of X-ray (and hence space) astronomy, the invention that earned him his Nobel; and, as Director-General of ESO, the exponent of ruthless focussed managerial skill of an order that would surely have guaranteed him success in any business.

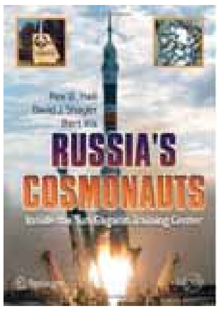
Most of us know someone who loathes Giacconi and yet despite this, most have a reluctant admiration for a man who invented large chunks of the soullessly efficient way we do astronomy today, and provoked a near-diplomatic incident with Chile by speaking his mind in a way that Directors-General are not supposed to do.

He writes movingly of his childhood in Fascist and post-war Italy; describes frankly how personal grief was a large factor is his career move back to Europe; and tells us that he never left one job before being sure of the next one, a sign of a vulnerability of which he is well aware. But this is also a man who describes the test phase of the Einstein X-ray satellite thus:

"A schedule of 1397 separate tests was developed, which had to be run 24 hours a day for 18 days...We actually achieved 23.5 hours a day in shifts for 30 days."

If you are interested in how "critical path" and "interface control" became essential tools of scientific creativity, read this book; it tells of a career that spanned, and made, enormous changes in how we do science.

Charles Jenkins
Mount Stromlo Observatory



Russia's Cosmonauts: Inside the Yuri Gagarin Training Center
Rex D. Hall, David J. Shayler, Bert Vis
Springer, Berlin / Praxis, Chichester, 2005 xxiv + 386 pp., €24.95 (softcover) ISBN 0-387-21894-7

The advent of the Internet means that nothing of historical note, in terms of scientific and technological advances, need now be lost. I find it staggering that so much of the history of physics has survived from past centuries, but also lament what has disappeared. We know much about Isaac Newton, because he himself ensured he would not be forgotten, but comparatively little about Robert Hooke, whose memory his enemy tried to erase.

Branch News

If only one portrait of Hooke had survived, so as to confirm that he was a hunchbacked dwarf, we might take a different view of what Sir Isaac meant when he wrote to Hooke that "If I have seen farther, it is by standing on the shoulders of giants."

By scanning photographs and documents of historical importance, and making them available on the Internet, the information is dispersed and no longer subject to destruction by flood, fire or insurrection. But first someone has to dig those documents and pictures out, and organise them. With the downfall of the Soviet Union, and the pressing concerns that therefore arose for the space industry there, the history of the 'other' manned space program could have been lost forever.

That this can no longer occur is due in no small part to enthusiasts like the authors of this book. Diligently they have gathered together a host of appropriately monochrome photographs, maps and detailed information concerning the Soviet space effort, particularly the manned program rather than the robotic space exploration projects, and gathered them into a hefty tome.

This is not scintillating reading, and some of the illustrations are almost amusing because of their apparent obscurity; for example, "The formal order transferring Pavel Popovich to the team in 1960." On the other hand, this book provides a welcome counterpoint to the sort of glossy production deriving from the American space program. It is not glitzy, but it is a significant printed resource. Doubtless it will soon be scanned and on the web itself.

Duncan Steel
Ball Solutions Group
Canberra, ACT

Editor's Note: See Sophie Vitesnik's article Scientific Study Tour of Russia on page 204 to read more about the Gagarin Training Center.

Branch News continued from page 186

September meeting news

The September meeting of the NSW Branch was held at the University of Sydney on 24 September. The invited speaker for the meeting was Dr Vivian Robinson from ETP Semra Pty. Ltd. His talk was entitled "Commercialising Research – From Scientist to Entrepreneur and Back Again".

Dr Fred Osman (left) and Dr Vivian Robinson (right).

The talk began with an explanation as to why a successful scientific entrepreneur would go back to being a scientist again: with funds, you can do your own research. In this case it was to help solve one of the larger problems facing humanity – the lack of fresh clean drinking water to large sections of the world community. Dr Robinson demonstrated his newest invention, a very small portable water purifier that could decontaminate, clean and disinfect a wide variety of polluted water sources for drinking. It was so small he carried it in his clothing without it being noticed and had the capability of cleaning about 10,000 litres of polluted water.

He then outlined how it was possible to go from a PhD student with a wife and child and no money, to running his own high technology manufacturing companies, all the while explaining some of the advantages and disadvantages of being an entrepreneur. As he said, the commercial world is not for everyone. You have to want to see your ideas turn into a successful product.

