Australian PHYSICS

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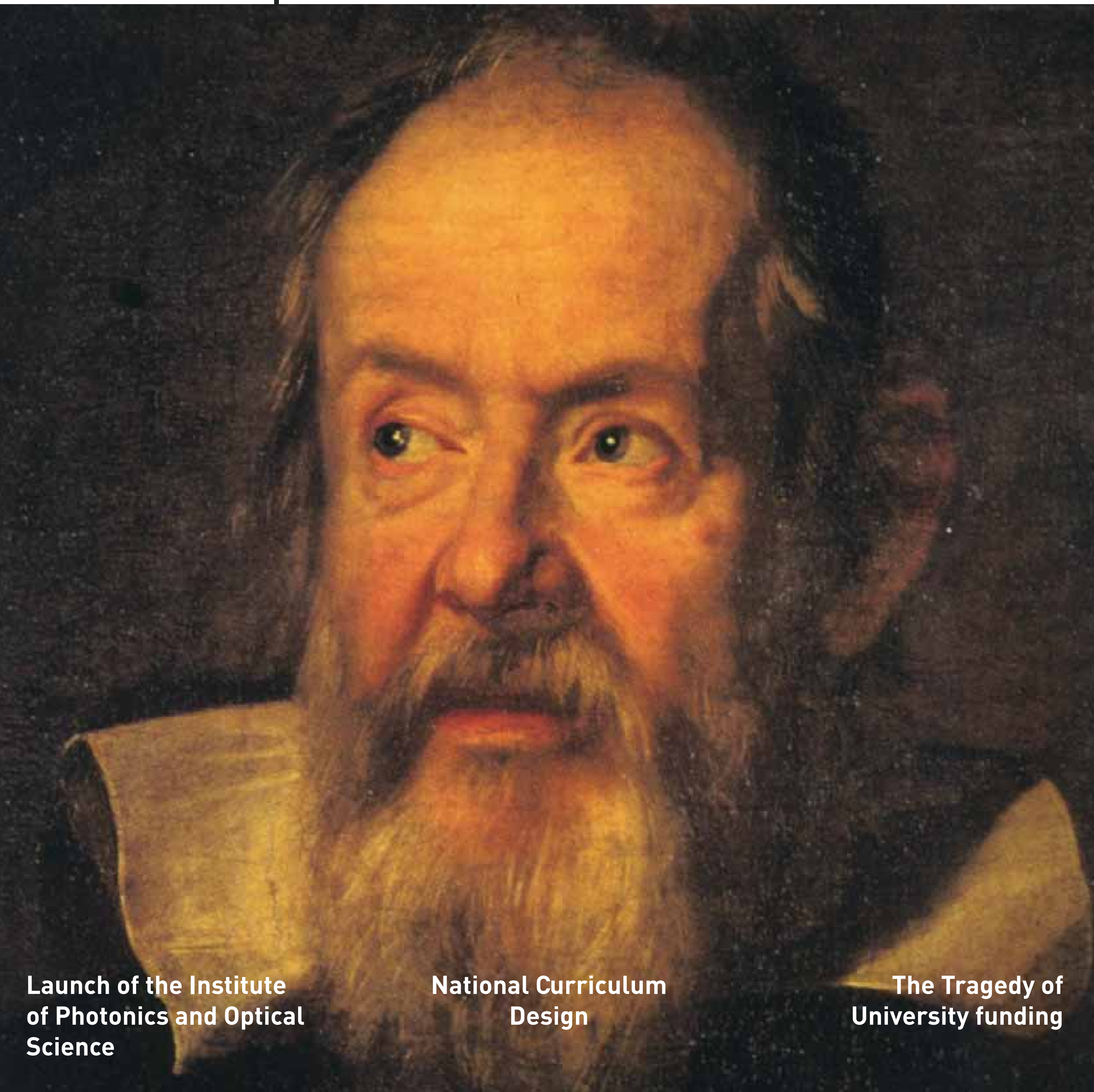
A Publication of the Australian Institute of Physics

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

Might Galileo have discovered Neptune?



Launch of the Institute of Photonics and Optical Science

National Curriculum Design

The Tragedy of University funding

Australian Physics
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Write an article for Australian Physics

We are looking for articles covering all aspects of physics in Australia. Perhaps your area of Physics is not well known, is unusual in some way, or you work at a smaller univeristy; perhaps your career has developed in uncoventional ways; if so, why not write an article for Australian Physics?

For more information contact editor-in-chief Dr M. L. Duldig at (Marc.Duldig@aad.gov.au).

Cover Image

Prof. David Jamieson investigates the possiblity that Galileo discovered Neptune long before any one else, but may not have been sure it was another planet. Read the full article on page 72.

Portrait of Galileo by Justus Sustermans 1597-1681 (Public domain)

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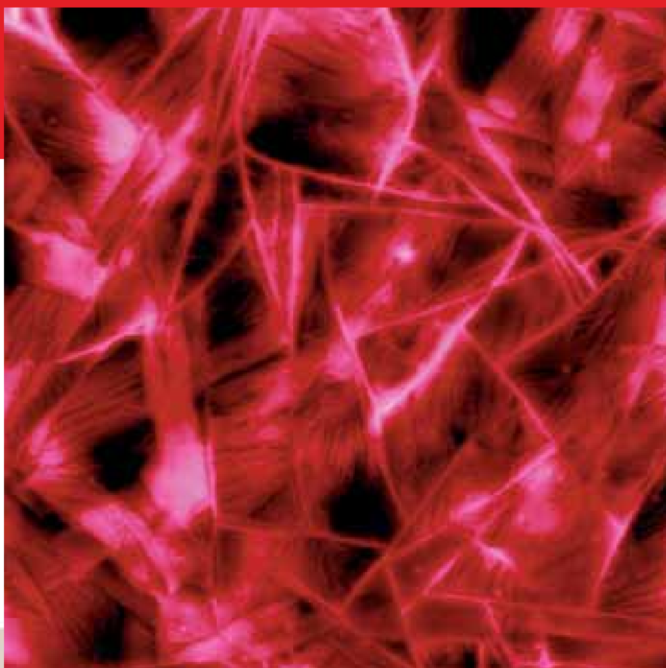

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Submission Guidelines
Articles for submission to Australian Physics should be sent in electronic format. Word or rich text format are preferred. Images should not be embedded in the document, but should be sent as high resolution attachments in eps, tiff or jpg. Authors should also send a short bio and a recent photo. The Editor reserves the right to edit articles based on length, space requirements and editorial content.

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Editorial

The way scientists choose to name objects, ideas, and theories can be simultaneously whimsical and damning, positive and negative if you will. This juxtaposition can lead to long lasting and tarnished results.

In physics we need look no further than the names of quarks: Top, Bottom, Down, Up, Strange and Beauty. None of these names have any physical connection to a particular property of the quarks – none of them can be said to be Up or even Strange for that matter – the names exist simply for identification purposes. Nevertheless, the names do make for good conversation starters with people outside of physics, and even though we may spend a substantial amount of time defending why the objects are so-named, at least we get to explain the physics along the way. In other matters, names, or more particularly the baggage that certain names carry, can be detrimental to our ability to carry conversations beyond the baggage.

I am reminded of a case that straddles physics and medicine. It was not long after nuclear magnetic resonance techniques were applied to materials science that the medical world realized it would also apply to organic materials, namely you and I; and thereafter the medical applications of NMR was born, except for one problem, the name. The word *nuclear* in the title of the procedure concerned so many patients, and quite possibly a few doctors, that with the flick of a pen Magnetic Resonance Imaging, or MRI was born. Patients were quite happy to flock to this new procedure knowing nothing nuclear was about to affect their precious bodies.

Physics is not alone. Just look at the publicity over swine flu, now called influenza A H1N1. So as not to hurt the economic prospects of pig farmers resulting from the fact that some people incorrectly feared they might catch swine flu from eating pork. Once again a simple, yet identifying, name wrestles our behaviour to the mat without any validity at all. No one thinks they will succumb to chickenpox from eating chicken, so why should some think we might catch swine flu from eating pork?

In the January/February 2009 issue of Australian Physics, Stephen Buckman and James Sullivan wrote about the their work with positrons and electrons at the ARC Centre of Excellence for Antimatter – Matter (see Experiments with Antimatter: New Australian Facilities, Jan/Feb 2009, page 18). That article has been both informative and, apparently, provocative as evidenced by it garnering two mildly disagreeable letters in as many issues. Such is the state of affairs with the name of the objects of our concern; they simultaneously simplify, and complicate, conversation.

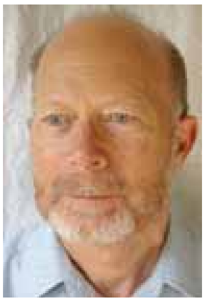
Now we have the film release of Dan Brown's book Angels and Demons – this movie will certainly cause much consternation among physicists. Now I am no destroyer of fun and can happily disable my rational side for the sake of entertainment. It may be exciting and captivating to think that the Vatican might be razed by a matter-antimatter device unless it is hunted down and defused, whatever that means; but we are not the problem, we know where the fiction and reality diverges. The problem lies with the very same people who refused to visit a medical NMR but would visit an MRI, or those would not eat pork because of swine flu.

What will we do if, and when, it becomes widely known that PET scans target body tissue with anti-electrons? And why stop there, in a 2006 CERN report it was claimed that "…antiprotons have four times greater cell killing power than protons, used in standard radiation therapy." Antiprotons! The horror.

John Daicopoulos

Submission deadline for the July/August 2009 issue is 29 June
Submission deadline for the September/October issue is 17 August

President's column
Federal Budget: surprisingly good for science!



In the last issue of *Australian Physics*, there was a short article about FASTS, the Federation of Australian Scientific and Technological Societies. FASTS represents the interests of some 60,000 Australian scientists and technologists, 'promotes their views on a wide range of policy issues to government, industry and the community', and 'works to influence science and technology policy for the economic, environmental and social benefit of Australia'. The membership of FASTS is not individuals, but the organizations to which they belong. The present membership of 61 societies (notably not including Engineers Australia) is grouped into clusters[1]. As president of the AIP, I am a member of the FASTS board, where I represent the physical sciences cluster[2].

As well as its advocacy role, FASTS collects and distributes relevant information to its membership. It plays, therefore, a pivotal role in ensuring societies such as the AIP are well informed about current issues. FASTS has the resources to do this due to capitation fees from member societies and a government grant. A typical example of information gathering was its summary of aspects of the recent federal budget of particular relevance to member societies.

The present government gained office with an agenda that promised an improved appreciation of the benefits of science to all aspects of community wellbeing. Given the present economic circumstances, it has been a welcome surprise that there is so much that is positive for science in the budget. In a significant breakthrough for space physics, an Australian Space Science Program will be established to support space research, innovation and skills development, and to coordinate Australia's national and international civil space activities, including partnerships with international space agencies. Feared cuts to government scientific agencies did not eventuate and both CSIRO and ANSTO received new infrastructure funding. New neutron research instruments for the OPAL reactor and a Centre for Accelerator Science at ANSTO, and a National Centre for Synchrotron Science at the Australian Synchrotron will provide resources for the Australian scientific community.

Welcome in the International Year of Astronomy is the decision to provide funding to continue operating the Anglo-Australian Observatory after the joint arrangement with the UK ceases in 2010, and to establish a national centre for Square Kilometre Array science in Perth.

For the university sector, chronic underfunding of teaching and research will be reduced: the former by increasing the rate of indexation of operating grants; the latter by increasing the infrastructure funding that accompanies competitive grants. While welcome and overdue, these changes are not due to begin until 2011-12. They have not only to survive the future budgetary effects of the global financial crisis, but also the next federal election. A new category of postdoctoral fellowships (Super Science Fellowships), in targeted research areas, will improve opportunities for early career researchers, although the uncertainty of three-year appointments continues to be a disincentive to long-term career satisfaction.

Leaving aside the budget, the recent decision to embark upon a national broadband network involving fibre-to-the-home has been an exciting development. Instead of being a perennial laggard, Australia will be among the leaders in the provision of communications infrastructure. It will provide exciting opportunities in scientific collaboration and education. It is not simply a case of doing faster the things we do now, but rather of things that are only imaginable now (and maybe not even imagined yet) becoming possible. It is the kind of bold step that we see so infrequently.

Although individual funding decisions, at budget and other times, will have supporters and detractors I think we can all be pleased that there appears to be a new recognition of the role that science and innovation must play in Australia's future, and that we need to invest appropriately to ensure this happens.

1. Agriculture and Food Sciences, Aquatic Sciences, Biological Sciences, Chemical Sciences, Mathematical Sciences, Medical and Cognitive Sciences, Physical Sciences, Plant and Ecological Sciences, Technological Sciences, General Members
2. The members of the FASTS physical science cluster are: Astronomical Society of Australia, Australasian Radiation Protection Society, Australian Ceramic Society, Australian Institute of Physics, Australian Meteorological and Oceanographic Society, Australian Nuclear Association, Australian Optical Society, Australian Microscopy and Microanalysis Society, Society of Crystallographers in Australia and New Zealand, Vacuum Society of Australia

Branch News

Victoria

The Victorian Branch lecture in March was presented by **Dr Jacek Jasieniak** (CSIRO Molecular and Health Technologies) on 'Past, present and future trends in organic solar cells'.

In the 1950's Bell Lab scientists produced the first solar cell demonstrating that silicon could be used to convert the sun's light into electricity. The majority of currently available solar cells are still silicon based. These cells are now a well-established technology; unfortunately they involve high material and fabrication costs. The price of solar cells must be significantly reduced for solar energy to be competitive with current fossil fuels. Silicon-based technologies are unlikely to reach this target and so alternate technologies are becoming increasingly attractive.

One promising candidate is organic solar cells; a family of polymers that are both strongly light absorbing and electrically conducting. These polymers can be processed from solution and printed onto rigid or flexible substrates. They form an ideal material for the fabrication of large area solar cells and promise very low cost production.

Jacek's talk introduced the current physics of polymer based organic solar cells and discussed how molecular engineering is applied to maximize the fundamental processes for the operation of these devices, including how their architecture must be designed to maximize performance.

The April lecture on 'Surface acoustic waves: A new paradigm for driving ultrafast microfluidics' was delivered by Dr Leslie Yeo from the Department of Mechanical & Aerospace Engineering at Monash University.

Victorian branch chair Nicoleta Dragomir with Leslie Yeo, Monash University

Recently there has been significant interest in microfluidics - the manipulation of fluids at micron and submicron dimensions. This interest has been driven by a range of exciting practical applications in biomedicine and pharmaceuticals, homeland security, environmental monitoring and fuel cell technology.

Although current micro and nano technology has lead to the fabrication of very small chip-scale devices, the ability to move fluids through such small devices still relies on large benchtop syringe pumps - quite the antithesis of microfluidic philosophy.

Electric, acoustic and magnetic fields have been used to develop miniature pumps, valves, and other devices to fit on a chip, but they are both slow and inefficient.

Leslie's talk gave an overview of recent work at Monash on surface acoustic waves – the nanometre analogue of earthquakes - that propagate along the substrate of a piezoelectric material.

These waves can be harnessed for a range of rapid microfluidic applications, often two orders of magnitude faster than other methods.

New South Wales

The March meeting of the NSW Branch was held at the University of Sydney on 24 March and featured two unique topics in physics to launch the Branch's first double meeting of the year.

Our first speaker Dr Rob Robinson is the Acting Chief of Research and Head of the Bragg Institute at the Australian Nuclear Science & Technology Organisation, just outside Sydney. His talk gave us an insight into how Australian science is entering a new "golden age", with the recent start-up of bright new neutron and photon sources in Sydney and Melbourne, respectively.

Dr Robinson explained that the OPAL reactor and the Australian Synchrotron could be considered the greatest single investment in scientific infrastructure in Australia's history. Dr Robinson stated that fuel was loaded into the OPAL reactor in August 2006, and full power (20MW) was achieved in November 2006. The formal use commenced in 2007, and fully analysed data sets have now been taken on all seven of the initial suite of instruments. Three further instruments are in various states of construction, and substantial additional investment is also being made in sample-environment, extra instrumental options and polarised-neutron technology. An update was given on the status of OPAL, the performance of its thermal and cold neutron sources and instruments, and the talk showed the selection of the first scientific results and future plans.

The second talk of the night featured Professor Roger Lewis from the University of Wollongong. Prof Lewis is an active researcher in the area of terahertz science and technology. (The terahertz region of the electromagnetic spectrum falls between the infrared and microwaves.) The talk covered the areas of fundamentals of terahertz science and technology, the challenges presented, and how these are being addressed by current research. Beyond the rainbow lie "colours" imperceptible to the human eye. "Terahertz", or "T-rays" are a palette of these. T-rays offer a different and unique way of viewing our world. While terahertz (THz, 10^{12} Hz) radiation has been around for at least as long as the sun has been shining it has in the past been difficult to produce, manipulate and detect – certainly in contrast to the sophisticated technologies that have arisen in the radio and optical regions of the electromagnetic spectrum that bracket it.

Now, thanks to intense research over the past few years, the so-called "terahertz gap" between electronics and photonics is being bridged ever more strongly, opening up a myriad of practical applications. Detectors of THz radiation include the pneumatic Golay cell, pyroelectric and Schottky devices and, most sensitive, liquid-helium cooled bolometers. Each of these detectors has its limitations. THz optical elements are not as advanced as their visible optical counterparts: metallic mirrors are used extensively; lens materials suffer a combination of difficulties due to relatively high

refractive index on the one hand and relatively high absorption on the other. Better THz emitters will assist in all applications of THz technology and this has been the subject of intense research lately.

