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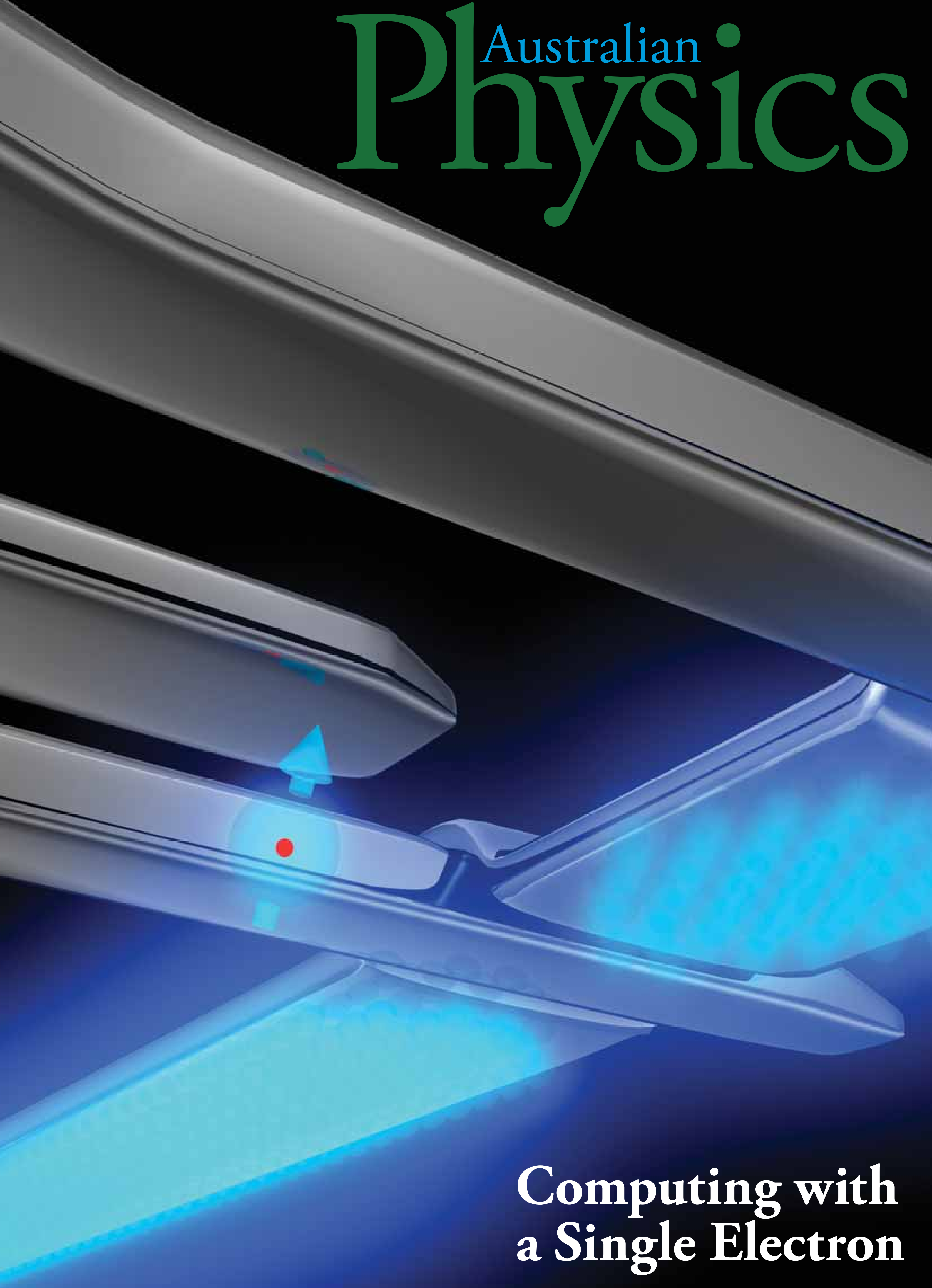
Australian Physics



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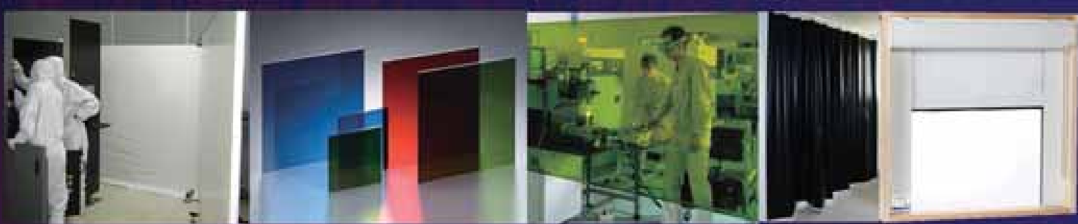

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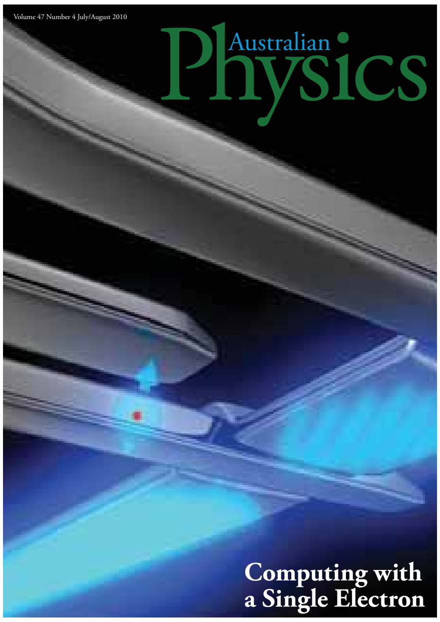

Cover
Artist's impression of a phosphorus atom (red sphere surrounded by a blue electron cloud, with spin) coupled to a silicon single-electron transistor, to achieve single-shot readout of the phosphorus electron spin.

Credit: William Algar-Chuklin, College of Fine Arts, University of New South Wales.

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Editorial

You and the new Australian Physics

In this issue of ***Australian Physics*** we bring interesting articles discussing many aspects relevant to Physicists like career options, Olympiad, award winner stories, Nobel award-related research in Australia, and much more.

Following the editorials we have a very informative article from John Macfarlane on Superconductivity, Rachel Barker brings us an interesting article on her career entitled Life after Physics. Ross McPhedran wrote the most inspiring retrospective on Graham Derrick's carrer.

Ken Baldwin, winner of the Barry Inglis Medal describes modern Quantum Mechanics.

The cover was kindly provided by William Algar-Chuklin from the College of Fine Arts of the University of New South Wales.

In *Book Reviews* we have selected three interesting books for you. These reviews were provided by Manoj Sidhar and Jason Dicker from Launceston.

At the end we provide a list of good conferences to be held during the next year for your information.

Some changes in the magazine production have been necessary. As a result of an increasing work load in my current position I sadly requested to the Editor-in-Chief that I stand down as Editor following the production of this issue of the magazine. I was planing to stay longer. Nevertheless, I hope I made a valuable contribution to the Australian Physics with a new design. I will certainly support the magazine where it is in most need: with articles.

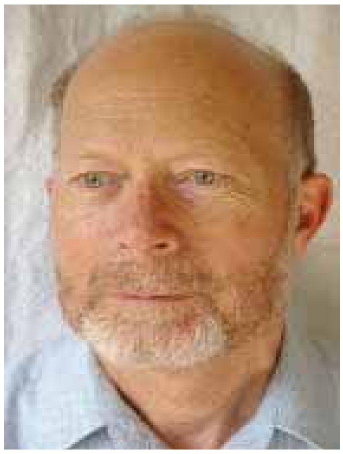
I would like to reinforce the importance of having readers of the Australian Physics writting to our magazine. It is impossible to keep the magazine on schedule without your contribution. I also received contructive comments from a large number of readers. This is a great! Some of the comments I received are captred in this new issue.

Thank you all for writing to me and sharing your opinion. I am sure the new editor, Peter Robertson from Melbourne University, will appreciate your continued support.

Finally, I would like to express my gratitude to all colleagues at AIP. I have received incredible support from Marc Duldig, our Editor-in-Chief, from our editorial board, associate editors, from Brian James, John Macfalarne, now our Book Reviews Editor, and Don Price from CSIRO for a list of samplings that attracted his attention recently.

Good bye,
Paulo de Souza

President's column



Does the AIP have an opinion? So far in my term as president I have not been called upon to present the 'AIP view' on a matter of public controversy. I do wonder, however, how to respond if such a situation arises. There are several documents on our website that provide some guidance (*1*). We have a mission statement that indicates various areas of advocacy that are considered fundamental to our purpose as the professional society for physicists in Australia. We also have a code of ethics codifying precepts of professional ethical behaviour. Members probably do not consult these on a regular basis, but now prompted you might find it instructive to do so. It is my judgement that these two documents are not controversial and any member who put their mind to the notions of a mission statement for the AIP and ethical guidelines would come up with similar sentiments. Those on the website have the benefit that at some time in the past they were prepared not on the whim of an individual but with input from the executive and others and have undergone some evolution since originally developed.

We also have a policy document prepared originally in 2001 but having undergone a number of revisions since then. Our policy activities, however, are not as well developed at those of some comparable organizations. Consider, for example, the UK Institute of Physics (IOP) where the notion of policy, broadly interpreted (*2*), covers more than simply the preparation of statements of policy. It includes preparation of briefing notes, initiation of consultations with relevant bodies, definitive compilations of statistics relating to physics education and research, and links to national and international governmental and non-governmental bodies that are involved in issues that affect physics as a discipline, and by implication physicists too. These resources make the IOP well prepared for responding quickly to relevant issues as they arise. A similar situation applies to the American Physical Society (*3*).

Academies such as the Australian Academy of Science (AAS) and the Royal Society issue policy documents from time to time, often based on groups of experts assembled for the purpose. To recent examples are the report Australia's Renewable Energy Future by the AAS (*4*) and the Royal Society's Climate change: A Summary of the Science (*5*).

By comparison our policy statements are modest and constrained by limited resources. Under the guidance of our most recent science policy convenor, Dr Judith Pollard, a Community policy was developed to replace the Public and Environment policies (*1*). We are, however, seeking expressions of interest from members in continuing the work of revising and developing our policy statements. I welcome contact from interested members.

Ways in which the AIP puts forward a point of view include submissions to enquiries and nominations to various committees. I give a recent example. The AIP made submissions in relation to the draft national curricula on K-10 Science and Senior Physics. In order to take account of a wide spectrum of opinion these were prepared by the Physics Education group, with later fine tuning by PEG members, the AIP executive and taking account of comments of other like-minded interested parties (such as the Australian Council of Deans of Science). I am confident that a broad range of views were sampled before making the submission, but the result is likely to be a compromise and more muted than some concerned members might prefer.

This example highlights a problem with preparing a policy on matters of public controversy (e.g. nuclear power, climate change). Members can be expected to have a good understanding of such issues and may be more homogeneous in their views than the general public but there will nevertheless be a diversity of view that obviates the AIP taking a strong partisan view.

In writing these columns I am, of course, expressing my opinion, supported I hope by reasoned argument, but not necessarily expounding AIP policy. Members sometimes disagree with what I say and there is no reason why a member might not hold a different point of view and is fully entitled to express that by, for example, a letter to the editor. In fact I would like to see more correspondence from members; perhaps I am not sufficiently controversial!