The largest benefit of being a successful entrepreneur was knowledge that you could do well by your own abilities. You owed nothing to anybody for your success or position in life. The hours were generally longer than salaried academics. But you enjoyed doing it so it was almost like getting paid for a hobby.

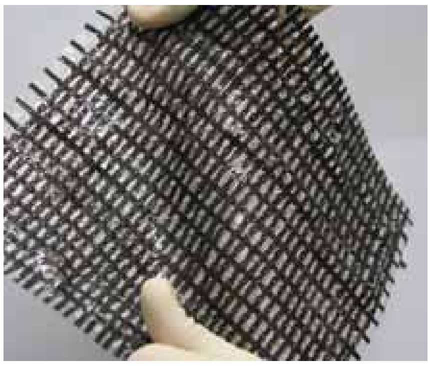
Entrepreneurial life meant an ability to succeed and be rewarded, but also an ability to fail. It gives any scientist a different outlook on life than that gained from a purely academic career. But as he said, being a scientific entrepreneur means you have access to your own laboratory. There is a risk moving from academia to industry; but the rules for the commercial world are simple and easy to learn with many rewards for making a successful transition. You never forget your scientific background and have many opportunities to continue research. In his case, he continued to develop new electron detection materials so that his product could maintain the highest signal to noise despite developments in the academic world. Along the way he was associated with some prestigious developments.

Finally, he discussed a different approach to understanding the world which could be applied to fundamental physics. Pointing out that Einstein introduced an approximation when deriving his field equations and then supplied a space-time geometry equation that was the result of eliminating that approximation, Dr Robinson showed a different model for the structure of matter, one which he claims derives a number of properties of matter, such as spin, charge, magnetic moment and mass in a manner in which he said the moving particle would automatically produce the special relativity corrections. He also mentioned that his model matched the observed dimensions of both the proton and electron.

The talk was well received and geared to scientists and members of the public alike with many discussions continuing later at a nearby Italian restaurant. The Australian Institute of Physics thanks Dr Vivian Robinson for his outstanding lecture!

Samplings

Stretching the boundaries of electronics
http://physicsworld.com/cws/article/news/35354



Credit: Science/AAAS

Physicists in Japan have found a way to disperse carbon nanotubes into a liquid polymer in order to create a rubbery material that conducts electricity. The inventors say that their material, which is more conductive than other elastic materials, is an important step towards realizing "stretchy" electronics for robotics and other electronic devices.

In the past when researchers have tried to create nanotube–polymer composites, strong intermolecular forces between the nanotubes has always made the structures clump together, producing a weak material.

However, by grinding nanotubes with an ionic liquid, the Japanese group — led by Takao Someya from the University of Tokyo — has managed to make them evenly dispersed.

Laser beams are entangled in space
http://physicsworld.com/cws/article/news/35171
Physicists in Australia and France have worked out a way to entangle the spatial properties of two laser beams for the first time. Such entangled beams could someday be used to make optical measurements at higher degrees of accuracy than possible with a single beam and even transmit large quantities of quantum information.

In principle, entanglement could be exploited in a wide range of applications such as the secure transmission of quantum-encrypted information or in quantum optical-measurement systems that are more accurate than their classical analogues. Now, Hans Bachor and colleagues at the Australian National University have managed to entangle simple spatial properties of two laser beams — the directions of travel and positions of the beams.

Carbon nanotubes, without the 'nano'
http://physicsworld.com/cws/article/news/35364
There are carbon nanotubes, fullerenes and nano-foams, but now researchers have discovered yet another new type of carbon material: colossal carbon tubes. Thousands of times bigger than their nano counterparts, these tubes have exceptional mechanical and electrical properties and could find applications from microelectric devices to bullet-proof body armour.

In the last 20 years, researchers have discovered several new forms of carbon in addition to graphite (the type of carbon found in pencils) and diamond. The colossal carbon tubes, invented by Huisheng Peng and colleagues at Los Alamos National Laboratory in the US and Fudan University in China, are 40–100 μm in diameter and are centimetres long, which makes them — unlike carbon nanotubes — visible to the naked eye. The researchers make them using a chemical vapour deposition process that involves heating a mixture of ethylene and paraffin oil at up to 850 °C in a quartz tube furnace (Physical Review Letters in press).