Practical applications span secure communications, especially for secure local area networks, where the absorption of THz radiation by atmospheric water vapour ensures the signal is highly attenuated and less liable to eavesdropping; security applications, including stand-off detection of concealed weapons and explosives and non-contact scanning of mail for illicit substances; sustainability, in sorting and monitoring plastics; medicine, especially in dental and dermatological applications where additional and complementary information is available compared to X-rays; agriculture, in the measurement of hydration in real time.

Student Prize Giving

The Australian Institute of Physics has been very active each year in acknowledging prizes for the best graduating students from each University in recognition of there outstanding achievements in Physics. This initiative has been set-up to recognize and target students to be involved in future AIP initiatives. On 1 April the AIP secretary Dr Graeme Melville attended the UNSW prize giving ceremony and presented a $400 cheque and an AIP certificate to Mr Gidon Jones for his outstanding recognition in attaining the highest aggregate in the Bachelor of Science program. On 22 April the AIP secretary Dr Graeme Melville also attended the Macquarie University prize giving ceremony to award the AIP prize to Mr Chris Wood for his outstanding achievements in Physics. The AIP congratulates both students on there achievements.

April

The April meeting of the NSW Branch was held at the University of Sydney on 28 April and featured two unique topics in physics to launch the Branch's second double meeting of the year.

Our first speaker Dr Bruce Yabsley is a particle physicist with interests in flavour physics, neutrinos, and statistical methods. In the nineties he worked as part of the Australian team on the NOMAD experiment at CERN, completing a PhD on neutrino oscillations. He has presented reviews at international conferences on new physics in charm decays, anomalous quarkonium-like states, and quantum entanglement; and serves on the advisory committee for the International Workshops on Charm Physics. Bruce is currently an ARC Australian Research Fellow at the University of Sydney, where he is pursuing research into the structure of mesons.

From left to right, Dr Graeme Melville (AIP Branch Secretary), Professor Roger Lewis and Dr Fred Osman, (AIP Branch Chair).

His talk gave us an insight into the Standard Model of particle physics – describing the fundamental constituents of matter, and their interactions – that has been extraordinarily successful.

The second talk of the night featured Professor Joe Wolfe from the University of New South Wales. Joe has won awards and medals from the acoustical societies of Australia, France and America. Joe is also a composer. His most notorious orchestral work is The Stairway Suite, a set of symphonic variations on Stairway to Heaven, each in the style of a different composer. His talk introduced some of the interesting effects, including multiphonics or chords produced in woodwinds by superposition of standing waves, and the interactions between the resonances of the bore and the vocal tract. Wind instruments have a valve (reed, player's lips, air jet) coupled to two acoustic waveguides: the bore of the instrument (downstream) and the player's vocal tract (upstream). The talk gave an introduction to each of these elements, discussed some of the subtle and interesting effects that arise and illustrated them with demonstrations.

The didjeridu, of course, uses variation in timbre rather than pitch to create musical structure. Large magnitude peaks in the impedance spectrum of the player's tract inhibit bands of harmonics in each frequency range where they occur. The remaining bands of harmonics fall in the same range as the formants of the voice, and so are especially noticeable as the player varies them. In another technique, called vocalisation, the lips and vocal folds both vibrate to modulate the flow of air, resulting in complex sound spectra with sum and difference frequency terms. To study this, the vibrations of the lips and vocal folds were measured independently via skin electrodes, which show the increased electrical admittance when the lips and folds make sound. The team has shown how vocal tract effects are sometimes important on reed instruments. The saxophone has strong resonances only in the lowest 2.5 octaves of its range. Above this range, the player must tune a resonance of the tract near to the frequency of the note played. Tuning of the tract resonance is also required for some exotic effects on clarinet, including the famous glissando in the opening bars of Gershwin's 'Rhapsody in Blue'. Wolfe thanked the team of collaborators and students whose work was reported in this overview talk, including Jer Ming Chen, Paul Dickens, Neville Fletcher, Lloyd Hollenberg, Ben Lange, Alex Tarnopolsky and especially Wolfe's long-term collaborator, John Smith.

Dr Frederick Osman

South Australia

On 26 March the SA Branch held its annual presentation of the Bronze Bragg medal and certificates. The medal, awarded for the best performance in the 2008 Year-12 Physics exam and presented by Dr Michael Anderson (of the software company "Run with Robots") went to Danielle Fitzpatrick. Dr Anderson also presented certificates to 14 students who scored 20/20 in the exam. Dr Anderson then gave a public lecture on "Physics and Movie Visual Effects". He explained that the way movies are produced has changed drastically in the last 15 years. Using computer generated visual effects for anything dangerous, unnatural or expensive has become commonplace. Explosions, huge sets, lightning and water are examples of components often faked using computers. He discussed the physics involved in creating such effects, as well as the physics involved in getting these effects on to film. Dr Anderson showed that knowledge of the laws of Physics is of great benefit in producing movie visual effects, even when it is necessary to "bend" the laws to get what the director wants. The talk was well illustrated with animations and examples of the finished products from well-known films.
Laurence Campbell

Dr Michael Anderson presents Danielle Fitzpatrick with the Bronze Bragg medal

SA branch chair Dr Giuseppina Dall'Armi-Stoks and Dr Michael Anderson with the Bronze Bragg medal winner and the 14 students who received certificates.

Letter

Dear Sir.
Sullivan and Buckman in the introductory part of their article in the January/February 2009 issue of Australian Physics state on page 18: *Anderson's experiment verified the mind-boggling insight displayed a few years earlier by Paul Dirac in interpreting negative solutions for the 'Dirac Equation' ... as the existence of a positive electron, or the positron.* They give a reference to a 1928 paper by Dirac.

The story that Sullivan and Buckman present of Dirac and the positron was one I had imbibed years ago and believed until I read Tony Rothman's book *Everything's Relative and Other Fables from Science and Technology*[1]. In this book Rothman presents his findings when he critically examined some of the popular stories that are propagated about discoverers and inventors. One of the stories he looked at was that about Dirac and the positron. On page 96 of his book, he states that:

> *... there is no mention of antiparticles in the two famous 1928 papers; those are devoted entirely to the fundamentals of the theory. The "prediction" comes two years later, in a 1930 paper Dirac titled "A theory of Electrons and Protons." Protons? ... When Dirac found his negative-energy solution, he realized that it could be described by a positive charge. The only particles around with positive charges were protons, and in his paper he quite clearly states "the holes...are the protons."*

He never says anything about antielectrons or antimatter.

Rothman, on page 97, quotes from Dirac's Oppenheimer Memorial Prize acceptance speech[2]. Dirac, when referring to his early work, states that the only particles of positive charge known at the time were protons and

> *'...that was a worry because the protons ... are very much heavier.'* He went on to state: *But still, I thought there might be something in the basic idea and so I published it as a theory of electrons and protons, and left quite unexplained how the protons could have such a different mass from the electrons.*

In the part of this speech quoted by Rothman, Dirac asserts that it was Herman Weyl who maintained that the holes had to have the same mass as the electrons.

Rothman suggests that the fact that so many physics textbooks misattribute the prediction of positively charged electrons to Dirac is '...direct proof that nobody bothers to read Dirac's papers anymore.'.
Graham Day
Heathpool SA

References

[1] T. Rothman, Everything's Relative and Other Fables from Science and Technology, John Wiley and Sons, Inc., Hoboken, New Jersey, 2003
[2] P.A.M. Dirac, The Development of Quantum Theory, Gordon and Breach, New York, 1971, pages 51-55

Council News

Report from AIP Council Meeting 12-13 February 2009

The annual meeting of the AIP Council was held at the University of Melbourne. The AIP council consists of the Executive, Immediate Past President and Branch Chairs. While it is the decision making body, many of its function are delegated to the Executive, as allowed by the constitution. Representatives of groups and cognate societies are invited to attend and present reports.

From reports by the executive

• During 2008 much effort was devoted to introducing web-based management. Despite teething problems this will lead to improved efficiencies and enable more funds to be directed to other activities including to branches.
• Noting that industrial physics was an important career option, it was recognised that the AIP needs to get this message to career guidance counsellors, and to provide better support for this membership cohort,
• There is one vacant position on the executive, and it would be useful to have someone who can engage with younger members.
• A change in printing contractor, has allowed us to print Australian Physics in all-colour at reduced overall cost. Seeking more articles of an appropriate nature, and increasing advertising revenue remain critical issues. The editorial board is being reformed.
• The congress in Adelaide produced a surplus.
• The budget for 2009 includes a significant one-off item for the website development
• Subscription renewals were lower than usual at the time of the Council meeting, probably due to the delays associated with introducing web-based renewal As a result the early-bird date had been extended to the end of February.
• The StudentLink scheme had started slowly, but 13 Physics departments have now joined the scheme,
• There were five accreditations during 2008, and there have been enquiries from the universities in Bahrain and Saudi Arabia
• The meeting showed by acclamation its appreciation of departing executive members: David Jamieson (past president) and Ian Bailey (secretary)

From reports by branches

Australian Capital Territory: Most successful activities are laboratory tours. A highlight of 2009 will be a visit from Eric Mazur to contribute to the National Workshop on Interactive Learning in Undergraduate Physics.
New South Wales: The fee for industry day had been increased without affecting the strong support for the event.
Queensland: The youth lecture tour had been very effective, and the Tools of Science program run by Norm Heckenberg also attracted a lot of interest.
South Australia: The national science week awards event was a great success, as was the student night where postgraduate students talked about their research.
Tasmania: Public lectures have been successful, and in particular Bob Delbourgo's lecture on the Nobel Prize. The professional development seminar for teachers was successful and provided a useful networking event.
Plans were in progress for the student quiz day, to be run concurrently in two centres.
Victoria: The July lectures at the University of Melbourne were very successful. The Switch on to Physics program run by Dan O'Keeffe, continued to be very popular, with 1100 students participating. However, the program may have to be discontinued due to lack of funds.
Western Australia: The main activities are the deLaeter youth lecture, that was very well attended, the postgraduate student conference and the industry evening.

From reports by groups

Solar, Terrestrial and Space Physics: The group has participated in three international conferences, two of which were held in Australia. Consideration was being given to giving an award for the best paper published by a postgraduate student in a refereed journal.
Condensed Matter and Materials: The central activity of the group was the annual Wagga conference. It is hoped that it could be run in New Zealand next year.
Physics Education: There was good attendance at Congress events. The group has been working on a response to the National Curriculum framing paper, and is cooperating with the ACT branch to bring Eric Mazur to Australia.
Women in Physics: Cathy Foley had attended the Women in Physics conference in Seoul, Korea. It was clear that Australia is doing well with respect to the participation of women in physics, especially in the proportion holding senior administrative positions.

From reports by Cognate Societies

Australasian College of Physical Scientists and Engineers in Medicine: Last year had seen the first student graduate from the five-year training program for medical physicists.
Astronomical Society of Australia: The number of members was increasing. Highlights of the year were Brian Schmidt winning the Gruber prize for cosmology, Roy Allen being celebrated for his 31 years of service on the ASA Council, and the inaugural theoretical astrophysics school. A joint AIP/ ASA IYA lecture tour is being organised,
Australian Optical Society: It was noted that the optical society of America had decided to form student chapters in universities, and this was showing signs of being a successful initiative.
Australasian Society for General Relativity and Gravitation: Australia's role in gravitational wave detection received a major boost in 2008 with the awarding of an ARC LIEF grant titled "Australian Partnership in Advanced LIGO" to the ANU and the University of Adelaide. Australia becomes the 3rd international partner in the US Advanced LIGO Project along with the UK and Germany.

Other matters

• Planning for the 2010 congress, to be held in Melbourne 5-10 December 2010, is underway.
• The AIP response to the Framing Paper on the National Science Curriculum is being prepared by Physics Education Group with advice from AIP education convenor Mark Butler,
• Various membership strategies were discussed, including reduced student membership, a larger discount for cognate society members, and a members-only section on the AIP website.

News

Sea Ice Physics and Ecosystem eXperiment

The Sea Ice Physics and Ecosystem eXperiment (SIPEX) was Australia's first major field program contributing to the goals of the International Polar Year (IPY). The experiment was conducted from the icebreaker Aurora Australis in September and October 2007 and involved 45 scientists from 12 countries. The multi-disciplinary experiment focused not only on the physics and biology of the sea ice, but the strong interactions and dependencies of the structure, thickness and snow properties and their effects on the under-ice algae and ecosystem of the Southern Ocean.

SIPEX was timed to coincide with the period of maximum sea ice extent. We had an ambitious objective – to penetrate hundreds of kilometres of sea ice until we reached the coast of Antarctica. The ice conditions we encountered were particularly difficult at times, with some incredibly thick ice making it very hard to get the ship where we wanted to go. But with some excellent navigation from the Captain and officers we achieved our objective, arriving at the Antarctic coast approximately 10 days after first reaching the ice edge. We then steamed west past the coastal fast ice and the Dalton Iceberg Tongue, and pushed our way north again through the sea ice until we reached the ice edge again.

While in the sea ice we stopped at 15 'ice stations', where we took a series of measurements to characterise the sea ice environment. Each ice station took between 12-24 hours, with up to 50 scientists working out on the ice floes at once.

At every ice station a key set of measurements were made along a 200 metre-long transect, and were coordinated to provide detailed surface measurements of the ice and snow properties of the ice floe.

Once all the snow measurements were completed a group of hardy souls, known as the drilling team, would measure the ice thickness at one metre intervals. This is a fairly easy task when the ice is relatively thin and level, but when the ice is ridged it can be over five metres thick and drilling through it can be a problem – even with an electric power drill and auger. The thickness data provide a detailed profile of the variability in ice thickness across the floe, which together with information from ice cores, tells us how the ice floe formed. The ice cores were usually taken at three places along each transect and then analysed in a freezer laboratory on the ship to reveal the crystal structure of the ice, its salinity and other chemical parameters.

Surface measurements were used to validate other instruments, such as the laser altimeter and snow radar, which were mounted on a helicopter. The helicopter-based measurements provide information over much larger areas (hundreds of kilometres), but the information collected along the thickness transects helps to validate, or 'anchor' the aircraft measurements with real surface measurements. At each ice station the helicopter would fly over the transect to compare airborne and surface measurements. The aircraft measurements helped to validate satellite-based measurements, which provide data over the entire Antarctic sea ice zone. This information can then be used to detect larger-scale changes.

Image courtesy of Australian Antarctic Division

A great deal of data were collected during SIPEX that will not only improve our understanding of the physics and biology of the Antarctic sea ice zone, but also provide a baseline against which any future changes can be assessed.

Anthony Worby
Australia Antarctic Division

Solar Linkages to Atmospheric Processes

Solar Linkages to Atmospheric Processes (SLAP) is an International Polar Year project investigating the links between changes in solar output and weather and climate. Thunderstorms and lightning strikes drive electricity around the world and form part of a global 'atmospheric electric circuit' that flows between the ground and the lower reaches of the ionosphere – about 80km up.

Thunderstorms and electrified clouds are the 'batteries' of the atmospheric electric circuit, which drive the current from the ground to the ionosphere, while lightning is a visual representation of the current. The flow of current around the world is modulated by cosmic rays, which control atmospheric conductivity. (Cosmic rays are in turn modulated by the solar wind). The circuit is completed when the current trickles back to Earth, in regions remote from thunderstorm activity, such as Antarctica.

Through the International Polar Year (IPY) project, Solar Linkages to Atmospheric Processes, Australian Antarctic Division scientist, Dr Gary Burns, and his colleagues Drs Oleg Troshichev and Alexandr Frank-Kamenetsky of the Arctic and Antarctic Research Institute, are measuring the atmospheric circuit high on the Antarctic plateau at Vostok, near the centre of East Antarctica. Instruments have also been deployed at three sites in West Antarctica by Dr Martin Jarvis of the British Antarctic Survey and another will be deployed at the French-Italian station, Concordia, at Dome C, in January 2009.

Meteorological and solar variability influences on the atmospheric circuit are well established. The question now is whether the electric circuit actively links solar variability and weather,

Image courtesy of Australian Antarctic Division

or if it responds passively to both meteorological and solar variations. Understanding this interaction is important because changes in the global electric circuit, caused by solar variability, could alter the conditions under which thunderstorms develop. Recent results from Dr Burns and his colleagues support an active link.

A theory under investigation is that current flowing through the atmospheric electric circuit influences cloud formation. Measurement of the circuit will enable investigation of the cloud microphysics processes and meteorological responses (such as thunderstorms) at sites around the world.

Accurate measurements of the atmospheric electric circuit could also enable scientists to monitor changes in global thunderstorm activity as the world warms.

'It's thought that an increase in temperature of one degree Celsius could increase meteorological electrical activity by 10 percent,' Dr Burns says. 'So changes in the global electric circuit could provide an indication of the way the Earth's weather is changing.'

A model of the global electric circuit has been developed by collaborators at the University of Texas, Dallas, incorporating variations in cosmic rays, energetic particles, natural radioactivity and aerosols. Outputs from the model will be compared with measured atmospheric circuit responses to these variations, to refine understanding of the processes involved.