1. The location for matters discussed here is: http://www.aip..org.au/about.php

2. http://www.iop.org/policy/

3. http://www.aps.org/policy/

4.http://www.science.org.au/reports/documents/AusRenewableEnergyFuture.pdf

5.http://royalsociety.org/climate-change-summary-of-science/

Superconducting Applications:

Across the Electromagnetic Spectrum

by John Macfarlane

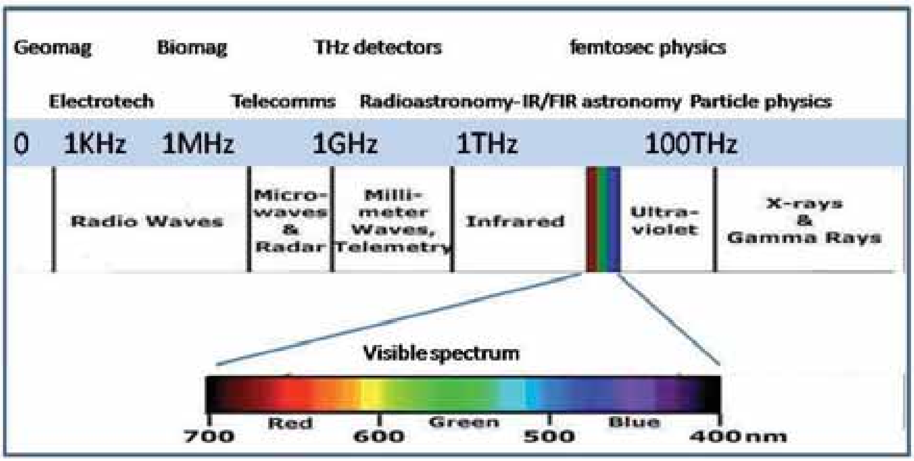


Fig. 1. Representation of superconducting applications across the electromagnetic spectrum.

A personal view of how the superconducting revolution took place over the past half-century, and how it affected the discipline of electrical metrology at CSIRO, was depicted in an earlier Australian Physics article (*1*). The evolution of work on the unique phenomena of superconductivity has of course, spawned a much broader diversity of research in electronic/electromagnetic applications, very few of which are based on the original property of zero-resistance that was described by Kamerlingh Onnes in 1911 (*2*). The more subtle, and powerful, macroscopic quantum effects have proved to be a much richer field for new device physics. Here I attempt to present a "scrap-book" together with some personal thoughts on a few recent activities across the spectrum, including minerals exploration, sub-ocean surveying, geo-archaeometry, THz remote sensing, and the detection of single-photons for radio astronomy and quantum information. A schematic diagram illustrating a few of the applications of superconducting devices across the electromagnetic spectrum is shown in Figure 1.

Fig. 2. Members of the Superconducting Devices team in cleanroom garments, ca. 2003.

"What we see now far exceeds our expectations. We are utterly surprised by the scale."

Major advances in the design, fabrication and testing of superconducting materials and devices were of course, crucial requirements in this progress, and depended in a fundamental way on the development in many laboratories of new micro-lithographic skills (*3*). A representative photograph of the Cleanroom Superconductivity Team at CSIRO Lindfield, taken around 2003, is shown in Figure 2.

Geomagnetic Exploration: under the Earth

The discovery and exploitation of mineral ore bodies has relied heavily on magnetic measurement techniques. Subterraneous, on-surface and airborne equipment may be applicable in particular situations, and either Transient Electromagnetic (TEM) or Magnetotelluric (MT) methods are used. Other applications in addition to mineral exploration include Unexploded Munitions (UXO) detection, sub-sea mapping, and archaeometric studies. For these applications, the sensitivity of superconducting detectors to low-frequency (0.01 Hz – 10 kHz) magnetic fields and/or gradients is their key property. (*4 - 6*).

In the TEM method, fundamental physical principles such as Faraday's Law of electromagnetic induction, and Lenz's Law, are invoked. Typically a loop of wire, the transmitter (up to 100 m diameter), is laid on the ground and energised by a steady (dc) current (Figure 3). At a precisely-recorded time, the current supply is cut off and by Faraday's Law, a compensating transient current is induced in any conducting bodies in the vicinity. The subsequent decay of such induced currents is accompanied by decaying magnetic fields, B. Information about the existence and distribution of conductive materials in the ground can be inferred from the magnitude, and particularly the time variation, of these fields. The detected signal in the traditional coil, by Lenz's Law, is consequently proportional to dB/dt. If however the detector consists of a magnetometer, such as a SQUID (Figure 4), the signal is directly proportional to B instead of its time derivative, and is less strongly attenuated by the presence of undesired conducting overlayers (Figure 5). According to CSIRO, the addition of the SQUID B-field sensor to the standard time domain off-time EM system leads to better-quality EM results with improved S/N ratio. At the same time it provides the conductance discrimination capabilities needed to detect small, long-time constant (>>10ms), pyrrhotite-hosted, Ni-Cu sulphide targets at depths of greater than 100m.

In 2007, CSIRO Materials Science and Engineering awarded the LANDTEM team the CSIRO Medal for Research Achievement. (*7*).

High temperature superconducting quantum interference device (SQUID) magnetometers were developed in a collaborative project between BHP and CSIRO specifically for application in airborne time domain electromagnetic (TEM) surveying. The principal obstacle for the receiver was in overcoming the

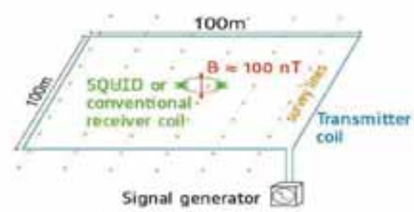


Fig. 3. Schematic layout of Transient Electromagnetic Method.

Fig. 4. A preliminary feasibility field trial of a simple liquid-nitrogen-cooled SQUID.

high dynamic variables in the environment of the towed receiver bird and the consequent high level of noise associated with motion of the sensor in the Earth's magnetic field. A specially designed suspension system (Figure *7*) was developed to isolate the sensor from higher-frequency motions of the towed bird.

A novel rotating magnetic gradiometer system (GETMAG) was subsequently designed (Figure 8), constructed, and demonstrated (Figure 9). By making measurements about three separate axes, the full magnetic gradient tensor is determined (*8*).

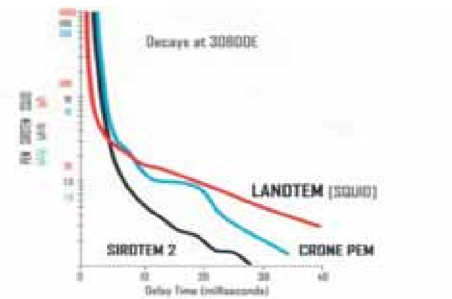


Fig. 5. SQUID long-time TEM response compared with other techniques.

Under the Oceans

A developing method of marine hydrocarbon exploration, the controlled source electromagnetic (CSEM) method, can discriminate beneath the sea floor between reservoirs which may contain economic concentrations of hydrocarbons and those that are full of salt water. In shallow water, waves, swells and ocean currents (among other things) create electromagnetic noise which can be minimised by exploiting magnetic tensor gradiometry. This research initiative, OCEANMAG, builds upon technologies developed by CSIRO Materials Science & Engineering and Exploration & Mining Divisions (*9*).

Archaeometry

Complementary geomagnetic research is being carried out by the Jena group (*10*).

A one-channel SQUID magnetometer system (vertical field component) was adapted to rough conditions in the field. Chwala *et al.* (*10*) reported on measurements in South Africa over a geophysically interesting target in real production mode. Transients up to 200 ms could be recorded, which is about a factor of 100 more than with conventional coils.

In addition to detecting naturally-occurring minerals, the Jena group adapted their SQUID gradiometer system for magnetic archaeometry. Mapping of the Earth's magnetic field or its gradient is a widely used method in archaeological prospection. The use of SQUID's promises to be advantageous for archaeometry, since they combine a high field resolution with a large bandwidth. Compared to conventional Cs vapor sensors SQUIDs can be used for much faster magnetic mapping, allowing, for the first time, the investigation of huge archaeological features in a reasonable time period.

Fig. 6. Dr David Dart and Dr Cathy Foley during early LANDTEM development, ca. 1990.

Electrotechnology

The early applications of superconductivity in electrical measurement technology and standards were fully described in a previous article (*1*), and will not be repeated here. Wider adoption of SQUID techniques has however been encouraged by a number of commercial enterprises (*e.g.*, Figure 10). A useful overview (*11*) was presented at the International Superconducting Electronics Conference, held in Sydney in June 2003 (Figure 11).

Biomagnetism

The sensitivity of SQUIDs to minute magnetic fields led to their use in studies of magnetic activity in living animals, including humans. At first limited to magnetocardiography, where relatively large fields are produced by the muscle activity, the study of evoked brain signals became possible as

Fig. 7. Assessment of SQUID gradiometer performance in proximity to operational aircraft, ca. 1996.

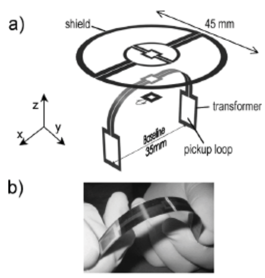


Fig. 8. Sketch of rotating magnetometer based on flexible YBCO tape.

SQUID technology improved from the 1970s onwards (*12*).

MRI and LHC

Large numbers of high-stability, high field (>5T) superconducting magnets are installed in hundreds of MRI machines around the world. The sensitivity of SQUIDs to low-frequency signals has made possible the study of low-field MRI (*13, 14*). The Large Hadron Collider, in addition to many other particle accelerators, is also a conspicuous consumer of superconductors and liquid helium.

THz remote sensing

Due to its unique characteristics, the terahertz (THz) electromagnetic spectrum offers a wide range of potential applications in areas of material characterisation, non-destructive testing, security screening, medical imaging, and biological analysis. Novel compact solid-state sources and detectors are being sought for THz radiation and detection. A THz imager based on a high-tc superconducting (HTS) step-edge Josephson junction detector operating at 77K was recently demonstrated (*15*).

Telecommunications

In the latest mobile-phone base stations, an HTS filter provides a lower insertion loss and sharper band pass profile than a conventional filter, for improved receiver sensitivity and lower transmission output power.The tremendous stop band attenuation can also reduce the linearity requirements of the power amplifier. Notwithstanding the above, the principal effect of placing an HTS filter on the front-end of the base station is to achieve extremely low out-of-band emissions.

Together wth recent experimental work, modelling studies have been done on active GHz and THz HTS oscillators, for possible telecoms applications (*16*).

Astronomy, Cosmology and Quantum Information

In these demanding applications, the essential property of superconducting devices is their sensitivity to single photons from the infra-red to millimetre-wavelength regions of the electromagnetic spectrum, with photon energies in the range 10^{-19} to 10^{-22} eV. Broadly,

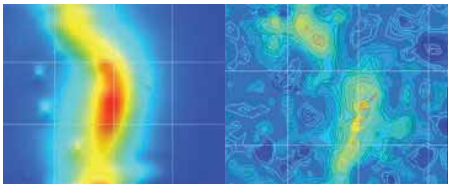


Fig. 9. Magnetic maps of the same area made using CSIRO's GETMAG™ (right) shows details of depth and shape not revealed by a conventional TMI survey (left).

the type chosen is determined by a trade-off between energy sensitivity and response time requirements: either as thermal (bolometer) sensors or as band-gap photoconductors. The former tend to have long reponse times (μs), and the latter, ns to ps. Parameters including absorptivity, energy gap, thermal conductivity, thermal mass, noise and dark current have to be considered for each application. Large bolometric-type arrays (>10000 pixels) have been developed for astronomical imaging in the far-infrared. Nano-scale devices for ultrafast energy-resolving particle detection have also been reported.