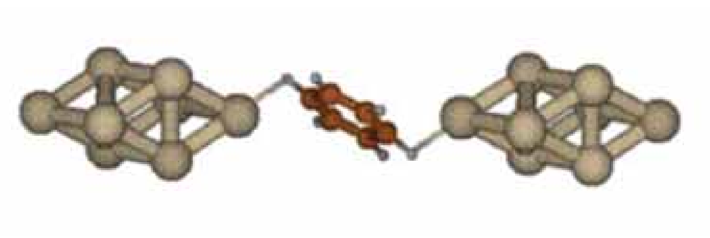
Diamonds are for tethers
http://www.nature.com/nature/journal/v454/n7205/full/454708a.html
Modified diamond nanowires produce an electrical response on binding to DNA. This discovery could pave the way to robust biosensors that use electrical signals to detect molecules.

Diamonds are well known for their tunable electronic properties which has led to impressive advances in the use of diamonds for sensing applications. Reporting in Angewandte Chemie (47, 5183–5185 (2008)), Yang et al. describe a method for making biosensors from diamond nanowires. Their devices produce an electrical signal on binding to DNA molecules, and are so sensitive that they can detect vanishingly small amounts of the target molecules (picomolar concentrations).

Ballistic breakthrough could lead to molecular logic gates
http://physicsworld.com/cws/article/news/35288
The first highly-conductive connection between a single organic molecule and a metal electrode has been made by an international team of physicists. This achievement could lead to the development of 'molecular electronics' devices with the potential to be smaller and faster than conventional transistors and logic gates.

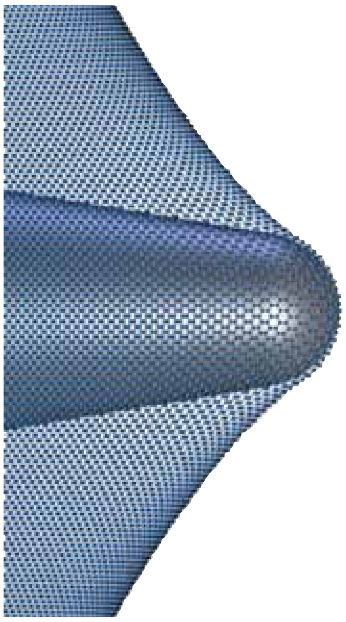
A high conductance would be possible if electrons were allowed to travel 'ballistically' across the metal-molecule junction – whereby every electron that enters the junction travels straight through more or less unhindered.

This occurs in many carbon nanotube devices or single-atom contacts, which reach the quantum of conductance — the maximum conductance possible for a single electron channel. However, this has never been achieved in single-molecule junctions before.



Snapshot from a computer simulation of the molecular junction being stretched. Courtesy: J van Ruitenbeek

Now, Jan van Ruitenbeek of the University of Leiden in the Netherlands along with colleagues in Australia (S. Wohlthat, Chemistry, University of Sydney), Germany and Spain may have solved this problem by making the first highly conductive molecular junctions. This involved binding benzene molecules directly to platinum metal electrodes, and the team found that the conductance of these devices reaches the maximum value possible for a single electron channel.
Phys Rev Lett 101 046801



Artist's impression of the indentation of a single atomic sheet of graphene by a diamond atomicforcemicroscope tip. Courtesy: Science

Graphene has record-breaking strength

http://physicsworld.com/cws/article/news/35055

Graphene is the strongest material in the world, according to new experiments done by researchers at Columbia University in the US. The secret to the material's extraordinary strength, says the team, lies in the robustness of the covalent carbon-carbon bond and the fact that the graphene monolayers tested were defect-free.

Since "wonder material" graphene - sheets of carbon just one atom thick - was discovered in 2004, it has been shown to be an extremely good electrical conductor; a semiconductor that can be used to create transistors; and a very strong material. But now, Columbia University's James Hone, Jeffrey Kysar, Changgu Lee and Xiaoding Wei have shown that it is the strongest material ever.

The researchers measured the intrinsic strength of the material — that is the maximum stress that a pristine (or defect-free) material can withstand just before all the atoms in a given cross-section are pulled apart at the same time. This was found to be 42 Nm–1 and represents the intrinsic strength of a defect-free sheet.

A physicist links magnetism, force and fatigue

http://www.nature.com/nature/journal/v454/n7202/full/454257e.html

Seth Putterman (UCLA) has written the following interesting commentary on a recent paper by Guralnick et.al., about the origins of fatigue damage in steels.