The atmospheric electric circuit responds quickly to global thunderstorm activity. Thunderstorms preferentially occur in summer, over land in the equatorial and mid-latitude regions and in the local afternoon (see for example *http://thunder.msfc.nasa.gov/data/OTDsummaries*).

Dr Gary Burns
Australian Anatarctic Division

Dr Jean E Laby (1915-2008) inducted to the Victorian Honour Roll of Women 2009

The Victorian Honour Roll of Women recognises and celebrates the achievements of Victorian women. All of the inductees have used their skills, knowledge, and commitment to better their communities. They have excelled in their chosen fields and are testament to the depth of talented women we have in Victoria.

"Being the first female PhD in physics showed it could be done. She pushed on the doors that were locked to women and burst through them" said Professor David Jamieson, Head of the School of Physics. In 1959 Dr Jean Laby became the first woman to receive the Doctor of Philosophy degree in physics at the University of Melbourne. Jean was one of Australia's pioneer atmospherics physicists and the sole female atmospherics physicist of her generation, and her work gained international recognition. She had several papers published in Nature. As a role model she opened the way for women to participate equally within the scientific and academic world at a time with obstinate gender hurdles.

Professor David Jamieson from the University of Melbourne described Jean as a 'trailblazer'. "There is a legion of female PhD students who have followed on from Jean's legacy." Jean and her sister, Bet spent much of their childhood at the university) accompanying their father, Professor Thomas Laby, who was head of what is now called the physics department. Not only did Jean inherit her father's love of physics, but also the desire to teach. According to Professor Jamieson: "The two don't always go together. Scientists aren't always the best communicators."

Image courtesy of University of Melbourne

Dr Jean E Laby

In 1961 Jean took up the position of senior lecturer at the Royal Australian Air Force Academy at Point Cook and remained the only woman on staff until 1980. In 1975 she obtained a $25 000 (USD) grant for a global study of climatic impact and developed lightweight micro-electric control systems to automate the collection of high altitude atmospheric data. Jean and her colleagues can claim to be the pioneers in an experimental technique that continues to be of critical importance today to our understanding of, and the interaction with, the Earth's climate. "She laid the foundations for climate change and pollution studies with the techniques they developed."

Jean also travelled to South Africa and South America to undertake atmospheric research with high-altitude balloons. "They camped out in fields in primitive conditions and she just put up with it, along with all the discrimination".

University of Melbourne

A photonics simulator for secondary science students

How can we improve perceptions of science amongst high school students? We are tackling this question by creating an educational computer game in photonic communications systems. We aim to inform and engage students about how information is coded digitally and then sent through networks from source to receiver by allowing the students to build their own network and see their message as it travels through the network. Our program is aimed at students in years 9 – 11 before they consider final subject choices for HSC and when they may not yet have chosen a career path. We have identified specific curriculum objectives the simulator can address, including applications of light for "the world communicates" as well contributing to hands-on experience of problem solving.

We have trialled the program in several schools, and are keen to extend its use into more secondary schools. It offers a downloadable movie to help in "getting started" and is self-correcting in the sense that students can check when a network is working because it transmits the desired message error-free to the correct address.

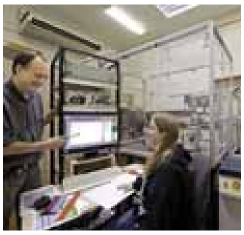
We acknowledge modest support from the SPIE Education and Outreach Fund. The program is freely available and we encourage both teachers and their students to try it! You need Flash to be loaded on your PC or Mac computer for it to work. We are keen to receive your feedback! *http://web.science.mq.edu.au/groups/cudos/education/Simulator.html*
Judith Dawes, Dept of Physics, CUDOS, MQPhotonics, Macquarie University

The Hutton-Westfold Observatory
The new Hutton-Westfold Observatory will be used extensively by Monash University astrophysics students, and represents a vast improvement upon previously available facilities. Monash students will be able to observe stars and distant galaxies that are ten thousand times fainter than what can be seen with the unaided eye. These observations will allow students to discern much about these celestial objects and the Universe in which we reside. The facility has been developed jointly by the School of Physics and the School of Mathematical Sciences, and is named in honour of the late Don Hutton and the late Kevin Westfold, who made significant contributions to astronomy and student learning at Monash University over the course of several decades.
Monash

NMI turns 5!
Australia's National Measurement Institute (NMI), turns 5 on 1 July 2009. NMI is the country's peak measurement organisation, responsible for the national measurement infrastructure and for maintaining Australia's primary standards of measurement. Created in 2004 with the integration of three long-standing measurement organisations into a single institute, NMI is the only 'one-stop shop' for all disciplines of measurement – analytical, biological, chemical, legal and physical.

On 1 July 2010, NMI will take responsibility for trade measurement nationwide.
National Measurement Institute

Monash School of Physics begins research at a new ultra-bright x-ray coherent diffraction facility.
A new ultra-bright x-ray facility has been recently commissioned at the School of Physics. The facility can produce diffraction images of nanostructures with spatial resolution of better than 5 nm. A 3rd Year Physics student, Stephanie Windebank (pictured right) has conducted a mini-project, under supervision of A/Prof. Andrei Nikulin (pictured left), to study specific Bragg diffraction patterns from a rolled multilayered AlGaAs nano-tube.
Monash



WEST Australian scientist Professor Michael Tobar has been awarded the Barry Inglis Medal for Excellence in Practical Measurements by an Individual in Australia.
The Minister responsible for Australia's National Measurement Institute, Dr Craig Emerson, made the announcement while in WA.

The announcement coincides with World Metrology Day which commemorates the signing of the Metre Convention on 20 May 1875. Metrology is the science of measurement.

"Professor Tobar, of the University of Western Australia, has worked at the leading edge of sophisticated frequency control systems for many years leading to patents of inventions with commercial applications," Dr Emerson said.

"In particular, his work with oscillators forms the basis for the next generation of radar, telecommunications and precision measurement applications."
The Barry Inglis Medal was created in honour of the first Chief Metrologist and CEO of the National Measurement Institute.

It acknowledges and celebrates outstanding achievement in measurement research and/or excellence in practical measurements by an individual or group in the fields of academia, research or industry in Australia.

The NMI Prize for excellence in measurement techniques for a scientist aged 35 years or under has been awarded to Associate Professor Eric May, also of the University of Western Australia.

"The award recognises Associate Professor May's contribution to gas measurements and the successful application of measurement techniques to resolving industrial problems."
University of Western Australia

ACOLS ACOFT 09 conference

ACOLS ACOFT DS•2009

29th November - 3rd December, 2009
The University of Adelaide, South Australia

ADVANCE NOTICE & CALL FOR PAPERS

It is with great pleasure that we invite you to participate in the Australasian Conference on Optics, Lasers and Spectroscopy and Australian Conference on Optical Fibre Technology in association with the International Workshop on Dissipative Solitons, Sunday 29 November to Thursday 3 December at the University of Adelaide, North Terrace Campus, close to the central business district of the City of Adelaide.

The Conference will bring together delegates from around Australia and internationally. Plenary and keynote lectures by world-leading researchers, both national and international, will ensure a vibrant and exciting program. The four-day scientific program will also include parallel presentations, poster sessions and a trade exhibition.

Submission of Papers

Paper submissions are now being accepted. Papers of no more than two (2) A4 pages should be submitted by Monday 3 August 2009. Please refer to the web site for submission details and format instructions.
http://www.plevin.com.au/acoftacols2009

Important Dates

Call for papers close	3 August 2009
Call for papers acceptance advice	14 September 2009
Early bird registration close	12 October 2009

Plenary Speakers

Kenneth Ghiggino, Head of School and Masson Professor, School of Chemistry, University of Melbourne, Australia

Professor Rudi Grimm, University of Innsbruck and Scientific Director, Institute of Quantum Optics and Quantum Information, Austrian Academy of Sciences, Austria

Simon Poole, Director, New Business Ventures, Finisar, Australia

Professor David Richardson, Deputy Director, Optoelectronics Research Centre, University of Southampton, UK

Professor Harm Rotermund, George Munro Professor of Physics & Chair Department of Physics and Atmospheric Science Dalhousie University, Canada

Professor Andrew G. White, ARC Federation Fellow Department of Physics, University of Queensland, Australia

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ENGINEERS AUSTRALIA

Launch of the Institute of Photonics and Optical Science

by Simon Fleming and Ben Eggleton

The 23rd of April was a significant day in the history of optics and photonics in Australia. It saw the formal opening of the University of Sydney's new Institute of Photonics and Optical Science (IPOS). The institute was opened by Senator Anne McEwen, Chair of the Standing Committee on Communications, Environment and the Arts and the opening was followed by a symposium "The Photonic Universe: Faster, Further, Smarter" where international and national experts explained the current state of the art in photonics and the opportunities this field offers across a broad range of disciplines including communications, energy and astronomy.

The establishment of IPOS is significant for many reasons. The University of Sydney has a long history of research excellence and real world impact in photonics, optics and astronomy; however, this has been in a number of different groups, some of which have been transient being based on grant funding. This new initiative brings all this expertise into the one permanent entity, the new IPOS. Specifically it brings together the University of Sydney researchers in CUDOS, an ARC Centre of Excellence, those from the Optical Fibre Technology Centre, the Fibre Optics Laboratory in the School of Electrical Engineering, the Astrophotonics group in the Sydney Institute for Astronomy and several others. This gives critical mass (currently ~80 researchers, including two Federation Fellows and two ARC Professorial Fellows) together with a breadth and depth unique in a single university. The institute also brings research and education under one banner with a new Masters in Photonics starting in 2010.

The photonics community had definitely come together at this event and there was a real buzz about the future of photonics and optics in Australia.

The Symposium aimed to set the context for IPOS in the 21st century. After the rapid deployment of photonics in telecommunications through the 1990s, photonic technology has steadily extended into an ever-widening range of application areas across the pillars of society. Experts from these application areas provided us with insights on the current state of the art and the emerging opportunities.

Of course, telecommunications remains the most significant application for photonics, and the plenary speaker gave an entertaining, informative and visionary talk on photonic telecommunications. Professor Alan Willner from the University of Southern California is regarded by many as the world's foremost authority in this area. He reviewed the field and provided some thought provoking ideas, in particular about our wasteful use of capacity. He told that since the earliest days of optical fibre communications there has been a pervasive view that the capacity is so large it can be considered to be effectively unlimited. A key point he made was that those days are over and that we are approaching

Professor Ben Eggleton, IPOS Director in the Terabit per-second laboratory explaining recent research breakthroughs to Senator Anne McEwan. The Terabit per-second laboratory is part of the ARC Centre of Excellence, CUDOS, the Centre for Ultrahigh-bandwidth Devices for Optical Systems, which is headquartered in IPOS within the School of Physics.

the capacity limitations. This will force us to develop new ways to more efficiently use the capacity including allocating channels based on requirement, not in fixed capacity blocks. Many aspects of his talk were very relevant to Australia following so closely to the Government's announcement of an FTTH rollout to substantially increase traffic across the networks.

The second speaker was Dr Peter Skovgaard, senior scientist with Danish company Crystal Fibres, the world-leader in the microstructured fibre. These fibres have been the subject of intense research effort over the last decade and are now having significant impact across a wide range of applications, such as high-powered fibre lasers. Peter introduced these fibres and his company and then reviewed many of the important applications, including several that are the subject of existing collaborations with IPOS researchers.

Next up was a domestic star: Dr Simon Poole, a serial entrepreneur who is Director, New Business Ventures with Finisar. He gave us a look at what the future holds for the optical communications industry from both a technology and a business perspective. Whilst he carefully did not reveal what technology he would pick if he were looking at a new start-up now, he provided fascinating insights on how to make that choice.

He was followed by Dr Pierre Kern from Laboratoire d'Astrophysique de Grenoble/CNRS/Université Joseph Fourier. Pierre created the field of

From left to right: Prof Martijn de Sterke (IPOS Associate Director), Prof Ben Eggleton (IPOS Director), Prof Michael Spence (Vice Chancellor of the University of Sydney), Senator Anne McEwan, Professor Anne Green (Head of School of Physics)

astrophotonics (applying photonic technology to the development of astronomical instruments) and he and IPOS's Joss Bland-Hawthorn are the trailblazers in this field. He gave a fascinating talk on how tiny optical components can be used to integrate arrays of telescopes into, effectively, one truly huge instrument.

Australian experts provided excellent talks on the status and opportunities of photonics in Life Sciences, Solar Energy, Quantum Measurement and Astronomy. A series of rapid fire short presentations gave quick updates on several different hot topics in photonics, including Fibre Lasers, Holey Polymer Fibre, Metamaterials & Invisibility Cloaks, Optical Pulse a la Carte and Silicon Photonics.

Lunch and a cocktail reception provided networking opportunities and it was clear that everyone made good use of this time. The photonics community had definitely come together at this event and there was a real buzz about the future of photonics and optics in Australia.

Senator Anne McEwan and Professor Ben Eggleton unveil IPOS plaque to launch new institute.

AIP Honours Scholarship 2009 - Sophie Underwood

The Australian Institute of Physics is pleased to announce that Sophie Underwood has been awarded the AIP honours scholarship for 2009. Sophie was selected as the recipient on the basis of her outstanding academic record and enthusiasm for physics.

Sophie is currently undertaking a Theoretical Physics Honours degree at the University of Adelaide. She says that one of "...the highlights of her university career so far was the opportunity to work for the Gemini South Observatory in Chile for ten weeks over the summer of 2008-09. Watching the telescope in operation on the summit of a mountain in the Andes, beneath the radiant Milky Way in a sky devoid of any light pollution, was certainly an unforgettable experience!"

AIP congratulates Sophie Underwood.

Australian Institute of Physics

Galileo's miraculous year 1609 and the revolutionary telescope

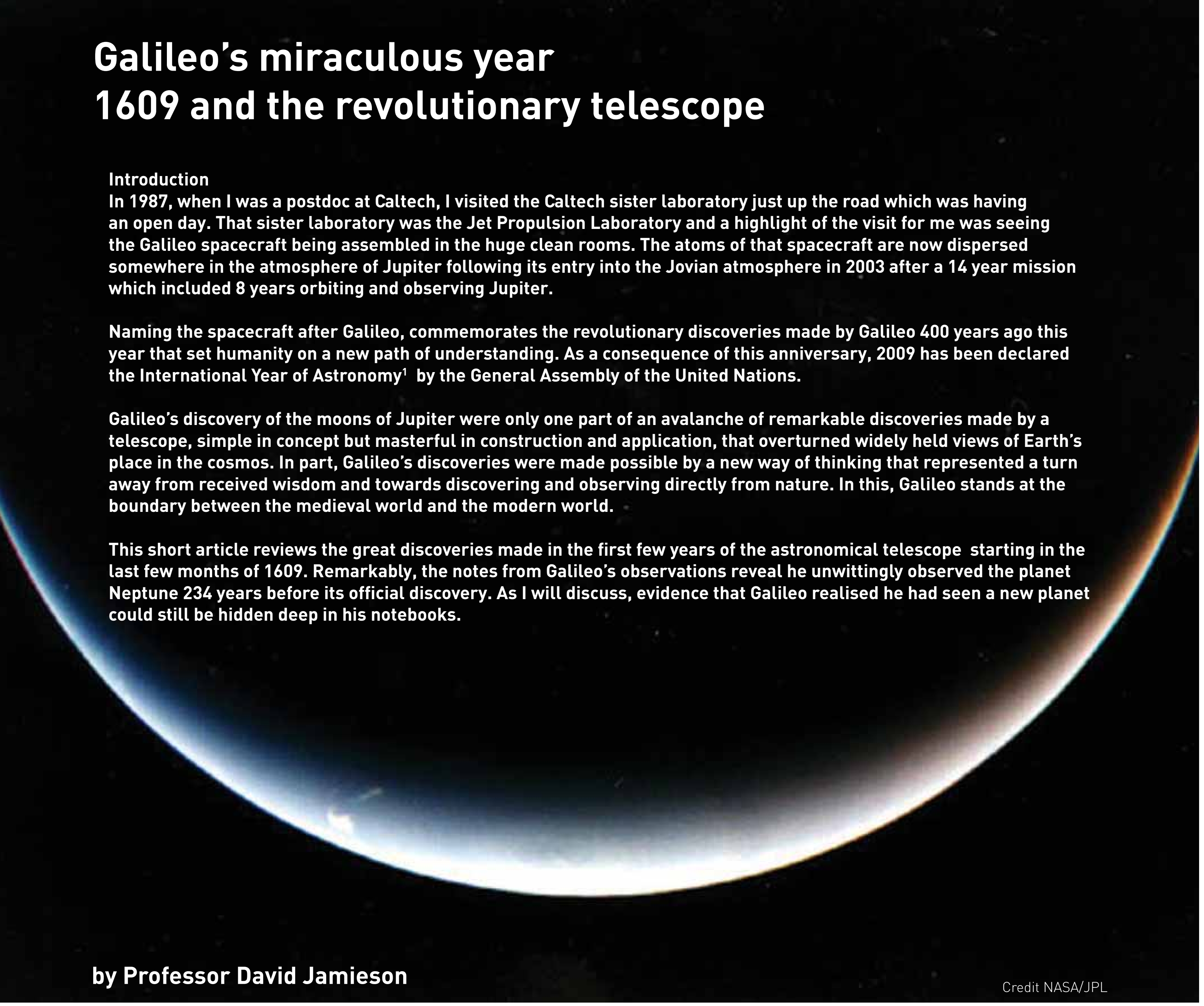
Introduction

In 1987, when I was a postdoc at Caltech, I visited the Caltech sister laboratory just up the road which was having an open day. That sister laboratory was the Jet Propulsion Laboratory and a highlight of the visit for me was seeing the Galileo spacecraft being assembled in the huge clean rooms. The atoms of that spacecraft are now dispersed somewhere in the atmosphere of Jupiter following its entry into the Jovian atmosphere in 2003 after a 14 year mission which included 8 years orbiting and observing Jupiter.