Cryogenic detectors are extremely sensitive and have a wide variety of applications (*17*) but are difficult to integrate into large arrays like a modern CCD (chargecoupled device) camera. As current detectors of the cosmic microwave background (CMB) already have sensitivities comparable to the noise arising from the random arrival of CMB photons, the further gains in sensitivity needed to probe the very early Universe will have to arise from large arrays. A similar situation is encountered at other wavelengths. Sensitivities are within an order of magnitude of that needed for CMB observations. Among cryogenic detectors, superconducting detectors are especially attractive because thin-film deposition and lithographic patterning techniques may be used to produce large arrays (*18*). Absorption of above-gap photons in a superconductor causes Cooper pairs to be broken into electrons or quasiparticles.

The kinetic inductance detector (KID) (*19*) is a relatively new device that promises high-sensitivity, large format sub-millimetre to X-ray imaging arrays for astrophysics. The KID comprises a superconducting thin-film microwave resonator, capacitively coupled to a probe transmission line, which allows the deposition of energy to be detected by virtue of the perturbation in the phase of the resonance. Frequency multiplexing enables large detector arrays. Such devices are commonly known as microwave kinetic inductance detectors, or MKIDs, because the inductive (frequency shift) signal is considerably larger than that arising from a resistive transition.

The inductive rather than resistive transition edge is further exploited in the inductive superconducting transition edge detector, (ISTED) (*20*), recently proposed for applications in single-particle and photon detection, which depends for its operation on the magnetic and thermal properties of ultrathin, small-area superconducting structures. The device responds to the modulation of penetration depth in an ultrathin superconducting absorber by incident photons or particles. The absorber is in the form of a superconducting patch, located within and inductively coupled to a surrounding SQUID ring. In the presence of an applied perpendicular magnetic field, the energy sensitivity is optimized by operating the device in the regime where the penetration length is much greater than the absorber dimensions.

The low-noise properties of SQUID-based amplifiers are essential in the search for Cosmic Dark Matter (*21*), while their ability to resolve single-photon energies is applied in optical astronomy (*22*). The success of nano-lithography in producing reliable SQUIDs and junctions on the nano-metre scale has opened the way to Quantum Information devices, based essentially on the magnetic manipulation and detection of single Bohr-magneton spin flips (*23, 24*).

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Dr John Macfarlane is our Book Review Editor.

Life after Physics

from Fourier Series to Time Series: a short journey

by Rachel Barker

When I was studying physics and mathematics, in my university years, I would periodically hear that there were organisations that were very much in need of people like me. I heard that some of them didn't know how badly they needed trained physicists and mathematicians, and some of them did. But I didn't know which organisations they were. I tried at the uni careers centre they didn't have much listed under physics or maths, though they did for other skill sets. I tried in the newspaper, and didn't come up with much.

I found this awfully dispiriting. But now I think it's just a reflection of how rare the skills are in the first place. When the Australian National University graduates 400 science graduates, of which maybe 10 did 3rd year physics, maybe 10-20 did 3rd year maths, and there are also computer science, arts, and law graduates to consider, then I have to admit yea; there aren't many maths or physics graduates to fight over.

Well, I now work for an organisation that is acutely aware of this problem. I work for an organization that will bend over backwards to keep its staff ñ knowing that other organizations will bend over backwards to hire them away. I work for an organization that has a history of hiring every graduate they can find that meets their standards; granted, the standards are high, but the organization is one of the world's best in its field. The field is statistics, and the organization is the Australian Bureau of Statistics. But perhaps I should start nearer the beginning.

In high school, I took part in the Tournament of the Towns each week I would visit ANU for an hour and a half's lecture on some mathematical topic or other. I understood only small fragments of it, but I loved it anyway. In year 10, I was invited to join a vaguely similar program for Physics, the Australian Physics Olympiad. This, too, was difficult - but I could do it and better than I could do the maths so this, I decided, was where my future lay.

I loved the Physics Olympiad. I loved getting together with some of the brightest kids in Canberra (or Australia, at some points) to learn stuff that wasn't rehashed in endless boring detail (unlike school), where every question set the lecturer off in another fire of enthusiasm, where there were in-jokes and conundrums relating to the world I could see and touch, where some of my maths saw its first practical use and other mathematical techniques were explained well before they came up in mere maths classes. Good friends, high pressure, great variety. When I could no longer study as a Physics Olympiad student, I came back as a tutor later a lecturer and organizer.

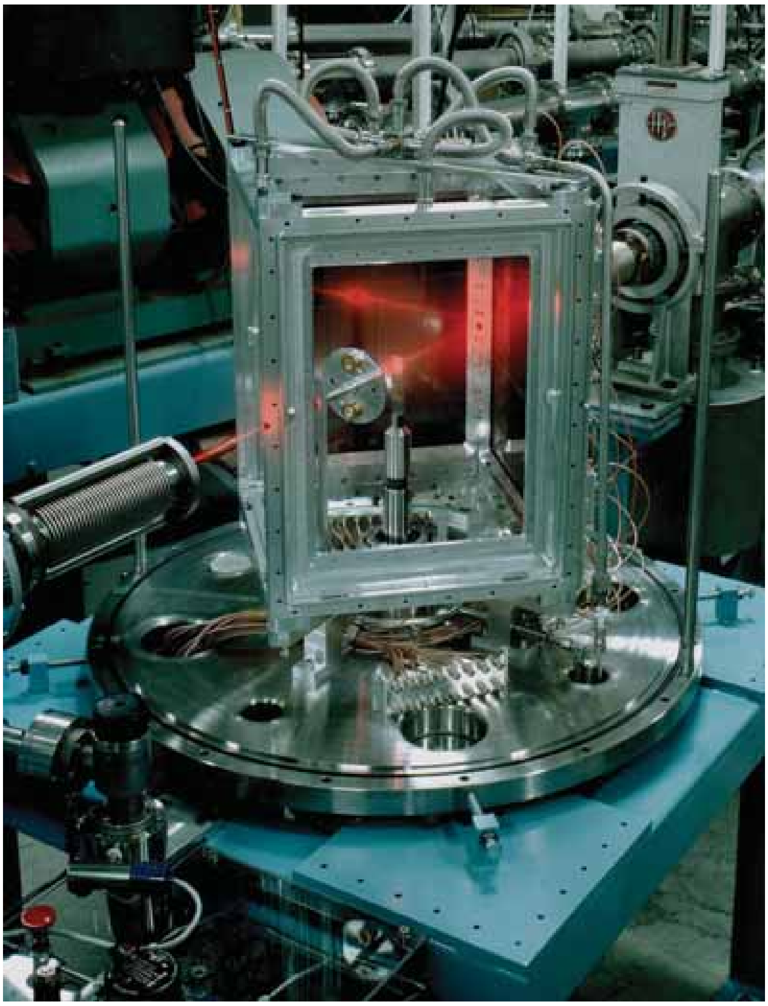

Fig. 1. A laser illustrates the flight path of a beam of accelerated atoms onto a thin target foil, where tiny amounts of fusion should occur, followed mostly by fission. This detector array collected the fission fragments I analysed in my PhD, looking at their spatial distribution and confirming that it changes as it should when the target atoms have intrinsic angular momentum.

Undergraduate studies were great too. Many of the friends I'd met through Physics and Maths programmes came to the Australian National University to study. I think I did every single third year physics course that ANU offered at the time - not normally possible, but I sat the first year exams and got a HD, so they let me (and a few others from the Physics Olympiad) go straight into second year. I did Honours - not brilliantly, but I thought I'd had a bad year.

I was therefore completely unprepared for life during a PhD. I was working on one task, not several. There were no timetables. We did not know if the problem was soluble or not. My supervisors were lovely friendly supportive people; possibly too kind to me, but they did give me at least one urgently needed boot up the rear, when I was managing my time extremely poorly. (I then worked out that I was trying to fit 196 hours into a 168 hour week this didn't work, and my PhD was taking the brunt of it and I learned to say no to things. One of many lessons of enduring value.)

I went through several of the low points experienced by many PhD students - loneliness, isolation, loss of motivation. I knew I wasn't working as well as I possibly could, and I never completely mastered that. I did the best I could, setting my sights on nearer goals like the publication of the next paper, or the writing of a program that could automate a tedious task. I took helpful advice from wherever I found it, not least my eventual spouse, rationed my distractions, and it worked; I submitted my PhD in Nuclear Physics in early 2003.

I came out of the PhD with many useful, transferable skills. How to break up a nasty equation or a big task into manageable pieces. How to document work and write a decent paper. How to pay attention to detail,

Fig. 2. Rachel offers help to one of ABS's front desk staff. Explaining things is a normal part of work in Methodology ñ not only explaining the methods and tools, but also the software.

to anticipate problems and to investigate them. How to persist, I've come to believe that even the best of jobs has its dull bits.

Now the natural progression from a PhD in physics is usually expected to be a researcher.

"... the natural progression from a PhD in physics is usually expeced to be a researcher. Many people have asked me why I didn't go that way."

Many people have asked me why I didn't go that way. There are many reasons, and here are some.

- Pure research tends to the very long term perspective - some of it will underpin great results some decades into the future. I wanted to see the effects of my own contributions which requires a shorter horizon.
- I was working on something that had little or no time pressure. I concentrate much better under pressure.
- For a career in research, it is important to work with different people and in different places. For some people, this is a great thing they get to travel and make new friends. For me it wasn't; I wanted to stay near my friends and family. I wanted to settle down with my prospective husband and raise children.
- In published work it is important to be rigorous, to have attended to every detail. I wanted to be able to stop once the major points were all addressed. I wanted variety.

Ultimately I thought that what brought me to Physics wasn't just the beauty of the way the world fit together; it had something to do with logic and mathematical reasoning, something to do with solving problems, something to do with people working together; and these things could be found in other places besides physics.

So I went looking for them. I landed a job in Defence Signals Directorate, and passed the security clearance with apparent ease.

And left after the first day. Nothing against DSD and they would have loved to keep me, but there had never been any secrets between my beloved and I, and needing to keep my work secret was unexpectedly shattering; we couldn't do it. So we didn't.

It's largely chance that brought me to the Australian Bureau of Statistics. I spent four months unemployed, and submitting job applications every week - mostly for jobs I could do adequately, not ones that tapped my real skills; but when I was interviewed at ABS, they put a graph in front of me, and I remarked on all the key points before they even managed to ask a question about it. I started work just two weeks later, at a higher salary than most graduates recruited in the same round, largely because of my PhD.

Physics turns out to be a surprisingly good foundation to build a statistical career on. As physicists, we know plenty about analysis, significance, models, graphs, and errors. Actually, we know more about errors than statisticians seem to, and I have a long term plan to get the ABS to adopt some of the techniques physicists have used for decades - including simple and straightforward things like graphing error bars.