"If a metal bar is repeatedly stretched and released it becomes fatigued and, eventually, ruptures. The latter can occur suddenly and unexpectedly: sometimes materials scientists can find no obvious thermodynamic hint that a steel rod is about to break. I am interested in fatigue because it parallels other phenomena that concentrate energy density, such as triboluminescence, whereby diffuse stress makes a crystal glow.

In both triboluminescence and fatigue, applied forces cause molecular rearrangements. But fatigue also involves nanometre-sized defects that accumulate during the useful life of a piece of metal and organize themselves into a soft spot. Recently, Sidney Guralnick and his colleagues at the Illinois Institute of Technology in Chicago measured how much work is needed to complete each 'stretch and release' cycle in rods of AISI 1018 steel, a common low-carbon steel that is used in vehicle parts such as gears (S. A. Guralnick et al. J. Phys. D Appl. Phys. 41, 115006; 2008). This allowed them to follow changes in the material's response to force as it fatigued. A shift occurred at merely 12.3% of the time to rupture. What is happening inside the steel at this point is mysterious, but the number holds true even when the useful life of identically manufactured rods varies by a factor of 200.

Further clues will no doubt come from steel's piezomagnetism — the fact that its magnetism varies with the degree of stretch experienced. This relationship is complex: even when the metal is so slightly strained that it goes back to its original shape on release, its magnetic field does not return to the pre-stretched state. Investigations into this property may uncover the organizing principle of the nanometre-sized defects that underlie metal rupture."

Plasmons put laser light on the straight and narrow

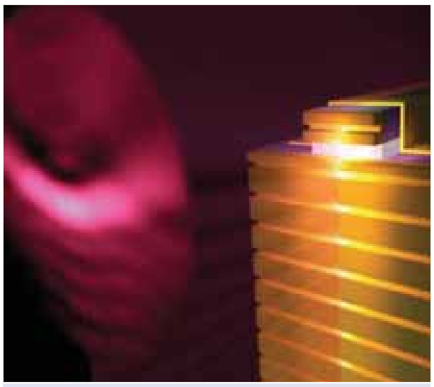
http://physicsworld.com/cws/article/news/35248

Researchers in the US and Japan have devised a simple way generate a nearly parallel beam of light from a semiconductor laser — without the need for bulky and expensive lenses.

Instead, a patterned metallic film is used to absorb divergent light from the laser and reemits it one direction. The team says the technique – which relies on collective electronic excitations called "plasmons" — could make semiconductor lasers cheaper, smaller and more efficient.

As most laser applications require a collimated beam with a much smaller divergence than is usually obtainable from semiconductor lasers, the light is usually collimated by placing a high-quality lens with a large collection angle (or numerical aperture) at the laser output.

Unfortunately, that makes semiconductors more expensive and relatively bulky. Now, however, Nanfang Yu, Federico Capasso and colleagues at Harvard University in the US, along with researchers at the optical-equipment maker Hamamatsu Photonics, have collimated laser light by placing a thin, patterned metal film on the output facet of a semiconductor laser (Nature Photonics doi:10.1038/nphoton.2008.152).



Artist's impression of the plasmonic collimator: the slit is at the top of the image and the grooves are below the slit. Courtesy: Harvard University

Product News

Coherent

TMC products improve vibration isolation by an order of magnitude

Current and emerging research technology is placing an ever more stringent demand on the control of environmental influences such as building and acoustic vibration. The Technical Manufacturing Corporation (TMC, USA) has been providing isolation products to meet these challenges for 40 years. As a dedicated specialist, TMC's isolation products are at the top of the field for performance yet remain cost effective.

TMC's Precision Electronic Positioning System with Vibration Cancellation (PEPS-VX) upholds this philosophy. Through the use of non-contact height sensors and proportional electronic valving, the design takes advantage of the exceptional mid to high frequency passive isolation of a pneumatic system combining it with the low transmissibility and sub-Hertz frequency resonance of a true active isolation system. With vertical closed-loop resonance ~0.2Hz, the 0.5-7Hz frequency band is an order of magnitude more efficient in isolation compared with a standard air isolator.