Naming the spacecraft after Galileo, commemorates the revolutionary discoveries made by Galileo 400 years ago this year that set humanity on a new path of understanding. As a consequence of this anniversary, 2009 has been declared the International Year of Astronomy[1] by the General Assembly of the United Nations.

Galileo's discovery of the moons of Jupiter were only one part of an avalanche of remarkable discoveries made by a telescope, simple in concept but masterful in construction and application, that overturned widely held views of Earth's place in the cosmos. In part, Galileo's discoveries were made possible by a new way of thinking that represented a turn away from received wisdom and towards discovering and observing directly from nature. In this, Galileo stands at the boundary between the medieval world and the modern world.

This short article reviews the great discoveries made in the first few years of the astronomical telescope starting in the last few months of 1609. Remarkably, the notes from Galileo's observations reveal he unwittingly observed the planet Neptune 234 years before its official discovery. As I will discuss, evidence that Galileo realised he had seen a new planet could still be hidden deep in his notebooks.



by Professor David Jamieson

Credit NASA/JPL

The Discoveries

Galileo Galilei was born in 1564 in Pisa. He had a position as a professor of mathematics in Pisa before moving to the University of Padua in 1592. There, in late 1608 or mid 1609, he heard[2] of a "spyglass" invented in the Dutch republic. He quickly designed his own version from first principles and by November of 1609 was making observations of the night sky. After clearing up any doubt that what he was seeing was real and not artefacts in the glass of the lenses, he published his first comprehensive book of astronomical observations in March of 1610. Although Galileo is not the first to observe the sky, he was the first to publish.

So great was the interest in his work (rumours must have already been spreading widely prior to 1610) that Sir Henry Wotton, English Ambassador to the Republic of Venice obtained a copy and sent it to the King of England, on the day of publication, with a cover letter[3] stating that the author "*runneth a fortune to be either exceedingly famous or exceedingly ridiculous*". The book was "Sidereus Nuncius"[4] which translates to "Starry Messenger". It was published in the lingua franca of science in the 17th Century: Latin.

This slim tome contains an astonishing list of discoveries. The Moon was found to have dramatic surface texture including mountains and craters casting long shadows if the phase was right. Familiar constellations were found to have vast numbers of new stars invisible to the unaided eye but clearly seen through the telescope. More than 34 stars were visible in the constellation of the Pleiades, many more than the nine or so visible to the unaided eye[5]. Even more astonishing was the report that Jupiter was seen to have four tiny moons in orbit around it. These four moons were discovered between 10 and 16 January 1610[6].

Galileo named them the "Medicean Stars" in hope of getting financial support from Cosimo II de'Medici, the Grand Duke of Tuscany. The discovery of moons orbiting Jupiter was very radical because this was the first time objects had been observed orbiting a planet other than Earth.

After publication of Sidereus Nuncius in March 1610 Galileo continued to make discoveries. He observed that there was something odd about Saturn. At the limit of resolution of his telescope, he saw two "lobes" sticking out each side of the planet. He established the primacy of his discovery by sending an anagram to Kepler shortly after 25 July 1610 that reads

"*smaismrmilmepoetaleumibunenugttauiras*"

and then rearranged as

"*Altissimum planetam tergeminum observavi*"

translates to[7]:

"*I have observed the highest of the planets [Saturn] three-formed*".

Much later, in 1616, these lobes were observed to vanish, until the idea of thin rings around the planet explained these puzzling observations.

In September of 1610 was the discovery of the astonishing phases of Venus[8]. Although Venus just looks like a very bright star to the unaided eye, telescopic observations showed it to exhibit phases like the Moon. Galileo again established the primacy of his discovery by sending an anagram (in Latin) to Kepler[9]:

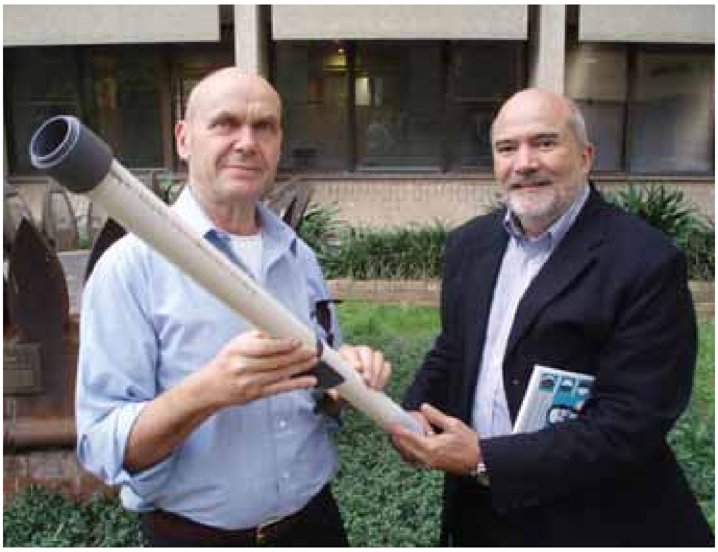
"*Haec immatura a me jam frustra leguntur oy*"[10]

This too may be rearranged to read:

"Cynthiae figuras aemulatur mater amorum"

and then translates to:

"*The mother of love imitates the shape of Cynthia*".



Roland Szymanski (left), occasional telescope maker, and David Jamieson (right), author, inspect Roland's replica of Galileo's 1609 x20 telescope made with modern materials in May 2009 at the School of Physics, University of Melbourne.

Sadly, we no longer report important scientific discovers in such poetical terms. The variations of the visible phase of Venus and the correlations with the observed size of the planet in the eyepiece of Galileo's telescope could only be explained if Venus orbited the Sun and not Earth. Later, he discovered sunspots[11] (as had many other people by then) and began demonstrating them to other people in 1611.

The Telescope

All this was made possible by a telescope of unprecedented power and quality, fabricated by Galileo's own hand. Indeed Galileo's telescope was of such high quality that for more than 20 years after 1609 he had a monopoly on the supply of high quality astronomical telescopes. His access to the products of the great glass industries of Venice, his knowledge of optics and his high manual skills were the key factors in his success. The key innovation in his astronomical telescope was a high-precision planar-convex objective lens which was combined with a planar-concave objective lens in the now immortal "Galilean telescope configuration". Convex lenses were already in mass production to combat presbyopia[12] (from the Greek for "old person"). Likewise concave lenses to combat myopia[13] were also in use. It was Galileo's genius that saw the potential of combining these lenses, with carefully selected focal lengths, to make a workable astronomical telescope.

The actual objective used in some of the important discoveries is on display[14] at the Museum of Science in Florence, which I had the pleasure of visiting in December of 2008. In fact I was obliged to purchase a set of +1.5 Dioptre spectacles from a supermarket in Florence to allow me to read the fine print in the museum guidebook.

When looking at Galileo's original objective lens in the museum display cabinet, now unfortunately broken in several pieces, I was amazed that so slight a piece of glass could have been responsible for so many revolutionary discoveries. Galileo's telescope incorporated many innovations, not just the lenses, as revealed by people today seeking to make replicas as close as possible to the original[15].

Then, as now, Galileo had to keep a close eye on the financial support for his research. So in a letter to the Duke of Tuscany, a potential funding agency, he wrote[16]:

> *"Most Serene Prince. Galileo Galilei most humbly prostrates himself before Your Highness, watching carefully, and with all spirit of willingness, not only to satisfy what concerns the reading of mathematics in the study of Padua, but to write of having decided to present to Your Highness a telescope ("Occhiale") that will be a great help in maritime and land enterprises. I assure you I shall keep this new invention a great secret and show it only to Your Highness. The telescope was made for the most accurate study of distances. This telescope has the advantage of discovering the ships of the enemy two hours before they can be seen with the natural vision and to distinguish the number and quality of the ships and to judge their strength and be ready to chase them, to fight them, or to flee from them; or, in the open country to see all details and to distinguish every movement and preparation."*

He tried a number of lens combinations, aiming for the highest possible magnification with the sharpest view. The most successful combination appeared to consist of a hand-ground plano-convex objective with a focal length of 980 mm and a diameter of 37 mm teamed with a plano-convex eyepiece of focal length of -47.5 mm and diameter of 22 mm. The objective was stopped down to 12 – 25 mm to limit aberrations and the combination gives a magnification of about 20. The magnification is handy, but the benefits of

collecting light through a 25 mm diameter lens and focussing it through the 6 mm diameter human iris should not be overlooked! The telescope allowed Galileo to see objects with a brightness of about 9th magnitude compared to the unaided eye's limit of about 6th magnitude. For comparison, the moons of Jupiter have a brightness between 5th and 6th magnitude.

A significant difficulty with the Galilean telescope for astronomy is that the field of view is very narrow. For example the 20 magnification telescope has a field of view of only about 0.13° which is about one quarter of the full Moon. This would have made it difficult to get an overview of the Moon, to say nothing of the need to constantly tweak the telescope to compensate for the rotation of the Earth!

The Moons of Jupiter and the heliocentric model

Following his discovery of the four Galilean moons of Jupiter from 7 - 10 January 1610, Galileo spent many years tracking their orbits. Page after page of his notebooks record his meticulous observations[17]. Reproductions of most of these notebooks are now available online at the Institute and Museum of the History of Science in Italy[18,19].
By 1612 he was using a fully quantitative and precise technique, now lost, to measure the distance of each of the four moons from the centre of Jupiter in units of the diameter of Jupiter. He also took great care to record "fixed stars" that drifted through the field of view during his observations as he tracked Jupiter's movement across the sky.

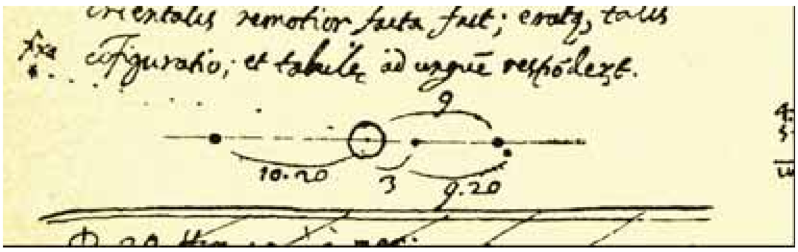


Fig 1 Galileo's notebook for December 28 1612. The object labelled "fixa" on the left is Neptune. Image credit by kind permission of the Ministero per i Beni e le Attività Culturali della Repubblica Italiana/Biblioteca Nazionale Centrale di Firenze.

The discovery of objects orbiting a planet other than Earth created severe difficulties for one of the primary justifications of the geocentric model of the solar system that required everything to orbit Earth. The observed variations in the phases of Venus could really only be explained by the heliocentric model. But the most salient feature of the heliocentric model was that the Earth moved relative to the Sun AND the stars. Therefore stars, if assumed to be at varying distances from the Earth, should exhibit parallax as the Earth changes position in its orbit over the course of a year. Galileo was well aware of this feature of the heliocentric model and made several attempts to detect this parallax. He did this by making assumptions about the distances to the stars and calculating the magnitude of the expected parallax.

He made the very reasonable assumption that stars were suns like our own and therefore that the size and brightness of the star disk observed in his telescope could be used to estimate their distance. In the case of the double star Mizar he estimated that the two stars were 300 and 450 Astronomical Units (AU) distant from the Earth, with the consequence that the annual parallax should be significantly larger than their angular separation[20,21] than he observed in January 1617. Unfortunately his assumptions about the distances to the stars were significantly underestimated.

Wave optics was unknown to Galileo and so he did not recognise that the star diameters he measured were due to diffraction through the collimators of his lenses (and other effects), not the true magnified star diameters.

Over the years, the two stars of Mizar did not show any parallax that Galileo could observe. Of course no such parallax of Mizar, true distance around 5 million AU, or any other closely spaced pair of stars, could be observed with Galileo's telescope or any other technology before the 18th century. Indeed it was the observation of stellar aberration[22] by James Bradley in 1725 that first detected Earth's orbit around the Sun. This is an effect that arises from the changing direction of Earth's velocity vector and produces a shift in the positions of the stars an order of magnitude larger (and 3 months out of phase) compared to stellar parallax.

Galileo's failure to observe stellar parallax must have puzzled him. Especially as critics of the heliocentric model demanded this hard evidence[23] before abandoning the geocentric model. Perhaps he realised there was something wrong with his assumptions? In any case his observations of Mizar and other closely spaced stars do not appear to have made it out of his notebooks and into any of his publications.

Galileo's Observations of Neptune

Just about all of the "fixed stars" he records in his notebooks while observing Jupiter appear in modern star catalogues. However one of those "fixed stars", seen in December 1612 and January 1613 does not appear in any catalogue. This particular "fixed star" turns out to be something entirely different: Galileo was actually observing the planet Neptune. These observations were made 234 years earlier than the official discovery of Neptune in 1846[24]. It is remarkable that Neptune has yet (in 2009) to complete one orbit around the Sun since its official discovery, because its orbital period is 165 years. The first orbit will be completed in 2011.

The story of Galileo's observations of Neptune is remarkable, and a striking example of his skill and care making quantitative observations with very simple apparatus that have stood the test of time. Galileo's observations of Neptune were discovered by Kowal and reported in the journals Nature[25] and Scientific American[26] in 1980. Kowal also provides a commentary on the circumstances of the discovery and the aftermath in a short essay[27] posted on the web site of *DIO: The International Journal of Scientific History* in 2008.

Galileo's notes show he made several observations of the planet Neptune in December 1612 and January 1613. He uses the label "fixa" where he plotted the position of Neptune in his notebook, indicating, at least initially, that he believed he was observing a fixed star and not a planet.

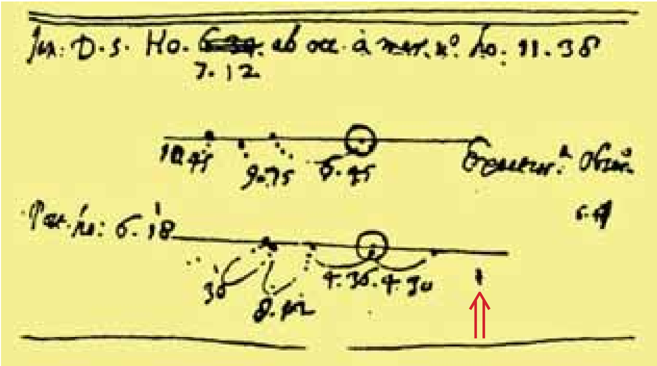


Fig 2 Galileo's notebook from 6 January 1613: The unlabelled mark to the lower right (identified by the red arrow) is Neptune. The mark is not present in the on-line images of Galileo's notebooks. Reproduced from Standish and Nobili. Image credit by kind permission of the Ministero per i Beni e le Attività Culturali della Repubblica Italiana/Biblioteca Nazionale Centrale di Firenze.

Even more remarkable is that Galileo's notes of 28 January 1613 suggest he saw Neptune move when it passed in close conjunction to an actual star. Yet it appears he did not follow up this observation, and no further entries in his notebooks have been identified that suggest Galileo was aware of the possibility of a new planet. If Galileo had used his observations to propose the discovery of a new planet, it would have been the first time a planet had been discovered by humanity since deep antiquity, and would be without precedent in recorded history.

The first two of three observations of Neptune identified by Kowal were both made on 28 December 1612. The third observation was on 28 January 1613. On 4 January 1613, in between these two dates, Neptune was actually occulted by Jupiter.

The reason why Neptune was visible in close proximity to Jupiter over a time span of a month was that Jupiter and Neptune executed a retrograde loop (direction reversal) on 13 January 1613 as the Earth overtook them in orbit. This maximises the amount of time they are visible in close proximity in the sky.

A further article by Standish and Nobili[28] report a possible additional observation of Neptune that is represented by an unlabelled mark in Galileo's notes from 6 January 1613. This mark, *which is not reproduced in images of Galileo's notebooks posted on the web*, is clearly seen to be a deliberate record of an observation because of the physical evidence of the page itself. This reveals, as reported by Standish and Nobili, a dimple in the page made by the deliberate press of the nib of an ink pen into the paper.

As pointed out by Kowal and Drake, the observations made by Galileo on 28 January are quite remarkable. First, Neptune appeared in close proximity to an actual star. Second, although the actual star could be plotted in Galileo's notebook on the same page as Jupiter and its satellites, Neptune could not because it lay further from Jupiter beyond the position of the actual star. So Galileo included an inset drawing of the actual star with Neptune included as well.

Galileo's notes on his observations, as pointed out by Kowal and Drake, indicate that Galileo recalled seeing both Neptune and the actual star the previous night, but he did not record them in his notebook. However he notes on his 28 January observations that "*After the fixed star **a**, another was following in the same line in the same way as **b** did, which was also observed on the night before; but they seemed to be further away relative to each other*"[29] (here ***a*** is an actual star and ***b*** is Neptune). Kowal and Drake point out that from 27 to 28 January Neptune would have moved 2.5 Jovian radii closer to the actual star. Clearly Galileo had seen this motion.