ABS took me into the Methodology Division, they don't have enough mathematical minds to fill the whole organization, they gather most of the best in one place and get them to do the difficult maths for everyone else. There, I found that my instincts were sound. I knew what needed to be done, but initially I couldn't always explain why. It was a great pleasure doing the Survey Methods training with other graduates, because it gave me the equations and concepts that I needed, the formal grounding to support and explain all my instincts. It was about as demanding as an average university course, you know, the kind you tackle three of in one semester - and was entirely on work time!

I thought when I first started that Methodology was about as good as it could get for me. Firstly, there was a good group of bright people to be friends with. Then there was a weekly seminar program where I got to hear about all the interesting things other people were up to. Then there were clients who'd call or email saying 'We need help with X' - and I'd complete it, often within a few days, and they'd be happy. There were and are unsolved problems, but there are also plenty of challenges that are none too hard to solve. I had to learn SAS - in a previous year I'd been discouraged from applying to Methodology by a selection criterion specifying SAS as desirable; but I found it easy to learn and became one of the division's expert users. There's graphs to study, and algebra if you are so inclined, and real world conundrums to think through.

Surprisingly, though, it got better. I should explain that the hundred mathematically inclined folk in Methodology tackle a very wide range of things; some focus on analysis, on wringing new information out of data new and old; others work on survey design, on estimation techniques new and old, on trouble-shooting, on software testing (software development is usually but not always tackled by the 300 odd programmers in the Technology Services Division); the list goes on. People rotate to new roles from time to time; usually at least once in the first year, later by mutual consent. I started in survey design and estimation.

When I returned from my second period of maternity leave, I asked to take a turn in Time Series Analysis. I should have asked sooner. I don't think you could get me out of here with a crow-bar.

This section is one of the fastest-paced in

"I work here with more passion and vigour than I brought to my PhD, and my single biggest frustation is that I can see all these great things I'd love to do that would make a real substantial difference going forward and I only have time to do a few of them. Would anyone like to come and help?"

Methodology, with a week being a long time to spend on one task; there are often special queries coming through, and many of them relate to interesting real world events; there is a real opportunity to make a difference - though one thing remains slow; to get big changes adopted you need to be patient and work through channels. ABS is cautious and checks stuff very carefully before adopting it.

Time Series is one of the most team-focused sections in methodology, much of the work can be shared, or picked up by someone else at a moment's notice; as a mother of two small children I found this excellent when they got sick. When I started, most of the section worked part time, due to children, or study, or both. (Since then, people have rotated into other areas and the mix has changed.)

Further, after a year's good work, they gave me training responsibilities. For all my introverted nature, I love teaching. One of the things I've done since then is develop lectures in Fourier Analysis; I loved it when I met it in physics courses; and it underlies almost everything in Time Series Analysis, and my polls found that few of my colleagues knew what it was. But if you can get your head around Fourier Series, then Time Series is an open book.

(What do Time Series do? Well, think about newspaper articles on things like the unemployment rate. They often quote 'Seasonally adjusted' - that's us or 'Trend' - that's us too. Not that my section turn human attention to every such figure; we concentrate on the difficult (read: interesting) ones.)

Methodology take in a broad range of people, as I said to start with, they can't get enough people with high mathematical skills. Time Series seems to be a good spot for physicists, but the division also has a supply of economists, and pure mathematicians, and teachers, as well as the predictable number of graduates from statistics degrees. That's just among the people whose backgrounds I happen to know.

Methodology have a long and almost sacred history of treasuring and training their staff, and seeing them go on to great things. A disproportionate fraction of ABS's most senior staff started out in Methodology; many of them speak of the division's founder, Ken Foreman, as a wonderful mentor who gave them great training and opportunities when they started - they pay it forward.

There are other concrete ways that ABS shows the high value it places on its staff. Methodology in particular is nothing without its people. I've seen colleagues take a year off - or three - to travel, or study, or pursue other objectives; when they come back, a job is available for them, even if they're only in Australia for months, and irrespective of which capital city they are in. When I started my family, and found it difficult to balance life and work, my supervisor pointed out the option of going part time. To me it's the best of both worlds, I get to do real work *and* spend real time with my kids. Twice in the last year I've seen an almost irreplaceable individual rotated to their section's loss. Why? They wanted to do something different, and rotating them was better than losing them.

Is there a fly in the ointment? There's one we're under-staffed, and we know it. There's too much to do, and it's hard to find new staff who have the mathematical skills we need and are sufficiently well rounded; we cannot work in isolation, we need to listen and to communicate, sometimes to inspire, always to work as one part of a team.

I work here with more passion and vigour than I brought to my PhD, and my single biggest frustration is that I can see all these great things I'd love to do that would make a real and substantial difference going forward and I only have time to do a few of them. Would anyone like to come and help?

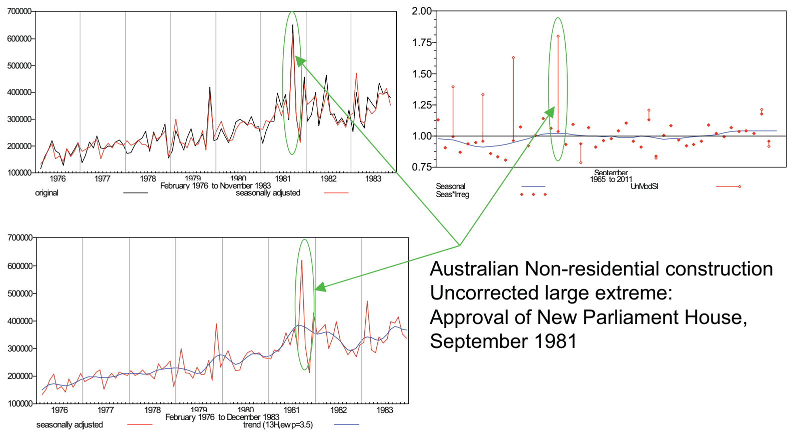

Fig. 3. An outlier is highlighted in three different ways in the same time series data. Such 'black swan' events need special treatment in Time Series Analysis. When they show up, the next step is to find out what real-world story underlies the unusual number.

Samplings

Plasmonic sensor detects viruses

http://physicsworld.com/cws/article/news/44395

The first biosensor made from plasmonic nanohole arrays has been unveiled by researchers in the US. The device, which exploits "extraordinary optical transmission", can detect live viruses in a biological solution.

Plasmonics is a branch of photonics that employs surface plasmon polaritons (SPPs), which arise from the interaction of light with collective oscillations of electrons at a metal's surface. The new sensor was made by Hatice Altug and colleagues at Boston University and exploits SPP resonances that occur in plasmonic nanohole arrays. These are arrays of tiny holes just 200–350 nm across and spaced 500–800 nm apart on very thin noble metal films, such as those made of gold. At certain wavelengths, the nanohole arrays can transmit light much more strongly than expected for such a collection of apertures. This phenomenon is called extraordinary optical transmission (EOT) and it occurs thanks to SPP resonances.

The resonance wavelength of the EOT depends on the dielectric constant of the medium surrounding the plasmon sensor. As pathogens bind to the sensor surface, the refractive index of the medium increases, increasing the wavelength of the plasmonic resonance. This shift can then be measured to identify the presence of virus paricles.

Different viruses can be detected by attaching highly specific antiviral immunoglobulins to the sensor surface. Different immunoglobulins can capture different viruses from a sample solution. The researchers have already used their device to detect pseudo viruses that look like highly lethal viruses, such as Ebola and smallpox.

The research team states that the technique has many advantages over conventional virus detection methods such as polymerase chain reaction (PCR) and cell culturing, and that the detection platform is also compatible with physiological solutions (such as blood or serum) and is not sensitive to changes in the ionic strengths of these solutions. They say it can reliably detect viruses at medically relevant concentrations. Next on the list for the researchers is to make a portable version of their platform using micofluidics.

The current work was published in Nano Letters where sensitivities and comparison with techniques such as ELISA are discussed: http://pubs.acs.org/doi/abs/10.1021/nl103025u

Honeycomb windows that could harvest the Sun

http://physicsworld.com/cws/article/news/44300

A materials science breakthrough in the US and Taiwan could lead to a new type of window that can harness the power of the Sun. The newly created transparent material can efficiently capture photons to generate electricity thanks to its honeycomb structure, which blends the properties of a semiconductor polymer with those of a carbon-rich fullerene. The chosen polymer, P1, is efficient at absorbing photons, which causes electrons and holes within the material to combine into bound states known as excitons. The role of the fullerene is to then undo this process by dissociating the electrons and holes. Suitably placed electrodes can then extract the charges to produce photocurrents.

Mircea Cotlet, one of the researchers based at Brookhaven National Laboratory, said that the biggest challenge was finding a way to merge the polymer and fullerene into a honeycomb lattice. His team achieved this by creating a flow of micron-sized water droplets across a thin layer of the polymer/fullerene solution. Water droplets then self-assemble into large arrays within the solution. Once the newly formed solution has evaporated it leaves behind a hexagonal honeycomb pattern over a large area of the polymer, which the researchers observed using scanning probe and electron microscopy.

The team now intends to develop the work by implementing the honeycomb into devices and carrying out a number of tests. Among the applications that could spring from the work are optical displays and devices, including transparent solar cells. Another possibility is to incorporate the honeycomb films into windows. As the polymer chains gather mostly at the edges of hexagons, the films would remain mostly transparent with remaining chains spread thinly across the hexagon centres.

The research is described in a research paper in Chemistry of Materials: http://pubs.acs.org/doi/abs/10.1021/cm102160m?journalCode=cmatex

Information converted to energy

http://physicsworld.com/cws/article/news/44385

Scientists in Japan have shown experimentally that a particle can be made to do work simply by receiving information, rather than energy. They say that their demonstration, which uses a feedback system to control the electric potential of tiny polystyrene beads, does not violate the second law of thermodynamics and could in future lead to new types of microscopic devices.

The experiment, carried out by Shoichi Toyabe of Chuo University in Tokyo and colleagues, is essentially the practical realization of a thought experiment proposed by James Clerk Maxwell in 1871. Maxwell envisaged a gas initially at uniform temperature contained in a box separated into two compartments, with a tiny intelligent being, later called "Maxwell's demon", controlling a shutter between the two compartments. By knowing the velocity of every molecule in the box, the demon can in principle time the opening and closing of the shutter to allow the build-up of faster molecules in one compartment and slower ones in the other. In this way, the demon can decrease the entropy inside the box without transferring energy directly to the particles, in apparent contradiction of the second law of thermodynamics.

Among the many responses to this conundrum was that of Leó Szilárd in 1929, who argued that the demon must consume energy in the act of measuring the particle speeds and that this consumption will lead to a net increase in the system's entropy. In fact, Szilárd formulated an equivalence between energy and information, calculating that kTln2 (or about 0.69 kT) is both the minimum amount of work needed to store one bit of binary information and the maximum that is liberated when this bit is erased, where k is Boltzmann's constant and T is the temperature of the storage medium.

Toyabe and colleagues have observed this energy-information equivalence by varying an electric field so that it represents a kind of spiral staircase. The difference in electrical potential between successive steps on the staircase is kT, meaning that a thermally fluctuating particle placed in the field will occasionally jump up a step but more often than not it will take a step downwards. What the researchers did was to intervene so that whenever the particle does move upwards they place the equivalent of a barrier behind it, preventing the particle from falling beyond this point. Repeating the process allows it to gradually climb the staircase.