The PEPS-VX can be combined with a range of pneumatic isolators including TMC's compact sub-Hertz pendulum to provide sub-Hertz resonance in both vertical and horizontal axis. As PEPS-VX uses non-contact height control sensors, removing the traditional mechanical valve, re-levelling accuracy is dramatically improved and settling time is decreased. The PEPS-VX system can be purchased as an inexpensive upgrade to current air isolation systems to provide high performance for critical applications.

Combine with TMC's highly damped optical tabletops, acoustic enclosures or field cancellation systems to take full advantage of today's high resolution instrumentation.

For more information please contact Christian Gow at:
Coherent Scientific Pty. Ltd.
116 Sir Donald Bradman Drive
Hilton SA 5033
www.coherent.com.au
sales@coherent.com.au

New! Terawatt Ti:Sapphire Amplifiers

The unique high-energy Hidra Ti:Sapphire ultrafast multi-stage amplifier series is now available with 100mJ at 10Hz for terawatt applications.

The first stage of the fully-integrated Hidra amplifier is based on the Coherent Legend-Elite regenerative amplifier, pumped by the Evolution DPSS Nd:YLF (1kHz or 5kHz). The second stage of the amplifier is then pumped by a Nd:YAG (10Hz or 20Hz). The result is ultimate amplifier flexibility, offering the researcher access to mJ output at 1kHz or 5kHz, up to 100mJ output at 10Hz and the possibility of simultaneous kHz / 10's Hz output. The Hidra is available in 40fs ("USP"), 130fs ("F") or 1ps ("P") versions.

Features include:
- Two stage, high efficiency design based on regenerative and beam-optimised multipass amplifier designs
- Can be seeded by a choice of Coherent Micra, Mantis, Vitesse or Verdi / Mira Ti:Sapphire oscillators
- Up to 100mJ output energy
  - 40fs ("USP"), 130fs ("F") or 1ps ("P") versions
- Front-end repetition rate options of 10Hz, 20Hz, 1kHz or 5kHz
- Simultaneous kHz / 10's Hz operation options
- Vacuum compatible mounts option for terawatt vacuum environments
- Superior pulse-to-pulse stability < 3% rms
- TEM00 beam quality

For more information please contact Gerri Springfield at:
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Fibre-based Picosecond Laser for Micromachining

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

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

The laser is available in three versions as follows:
Infrared: 18W average power at 1064nm
Visible: 8W average power at 532nm
UV: 4W average power at 355nm

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

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

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Newport

Wyko NT9100 High Resolution Optical Surface Profiler from Veeco (USA)

The new bench-top Wyko NT9100 Optical Profiling System is the 9th Generation of the industry leading Wyko line of Optical Profilers. The NT9100 employs coherence scanning interferometry, also known as white-light interferometry, white-light confocal, or vertical scanning interferometry to produce high-resolution three-dimensional surface maps of the object under test.

The NT9100 has many advantages of competing designs including: easy measurement set-up, fast data acquisition, comprehensible and extensible data analysis, and angstrom-level repeatability.

A data stitching option adds a motorized stage and software module allowing scans of larger surface areas. An X-Y stage automation option brings programmability to the NT9100, a first for a Wyko tabletop profiler. Industry-leading Wyko 3D-Vision surface software provides over 200 built-in analyses as well as automated measurement sequences in an easy to use, flexible and powerful software package.

Features and benefits:
- Accurate, high resolution surface topography
- Sub-nanometer vertical resolution
- Stitching option for large area, high resolution surface scans
- Complete system including 3D-Vision surface analysis software
- Compact easy to use benchtop design
- Ideal for advanced materials research, PV research, waveguides, MEMS, thick films + many more

For more information contact Neil McMahon or Jim Efthimiadis at NewSpec *sales@newspec.com.au*
Tel: 08 8463 1967

Digital Delay / Pulse Generator from Berkeley Nucleonics Corp. (USA)

Berkeley Nucleonics Corporation (BNC) of San Rafael, CA, has released the Model 575 Series of Digital Delay / Pulse Generators. BNC has been design and manufacturing Pulse and Digital Delay Generators for 47 years and the Model 575 is the latest generation product that combines the properties of a pulse generator with that of a digital delay generator.

The Model 575 is a multi-channel pulse generator and digital delay generator in a single bench top instrument. A true pulse generator provides independent control of rate, delay and width with an external trigger. The 575 is the only multi-channel unit to permit differing rates for all channels; for example, Ch 1 can be set to 20 MHz, Ch 2 at 5 MHz, Ch 3 at 50Hz. There is an option for a separate external trigger input for each channel, or all channels can be triggered from the same common trigger.