The absence of follow-up observations is puzzling. Kowal and Drake speculate that bad weather or difficulties relocating Neptune once it moved out of the field of view when the telescope was trained on Jupiter prevented further observations. There is no evidence yet found that Galileo formed the hypothesis that he had seen a new planet on the nights of 27 and 28 January.

However, I suggest the unlabelled mark on 6 January might be a retrospective record made by Galileo after he made the remarkable observation on 28 January. Given he depended only on his memory of the observations made, but not recorded, on 27 January to identify the motion of Neptune (***b***) relative to the fixed star (***a***), then it is possible the mark on 6 January was made from memory AFTER he made the observations on 28 January. If so, this would suggest he did indeed form the hypothesis that he had seen a new planet which had moved right across the field of view during his observations of Jupiter over the month of January 1613.

This particular "fixed star" turns out to be something entirely different: Galileo was actually observing the planet Neptune.

Therefore it would be very interesting to see if trace element analysis of the unlabelled spot from 6 January could identify the date on which it was recorded. 6 or 28 January? If the latter, I would propose this could construe evidence that Galileo was thinking about the possibility he had discovered a new planet.

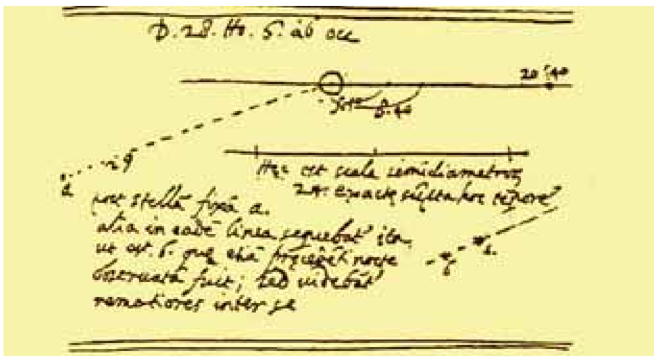


Fig 3 Galileo's notebook from January 28 1613: The object labelled "**b**" on the inset lower right is Neptune. Image credit by kind permission of the Ministero per i Beni e le Attività Culturali della Repubblica Italiana/Biblioteca Nazionale Centrale di Firenze.

Trace Element Analysis of Galileo's Inks

This proposal arises from prior use of trace element analysis of Galileo's inks establishing the dates of some of his undated writings. The National Institute of Nuclear Physics at the University of Florence has had considerable experience in the analysis of Galileo's inks using Proton Induced X-ray Emission (PIXE). Manuscripts from the years 1600, 1605-09, 1617 and 1636 have been analysed[30]. The analysis covered both the background parchment and the inks employed in the writing. On the PIXE evidence, the relative concentration of K, Ca, Fe, Cu, Zn and Pb allow, in some cases, identification of the date at which a document was written to a precision of three months (see for example a case study in the development of Galileo's theories of mechanics[31]).

The challenge of using trace elements to identify the date of the unlabelled spot on the page for 6 January, 1613, is much greater than using trace elements to date a manuscript. This is because when two manuscripts are compared, the entire surface area of each manuscript can be used for comparison. Here we seek only to compare the composition with a single spot to the composition of the writing ink in the remainder of the manuscript. However, the Florence group have identified large variations in the composition of the ink in a single manuscript[32]. These variations that are larger than the accuracy of the PIXE measurements themselves, suggest real variations in the ink composition are responsible.

It would be very interesting to see if the ink composition could be employed to link the unlabelled dot of 6 January, 1613, with the ink used on 28 January, 1613. If such a link could be established, this could be interpreted that Galileo understood he was seeing something unusual that was, perhaps, a new planet.

But I would suggest another intriguing possibility presents itself. Galileo's habit of sending cryptic anagrams to his correspondents to establish the primacy of his discoveries has already been explained here. It is therefore possible that there remains, undiscovered in the Galileo literature, an anagram put there by Galileo to establish the date of his discovery of Neptune. However, as yet no such anagram has been uncovered. Perhaps there is such an anagram hidden in his notebooks or in his voluminous correspondence revealing that he considered the possibility he had discovered a new planet. This would indeed be an even more remarkable addition to the already impressive list of discoveries that make the 400th anniversary of Galileo's telescope worth celebrating!

Obviam Valens Tamen Pavor[33]

Footnotes

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13 http://en.wikipedia.org/wiki/Myopia
14 http://brunelleschi.imss.fi.it/telescopiogalileo/index.html
15 http://www.pacifier.com/~tpope/index.htm
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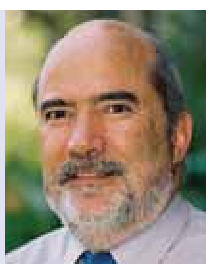

Multi-layered national curriculum design principles

by Neil Champion

In the context of discussions about a national curriculum, this paper argues that the physics curriculum needs to combat teachers' and students' disengagement from the current canonical, transmission paradigm. It can do this by allowing local variations in the curriculum that, while teaching the canon, include innovative and emerging physics in the curriculum. This will ensure that the curriculum does not stagnate and that community-connectedness at local, regional, national, and international levels is enhanced. By characterising physics as a science of puzzle-solving students can be engaged in meaningful contexts, and can experience a curriculum that integrates science understanding, science skills and science as a human endeavour. Dealing simultaneously with the multiple layers of an engaging curriculum can re-enthuse teachers and motivate students to proceed to tertiary study or to careers in science, engineering and technology. If the opportunity is not grasped, the curriculum will continue to fail to equip students as scientifically well-informed citizens and/or expert puzzle solvers and innovators. -

The National Curriculum Board is in the middle of a significant consultation process to shape the national curriculum in English, mathematics, science and history. It is making an important contribution to the development of science education with a well supported, sophisticated and nuanced approach. As we go down the path of a national curriculum it is hoped that none of the necessary layers in this approach gets lost. This paper outlines the state of play in the development of the national curriculum, then provides arguments supporting the National Curriculum Board's conceptualisation of science curricula, particularly the interplay of science understanding, science inquiry and science as a human endeavour. These arguments are supported by a holistic exposition of what the physics and science curricula could achieve through flexible, contextualised, options-based programmes which are in line with evidence about engagement in science, Kuhn's theorisation of science as puzzle solving, Feynman and others' championing of interdisciplinarity, and calls for innovative research to be harnessed to secondary teaching.

The National Curriculum Board's initial paper for science proposed "*a better balance between the traditional knowledge focused science and a more humanistic science curriculum that prepares students for richer understanding and use of science in their everyday world.*"[1] Three post-compulsory science studies – physics, chemistry and biology – were proposed, along with an applications-based fourth study for students wishing to take only one science.

As a result of consultation on the initial paper, the National Curriculum Board recently released a framing paper for further comment until the end of February 2009.[2] The framing paper proposes, in the senior years, to develop national curricula for "*physics, chemistry, biology, and environmental science … and an additional, interdisciplinary course.*"[3] Responses to this framing paper are currently being prepared and digested. The proposal leaves open the development and redevelopment of other science courses, based most probably on sciences currently accredited by the States.[4]

The purposes advanced for science education, in both the initial advice and the framing paper, are consistent with developments in science education theory, research and policy, which have all pointed, over the last ten years at least, to the education of a scientifically capable person who can take their place in a scientifically and technologically advanced society. In summary, the goal of science education is to develop

> *...the capacity for persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well being.*[5]

Effective science education should result in an interested, knowledgeable, engaged, sceptical person committed to evidence and capable of identifying and tackling questions that are worth solving. Such a person is empowered to take their place as scientist, technologist, and/or scientifically well-informed citizen.

Yet such an outcome has not been attained through current science curricula. There is clear research evidence of "*a consistent view that many of the problems and issues in science education stem from the nature of the curriculum, which is viewed as content heavy and alienating to the majority of students.*"[6] This disengagement results from the interplay between over-reliance on the transmission of the canon of science, loss of connection with meaningful contexts for learning, and the perceived difficulty of science.[7] It is affected by the rigidity of curricula that are canon-heavy and which cannot respond quickly to emerging opportunities, including emerging industries and research findings.

A national curriculum in secondary physics must include the accepted canon of physics, but needs to be wary of the failures of curricula that have been canon heavy. Transmissive teaching of the canon is disengaging and irrelevant to many students.[8] This is one of the reasons why, despite the high level of unanimity about the chemistry and physics canons as expressed in the curricula of different jurisdictions, there is no clear agreement about how to proceed.[9] Accordingly, a

> *...single syllabus, … would not of itself address issues such as the lack of interest and engagement … without a different kind of implemented curriculum. … a simple alignment is*

unlikely to make a significant impact on the current problems relating to disaffection with science. These problems relate in part to students' perceptions of the different science units at the senior secondary level. … The evidence reviewed suggests that a different perspective is required, particularly at the senior science level, to provide curricula with the broader-based content that promotes scientific literacy and appeals to a wider range of students.[10]

The canon is not, in and of itself, enough for the national physics curriculum. Space needs to be created for the inclusion of local, regional, national and international developments in particular areas of physics, worthwhile emerging puzzles, and the particular purposes of secondary education. What is taken to be essential should comprise a significant but not complete part of a national curriculum. The rest of the curriculum should allow for variation. This can make science engaging by taking advantage of the varying contexts which are relevant and immediate for particular groups of students, and by relating to contemporary scientific problems, research and technologies. Varying options for schools could also connect students and their understanding of science with their communities, thus both engaging students and encouraging a scientifically competent society which views and reflects on science as a human endeavour.

A core and option design would leave open the opportunity for local and regional variations in curriculum, such as the world-first secondary curriculum in photonics and in synchrotron physics already in place in Victoria, the latter in response to the opening of the Australian Synchrotron, the introduction of physics related to emerging and innovative industries, such as nanotechnology and space science, and optional studies in medical physics, astrophysics and alternative energy generation. It is risky to include new physics in the physics curriculum, but more risky to stagnate. I have argued elsewhere that the "*challenge is to maintain a core of physics that can support the introduction of new physics, thus providing space for innovative and emerging physics within the curriculum*", and that this should be introduced progressively and gradually, allowing "timely change to be managed effectively".[11]

A core and options based curriculum would combat the key risk of stagnation posed by students' disengagement. As the National Curriculum Board's framing paper argues, it is "*current research and its human uses and implications that motivates and excites students.*"[12] The human uses and applications of science are best understood through local contexts and current and emerging issues, necessitating flexible options in curricula. This goes hand in hand with community-connectedness, a proven method of engaging students, in which students become involved in partnerships with tertiary institutions, business and industry.[13]

This approach is consistent with the framing paper's advocacy of a contextual approach to learning that is responsive to learner and situation:

A more balanced and engaging approach to teaching science will typically involve context, exploration, explanation and application. Wherever appropriate, students should be actively involved in the science topic or concepts to be taught. This requires a context or point of relevance by which students can make sense of the ideas to be learnt. The context may vary depending on the students, school or location.[14]

Different regions and localities provide a range of opportunities for business, industry and the tertiary sector to engage locally with jurisdictions and schools, to enhance the connectedness of students with their community. The opportunity should be available for students or schools to enter into partnerships with, for example, a wind energy company in Western Australia, a geophysics department at Adelaide University or a photonics start-up company at the Technology Park in Sydney. This is not to deny the connectedness that students gain as a result of tackling the 'big ideas' of physics, nor to reduce the concept of community to geographic proximity, only to emphasise the need for local tertiary institutions, businesses and industries to form partnerships with schools and jurisdictions to enhance the practicality and meaningfulness of educational experiences.

A national curriculum in secondary physics must include the accepted canon of physics, but needs to be wary of the failures of curricula that have been canon heavy.

Engaging students and creating scientifically capable individuals, equipped to face current issues in their communities or professions also involves an interdisciplinary approach, in keeping with real-world problems and current scientific research.[15] Critical issues for the planet that are worthy of consideration within a national physics curriculum might include the enhanced greenhouse effect, efficient energy production and use, communications and sustainability. In order to take these critical issues into account, a place would need to be found, for example, for optoelectronics, atmospheric physics, space weather, geophysics, and energy production and consumption.

A core and option design for all sciences would open up opportunities for such interdisciplinary links. Already, physics and chemistry lay claim to atomic and nuclear physics. Biology and environmental science also have genuine claims on the territory. If domain specific understanding and related skills are seen to be part of the canon for a subject, they would be included in that subject's core curriculum. The core detail (e.g. nuclear physics) in one subject may be similar to, or different from, the core detail in another subject. An option that enables students from each of the interested domains (physics, chemistry, biology) to engage in deeper learning could then be developed. For example, students located near ANSTO's Lucas Heights facility in Sydney, or students who can enter a related online portal or community of learning, could engage in an option related to nuclear waste management and treatment in Australia or across the world. This is a complex puzzle that requires insights from physics, chemistry, biology and environmental science, and could excite and engage students

no matter in what domain they begin their exploration of the puzzle. Students who have studied relevant physics core will bring their insights to share with students who have studied related core in another science domain. The conversation between students as they translate their knowledge for each other is likely to enhance learning.

Puzzle Solving

The kind of learning in physics, and in the sciences more broadly, can be described as puzzle solving. This next section is an exposition of this notion of physics as it relates to the National Curriculum Board's conceptions of science and its proposals for a national curriculum. In order to advance the cause of an engaging and effective science education, the National Curriculum Board's framing paper proposed three inter-related elements for the national science curriculum. All three components are essential if the national curriculum is to develop a scientifically competent polity as well as expert science practitioners.

The idea of physics as puzzle solving highlights the need for a curriculum, which is contextualised or otherwise made meaningful for students.

The three inter-related elements are (a) science understanding, (b) science inquiry skills and (c) science as a human endeavour.[16] Science understanding includes the bases of explanations that lead to valid conclusions, justifiable predictions and generalised application to novel situations. Science inquiry skills include posing realistic questions, acting rationally to collect and analyse data, and communicating questions, procedures, data and conclusions effectively. Science as a human endeavour deals with the ways that science is shaped by, and shapes, human experience.

The first two elements, science understanding and science inquiry skills, let students be inducted into the process of science and what is already worth knowing from a scientific perspective. Scientific understanding and enquiry go hand in hand. They can be conceptualised as the outcomes and processes of solving problems or puzzles. According to Kuhn, "*[p]uzzles are … that special category of problems that can serve to test ingenuity or skill in solution*".[17] Thus, the national curriculum should support this conceptualisation of science as puzzle-solving rather than as fundamentalist, canonical fact transmission.

The puzzles in physics are many and varied. They deal with the nature of matter and the Universe, from the impossibly small to the impossibly large. The puzzles cross the divides between subjects. The structure of DNA was solved with the tools of physics. New puzzles, the province of biologists, chemists and psychologists, arise from this discovery, and from the use of functional imaging systems developed and refined by physicists. Efficient and responsive telecommunications arise from solving puzzles about the nature, structure and strengths of materials as well as the transmission of signals in efficient ways. Transportation and buildings are improved by the application of the principles of physics. Deep knowledge of thermodynamic systems materially improves the likelihood of effective responses to the causes and effects of global atmospheric change.

The design of a puzzle solving curriculum will need to be flexible to account for students' own interests. At the same time it will need to be able to expose, in an articulate form, generally applicable principles of puzzle-solving. These principles, the canonical, generally applicable principles and methods of science, are not inimical to but part of science's nature as a puzzle-solving enterprise. As Kuhn puts it:

> *If it is to classify as a puzzle, a problem must be characterized by more than an assured solution. There must also be rules that limit both the nature of acceptable solutions and the steps by which they may be obtained.*[18]

Puzzles that test ingenuity and skill require the development of sophisticated analytic tools of the physical, chemical and biological sciences: the development of effective theories, models, generalisable and reproducible conclusions. Speculative explanations of the 'new age', astrology or 'creationism', or Aristotelian rather than Galilean explanations of motion, do not accord with the approved rules by which data are collected, sifted and sorted. They do not fit accepted theories or use acceptable steps to reach a solution, and thus do not meet the requirements of an acceptable modern scientific solution.

The idea of physics as puzzle solving highlights the need for a curriculum, which is contextualised or otherwise made meaningful for students. It also supports the teaching of canonical physics and the history of physics as a human endeavour. To participate and engage in science, students need to be able to engage with problems that are worth solving. They need to be given opportunities to decide for themselves their own puzzles of interest, and to evaluate the purposes and details of puzzles that others, especially expert puzzle solvers, have attempted. They need to be able to recognize the dimensions of a puzzle and the criteria by which it may be said that the puzzle has been solved for the time being.

These are significant reasons to lead students into the scientific paradigm and to put that enterprise on a human footing. In this way, students can be engaged in what constitutes an adequate method by which decisions can be made about the physical world and its impact on human behaviour.[19]

Physicists and social scientists are sometimes suspicious of conceptualising and teaching science as a human endeavour. On the one hand, physicists are suspicious of narratives embedded in history and social sciences because they [seem to] make physics subjective rather than objective. On the other, social scientists and historians are suspicious because teleological narratives by physicists about the 'progress of science' are inclined to be hubristic, simplistic and redolent of the 'great man' view of history.