The experiment consisted of a 0.3 μm-diameter particle made up of two polystyrene beads that was pinned to a single point on the underside of the top of a glass box containing an aqueous solution. The shape of an applied electric field forced the particle to rotate in one direction or, in other words, to fall down the potential-energy staircase. Buffered by the molecules in the solution, however, the particle every so often rotated slightly in the opposite direction, allowing it to take a step upwards.

By tracking the particle's motion using a video camera and then using image-analysis software to identify when the particle had rotated against the field, the researchers were able to raise the metaphorical barrier behind it by inverting the field's phase. In this way they could gradually raise the potential of the particle even though they had not imparted any energy to it directly.

The research is published in Nature Physics (http://www.nature.com/nphys/journal/vaop/ncurrent/full/nphys1821.html), with a commentary article by Van den Broeck: (http://www.nature.com/nphys/journal/vaop/ncurrent/full/nphys1834.html).

Samplings

Phonon "Lesers"

Two independent research groups have unveiled the first phonon "lasers" – devices that emit coherent sound waves in much the same ways as lasers emit coherent light waves. Sometimes called "sasers", one of the devices emits sound at about 400 GHz while the other operates in the megahertz range.

Such very high frequency sound could be used to probe the interiors of tiny objects – and the ability to create laser-like beams of sound could lead to new imaging applications. Indeed, the differences between the two devices suggest that sasers could be made to operate over a wide range of frequencies.

Just as lasers rely on stimulated emission of photons, sasers require stimulated emission of phonons. While there is no reason why stimulated emission shouldn't work for phonons, physicists had struggled to find materials in which stimulated emission – rather than random spontaneous emission – is the dominant decay process. Now, two independent groups have come up with two very different solutions to this problem.

At the University of Nottingham in the UK, Tony Kent and colleagues have made a saser that operates at about 440 GHz. Their device comprises alternating layers of the semiconductor gallium arsenide (GaAs) and the insulator aluminium arsenide (AlAs). Meanwhile at the California Institute of Technology (CalTech), Ivan Grudinin and colleagues use two microwave resonators – each about 6 μm in diameter and made of silica – to create the phonon-producing transition for their saser. The resonators are separated by a gap of about 1 μm, which is small enough for the devices to be coupled via light waves to form a two-state quantum system.

The devices are described in Phys. Rev. Lett. **104** 083901 and Phys. Rev. Lett. **104** 085501. See also:
http://www.nature.com/nature/journal/v464/n7285/full/464011b.html.

Magnetic resonance and microfluidics

http://www.sciencemag.org/content/330/6007/1078.full

Magnetic resonance imaging (MRI) is a well-established clinical tool that is routinely used to locate cartilage or ligament damage, cancerous lesions, and blood vessel occlusions; when combined with magnetic resonance spectroscopy (MRS), it can even map brain function. The image contrast in MRI instruments comes from the change in orientation of the rotational axis (precession) of atomic nuclei in a magnetic field, and can be adjusted to selectively image tissues on the basis of oxygen content, diffusivity, flow velocity, and other properties. Microfluidic "lab-on-a-chip" (LOC) devices represent an emerging technology with potential applications in medical diagnostics. These devices flow samples (which often consist of suspensions of cells) and reagents through miniaturized chemical reactors, and are typically fabricated via lithographic methods similar to those used in microelectronics. Although in principle, MRI should be the ideal tool for monitoring reactions on LOC devices, in practice this turns out to be notoriously difficult because of limitations in sensitivity and resolution. Now, writing in Science, Bajaj *et al.* (access link above) present an ingenious method that allows sensitive MRI measurements on an LOC device by recording magnetic resonance signals from the spent fluid that exits the device.

See also a Science Perspective article by Utz and Landers: http://www.sciencemag.org/content/330/6007/1056.full.

There is also an interesting commentary article by Griffin in Nature about enhancement of nmr signals from molecules attached to solid surfaces:
http://www.nature.com/nature/journal/v468/n7322/full/468381a.html.

Materials ecology: an industrial perspective

http://www.sciencemag.org/content/330/6006/919.full

There are many reasons for the current drive for more sustainable industrial processes, including a desire for enhanced societal value, lower-energy demand, less waste, and more effective products. Industrial ecology is now a thriving sector of engineering design and practice and has become a welcome part of modern industrial life. It derives from a high-level systems study of the energy and material flows through industrial processes. The aim is to improve sustainability by closing loops and recycling materials. "Materials ecology," a less well known concept, was examined at a recent US-European Frontiers of Engineering event held in the UK. Several of the ideas presented in this Science Perspective article crystallized during the series of talks and ensuing panel discussion.

'Super-twisted' light detecting biological molecules

http://physicsworld.com/cws/article/news/44309

Researchers at the University of Glasgow in the UK are the first to have created "super-twisted light" in the lab. The light is so-called because it has a high degree of circular polarization and could be used to detect minute quantities of biological molecules in solution. Indeed, super-twisted light could help scientists study the proteins responsible for neurodegenerative diseases such as Alzheimer's or Parkinson's.

Most biological molecules have a certain chirality (right- or left-handedness) and this intrinsic property can be used to detect biomolecules in "chiroptical" spectroscopic techniques such as circular dichroism, optical rotatory dispersion and Raman optical activity. Here, scientists typically measure the small differences when left- and right-circularly polarized light interacts with a chiral sample. In circularly polarized light, the electric field vector rotates around the direction of propagation creating a right- or left-handed helix.

Although widely employed, these techniques are not all that sensitive because chiroptical effects are inherently weak. As a result, the techniques can only be used to study samples containing relatively high concentrations of target molecules. Recently, researchers put forward the idea of using "super-twisted" light in such techniques to increase sensitivity. This light has a greater level of chirality than that of ordinary circularly polarized light because it is twisted much "tighter". However, the problem was that, until now, no-one knew how to create it in the lab.

Malcolm Kadodwala and colleagues produced their super-twisted light by shining ordinary light through a specially designed metamaterial made up of chiral gold nanoparticles. The light produced allowed the team to detect certain proteins at picogram levels, a sensitivity a million times greater than that possible with current chiroptical techniques. The light seems to be particularly effective at detecting amyloid proteins – insoluble molecules that stick together to form plaques. These plaques are thought be responsible for certain neurodegenerative diseases.

The work is reported in Nature Nanotechnology:
http://www.nature.com/nnano/journal/v5/n11/full/nnano.2010.209.html.

The power behind cytochrome P450

http://www.sciencemag.org/content/330/6006/933.full

Drugs, toxins and a range of metabolic substrates are detoxified in the liver by family of iron-containing enzymes called cytochrome P450. The iron component transfers oxygen to compounds that are often highly resistant to chemical reaction, but we know very little about the mechanism of this vital detoxification process. Rittle and Green (link above) have now managed to capture the P450 reaction intermediate by freezing a solution of the enzyme as it reacts with an oxidant. Spectroscopic techniques and kinetic studies then revealed an iron(IV) oxo intermediate that passes its oxygen along to the substrate with remarkable speed. See also a Science Perspective article by Sligar: http://www.sciencemag.org/content/330/6006/924.full.

Samplings

Optical transistor in silicon is a first

http://physicsworld.com/cws/article/news/44340

Researchers claim to have fabricated the first all-optical transistor on a silicon chip. This device allows the transmission of light emitted by one laser to be governed by the intensity of another. This novel transistor was made by researchers at EPFL in Lausanne, Switzerland, and the Max Planck Institute for Quantum Optics in Garching, Germany. According to the team, the device promises to provide another building block for constructing all-optical integrated circuits. Such circuits could dramatically improve the efficiency of telecommunication networks because they would eliminate the need to convert optical information to electrical pulses – which can be processed easily – and then back to light.

The team employed standard nanofabrication methods to make the transistor, a taper consisting of a silicon dioxide disc with a rimmed edge sitting on a silicon pillar. The ability to make devices in silicon is important because the material is widely used in the electronics industry.

To operate the device, the frequency of one laser beam (the "probe") is tuned to an optical resonance of the silicon dioxide structure. The result is that the structure behaves like an optical cavity, with the incident light bouncing endlessly around its rim. No light is transmitted through the taper since all the light is lost in the optical mode of the cavity.

A second "control" beam at a different frequency is then directed at the taper. Interaction between the two beams results in a beat frequency that also resonates with the disc and creates a mechanical oscillation. Interference between these three light fields results in the cancellation of the probe beam within the cavity. The presence of the control beam allows the probe beam to be transmitted through the taper as if it was not coupled anymore to an optical cavity. This is the optomechanically induced transparency effect.

Cranking up the intensity of the control beam increases transmission of the light from the probe laser through the structure, but it is impossible to realize complete transmission – this would require an infinitely powerful control laser.

The research is reported in Science:
http://www.sciencemag.org/content/early/2010/11/10/science.1195596.

Beetle beauty captured in silicon

http://physicsworld.com/cws/article/news/44389

Researchers in Canada have created a new material that mimics the brilliant iridescent colours seen in beetle shells. As the eye-catching effect can be switched off with the simple addition of water, the researchers believe their new material could lead to applications including "smart windows".

Structural colours, such as those on beetle shells and butterfly wings, differ from traditional pigments because the colour results from the interaction of light with periodic structures on the surface of the material. In certain biological materials, including the shells of scarab beetles, these exoskeletons take on a twisted or "chiral" structure, which causes reflected light to emerge circularly polarized.

Kevin Shopsowitz, working with colleagues at the University of British Columbia and FPInnovations, has now succeeded in mimicking this effect in a silica film. The breakthrough occurred with a certain degree of serendipity as the researchers were working with their industrial partner to develop forms of porous silica that could be used to store gases such as hydrogen. They were using nanocrystalline cellulose (NCC) as a template in silicon, which was then burned away to leave gaps within the silica.

But when Shopsowitz had forged the material, he discovered that is appeared to be iridescent, with the individual nanocrystalline cellulose rods organised into a "chiral nematic" structure. What is more, Shopsowitz's team show that the iridescence can be turned off by the simple addition of water, before returning again when the material is dried out. They claim that this ability to switch between iridescent and colourless films, combined with the ability to control the pitch of the spirals, could be used to develop smart windows that respond to environmental conditions. The work is described in Nature:
http://www.nature.com/nature/journal/v468/n7322/full/nature09540.html,
along with a commentary article:
http://www.nature.com/nature/journal/v468/n7322/full/468387a.html.

Antihydrogen trapped at CERN

http://physicsworld.com/cws/article/news/44343

Physicists at CERN in Geneva are the first to capture and store atoms of antimatter for long enough to study its properties in detail. Working at the lab's ALPHA experiment, the team managed to trap 38 anti-hydrogen atoms for about 170 ms. The next step for the researchers is to measure the energy spectrum of the atoms, which could provide important clues as to why there is much more matter than antimatter in the universe.

Antihydrogen is the antimatter version of the hydrogen atom and comprises a positron – or antielectron – and an antiproton. According to the Standard Model of particle physics, the energy levels of antihydrogen should be identical to those of hydrogen. Any deviations from this could help physicists identify new physics – and perhaps explain why there is much more matter than antimatter in the universe.

Although creating positrons and antiprotons is relatively easy, making antihydrogen is much harder. This form of antimatter was not isolated until 1995 – also in experiments at CERN. Making it stick around for long enough to study in detail is even more difficult. But in being able to trap antihydrogen atoms for 170 ms, the members of ALPHA, who come from 14 institutions in seven different nations, can now look forward to studying its atomic energy levels.

The work is described in Nature:
http://www.nature.com/nature/journal/vaop/ncurrent/full/nature09610.html.