Typically pulse generators do not offer fine resolution and accuracy of pulse delays and widths that a digital delay generator does. However, the 575 provides 250 ps resolution and up to 1 ppm accuracy for pulse delays and widths.

Before the Model 575, the market for Digital Delay Generators did not offer separate internal triggering rates for each of the channels. Now each channel can use the internal clock, a multiple of the internal clock (Clock-Divider), or one of two external trigger input connectors. For those that cannot use a common external trigger, this unique 'trigger per channel option' is ideal.

Modular output boards provide a variety of output options including both TTL and adjustable amplitude, 35V high voltage electrical and LED-optical at either 820nm or 1310nm. For those working only with optical triggering, an optical input is also available. Off-the-shelf transmitter/receiver pairs are used so one can easily match the output to the input and visa-versa.

The 575 features USB and RS-232 interfaces as standard. An optional communication module includes GPIB and Ethernet and Lab-View drivers are available.

Features:
- Delay Generator and Pulse Generator in same instrument
- High resolution: 250ps
- High accuracy: 1ppm
- Multiple channels, each can be triggered separately via different means
- Each channel can be individually set to a different frequency
- USB and RS-232 interfaces as standard

For more information please contact Neil McMahon at NewSpec Pty. Ltd.
neil.mcmahon@newspec.com.au
Tel: 08 8463 1967

New Motion Controller from Newport

The ESP301 is the successor to Newport's popular ESP300 motion controller. The ESP301 provides the same functionality as the ESP300 but includes a USB interface as standard and simplified front panel functions. For maximum compatibility, the ESP301 features the same motion commands and control algorithms and the same casing as the ESP300 allowing users to use existing stages and programs with the new controller.

The ESP301 can drive and control up to three axes of motion using any combination of DC or 2-phase stepper motors (up to 3A per axis) and is compatible with most of Newport's motorised linear and rotary stages and actuators.

Featuring a front panel interface Newport's unique ESP stage auto-detection and auto-configuration capability, the ESP301 provides easy operation and excellent functionality at an affordable price.

Key Features:
- 1 to 3 axes motion controller using universal driver technology (DC servo and 2-phase stepper motors)
- ESP technology, Newport's exclusive "plug-and-play" compatibility with ESP stages for easy setup
- 1000x programmable micro-step resolution for ultra-smooth low speed stepper positioning

- Synchronized circular/linear interpolation and continuous path contouring for complex motion profiling
- USB2.0, RS232 and optional GPIB communications link for easy computer interfacing

For more information please contact Neil McMahon at NewSpec Pty. Ltd *neil.mcmahon@newspec.com.au*
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Lastek

World's First 488 nm Diode Laser from Toptica!

TOPTICA Photonics AG extends its established diode laser series iBeam / iPulse by the wavelength 488 nm, a crucial excitation line for biophotonics and bioanalytics. Typical applications include flow cytometry, confocal microscopy and high throughput / high content screening (HTS / HCS).

Previously 488 nm excitation was obtained solely by Argon gas lasers or frequency doubled solid state lasers. From now on, the iBeam / iPulse diode laser system provides this wavelength, taking advantage of the new 488 nm single-mode diodes.

Comparing such diode lasers to gas or solid state lasers, the vital benefit is its direct modulation capability. The iPulse 488 offers both fast digital and analogue modulation. Thus external AOMs or similar devices become redundant. On special request, the iPulse switches between 3 power levels within few nanoseconds. Typical warm-up time lasts no longer than 5 minutes, significantly less than common Argon lasers require.

Key specifications of iBeam / iPulse 488 include:

• Excellent beam quality, i.e. wavefront error < 0.05 λ, $M^2 < 1.2$
• Ultrafast asynchronous pulse modulation up to 250 MHz (iPulse)
• Highest single mode fiber coupling efficiencies, i.e. > 60 % guaranteed, > 75 % typical and 87 % demonstrated
• Highest power stability (< 0.5 % drift within 48 hours)
• Wavelength coverage: 483 – 490 nm
• Output power: 20 mW
• CW and digital modulation
• 200 MHz asynchronous mod.λ
• < 1 ns rise time
• < 2 ns pulse width
• Analogue modulation up to 2 MHz
• TEMoo
• SM fiber coupling effic. > 70 % typ.