Including science as a human endeavour enables students to be led into the nature and processes of science. Chalmers

argues that, because there is a sense in which students become inducted into a guild of practitioners, they " *... acquire knowledge of a paradigm through their scientific education*."[20]

This proximal socialisation affects the way students absorb, integrate and operate on the world they inherit and embeds them, albeit incompletely and imprecisely, in the scientific paradigm. They become familiar with the provisional nature of science, the contestability of data, theory, conclusions and predictions. Students should also be inducted into physics through an examination of classical research findings. Chalmers argues that

> *...it is essential to understand science as an historically evolving body of knowledge and that a theory can only be adequately appraised if due attention is paid to its historical context. Theory appraisal is intimately linked with the circumstances under which a theory first makes its appearance.*[21]

The findings themselves may now be regarded as partial or even wrong. But they can expose the conditions under which pressure is brought to bear on the validity and reliability of the methodologies. The use of classical research developments can be a potent method of teaching the way in which science proceeds by such analyses, and by the data from new experiments that take different approaches, use technological advances, or refine the original methods to take account of criticisms. Moreover, students frequently hold views similar to those that have been found wanting in one-way or another as a result of cultural changes. This is true for example, for the physics of motion – there's plenty of Aristotelians out there! – so that an appraisal of the adequacy of such views can be extremely useful in sorting out student conceptions and misconceptions *vis a vis* Galilean and Newtonian ideas.

A local context of relevance can be used to help students pose interesting questions and evaluate them in terms of whether they are amenable to solution in the form posed, what the solution might look like, and what steps they need to develop in order to solve them. Within the same design, an historical approach can enable students to assess their own ideas against those that were once regarded as legitimate and to work through the reasons for their eventual rejection in favour of a more organised set of concepts that are consistent with current scientific ideas. In this way they may be better able to integrate current conceptualisations into their developing intellectual frameworks, to reflect those frameworks, and on science itself.

In this paper I have argued that there is no *a priori* reason to teach all students exactly the same physics curriculum across the nation. While guaranteeing a privileged place for the canon, a place must be found for the progressive introduction of innovative and emerging aspects of physics into the curriculum. This will ensure that the curriculum, and the teachers, do not stagnate. A tired curriculum produces disengaged teachers and provides no incentive for students to proceed to tertiary study or to careers in science, engineering and technology. Such a curriculum fails to equip students as expert puzzle solvers and innovators. The loss to society goes beyond the loss of students who are keen to pursue science-related studies and careers. It includes the loss of a well-educated polity that understands the need for scientific research (and expensive research facilities), and the importance of innovation for the long-term health of society. How these multiple factors play out in a multi-faceted secondary physics curriculum designed to produce both elite scientific performers and a scientifically capable polity is a challenge that is worth pursuing. It is a good Kuhnian puzzle.

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2 National Curriculum Board, National Science Curriculum: Framing paper, for consultation: 20 November 2008 – 28 February 2009, at *http://www.ncb.org.au/verve/_resources/National_Science_Curriculum_-_Framing_Paper.pdf*, last accessed December 2008.

3 Ibid., 56: "an interdisciplinary course that provides for students wanting to study only one science course in the senior secondary years. It could have an emphasis on contemporary science and technological applications."

4 One candidate for redevelopment is the study of psychology, which in Victoria attracts significantly more students than any other science. While presenting its scientific credentials throughout the Study Design, psychology is the least scientific, as measured by its recall and recognition examination. Unfortunately, large numbers of students, and therefore the next generation of our society, are currently inducted into the notion of science as a set of facts that are capable of memorization, rather than as a human enterprise where data drives conclusions that are always, in principle, contestable.

5 Denis Goodrum, Mark Hackling and Leonie Rennie, Report on the status and quality of teaching and learning of science in Australian schools (the Goodrum Report), 2001, section 2.2.1, *http://www.detya.gov.au/schools/publications/2001/science/chap2.htm*, last accessed June 2004. This definition is re-packaged in National Curriculum Board's paper, Science Initial Advice, page 6, which follows the identical definition in Leonie Rennie and Denis Goodrum, Australian School Science Education National Action Plan 2008-2012, Volume 1: The National Action Plan, *www.dest.gov.au/sectors/school_education/publications_resources/profiles/Australian_School_Education_Plan_2008_2012.htm*, last accessed December 2008.

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8 See discussion of research findings under the heading "Personal Value, Relevance and Engagement" in Australian School Science Education National Action Plan 2008--2012, Volume 2, 7f.

9 Gabrielle Matters and Geoff Masters, Year 12 Curriculum and Achievement Standards, DEST, 2007, claimed that there was more than 85% unanimity in content across jurisdictions for both physics and chemistry.

10 Australian School Science Education National Action Plan 2008-–2012, Volume 2, 10.

11 Neil Champion, Facing the Challenge of Change: Physics, Photonics and Synchrotron Applications in the Victorian Certificate of Education, paper presented at the 8th International Conference, Physics in the System of Modern Education, St. Petersburg (Russia), June 2005, 254-257.

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15 At Stage 3 (approximately age 12–15 years), the framing paper proposes "specific topics on contemporary science aspects and issues" that include recent scientific research findings. These are often interdisciplinary. Functional imaging techniques, for example, are providing new insights into links between brain functioning and behaviour. They are leading to major gains in neurobiology, neuropsychology and neuropsychopharmacology, gains that owe much to the devices and insights developed by physicists working in the interstices of the disciplines. The need for education to reflect interdisciplinarity has been clear for a considerable time, for example, in nanotechnology. Kinesin is being studied to see how very small parcels can be transported, molecular electronics and chemical/biological sensors are being developed, nanostructures and fullerenes in nature examined, as is the behaviour of nanotubes similar to the tubules of brain development. See Richard Feynman, There's Plenty of Room at the Bottom, Engineering and Science, Caltech, 1959, 6, available at *www.zyvex.com/nanotech/feynman.html*, last accessed December 2008. It might even be possible to promote interdisciplinary relations between the sciences and the humanities.

16 These are drawn from the Curriculum Corporation's Statements of Learning for Science, 2006.

17 Thomas S. Kuhn, The Structure of Scientific Revolutions, third edition, University of Chicago Press: Chicago, 1996, 36. (first published 1962)

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20 Ibid., 93.

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University funding: A National Tragedy

by David Blair

If I was the CEO of a large corporation with tens of thousands of employees and had encouraged them to spend more than a month per year working on activities that had less than a 20% chance of bringing in any profit at all, I think the shareholders would very rapidly decide to relieve me of my duties.

This is the current situation in universities. With the words Education Revolution still ringing dimly in our ears, it is very important that Kevin Rudd and Julia Gillard listen to understand what is happening to the top talent in our universities. These are the people who innovate, who invent and discover, who enthuse students, who train our future Nobel prize-winners and our Prime Ministers, the people who nurture and develop the intellectual capital on which our future depends. They do this effectively because they work at the cutting edge of their discipline and are actively involved in its development through research.

For those not in the system, it is important to understand how the system works. There are two groups of staff we need to identify. One are the University academics, who usually get appointed only after having had a distinguished international research career, and who's job description is to undertake both teaching and research. The second are researchers who have no ongoing appointment, and whose job depends entirely on external research funds. Their job description is to undertake research on nominated projects and usually they play a major role in the training of postgraduate students. They and their students are there because they love research, they know it is important and one way or another believe they can make a difference to the world. The postdocs are often the ones who do the most to inspire and enthuse the students. The students are also a key part of this innovation engine: they are the ones who ask probing questions, question the status quo and often trigger the conceptual jumps that lead to breakthroughs.

University funding has been so slashed to the bone in Australia that the universities themselves have minimal funds to support the research component. For the supply of research funds, we have a competitive funding system with many schemes including the Australian Research Council and the National Health and Medical Research Council, as well as many industry and state based schemes. Researchers put forward research projects that are sent to national and international experts in the field for comment, and then to committees that make a selection.

The problem is this: the funds made available to support this competitive system are grossly inadequate. The fraction of projects funded is typically one in five. The funds granted are often half of what was requested, even when every line item in the budget has been carefully justified as essential to the project. Thus the overall funding success is about one in five times 50% or about 10%. The depressing job of deciding who will be the lucky few is handled by committees of dedicated experts who struggle to find a way of distributing their few loaves and fishes to Australia's research community.
It is important for politicians to understand how this system they have created affects people's lives, the work output at Universities, the economy and Australia's international reputation. It is important that you, the reader also understand. You are almost certainly not a politician, but you can help politicians understand, because the present system is a national tragedy.

All through the year researchers have to plan their grants under innumerable programs with different rules and closing dates: Discovery Grants, Linkage Grants, Infrastructure Grants to name just a few. The programs have all been designed to spread the inadequate funds as fairly as possible. In planning their projects researchers often set up collaborations with international partners. The partners are often enthusiastic to participate because Australians are well known for their innovative research.

No one seems to be thinking about our intellectual capital.

Let's focus on the Australian Research Council's premier grant program, the Discovery Grants. Planning begins in December. In January the project planning becomes intense. The universities run workshops to help their researchers make their applications more competitive, they employ staff to scrutinise the applications trying to ensure that each is at the very top level. International partners have to provide letters from their university authorities authorising their participation and budget contributions. Little of this actually improves the research…it just makes it look better to help you beat your colleagues at other universities.

To put it plainly, we all rush around like a flock of starving chooks thrown a miserable handful of grain, each of us scrabbling to be in the top 10%.

In July the ARC sends out the peer review reports and offers the researchers the chance to respond to criticisms. In my school of physics at the University of Western Australia there was general euphoria last July because most people had reports with words such as "outstanding project", "very strong team", "outstanding track record", "potential for a major breakthrough".

Last November across the country the depression in the universities was palpable: as usual there was not enough money to go around and most people were unfunded. Researchers found they had no job next year, students found projects were not available, and international partners found that their collaboration with Australia could not proceed.

Some time ago I spent 3 years on ARC panels, doing the depressing job of rejecting many outstanding projects. From my experience more than one third of all projects are outstanding. If these were fully funded, research funding would need to triple, matching that of other developed countries. I want to give just a few examples of some

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unfunded projects that I know about from last year. First I should point out that I was not an applicant for a Discovery Grant last year, and I was successful in another scheme, so this is not the personal whinge of a loser.

One project was going to develop techniques for turning a normal PC computer into a supercomputer. In preparation for the project the research team had already demonstrated a 15-fold speed up compared with conventional desktop computers. US scientists had enthusiastically endorsed the project. Another project described a real breakthrough in a hot topic in physics…asking whether weird quantum behaviour applies to large-scale objects. I predict there will be a Nobel Prize for the first person to demonstrate the answer. The breakthrough gave Australia a real chance for being in the running. The team had US and French partners from top institutions…but it was not funded.

The repercussions of this terrible situation go beyond our boundaries. Australia is becoming known as a country that treats its research community with disdain. Research grants directly affect the top end of our education system, but it also trickles down and provides inspiration for our young people at all levels.

Another part of the education revolution promised before the last election was going to be the funds for school excursions. This would have allowed schools to visit universities and specialist facilities where there are fabulous facilities and a real willingness to inspire kids (assuming the staff are not in a state of depression over their failed dreams).

Both ends of the education system need attention.

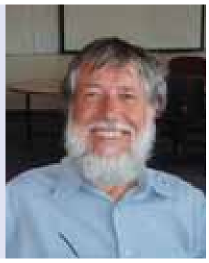
I think an economic analysis of the present system would show that hundreds of millions dollars are wasted every year through wasted time, depressed staff and lost opportunities.

Right now governments are spending huge sums of money trying to boost the economy. Cash handouts are being spent buying flat screen TVs made in China and white goods made in South East Asia: noble aid for our trading partners, nice for the buyers, and great for certain well known business owners.

Other money is being handed out for school buildings and roads. No one seems to be thinking about our intellectual capital. No one seems to be thinking about the people in the education sector who with more support could be working on ideas, technologies, and products that can make Australia more competitive, more creative, and more innovative. To invest in intellectual capital is to invest in the future. The money and the benefits would stay in Australia.

Australians deserve better.

David Blair is Director of the Australian International Gravitational Research Centre, 2007 West Australian Scientist of the Year and winner of the Prime Minister's Eureka Prize for Promoting Science.



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

*We would like to publish more articles about physics and physicists in industry or commerce. If you would like to write an article for Australian Physics on your area and activities to inform the Australian Physics community please contact the editor-in-chief Dr Marc Duldig (*marc.duldig@aad.gov.au*).*

Samplings

Good vibrations

http://physicsworld.com/cws/article/news/38102

Tiny sensors with the ability to roam can be a great aid to doctors, returning information from some hard-to-reach locations inside the body. A problem arises however in powering these devices; standard fuel cells are too large and it is very difficult to “replace the batteries” once a sensor is inside the body. Researchers in Italy are proposing a solution in which mobile electronic devices “harvest” the energy of natural vibrations inside the human body.

Gammaitoni and his colleagues have the idea to create sensors from piezoelectric materials, which generate tiny electric currents when flexed by ambient vibrations. Although the principle of converting ambient noise into useful energy is not a new idea, the researchers present a technique for “broadband” harvesting of a wide range of vibrations. Reporting their findings in Physical Review Letters, they claim that the nonlinear oscillators yielded 4 to 6 times more energy than the linear ones.

Algorithm discovers physical laws

http://physicsworld.com/cws/article/news/38550
http://www.sciencemag.org/cgi/content/full/324/5923/81
http://www.sciencemag.org/cgi/content/full/324/5923/85

Two physicists in the US have created an algorithm that can deduce physical laws from raw experimental data with little help from humans. Without any knowledge of physics or geometry, the algorithm discovered exact energy and momentum relations governing the dynamics of mass-spring systems as well as single and double pendulums.

The researchers envisage such algorithms speeding up the scientific process by reducing the time needed to identify potentially interesting models of particular systems.

Two new papers in the journal Science confront the problem of using artificial intelligence to automatically distill experimental data into new physical laws. One describes the development of a robot that can generate and then test hypotheses about biological systems, while the other, by computational biologist Michael Schmidt and engineer and computer scientist Hod Lipson of Cornell University in the US, explains how conservation laws can be generated automatically.

David Waltz, a computer scientist at Columbia University in the US, does not believe that the Schmidt and Lipson algorithm is likely to produce a truly profound result in the near future. But he believes that the general approach could become much more sophisticated, envisaging that intelligent systems could continuously look for correlations in the data from an ever larger range of experiments in such areas as astronomy, geophysics and particle physics. He expects that computational systems will exhibit increasing amounts of what we would today say requires human insight.

See also commentaries by Philip Ball in Nature: *http://www.nature.com/news/2009/090402/full/news.2009.212.html* and by Waltz and Buchanan in Science: *http://www.sciencemag.org/cgi/content/full/324/5923/43.*

Samplings by Don Price and Andy Scott

Searching for another home?

http://physicsworld.com/cws/article/news/38134

NASA’s Kepler mission successfully blasted off on Friday, 6 March aboard a Delta II rocket from Florida’s Cape Canaveral Air Force Station. By monitoring more than 100,000 stars for periodic dips in brightness, it can spot when a planet passes in front of them. Kepler will be in its own orbit around the sun, relatively far from Earth, so our planet will not interfere with observations. This will allow the mission to observe the same patch of sky uninterrupted for the entire mission of at least three-and-a-half years, allowing it to observe at least three transits of any planets it finds that are in one-year orbits, like Earth’s. That is the minimum needed to confirm that the event recurs at a precise interval, and so rule out confounding factors such as fluctuations in the brightness of the star itself.

Seeing inside living bodies with nanoparticles

http://physicsworld.com/cws/article/news/38499

Researchers at the Philips Research Labs in the Netherlands have imaged the flow of blood in a living organism for the first time using a medical technology known as magnetic particle imaging (MPI).

In the method, iron oxide nanoparticles were injected into the bloodstream of mice before their flow was traced through vital organs using a technique similar to magnetic resonance imaging (MRI).

If the technology can now be adapted for use in the human body it could be help to diagnose heart disease and cancer and to monitor the body’s reaction to the treatment of these conditions.

“MPI may be able to replace or compliment some MRI procedures, but it’s not likely that it would replace MRI altogether,” said Philip Grandinetti an NMR methods researcher at Ohio State University.”

Physicists have another go at Maxwell's demon

http://physicsworld.com/cws/article/news/38569

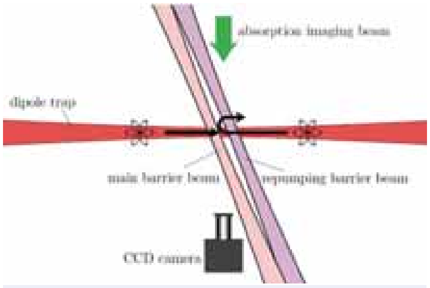


Diagram of the experiment done by Daniel Steck and colleagues.

Ever since James Clerk Maxwell dreamt up his demon nearly 150 years ago, physicists have had a lot of fun trying to create this mischievous fiend. Maxwell imagined his demon as a miniscule creature who can control a trapdoor in a gas to segregate hot atoms from cold.

He proposed this 'thought experiment' because it seemed offered a simple way of violating the 2nd law of thermodynamics by reducing entropy in the system without expending energy.

The general consensus amongst physicists is that the demon – as Maxwell had envisaged – would be impossible to realize. Largely because, in sorting the atoms, the demon must open and close the trapdoor at precisely the right times; to do this he would need to know the position and velocity of every atom at any given moment.

"In a sense, then, by having such knowledge, the demon has already transferred the entropy of the gas into his brain," said Daniel Steck, one of the researchers at the University of Oregon who have made the latest attempt to create the demon.