Giant Faraday rotation spotted in graphene

http://physicsworld.com/cws/article/news/44343

The polarization of light can be rotated by almost 6° as it passes through a single sheet of graphene in a magnetic field, according to an international team of physicists. This latest property of graphene – a sheet of carbon just one atom thick – was unexpected because large rotations normally occur only in much thicker materials. The scientists believe that this newly discovered property of graphene could be exploited in new devices that switch light using electric and magnetic fields.

The fact that the polarization of light can rotate as it travels through a material exposed to a magnetic field is, of course, nothing new. But because the size of this "Faraday angle" is proportional to the thickness of the material, graphene – being just one atomic layer thick – was not expected to generate a large rotation. However, Alexey Kuzmenko and colleagues at the University of Geneva have found that the material can twist the polarization of light by 0.1 radians, or about 6°. The result means that graphene has a bigger Faraday rotation per atomic layer than any other material – beating out its nearest semiconductor rivals in the infrared by a factor of 10. Researchers at the Fritz Haber Institute in

Berlin and the University of Erlangen-Nueremberg – both in Germany – and the Lawrence Berkeley Laboratory in the US were also involved in the work.

The work is published in Nature Physics:
http://www.nature.com/nphys/journal/vaop/ncurrent/full/nphys1816.html.

See also this review article on graphene oxide as a chemically-tunable platform for optical applications, in Nature Chemistry:
http://www.nature.com/nchem/journal/v2/n12/full/nchem.907.html.

Physics and the cell

http://www.nature.com/nphys/insight/physics-cell/index.html

Nature Physics has published an Insight issue highlighting a few areas of research in contemporary biophysics.

Penrose claims to have glimpsed Universe before Big Bang

http://physicsworld.com/cws/article/news/44388

Circular patterns within the cosmic microwave background suggest that space and time did not come into being at the Big Bang but that our universe in fact continually cycles through a series of "aeons". That is the sensational claim being made by University of Oxford theoretical physicist Roger Penrose, who says that data collected by NASA's WMAP satellite support his idea of "conformal cyclic cosmology". This claim is bound to prove controversial, however, because it opposes the widely accepted inflationary model of cosmology.

Discovery of 'arsenic-bug' expands definition of life

http://www.sciencemag.org/content/early/2010/12/01/science.1197258

NASA-supported researchers have discovered the first known microorganism on Earth able to thrive and reproduce using the toxic chemical arsenic. The microorganism, which lives in California's Mono Lake, substitutes arsenic for phosphorus in the backbone of its DNA and other cellular components.

Carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur are the six basic building blocks of all known forms of life on Earth. Phosphorus is part of the chemical backbone of DNA and RNA, the structures that carry genetic instructions for life, and is considered an essential element for all living cells. Phosphorus is also a central component of the energy-carrying molecule in all cells (adenosine triphosphate) and also the phospholipids that form all cell membranes. Arsenic, which is chemically similar to phosphorus, is poisonous for most life on Earth. Arsenic disrupts metabolic pathways because chemically it behaves similarly to phosphate.

The newly discovered microbe, strain GFAJ-1, is a member of a common group of bacteria, the Gammaproteobacteria. In the laboratory, the researchers successfully grew microbes from the lake on a diet that was very lean on phosphorus, but included generous helpings of arsenic. When researchers removed the phosphorus and replaced it with arsenic the microbes continued to grow. Subsequent analyses indicated that the arsenic was being used to produce the building blocks of new GFAJ-1 cells.

The key issue the researchers investigated was when the microbe was grown on arsenic did the arsenic actually became incorporated into the organisms' vital biochemical machinery, such as DNA, proteins and the cell membranes. A variety of sophisticated laboratory techniques was used to determine where the arsenic was incorporated.

The results of this study will inform ongoing research in many areas, including the study of Earth's evolution, organic chemistry, biogeochemical cycles, disease mitigation and Earth system research. These findings also will open up new frontiers in microbiology and other areas of research.

Nanotube rubber stays strechy at extreme temperatures

http://physicsworld.com/cws/article/news/44515

Researchers in Japan have developed a new viscoelastic material that remains stable over an incredibly wide temperature range – from –196 °C to 1000 °C. Scientists have been studying carbon nanotubes for the last 20 years because these materials have many remarkable properties that include extremely high tensile strength and high electrical conductivity. Now, Ming Xu of AIST in Tsukuba and colleagues have reported in Science (http://www.sciencemag.org/content/330/6009/1364.full) the discovery of yet another exceptional property in these tubes – viscoelasticity over a wide temperature range. This is the first such material of its kind as rubbery materials like these normally break down at high temperatures and become brittle when too cold.

The new rubber is made from a random network of interconnected single-, double- and triple-walled carbon nanotubes and has the same viscoelasticity as that of the most thermally resistant silicone rubber at room temperature. However, silicone rubber only retains its viscoelasticity between –55 °C and 300 °C. The new material remains flexible over a much higher temperature range, can recover its shape after being repeatedly deformed and shows excellent fatigue resistance.

According to the team, the network is highly stable over a broad temperature range thanks to the energy dissipated as the individual nanotubes zip and unzip at the points of contact. The carbon nanotubes themselves are also very heat resistant – between 2000 °C and 3000 °C – so an even broader temperature range might be possible for this rubber.

Science also has a Perspective article about this material:
http://www.sciencemag.org/content/330/6009/1332.full.

Guest molecule builds 3D nanostructures

http://physicsworld.com/cws/article/news/44479

The self-assembly of artificial 3D nanostructures on a surface has been achieved for the first time, claims a team of researchers in the UK. Self-assembly is an attractive bottom-up method for fabricating nanostructures. It is simple and quick, and does not require expensive equipment or extreme conditions. Until now, however, the technique has only been used to make simple periodic structures in 2D.

Neil Champness and Peter Beton's team at the University of Nottingham has now used self-assembly to build molecules upwards and outwards from a surface by introducing a "guest" molecule onto the surface. When additional "host" molecules are then added, these spontaneously arrange themselves around the guest, forming stable extra layers around the molecule.

The Nottingham team employed carbon-60, or buckyballs, as the guest molecules. The researchers introduced the C60 onto a surface patterned by an array of host tetracarboxylic acid molecules. These molecules provide an array of nanopores that are stabilized by hydrogen bonding and they can selectively trap other simple molecules, like C60. Because the C60 is a spherical-shaped structure, the acid molecules assemble around it, forming a 3D network. The self-assembly process is also reversible – for example, by adding planar molecules such as coronene that displace the C60.

The work is published in Nature Chemistry:
http://www.nature.com/nchem/journal/vaop/ncurrent/abs/nchem.901.html.

continued p 90

Obituary

Graham Derrick

13/06/1934 - 29/12/2010

by Ross McPhedran

Graham Derrick did his undergraduate degree at the University of Queensland, and moved from there to the University of Sydney in 1955 to do his MSc. (Qualifying) course, the equivalent of an Honours degree. (At that time, graduates not from the University of Sydney could not do Honours there.) It is recorded that Graham topped the class that year, and would have been given the University Medal if he had been a Sydney undergraduate. He then went on to do a PhD under the supervision of Professor John Blatt, the topic being "The Ground State of H3". One of the examiners, the famous Professor Herman Feshbach of MIT judged the thesis to be "a definitive work of great merit and importance".

Graham then went on to study for a year at the Institute for Advanced Study, Princeton University, before spending a year at the University of Manitoba as an Assistant Professor in Mathematical Physics. Graham returned to Australia in 1961 to take up a lectureship in the Applied Mathematics Department at the University of New South Wales. Graham was there until 1965, during which time he married his wife Diana. They raised four children (James, Sarah, Linda and Chris.)

From 1965 to 1972, Graham was at the University of St. Andrews, first as Lecturer, then Reader in Theoretical Physics. He was able to take a year's study leave at the Australian Atomic Energy Commission, Lucas Heights (1970-1971), before becoming Principal Lecturer in Theoretical Physics at the NSW Institute of Technology (now UTS). In 1974, Graham joined the University of Sydney, where he was promoted to Reader in 1976. He took early retirement from the University in July 1990.

Graham was a physicist with a deep and wide knowledge of his subject, who was able to contribute to the advancement of a wide range of fields: field theory, general relativity, elementary particles, statistical mechanics, nuclear physics and solid state physics. One of the things for which he is best known is the Derrick-Hobart Theorem (J. Math. Phys., 5, 1252-1254, 1964), which proves the instability of solutions of a wide class of nonlinear field equations. (This was discovered independently and simultaneously by Dr. R. Hobart.) Graham was interested both in the most fundamental questions of physics, like rendering the geometry of quantum mechanics compatible with the Minkowski light-cone of special relativity, and the most practical of applications, like the design of the optical security device for the 1988 Bicentennial bank note. (This featured a diffraction grating-based optically variable device, and did not last very long in circulation after it was announced that the OVD was practically indestructible, but even if it was destroyed the note remained legal tender.) Graham attended in succession in 1985 a Symposium on the Foundations of Modern Physics in Joensu Finland, and the International Solar Energy Congress in Montreal Canada.

I doubt there was any other individual attending both these conferences! Graham's work on solar energy commenced when he moved to the University of Sydney. He worked with Dr. Ian Bassett on the very new area of non-imaging optics, as Ian comments: Graham welcomed me when I was a shaky newcomer in the theoretical physics department. Later we collaborated on some work in "non-imaging optics" much of which eventually found its way into an article (whose authors included Walter Welford and Roland Winston) in Emil Wolf's Progress in Optics.

Graham also worked with me on the design of textured surfaces to diminish reflection losses for solar absorbers. The textures had to work well independent of polarization, which meant they had to be doubly periodic rather than singly periodic. This launched us into uncharted waters, so we profited from the opportunity that Graham had to take a sabbatical leave in Marseille, joining up with Daniel Maystre, Patrick Vincent and Michel Neviere to attack a problem which clearly was going to strain the computers of the late 70's. Graham had the brilliant idea to use a coordinate change in the style of general relativity to flatten the surface by "curving the space" above it. This idea is now at the heart of an emerging field called transformation optics. In an amazing coincidence, when we arrived in Marseille, we found Daniel had a PhD student, Jean Chandezon, who had had precisely the same idea. Jean developed his form of the transformation method with Daniel for singly periodic gratings. Graham, Daniel, Michel and I developed the method for crossed gratings, with certain differences caused by the need to fit our larger calculations on computers available at the time. The result was a series of papers which were probably twenty years ahead of their time: similar calculations are being carried out today, mainly advanced photovoltaic cells rather than for the photothermal systems we studied. Graham and his family impressed the researchers in Marseille with their ability to surmount the many difficulties in transplanting a group of six people (two with significant health problems) from an English speaking country to a far-away part of France. I will end this obituary by quoting Daniel Maystre (with Michel Neviere having expressed very similar sentiments):

Above all, I remember the long stay of Graham and his family in Marseille. They gave us a lesson of courage and showed us that human life is stronger than difficulties. If only for this reason, I will never forget.

Branch News

Victoria

What makes a physicist employable?

Piazza and beer were the order of the day as the Victorian branch organised its annual Undergraduate Careers Night in August. Hosted by the School of Physics at the University of Melbourne, the evening attracted approximately 40 science and engineering students from universities across the city.

Fig. 1. Careers night for Victorian undergraduate physics students.