Typical applications for the iBeam and iPulse series include:

• Flow cytometry
• Confocal microscopy
• Micro lithography
• Computer-to-plate
• Disc mastering
• Ellipsometry

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web: *www.lastek.com.au*

Gentec 3kW High Power Detector

Gentec-EO is proud to introduce the new HP60A-3KW-HE High Power Detector that can handle up to 3 kW of continuous power with water cooling. The new HP60A-3KW-HE is equipped with Gentec-EO's legendary absorber for the highest damage thresholds in the industry.

Features:

• High Power Handling: 3 kW of continuous power
• Thermally Stable: Insensitive to variations in cooling water temperature
• High Quality Absorber: For the Highest Damage Threshold in the industry
• Can be read directly by a PC when the USB version is used.

Specifications:
Effective Aperture Diameter: 60 mm Ø
Spectral Range: 0.19 – 20 μm
Maximum Measurable Power: 3000 W
Repeatability: ±1 %
Max. Ave. Power Density:
10 kW/cm² @ 500 W
3 kW/cm² @ 3000 W

Typical Lasers: Large Beam, High Power, YAG (various), Excimer, DPSSL and CO_2
Common Applications: Cutting & drilling, UV Machining, Surface manipulation, Lithography, Marking

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PHASIS Epitaxial Thin Films now at Lastek

PHASIS is a commercialisation of the University of Geneva, which is a renowned academic research institution in the fields of thin film technology, and ferroelectric and superconducting materials. The University of Geneva is also the home institution of MaNEP, the Swiss National Centre of Competence in Research Materials with Novel Electronic Properties.

PHASIS activities are concentrated on the production and distribution of gold substrates and epitaxial PZT thin films for both academic and industrial research, and practical applications. Surrounded with excellent know-how and research expertise, PHASIS has a strong commitment to applied research.

Au(111) / Mica Thin Film
PHASIS Au(111) thin films are epitaxially grown using RF magnetron sputtering on freshly cleaved high quality Mica substrates. The films present an extremely high degree of structural quality including sur faces with well defined terraces well adapted to local probe studies. These films can be advantageously used for SPM calibration purposes. Each substrate is individually packaged in pure nitrogen.

PZT2080 Pb(Zr$_{0.2}$ Ti$_{0.8}$)O$_3$ Epitaxial Thin Film
PHASIS PZT thin films are epitaxially grown using off-axis RF magnetron sputtering on (001) Nb-doped SrTiO3 substrates. The films present an extremely high degree of structural quality including surfaces with very low corrugation and also good ferroelectric properties. Such films are ideal for nanoscopic investigations of ferrolectric domains, i.e. using AFM it is possible to read&write ferroelectric regions with inverted polarization.

R&D within PHASIS
• PHASIS is involved in several applied research projects with both academic and industrial partners. For example, PHASIS is interested in the use of new materials to bring new insights in the field of gas sensors. Moreover, the flexibility of PHASIS' equipment allows the production of thin films with tailored properties.

• Surface quality control is a perpetual challenge. PHASIS provides local probe surface analysis using Atomic Force Microscopy (AFM) and/or Scanning Tunneling Microscopy (STM).

PHASIS is therefore very open to any special request – please just ask!

PHASIS - offering access to high-quality epitaxial thin films and BioNano gold substrates

For more information contact:
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web: *www.lastek.com.au*

Warsash

NEW 100 kHz Digital Joulemeter from Warsash Scientific

Warsash Scientific is pleased to unveil the latest product from Spectrum Detector…the **mach 5** 100 kHz Digital Joulemeter, a true technical breakthrough in fast, real time pulsed laser energy measurement.

Capable of better than 100 000 pps measurement with 12-bit accuracy, **mach 5** enables users, for the first time ever, to zero-in on each and every pulse of their ultrafast pulsed lasers.

The **mach 5** captures and stores up to 4 million pulses (40 seconds of data at maximum rep rate) and on command dumps them to the user's PC via a full speed USB 2.0 interface. Comprehensive data analysis and system control is provided by full-featured LabView software and drivers.

The **mach 5** is optimal for characterizing such high rep rate sources as diode pumped Q-switched YAG/YLF lasers and ultra short pulse fibre lasers. It is ideal for product development, final test, life test, laser diagnostics, process development and process control. The system is expected to find wide use in applications relating to solar cell processing, semiconductor via hole drilling, wafer scribing and micromachining. The system's compact detector probe and small electronics package also makes it easy to integrate into industrial laser systems for on-board diagnostics and control.