Dragging the demon into the 21st century, Steck and his colleagues readdress the riddle using the modern techniques of ultracold atom research.

The researchers created their demon using a laser array, which was focussed on a group of ultracold Rb-87 atoms. Lasers were tuned so their beams of light pushed differently on different atoms depending on their spin.

Keeping carbon out of sight but not out of mind

http://physicsworld.com/cws/article/news/38548
http://www.nature.com/nature/journal/v458/n7238/full/458583a.html
http://www.nature.com/nature/journal/v458/n7238/full/nature07852.html

Channelling vast quantities of carbon dioxide into deep underground bunkers sounds like the ultimate have your cake and eat it solution to ambitious international CO_2 emission targets. Now, a group of scientists remind us that before carbon capture and storage can become a viable option we need to first understand what happens to the CO_2 once it is buried underground.

The researchers, led by Stuart Gilfillan of the University of Edinburgh and the University of Manchester, studied a series of natural gas fields which are fed from beneath by natural CO_2 sources. Reporting their findings in Nature, they found that over 80 % of the carbon dioxide dissolves in groundwater, with only a small fraction reacting with the cavity walls to form carbonates.

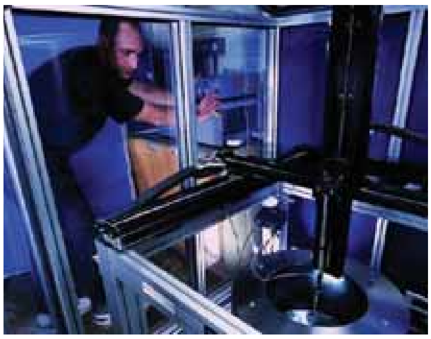
"Our findings confirm natural gas fields can be used to store CO_2 safely over millions of years. More importantly, it tells us we need to take a closer look at the mobility of CO_2 dissolved in these waters," Gilfillan told us.

International Year of Astronomy

Physics World has produced a special edition to mark the International Year of Astronomy. It may be downloaded free at *http://physicsworld.com/cws/download/si2009*. The issue contains articles about the search for exoplanets, the development of planetary exploration, a return to the Moon, plans for extra-large telescopes, and the legacy of Galileo. Six leading astronomers reveal the biggest challenges for the field, while five iconic images from astronomy are showcased.

Surgically clean

http://physicsworld.com/cws/article/news/38746



New sensor can give numbers to the cleaning of surgical instruments. Credit: National Physical Laboratory

Surgical instruments are cleaned by immersing them in a disinfecting liquid and firing high frequency acoustic waves through the mix, which causes tiny bubbles in the liquid to implode, a phenomenon known as cavitation. The force created when these bubbles collapse is enough to remove contaminants on the surface of the surrounding material. Given that each implosion leads to new bubbles, cavitation is believed to provide a very effective mechanism for cleansing. However, there are no established means of quantifying cavitation, and so researchers at the National Physical Laboratory (NPL) in the UK have developed a sensor that can monitor the amount of cavitation produced in cleaning vessels. The sensors, which are hollow cylinders fabricated from a thin layer of piezoelectric material sandwiched between special absorbers, are designed to sit in the liquid and record the spatially-variant, high-frequency "noise" of bubble implosions.

What's the time, Eccles?

http://physicsworld.com/cws/article/news/38726
http://www.sciencemag.org/cgi/content/full/324/5925/360

Last year researchers at NIST and JILA built an atomic clock based on around 2000 ultra-cold fermionic strontium atoms trapped in an optical lattice of overlapping infrared laser beams. The atoms were bathed in light from a separate red laser at a frequency that corresponds to an atomic transition in strontium. This made the light "lock into" the precise frequency of the transition and it thus oscillated between energy levels, just like the ticking of a clock. Now, tiny shifts in the frequencies of the clock ticks have been measured as a function of temperature.

The Pauli exclusion principle suppresses collisions between identical fermions, but these previously indistinguishable fermions become distinguishable due to laser-atom interactions. The probability that

Samplings continue on page 88

Prompt Critical

The Quantum Phase Operator: A Review (Series in Optics and Optoelectronics)

Ed. Barnett and Vaccaro
Taylor and Francis, Boca Raton, FL, 2007. 499pp.
ISBN: 1-58488-760-5

Aspiring students of theoretical physics must master two incommensurate descriptions of non-relativistic mechanics: classical (or Hamiltonian) mechanics and quantum mechanics. Typically, the student is led to believe that quantum mechanics is the more fundamental description of mechanical systems, while classical mechanics is some kind of approximation, valid for the sorts of systems studied by mechanical engineers. The incommensurability of the quantum and classical descriptions is written into the mathematical formulations of each. In classical mechanics, physical states are represented, in general, by probability distributions on phase space, while physical quantities are represented by real-valued, bounded, functions on phase space. In quantum theory, physical states are, in general, represented by positive operators, of trace one acting on Hilbert space, while physical quantities are represented by Hermitian operators.

A more modern, and more useful, representation of a physical quantity in quantum mechanics is in terms of a positive operator valued measure (POVM). Given a physical state and a POVM we can calculate the statistics of the measurement outcomes for that physical quantity, which is all that we can ask of quantum mechanics. This enables us to describe a far more general (and practical) class of physically relevant quantities than can be represented by Hermitian operators on Hilbert space. What can go wrong if you insist that physically relevant quantities be represented only by Hermitian operators is the subject of this book: the physical relevant quantity of interest is phase.

Phase enters Hamiltonian mechanics through the concept of action-angle variables. In the case of an oscillatory system, the action is proportional to the area bounded by a curve of constant energy in phase space, while the phase is an angle parameterising a point along the curve. In the case of a simple harmonic oscillator, which as Galileo discovered, has a period independent of energy, the action is equal to the energy times the period. Quantisation then proceeds by showing that only those energies are allowed for which the action is an integer multiple of Planck's constant. This implies the corresponding operator for energy has a discrete spectrum of equally spaced values, bounded from below. In dimensionless units, we call this operator the number operator. If we then insist that the canonical phase variable is to be represented by a Hermitian operator, we end up in some trouble, which follows immediately from the fact that the number operator is bounded from below.

If you want to learn how to define a Hermitian phase operator without getting into a whole lot of trouble you should read the first six chapters, which recapitulates the history of the troubles, beginning with Dirac, up to the resolution of the problem in the late 1980s, due to Pegg and Barnett. These chapters comprise a well chosen set of original papers, preceded by insightful introductions written by the editors, Barnett and Vaccaro. The advantage of learning the subject this way is the vicarious experience of reliving the colourful, and oft times confusing, way theoretical physicists make progress.

But must we insist that all physical quantities are to be represented by a Hermitian operator? Can we dispense with a Hermitian phase operator and find an appropriate positive operator valued measure for phase? The answer is yes and it is briefly discussed in the introduction to Chapter 3.

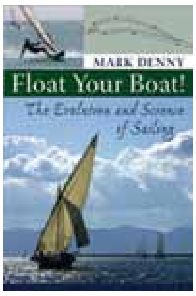
Given a Hermitian phase operator, canonically conjugate to the number operator, one can quickly derive an uncertainty principle analogous to the usual position and momentum uncertainty principle. This can then be used to arrive at a version of the time energy uncertainty relations. However you do not need a pair of Hermitian operators to define useful uncertainty principles. We have had a sensible time-energy uncertainty relation a lot longer than we have had a Hermitian phase operator, but it is not equivalent to the usual position and momentum uncertainty relation. There is a quite different way of viewing phase in quantum mechanics as simply a real number (mod two pi) that parameterises a one-parameter group of reversible state transformations (time in quantum mechanics is just such a parameter). We can then derive a bound on how well quantum mechanics permits us to estimate such a parameter, resulting in an uncertainty principle of the time-energy kind.

The last chapter is the most exciting. It concerns a quantum description of time presented in two profound papers by David Pegg - a fitting tribute to Pegg to whom the editors have dedicated the book on the occasion of his 65^{th} birthday. The first of these papers shows how time can emerge from an energy eigenstate for the universe, an "ageless" state, by appropriately portioning the universe into clock and everything else. This paper is remarkably clear and concise. (I once remarked on this to Pegg. He responded that when one writes a small paper about the entire universe, concision is necessary.) This approach to time prefigures what has become known as the relational approach to time in quantum gravity and anticipates the work of Gambini and Pullin, and work in quantum information theory on reference frames.

In this age of electronic archives and web based journals, it is not clear why anyone would need a book of reprints. I much prefer to read a screen than a piece of paper; it is easier to carry a laptop than a bag of books, and a lot cheaper to increase the screen font size than to buy a new pair of glasses. However, if you prefer sitting down with a coffee and a hardbound book, ask your library to buy this book. In any case, no one professing expertise in modern quantum optics can afford not to read it.

Gerard Milburn
University of Queensland

Note: Both Prof. Gerard Milburn and the Reviews Editor were students of David Pegg along with at least four other Australian academics now at Professor or Associate Professor level.

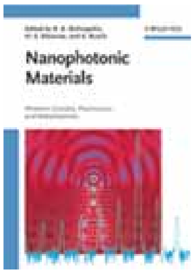


Float Your Boat! The Evolution and Science of Sailing
Mark Denny
Johns Hopkins University Press, Baltimore MD, 2009
ix&265pp.
ISBN: 978-0-8018-9909-3

The book aims at "explaining the evolution and science of sailing" and promises "not to water down the physics but to belay the math". The author uses an entertaining and witty style and does a good job coming up with simple explanations that are mostly good approximations.

On a historical background, with many good illustrations and with increasingly complex arguments Denny explains how sailing ships move and can make way to windward, starting with a simple momentum flux model, and proceeding to more complex aerodynamic models. His treatment of lift is good, as is his discussion of the overall forces and torques on a sailboat. The chapter aptly named "Flying through the water" on hydrodynamics, hull speed, wakes and keel design is simple but adequate. Denny uses mathematics sparingly, with the more complex parts in the appendix, and he does point out where the models may fail due to their simplicity… and where more serious scientists may complain.

The book treats a very difficult problem with sufficient rigour to be a significant improvement to the popular literature on the subject, and most sailors would improve their appreciation by reading it. The book does include some errors of varying importance such as implying that rafts do not make use of Archimedes' principle to float, that Vikings were unable to make precision scarfed joints and a number of confusing figure captions, including a ship with the apparent wind well ahead of the beam described as running before the wind. Overall, I enjoyed reading the book including the additional details in the appendices. While not taking the hint of calling it coruscatingly brilliant, I would certainly recommend it to all who sail or dream of sailing.
Jesper Munch
University of Adelaide



Nanophotonic Materials: Photonic Crystals, Plasmonics and Metamaterials
Eds. RB Wehrspohn, Kitzerow and Busch.
Wiley VCH, Weinheim, 2008
xxvii&436pp
ISBN: 9783527408580

Nanophotonic Materials is a beautifully produced book that addresses one of the most topical areas in optics today, the use of designed structured and composite materials for photonics. The topics are arranged in increasing order of topicality, beginning with photonic crystals and photonic crystal fibres (areas that now seem oddly mature), to the plasmonics, and newest and hottest of them all, metamaterials.

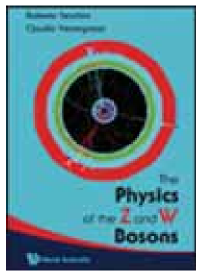
The title of the book gives the impression that this is a comprehensive review of these fields, which is actually slightly misleading. Although the chapters do review and reference the broader scientific literature (some chapters much more completely than others), the majority of the book is concerned with detailing the work of a German consortium in the area. This work has been substantial (covering 20 groups over 7 years) and generally very high quality, but the approach inevitably leads to variability in the chapters.

In some cases the chapters read more like journal papers than book chapters, and some the contribution of the consortium to the different fields described have been much more important than others. For example the section on photonic crystal fibres (Section III) is sparse and certainly not the best introduction the field, while the section on metamaterials is one of the most readable and interesting introductions I have seen.

The bulk of the book is related to photonic crystal research, including approaches to fabrication, modelling/design and characterisation, with a focus more on the fundamental science than device applications. Particular emphasis is paid to introducing tunability to photonic crystals, with the main approach being the infiltration of liquid crystals into the structure.

As someone who has followed this field only intermittently over the fast few years, I found the presentation generally excellent. Most chapters do not assume that the reader is already immersed the area, and there are a large number of full colour figures which greatly enhance the clarity of the explanations. It has probably also been helpful that the contributors span physics and chemistry/materials science- one senses that both communities have made and effort to make themselves intelligible to the other.

I found the last quarter of the book, on plasmonics and metamaterials, the most interesting. There are few existing books covering these areas (particularly metamaterials) making this contribution particularly timely. In addition, the work that is presented, for example on optical metamaterials, is truly state of the art. This is such a rapidly developing area that any review is only ever a snapshot of the experimental progress. But this is a particularly good one, and its combination with a clear explanation of some of the conceptual issues means that it will probably remain useful for sometime to come.
Maryanne Large
University of Sydney



The Physics of the Z and W Bosons
Roberto Tenchini and Cladio Verzegnassi
World Scientific Publishing
xv&419pp,
ISBN: 978-981-270-702-4

The W and Z bosons are the carriers of the Weak force, in the same way that the photon is the carrier of the Electromagnetic force. They are very heavy, about 80 and 90 GeV respectively. Those masses were predicted after the discovery of weak neutral currents at CERN in 1973. The proton-antiproton collier at CERN was built specifically to find the W and Z, which it did in 1983 at the UA1 and UA2 experiments, in collisions at up to 450 GeV per beam.

The physics of the Z was extensively explored over 10 years at CERN's LEP (Large Electron Positron) collider, in

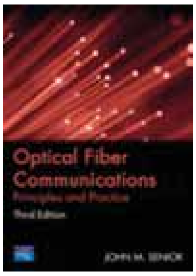
which counter-rotating beams were collided at or near the Z-pole. In its final years the LEP energy was doubled to produce a limited number of W pairs.

The baton then passed to the Tevatron collider at Fermilab near Chicago with proton-antiproton collisions up to 1 TeV per beam. That accelerator is still operating and studying the W.

This book is very theoretical in content, but at a level that any experimentalist working in this field should be able to comfortably handle. Sadly the section on detectors and accelerators occupies just 12 pages in over 400, and is weak.

Who would benefit from reading this book? All the theory is available in journals, but it is great to have it together in one volume. In my view it is a must for the library of any group active in HEP, but I cannot see too many individuals rushing out to buy it.

Stuart Tovey
University of Melbourne



Optical Fiber Communications. Principles and Practice 3rd Ed.
John M. Senior
Pearson Education, Essex, 2009
xlx + 1075 pp.
ISBN: 978-0-13-032681-2

This book was forwarded to me as a teaching academic in the field. It is an excellent text of all aspects of the "physical layer" of telecommunication networks, i.e, the physics of the optical elements and materials incorporated into the network.

In the preface the author clearly states his desire to produce a reference text for the engineers and scientists in the field and at 1075 pages there is nothing missing. Waveguide devices and integrated optoelectronic devices are well covered and are up to date as is the discussion of modulation formats and network capacity.

The other goal is production of an introductory text for undergraduate and postgraduate students of the field and there, I feel from a teaching perspective, this book has so much more information than could be reasonably presented in any single semester course that it is in danger of overwhelming the student. Still, that is the task in teaching Optical Communications and it is better to have the full story than not.

Overall, this book would compete with Fundamentals of Photonics by Saleh and Teich and the choice of which to use in support of a course in the subject depends on the individual lecturer with Senior aiming more at the overall practical handbook market and Saleh being more physics driven. If in the field, buy a copy for your library as it really is an excellent reference book.

John Holdsworth
University of Newcastle
Reviews Editor

Samplings continued from page 85

atomic collisions will occur depends on how the atoms in the ensemble are excited. The JILA team determined that when atoms are excited to roughly halfway between the ground and excited states, collision-related shifts in clock frequencies drop to zero. The technique has allowed the team to improve the accuracy of its clock by 50% so that it now neither gains nor loses a second in more than 300 million years.

Obama outlines science vision

http://www.sciencemag.org/cgi/content/full/324/5927/576-a

US President Barack Obama has pledged to increase the country's spending on research and development to create an "Apollo era" push for research into renewable energy. Speaking at the 146th annual meeting of the National Academy of Sciences in Washington DC, President Obama outlined a wide-ranging plan for science and technology including improving teaching of science in schools to reducing carbon emissions. Watch the video!: *http://www.youtube.com/watch?v=k5-MgZD5IMc*

Metals toughen spider's silk

http://physicsworld.com/cws/article/news/38803

http://www.sciencemag.org/cgi/content/full/324/5926/488

Spider's silk is already tougher than steel — but physicists in Germany have now found that it can be made even stronger by adding small quantities of metal. Spider silk is a polymer material made of thin crystalline sheets of proteins bound together by amorphous layers of amino acids.

Spiders make many different kinds of silk, but Mato Knez and colleagues at the Max Planck Institute of Microstructure Physics and Martin Luther University (both in Halle) studied "dragline" silk. This is the non-sticky stuff that spiders use to strengthen their webs and hang from.

The team began by harvesting silk from a live spider that they had caught in a nearby garden. After drying in vacuum, the fibres were exposed to a metallic vapour followed by water vapour, with the process repeated about 100 times.