A panel of four young physicists, Gaby Bright, Rohan Dowd, Ruth Plathe and Kent Wootton, talked about the work they do now, what they studied at university, and how they use physics in their jobs. Their careers have included laser reflectometry with the Australian Antarctic Division, particle physics at KEK in Japan, x-ray science at the Australian Synchrotron, and accelerator physics at CERN. The panellists described how a training in physics developed a number of valuable skills such as the ability to solve problems by addressing the fundamental issues; work with computers and computer programs; approach questions and issues from an analytic perspective; communicate complex ideas clearly; and, above all, be able to think outside the square.

This annual event continues to attract undergraduate students from across the universities, and student physics societies were well-represented. For many, the careers night provides the first opportunity to network with physicists outside their home institutions, and also provides their first contact with the AIP.

Nuclear power without radioactivity?

Radiation-free nuclear fusion could be possible in the future according to Professor Heinrich Hora from the Department of Theoretical Physics, UNSW, who gave the September lecture to the Victorian branch. Among the many solutions to the energy crisis currently being developed, nuclear fusion remains the ultimate goal as it has the potential to provide vast quantities of sustainable and clean electricity. But nuclear energy currently comes with a serious environmental and health hazard - radiation. For fusion to gain widespread acceptance, it must be able to produce radiation-free energy, but the key to this has so far remained elusive.

Conventionally, the fusion process occurs with deuterium and tritium as fuel. The fuel is spherically compressed with laser irradiation to 1000 times its solid state density. This ignites the fuel, producing helium atoms, energy and neutrons which cause radiation. However, fusion is also possible with hydrogen and boron-11, and this could produce much cleaner energy as it does not release neutrons. But this fuel requires much greater amounts of energy to initiate fusion and so has been widely thought not to be a viable option.

Now, an international team led by Hora has carried out computational studies to demonstrate that new laser technology capable of producing short but high energy pulses could be used to ignite hydrogen-boron fuel. The high energy laser pulses can be used to create a plasma block that generates a high density ion beam, which ignites the fuel without it needing to be compressed. Without the need for compression, the energy required to ignite hydrogen-boron is much lower than previously thought. Although the energy to initiate hydrogen-boron fusion is still higher than for deuterium-tritium, it is at least in the same ballpark which could make it competitive with the conventional approach.

Although some fusion physicists already believe hydrogen-boron is potentially the best route to fusion energy, Hora agrees that much more work is needed to fully understand this radical new approach. Its achievement will depend on continued advances in laser optics, target physics and power conversion technology.

For further reading see Y. Li, Highlights in Chemical Technology 7(10) (2010); H. Hora and J. C. Kelly, Australian Physics 46(4) (2009) 111-13.

Stiky tape and a pencil

Professor Steven Prawer and Dr Andrew Greentree from the University of Melbourne gave a joint presentation at this year's Nobel Prize Lecture in 'How to Win a Nobel Prize with Sticky Tape and a Pencil'. They described the work of Andre Geim and Konstantin Novoselov (both at the University of Manchester) for - according to the citation by the Swedish Academy of Sciences - their 'groundbreaking experiments regarding the two-dimensional material graphene'.

Graphene is a thin flake of ordinary carbon, just one atom thick. Geim and Novoselov extracted the graphene from a piece of graphite such as is found in ordinary pencils. Using regular adhesive tape they managed to obtain a flake of carbon with a thickness of just one atom. Many scientists thought that it would be impossible for such thin crystalline materials to be stable: they would instead become crinkled or rolled up at room temperatures.

Since it is practically transparent and a good conductor, graphene is suitable for producing transparent touch screens, light panels, and maybe even solar cells. When mixed into plastics, graphene can turn them into conductors of electricity while making them more heat resistant and mechanically robust. This resilience can be utilised in new super strong materials, which are also thin, elastic and lightweight. In the future, satellites, airplanes, and cars could be manufactured out of the new composite materials.

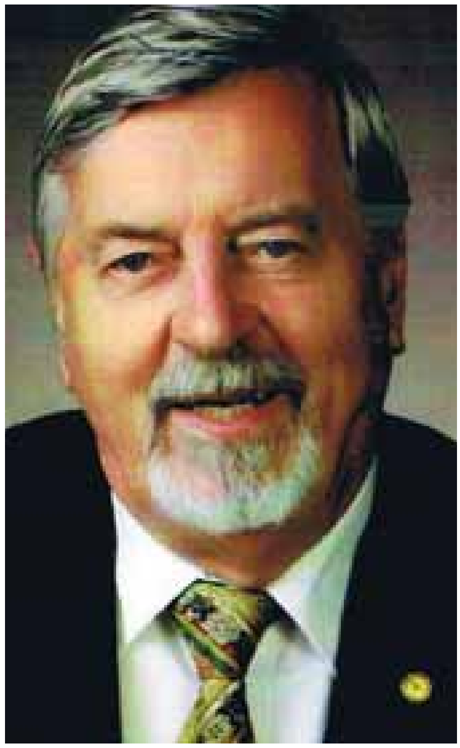

Fig. 2. Developing a new approach to fusion – Professor Heinrich Hora from the University of NSW.

The discovery of the extraordinary properties of graphene is the outcome of a long collaboration. Novoselov, 36, began working for

Fig. 3. Andre Geim and Konstantin Novoselov share the 2010 Nobel Prize for Physics for their discovery of the remarkable properties of graphene, a new form of carbon [courtesy: Russell Hart/University of Manchester].

Geim, 51, as a PhD student in the Netherlands and subsequently followed Geim to the UK. Both of them originally studied and began their careers as physicists in Russia. Now they are both professors at the University of Manchester.

The Victorian Branch's Nobel Prize Lecture held in October is an annual event begun over 30 years ago.

Congratulations - Prof Ray Volkas

Professor Ray Volkas from the School of Physics, University of Melbourne, has been appointed to the Editorial Board of Physical Review Letters as a Divisional Associate Editor. Ray will represent the division of 'Particles and Fields'. PRL is generally regarded as the most prestigious of the stable of journals published by the American Physical Society and its acceptance rate is thought to be the lowest of all. Authors do, however, have the right to appeal if they believe they have been treated harshly by the referees. Ray's role as Divisional Associate Editor is to adjudicate on whether a decision to reject a paper should be overturned. A small but significant number of authors are successful in their appeals. A secondary role will be to provide occasional advice to the permanent editors on papers submitted. Other Australians to have served recently on the PRL Editorial Board include Bob Dewar and George Dracoulis from the Australian National University. Ray took up his three-year appointment in July.

News from AIP VIC Branch were provided by Peter Robertson.

New South Wales

The NSW Branch of the AIP in conjunction with the Royal Society if NSW held its annual Postgraduate Awards Day on Tuesday 23 November 2010 in the Board Room, Darlington Centre, University of Sydney. Each New South Wales University was invited to nominate one student to compete for the $500 prize and Postgraduate medal on that day.

Fig. 4. From left, Dr Bill Kneprath (AIP) and Mr Daniel Huber (USYD).

The Royal Society of NSW as the co-sponsor also awarded a Scholarship prize of $500 as a separate award category for this event. Students nominated for the awards will also be invited as guests for the NSW AIP Branch annual dinner that follows the presentations. These awards have been created to encourage excellence in postgraduate work, and all nominees who participate in the Postgraduate Awards Day also received a special certificate recognising the nominee's high standing.

Students were asked to make a 20-minute presentation on their postgraduate research in Physics, and the presentation was judged on the criteria (1) content and scientific quality, (2) clarity and (3) presentation skills. The nominated speakers for 2010 were:

- Julian King
  University of New South Wales
  Evidence for Cosmological Spatial Variation of the Fine Structure Constant

- Varun Sreenivasan
  Macquarie University
  Dressing up Nanoparticles for Biomedical Applications

- Daniel Huber
  University of Sydney
  New Frontiers in Stellar Astrophysics: Asteroseismology and Long-Baseline Interferometry with Kepler and PAVO

- Matthew Foley
  University of Technology Sydney
  Luminescence Inhomogeneity in ZnO nanorods

- Bradley Michael Oborn
  University of Wollongong
  Monte Carlo simulations in Magnetic Resonance Imaged Guided Radiotherapy

- Mahdi Hosseini
  Australian National University
  Optical Slice-and-Dice

The winner of the AIP Postgraduate Presentation for 2010 was awarded to Daniel Huber from the University of Sydney with his work entitled New Frontiers in Stellar Astrophysics: Asteroseismology and Long-Baseline Interferometry with Kepler and PAVO. Daniel received the 2010 Crystal Postgraduate figurine, AIP merchandise

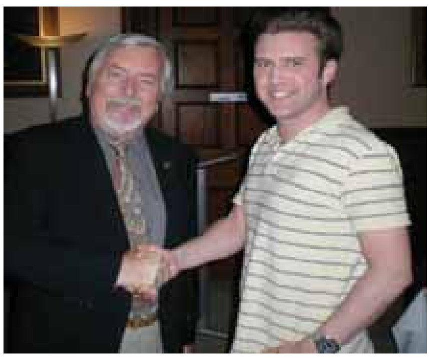

Fig. 5. From left, Professor Heinrich Hora (UNSW) and Mr Julian King (UNSW).

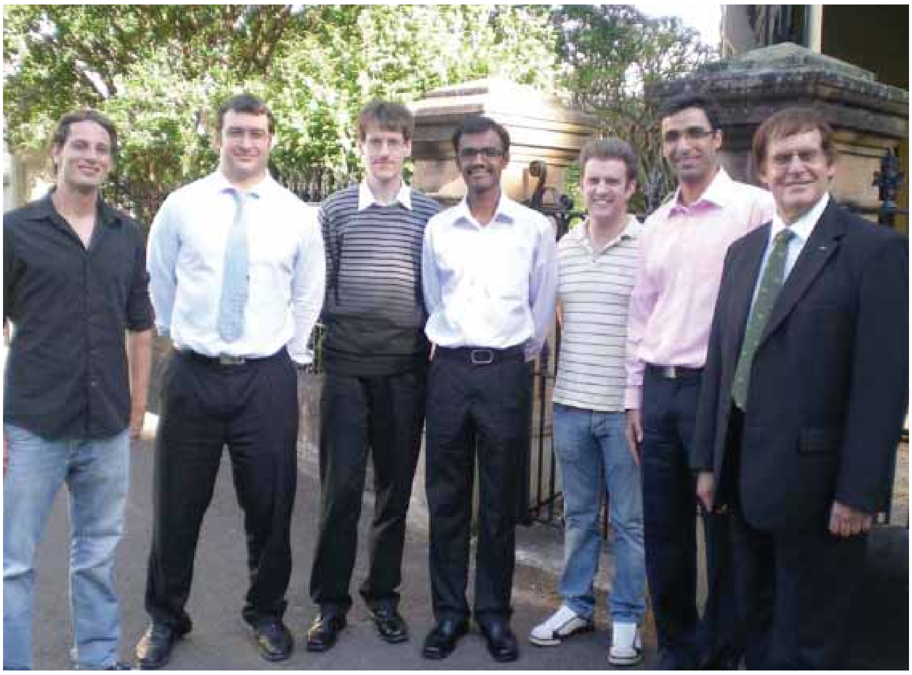

Fig. 6. From left to right, Mr Daniel Huber (USYD), Mr Bradley Oborn (UOW), Mr Matthew Foley (UTS), Mr Varun Sreenivasan (MAQ), Mr. Julian King (UNSW), Mr Mahdi Hosseini (ANU) and Dr Bill Kneprath (AIP).

and a $500 cheque from the AIP.