The **mach 5** is available with two specially-designed fast joulemeter probes: the M5-SJ high-sensitivity silicon probe for measurement from nJ to uJ and 0.19 to 1.1 um, and the M5-PJ Pyroelectric for measurement from uJ to mJ and 0.25 to 15 um. Key to these probes is a small integrating sphere with a 6 mm input aperture that extends the useful energy range and enhances spatial uniformity.

In addition the probes include a detector-mounted thermistor that is used for temperature compensation providing high accuracy and linearity at high average power levels. The complete system – probe and electronics – is accurate to better than 4% and is NIST traceable.

For additional information on this and other Spectrum Detector products, contact
Warsash Scientific Pty Ltd
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Conferences 2009

February 2-6
International Workshop on Effective Field Theories: From the Pion to the Upsilon
Valencia, Spain
http://ific.uv.es/eft09/

February 16-19
AdS Collective
Madrid, Spain
http://www.ift.uam.es/workshops/Ad-Scollective/

23-26 March
GREENHOUSE 2009
Climate change and resources
Perth, WA
www.greenhouse2009.com

May 18-23
The 4th International Sakharov Conference on Physics
Moscow, Russia
http://sc4.lpi.ru/

May 18-23
Interacting Stochastic Particle Systems
Montréal, Canada
http://www.crm.umontreal.ca/Math-phys2008/stochastics_e.shtml

May 25-29
Planck 2009: From the Planck Scale to the Electroweak Scale
Padova, Italy
http://www.pd.infn.it/planck09/

May 26-30
The 8th International Conference on Radioactive Nuclear Beams
Grand Rapids, Michigan, USA
http://meetings.nscl.msu.edu/rnb8

May 26-31
The 10th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2009)
San Diego, California, USA
http://groups.physics.umn.edu/ci-panp2009/

May 27 - June 1
Flavor Physics and CP Violation
Lake Placid, New York, USA
http://fpcp2009.syr.edu

June 8-13
Disordered Systems: Spin Glasses
Montréal, Canada
http://www.crm.umontreal.ca/Math-phys2008/spin_e.shtml

June 14-20
The 21st Rencontres de Blois: Windows on the Universe
Blois, France
http://confs.obspm.fr/Blois2009/

June 15-19
International Conference on B-Physics at Hadron Machines
Heidelberg, Germany
http://beauty2009.physi.uni-heidelberg.de

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

July 1-5
The 11th International Conference on Topics in Astroparticle and Underground Physics (TAUP 2009)
Assergi, Italy
http://taup2009.lngs.infn.it/

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

September 23
ICNEP 2009 - International Conference on Nanoscience, Electronics and Photonics
Vancouver, Other
http://www.waset.org/wcset09/vancouver/icnep/

The 22nd Canberra International Physics Summer School on "COMPLEX PHYSICAL, BIOPHYSICAL AND ECONOPHYSICAL SYSTEMS" 8-19 December 2008

Since 1988 the Canberra International Physics Summer Schools have provided intensive, first-class training in topical areas of physics that are not covered in many senior undergraduate programs. For this reason, the Summer Schools have proved very beneficial for senior undergraduate and postgraduate students and early-career researchers from universities and research organisations. The 2008 Summer School continues this tradition.

Aims and Scope
The 2008 Summer School covers a wide range of topics in complex physical, biophysical and econophysical systems. The Summer School brings together leading international and Australian experts in complex systems science providing students with a broad introduction to this exciting field.

During the afternoon program, students will be guided through computer-based projects integrating key ideas from complex systems and introduce some of the current software tools.

Students will also become part of the ARC Complex Open Systems Research Network (COSNet) which provides links to researchers around Australia and the world.

Target Participants
The Summer School is targeted towards 3rd and 4th year undergraduates, Masters and PhD students and professional researchers. The level of exposition will be senior undergraduate or beginning postgraduate. We welcome participation by students from both Australian and foreign institutions. Free board and lodging accommodation will be provided to out-of-town students.

Registration
The capacity of the Summer School venue is limited and places will be filled on a first-come, first-served basis.

Visit the summer school homepage for registration details and information on student travel scholarships.

http://wwwrsphysse.anu.edu.au/~ccs106/SUMMERSCHOOLS/SS22/index.html

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