The team found that the metal-treated silk could be as much as eight times as tough as the untreated material – with titanium appearing to have the greatest effect. Knez and colleagues performed X–ray and nuclear magnetic resonance studies of the treated silk to try to understand where the absorbed metals were located and why they made the material tougher. In each case they found that the metals had migrated into the bulk of the fibres.

The authors suggest that this result of enhanced toughness of spider silk could potentially serve as a model for a more general approach to enhance the strength and toughness of other biomaterials.

Silk was collected from an Araneus spider like this one. (Courtesy: Seung-Mo Lee, MPI Halle)

Product News

Warsash

New USB control for Wavelength's low noise laser diode driver

Warsash Scientific is pleased to announce the release of the new FL593FL, bringing Wavelength's low noise FL500 laser diode driver under USB computer control. This full speed USB controller comes with a robust driver, a simple Windows™ control interface, and an easy-to-use development API for rapidly building custom applications.

The FL593FL, with its on-board non-volatile memory to hold operational settings, will continue operating stand-alone after downloading configuration and disconnection from the PC. Alternatively, use the USB hubs to control multiple units from a single port.

Each device is displayed in its own window, complete with real-time data acquisition, limit and set-point monitoring, Interlock Enable notification, and custom configuration options.

Configurations can be saved and reloaded for consistency and efficiency with multiple operators. Plug-n-play using the default factory settings or use the API provided to tailor the FL593 for a specific function.

This adaptable module is ideal for remotely controlling multiple laser diodes – such as burn-in racks, L- I characterisation systems, and more. Set-point, current limit, constant current/constant power mode settings are all under computer control.

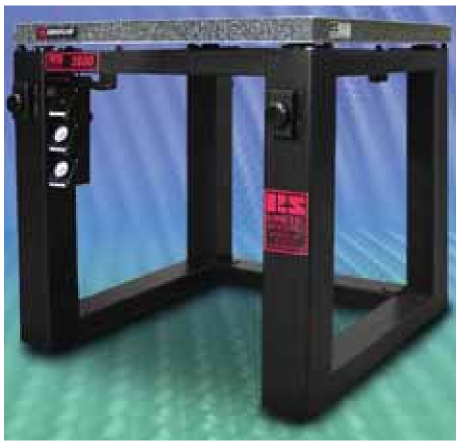
Optional analogue inputs facilitate up to 500 kHz modulation in constant current mode. Data acquisition period can be set from 100ms to 10 second intervals.

Features/Benefits

- Controls lasers with common photodiode cathode (Type A) configuration or isolated photodiode (Type B) configuration
- Independent Constant Current or Constant Power mode setting
- Drive 2 channels up to 250 mA each or a single channel up to 500 mA
- Wide supply voltage range: +4.5 to 9 V
- Analogue signal monitoring points
- Safety Interlock
- Includes input/output & USB cables
- Application software included
- Application programming interface (API)

Further information on this and other Wavelength Electronics laser diode drivers contact: Warsash Scientific
Tel: +61 2 9319 0122
Fax: +61 2 9318 2192
sales@warsash.com.au
www.warsash.com.au

NEW Ultra low frequency vibration isolation workstation from Kinetic Systems



Warsash Scientific is pleased to announce the release of a new ultra-low-frequency vibration-isolation workstation for lighter loads from Kinetic Systems.

Designated the 2800 Series LLHP, this new workstation is designed to meet the exacting vibration-isolation requirements of sensitive equipment weighing in the 100-pound range (200 pounds max.).

KSI uses its proprietary trifilar pendulum mounts and Active-Air suspension to provide exceptional horizontal axis vibration isolation that outperforms other mechanical systems, and a high level of vertical axis isolation.

The 2800 Series tabletop is 30" square, two inches thick, and can be constructed of lightweight aluminum extruded core or a variety of composite cores. Surfaces are available with or without mounting holes.

The compact, ergonomic design of the 2800 Series incorporates automatic leveling and low natural frequencies (1.1 Hz along horizontal axis and 1.4 Hz along vertical axis). The workstation can achieve vertical isolation efficiency of 96% and horizontal isolation efficiency of 97% (at 10 Hz and above).

Ideal for supporting atomic force microscopes, analytical balances, etc., the 2800 Series can be configured for Class 100 cleanroom compatibility and outfitted with a variety of accessories to increase the user's comfort and convenience (padded armrests, overhead equipment shelves, monitor stands, outlet strips for lighting, etc.).

Kinetic Systems workstations are proven performers in applications such as semiconductor processing, telecommunications, aerospace engineering, and medical research.

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

Enhanced FL500 laser diode driver now for RoHS Compliance

Warsash Scientific is pleased to announce the release of the re-engineered FL500 Low Noise Laser Diode Driver to integrate with higher temperature RoHS-compliant manufacturing processes. It is now compatible with reflow processing less than 250°C.

This surface mount chip is ideal for OEM instrumentation. It offers exceptionally low noise laser diode control that can be

configured either as two independent 250mA drivers or a single 500mA driver. The FL500 can run on a +3V Lithium-ion battery or up to a +12V power supply. Small size, low noise and modest power requirements make it the choice for handheld precision laser instrumentation.

For additional features, including current limit and photodiode feedback for Constant Power operation, the FL500 can be used with the FL591 evaluation board.

Further information on this and other Wavelength Electronics laser diode drivers please contact:
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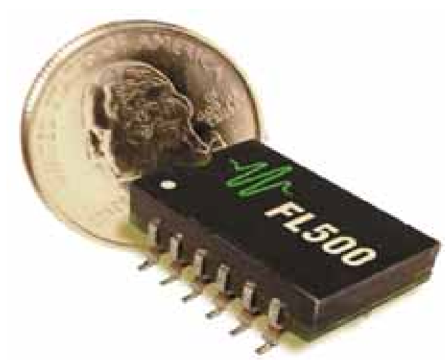
sales@warsash.com.au
www.warsash.com.au



Enhanced FL500 laser diode driver now for RoHS Compliance

SciTech

Andor Shamrock SR-500i imaging spectrograph

The new Shamrock SR-500i imaging spectrograph is a natural extension to Andor's existing range of spectroscopy detection solutions. The instrument will offer users enhanced multi-track capabilities and imaging quality for simultaneous multi-fiber optic probing, and direct-coupling micro-spectroscopy applications. Configurable with up to two inputs and two outputs, the SR-500i is compatible with a wide range of accessories including the mirror-based F/# matcher, swappable grating turrets and shutter and fiber optics bundles. The versatility of the instrument means researchers can easily tailor and upgrade their system to adapt to changing needs.

Used in conjunction with Andor's range of renowned high performance detectors, including the exclusive Newton EMCCD range, and spectroscopy-dedicated Solis software, the USB 2.0, pre-aligned and pre-calibrated SR-500i provides a powerful, yet user-friendly research instrument.

The Shamrock SR-500i confirms yet again Andor's reputation for offering flexible, user-friendly, high-end, high-quality Spectroscopy instrumentation. This detection platform is the ideal tool for physical and life science research using both multi-channel and single elements detection.

Andor Clara – Pushing Interline Further

Andor's expertise in scientific performance optimization has been harnessed once again. Clara has been designed to deliver the highest sensitivity performance achievable from a high-resolution interline CCD camera.

Based around the popular ICX285 sensor from Sony®, the Clara is ideally suited to high-resolution cell microscopy and OEM applications. Andor's proven UltraVac™ process, alongside close attention to thermal management, has resulted in deep air cooling to -45°C for elimination of darkcurrent, complementing a unique read noise of 3e- @ 1 MHz.

More dynamic events can be followed with outstanding quantitative stability via low noise 10 or 20 MHz readout modes, the data channeled through a trouble-free USB 2.0 interface. Andor's iCam technology enables market-leading acquisition efficiency through live cell microscopy software. The compact, robust design and accessible SDK, renders Clara ideally suited to OEM integration.

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Lastek

iChrome from Toptica

The newly introduced iChrome from Toptica is a fiber laser with the flexibility to set automatically the laser output to any wavelength in the visible – from 488 nm to 640 nm.

In contrast to conventional white light sources, the narrow bandwidth laser pulses are not filtered out from an intrinsically noisy supercontinuum. Moreover, even the coherence of the fundamental laser is preserved during the frequency conversion processes. This ensures that the visible light exhibits the best intensity noise performance.

Additionally all optical components are polarization maintaining. This results in a stable linear polarization of the output beam.

Fibre Coupled Output

The laser output of the iChrome is delivered by a single-mode and polarization maintaining fibre.

Independent from the chosen wavelength the fibre output exhibits a smooth TEM00 profile, an excellent beam product with M2 < 1.1 and a linear polarization with a PER > 1:100. The fibre makes the connection between the high quality light source and the experiment as simple as possible.

Pointing stability is guaranteed and all colours are delivered by the same fibre.

Fully Automated Operation

The entire laser system is extremely user friendly: No alignment procedures of any optical components distract the user from their main task – to produce results.

Besides the fibre delivery also the full automation of the premium light source helps to avoid wasting time. The built-in power PC controls all necessary parameters to ensure smooth operation every minute, hour, day, week and month. The power PC also hosts a web server and is equipped with an Ethernet connection. Therefore, all user commands can be sent from an ordinary web browser to the laser system.

Laser Specifications

Wavelength range	488 – 640 nm

Wavelength Setting

Accuracy	± 1 nm
Speed	≥ 50 nm/s
Line-up time	≤ 500 ms
Average fibre output power	> 1.5 mW
Repetition rate	40 MHz ± 1 MHz
Bandwidth (FWHM)	< 3 nm
Pulse width	3.5 ps ± 1 ps
Polarization	Linear, 100:1
Trigger output	Typ. -300 mV, 1 ns
Spatial mode	TEM00
Fibre delivery	PM SM fibre, 2 m length, MFD 4 μm @ 480 nm

Providing picosecond pulses, this laser features tunability from 488 to 640 nm making this laser a perfect tool for advanced microscopy but also other flexible next generation applications. The photonics community was surprised to see, that TOPTICA presented not just another conventional supercontinuum laser but a totally new laser concept to address this spectral area.

iChrome demonstrates intrinsic low noise, stable single colour and tunable polarized light output, thereby addressing solutions for the problems of the existing approaches on the market.

For more information please contact
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New Gentec-EO Tuner Power Meter with Needle

Stay Tuned... with the new TUNER Power Meter from Gentec Electro-Optics Inc.

This brand new meter presents both a large LCD display and an ultrafast needle, up to 10X faster than anything else on the market. It comes with more features than the competition, like min and max holds for both displays, comet tail needle and bargraph function.

As always, the new TUNER comes in Gentec-EO's ergonomic design, with a large LCD display and easy to use direct access keys.

Key Features

Ultra-Fast Needle

- Less than 1 second response time, for the most convenient laser tuning.
- Reads All thermopiles.
- Large LCD Display
  - 77 x 58 mm
  - 17.5 mm digits
  - Backlight (with optional AC adaptor)
- 3 Display Functions for the Needle
  - Normal
  - Tail (indicates speed)
  - Bargraph
- Also HIGH and LOW values hold

Specifications

Power Range	1 μW to 10 kW
Digital Resolution	
XLP Series	1 μW
UP Series	1 mW
HP Series	100 mW (HP60A) 1 W (HP70A)
Monitor Accuracy	±0.5 % full scale
Statistics	None

For more information please contact
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Coherent

Hidra High-energy, Low Repetition Rate Ti:S Amplifiers

The unique, high energy Hidra Ti: Sapphire Ultrafast Multi-Stage Amplifier Series is now available with 100mJ at 10Hz for terawatt applications.

The *Hidra* high-energy Ti:Sapphire ultrafast amplifier is a multi-stage, chirped pulse amplifier consisting of a grating-based pulse stretcher, regenerative amplifier for first-stage amplification, one or more power amplifier stages, followed by a grating-based pulse compressor. With its flexible platform design and a selection of lamp-pumped Nd:YAG laser and diode-pumped solid state lasers for pumping, *Hidra offers a path to terawatt peak power. All Hidra systems are upgradeable.*

The first stage of the fully-integrated *Hidra* amplifier is based on the Coherent Legend-Elite regenerative amplifier, pumped by Coherent's Evolution DPSS Nd:YLF (1kHz or 5 kHz). 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 millijoule output at 1kHz or 5kHz, up to 100mJ output at 10Hz and the possibility of simultaneous kHz / 10's Hz output configured with the correct options.

For the 10mJ, 25mJ and 50mJ *Hidra* systems the pulse compressor is contained within the *Hidra* enclosure. For the 100mJ *Hidra* the pulse compressor is contained in a separate enclosure. As an option this external compressor for the Hidra-100 is also available with vacuum-compatible mounts. In this case the customer has the option to mount the entire compressor inside their own vacuum enclosure to ease the transportation of the terawatt pulses to the experiment.

Features

- Two stage, high efficiency design: regenerative amplifier plus multipass amplifier
- Can be seeded by a choice of Coherent Inc *Micra, Mantis, Verdi/Mira* or *Vitesse* oscillators
- 10, 25, 50 or 100mJ pulse energy versions
- 40fs (USP) or 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
- Excellent beam quality
- Optional Pulse Slicer for increase nanosecond contrast ratio.

For further information please contact Gerri Springfield or Paul Wardill at
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Fax: (08) 8352 2020
www.coherent.com.au

New! Mid-Infrared Spectrum Analyser with Integrated Calibration

The 721B-MIR Laser Spectrum Analyser from Bristol Instruments provides the most complete spectral characterisation of CW and high-repetition rate mid-infrared lasers with output wavelengths between 4 and 11 micron. Michelson interferometry-based technology and advanced digital processing ensures accurate measurement of absolute laser wavelength and high resolution laser spectral analysis and every measurement is guaranteed by continuous calibration with a built-in wavelength standard.

Benefits include

- Wavelength measurement and spectral analysis with one instrument.
- Operation with CW and high-repetition rate pulsed lasers.
- Measures absolute laser wavelength to an accuracy of ± 1 part per million.
- Spectral resolution as high as 2GHz.

Please contact Margaret Davies at *sales@coherent.com.au* for further information.

Pizzicato Modelocked Picosecond Nd:YAG Laser from Quantel

New from Quantel, the *Pizzicato* is an all solid-state, high performance mod e-locked Nd:YAG laser offering up to 100mJ at 1064nm (10Hz). Based on a unique design, the *Pizzicato* features low jitter, high pulse-to-pulse stability with synchronisation capability.

The all solid state design is free from the constraints of previous designs that used liquid saturable absorbers while maintaining short pulse durations of 35ps.

Features

- All solid-state mode-locked laser
- Up to 100mJ at 1064nm
- 10Hz or 20Hz
- 35ps standard pulse duration
- Thermally regulated harmonic generation module
- Excellent energy stability
- External synchronisation with low jitter
- Thermally stabilised bench
- Extermal remote control module

For further information please contact Gerri Springfield or Paul Wardill at
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Conferences 2009

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

July 16-22
Europhysics Conference on High Energy Physics
Krakow, Poland
http://www.ifj.edu.pl/hep2009/

July 23-25
The 13th Paris Cosmology Colloquium
Paris, France
http://chalonge.obspm.fr

August 3-8
The 16th International Congress on Mathematical Physics
Prague, Czech Republic
http://www.icmp09.com/

August 2-29
IAGA 11th Scientific Assembly August 23-30, 2009
Sopron, Hungary
http://www.iaga2009sopron.hu

August 30 - September 3
The 3rd Joint International Hadron Structure Conference
Tatranska Strba, Slovak Republic
http://www.dthph.sav.sk/hs09

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

September 14-18
Quantum Theory: Reconsideration of Foundations
Vaxjo University, Vaxjo, Sweden
http://www.vQTRF5/

September 21-25
The 9th Conference on Quantum Field Theory under the Influence of External Conditions
Norman, Oklahoma, USA
http://www.nhn.ou.edu/qfext09/ Atomic Physics 2009

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

October 18 - 24
International Conference on Physics Education (ICPE) 2009
Bangkok, Thailand
http://www.icpe2009.net/

Oct 22-24
Shanghai International Congress and Exhibition on Renewable Energy 2009
Shanghai, P. R. China
http://www.sstec.com.cn

October 25-31
2009 IEEE Nuclear Science Symposium and Medical Imaging Conference
Orlando, FL, USA
http://www.nss-mic.org/2009

October 26-30
Galileo-Xu Guangqi Meeting on the Sun, the Stars, the Universe and General Relativity
Shanghai, China
http://www.icranet.org/index.php?option=com_cond=400&Itemid=802

November 24 - 26
Tenth International Symposium - Frontiers of Fundamental & Computational Physics (FFP10)
Perth, WA
http://www.ffp10.physics.uwa.edu.au/

November 24 - 26
2nd International Science Education Conference
Singapore
http://www.nsse.nie.edu.sg/isec2009

November 24-26
The 10th International Symposium on the Frontiers of Fundamental & Computational Physics
Perth, WA
http://www.ffp10.physics.uwa.edu.au/

November 29 - December 4
The 13th International Conference on Hadron Spectroscopy
Tallahassee, FL, USA
http://hadron.physics.fsu.edu/hadron09

December 15 - 19
Conference on Computational Physics 2009
Kaohsiung, Taiwan
Registration will open in March 2009
http://www.ccp2009.tw/index.asp

2010
August 2-10
Quo Vadis Bose-Einstein-Condensation?
Dresden, Germany
http://www.mpipks-dresden.mpg.de/pages/veranstaltungen/frames_ve-ranst_en.html