The AIP congratulates Daniel on this wonderful achievement. The five runner's up all received a small AIP medal and a special certificate recognising the nominee's high standing.
The winner of the Royal Society of NSW Scholarship Prize for 2010 was awarded to Julian King, University of New South Wales - Evidence for Cosmological Spatial Variation of the Fine Structure Constant. Julian also received AIP merchandise and a $500 cheque from the Royal Society of NSW. The Royal Society of New South Wales congratulates Julian on this wonderful achievement.

Fig. 7. From left, Dr Graeme Melville (AIP Branch Chair), A/Prof Adam Micolich (UNSW) and Dr Fred Osman (AIP Branch Postgraduate Convenor)

The Postgraduate Awards day was followed by a talk from our invited speaker A/Prof Adam Micolich, an ARC Future Fellow at UNSW working on the physics of nanoelectronic devices. His entitled talk was on "Surviving the school of hard knocks: Top ten tips from the ten years after my Ph.D.
The 2010 Awards Event was proudly sponsored by: The Australian Institute of Physics, The Royal Society of New South Wales, Campus Review and the CSIRO.

The talks were very well received and geared to scientists and members of the public alike with many discussions continuing later during the Annual dinner at the Buon Gusto Italian restaurant. The Australian Institute of Physics thanks Associate Professor Adam Micolich and all the Postgraduate speakers for there outstanding lectures!

News from AIP NSW Branch (November 2010) was provided by Dr Osmar Dr Frederick Osman, AIP NSW Branch Postgraduate Awards Convenor.

QUANTUM by

Gordon Troup, David Paganin, and Andrew Smith

'From the Mouths of Babes..'

In partial answer to a first year exam question, a student wrote 'electromagnetic waves cannot travel in a vacuum because there are no charges in it.' What if 'because' were substituted by 'if' or 'when'? The answer would then be close to current belief in what happens.

The vacuum can be polarised by an electromagnetic wave, provided in the language of Synge (*1*) it is not 'null' and 'wrenchless' . Null means that the magnitudes of the coplanar electric and magnetic fields perpendicular to the direction of propagation are in the same ratio as for a plane wave, and wrenchless means no field components in the direction of propagation. Thus our mathematically convenient (wrenchless) plane wave cannot polarise the vacuum. It is easy to prove that a plane wave with an intensity distribution across its wavefront has a wrench, and hence can polarise the vacuum. Any unguided electromagnetic wave must have an intensity distribution across its wavefront, therefore has a wrench, and so will polarise the vacuum. This leads to the thought that polarisation of the vacuum is necessary for an electromagnetic wave to travel therein. Since the null, wrenchless plane wave cannot polarise the vacuum, it cannot travel therein.

So now we have a physical reason, other than energy conservation, for ruling it outside the set of physically possible e-m fields.

After causing all this thought, it was considered that the student's reply had merit, and he/she was not seriously penalised.

Reference:

1. T.M.Synge, 'Relativity – the Special Theory' Ch.IX (North Holland, Amsterdam) 1958.

The authors are from the School of Physics, Monash Unviersity

Computing with a single electron

reported by Peter Trute

A team led by UNSW engineers and physicists have developed one of the key building blocks needed to make a quantum computer using silicon: a "single electron reader". Their work has been published in the journal Nature (*1*).

Quantum computers promise exponential increases in processing speed over today's computers through their use of the "spin", or magnetic orientation, of individual electrons to represent data in their calculations.

outlined in Nature the concept for a silicon-based quantum computer, in which the qubits are defined by single phosphorus atoms in an otherwise ultra-pure silicon chip. The new device brings his vision closer.

"We expect quantum computers will be able to perform certain tasks much faster than normal computers, such as searching databases, modelling complex molecules or developing new drugs," says co-author Prof Andrew Dzurak. "They could also crack most modern forms of encryption."

"After a decade of work trying to build this type of single atom qubit device, this is a very special moment."

In order to employ electron spin, the quantum computer needs both a way of changing the spin state (write) and of measuring that change (read) to form a qubit - the equivalent of the bits in a conventional computer.

In creating the single electron reader, a team of engineers and physicists led by Dr Andrea Morello and Professor Andrew Dzurak, of the School of Electrical Engineering and Telecommunications at UNSW, has for the first time made possible the measurement of the spin of one electron in silicon in a single shot experiment. The team also includes researchers from the University of Melbourne and Aalto University in Finland.

"Our device detects the spin state of a single electron in a single phosphorus atom implanted in a block of silicon. The spin state of the electron controls the flow of electrons in a nearby circuit," said Dr Morello, the lead author of the paper, Single-shot readout of an electron spin in silicon.

"Until this experiment, no-one had actually measured the spin of a single electron in silicon in a single-shot experiment."

By using silicon - the foundation material of conventional computers - rather than light or the esoteric materials and approaches being pursued by other researchers, the device opens the way to constructing a simpler quantum computer, scalable and amenable to mass-production.

The team has built on a body of research that has put Australia at forefront of the race to construct a working quantum computer. In 1998 Bruce Kane, then at UNSW,

"After a decade of work trying to build this type of single atom qubit device, this is a very special moment." Now the team has created a single electron reader, they are working to quickly complete a single electron writer and combine the two. Then they will combine pairs of these devices to create a 2-bit logic gate - the basic processing unit of a quantum computer.

The research team is part of the Australian Research Council (ARC) Centre of Excellence for Quantum Computer Technology, which is headquartered at UNSW. The team is led by Prof Dzurak and Dr Morello, with Mr Jarryd Pla and Dr Floris Zwanenburg as key supporting experimentalists. The paper's co-authors include Prof David Jamieson from the University of Melbourne; Dr Bob Clark, Australia's Chief Defence Scientist, and 10 other researchers from UNSW, The University of Melbourne, and Finland's Aalto University.

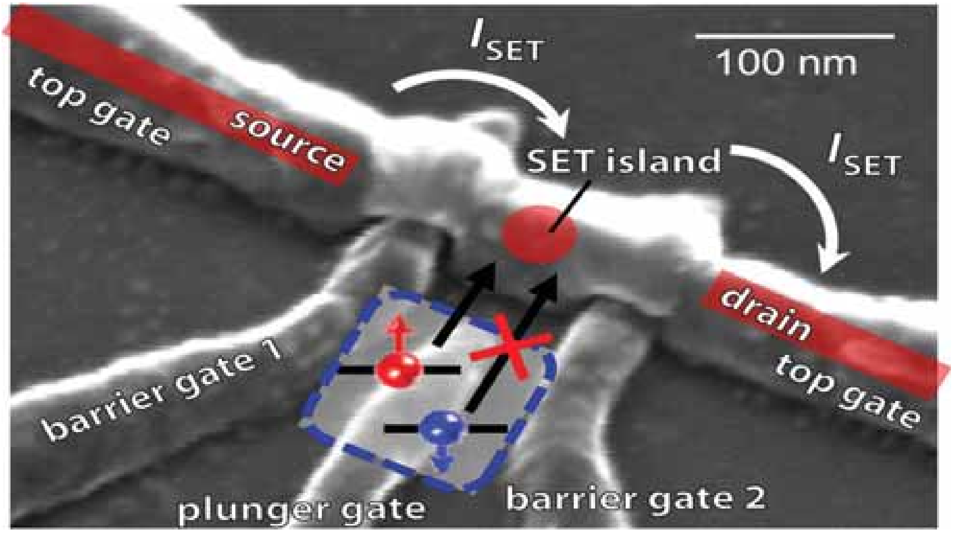

Fig. 1. Scanning electron micrograph of metallic electrodes on silicon oxide. The electrodes are isolated from each other so that there is no electric current flowing through them. A schematic illustration has been added to the figure representing the electron layer induced below the silicon oxide (source and drain) together with so-called quantum dot (SET island) which works as a charge detector. Furthermore, the dashed blue line shows a region where phosphorus donors have been placed in the silicon with the magnetic moment of the outermost electron pointing either up or down. The energy of spin-up state is higher than the energy of spin-down state in magnetic field. By controlling the voltage on a nearby plunger gate, the system can be brought at will into a working point where spin-up electron has enough energy to tunnel into the charge detector but the spin-down state of the same electron remains bound to the phosphorus. The detector is very sensitive to changes in the charge state of the phosphorus yielding noticeable current (ISET) after the spin-up electron moves. Thus the spin state of the electron can be measure by a single shot at any chosen time. Source: www.physorg.com

References:

1. Andrea Morello *et al.*, Single-shot readout of an electron spin in silicon, Nature **467**, 687–691 (07 October 2010) doi:10.1038/nature09392

Acknowledgements:

The research was funded by: the Australian, US, and NSW governments; UNSW; and the University of Melbourne.

This article is an excerpt produced by Peter Trute from the University of News South Wales Media Office.

The 2010 Physics Olympiad

by Hilary Hunt and Madeleine Barrow

In July 2010, five young Australians were fortunate enough to represent Australia in the 41st International Physics Olympiad. Attended by more than 80 countries around the world, each bringing a team of up to five students, the Olympiad is the most prestigious physics competition for high school students in the world.

In August each year, the National Qualifying Exam is sent to all interested schools in every state in Australia. Only the brightest and most enthusiastic students sit the exam and, from them, the top 24 are chosen to attend a two-week intensive physics camp in January. This camp is not for the faint-hearted and the 24 was eventually cut back to just eight. The team would represent Australia in the Asian Physics Olympiad – an Olympiad held exclusively for countries of the Asia-Pacific region. Another intensive week of training over Easter and we were ready to go.

As the host of the 2010 Asian Olympiad, Taipei organised our accommodation and took care of everything we would need over the next week. The competition kicked off at the Opening Ceremony, attended by the Vice President of Taiwan and other dignitaries. We saw displays of traditional Taiwanese and Chinese music, as well as speeches from the organising committee. It was then that we realised that we were expected to put on our own performance – as the first team to walk on stage, we warmed up the audience with a resounding rendition of Waltzing Matilda. The exams at the Asian Physics Olympiad were challenging and stimulating to say the least, but allowed us to showcase our skills.

After the results were tabulated, our program directors selected a team of five to represent Australia at the International Physics Olympiad. There were three boys from Sydney Grammar School and we two from MacRobertson Girls High School in Melbourne. Two months later, we were on the plane again to Zagreb. As one of the first teams to arrive, we had several days to potter around the medieval city and to experience traditional Croatian culture. Highlights included the birthplace of Nicholas Tesla and the Plitvice lakes national park. The theoretical exam focused on the techniques of imaging charges, nuclear physics and thermodynamics, while the five-hour experimental paper explored energy in the curvature of surfaces and magnetic equilibrium. Both were fascinating papers.

Both Olympiads provided us with immense rewards: not only did we have the chance to think beyond the high school curriculum, but we formed important friendships and developed strong connections to the science world. We would like to encourage all young physicists to try their luck at the National Qualifying Examination – after all, you never know where it could take you.

This was an incredible experience which certainly showed us the intrigue and versatility of physics, and we'd like to thank the Victorian Branch of the Australian Institute of Physics for their support.

Fig. 1. The Australian team before the opening ceremony of the 41st International Physics Olympiad in Zagreb - Bob Wu, Andrew Kam, Hilary Hunt, Madeleine Barrow, Alex London

The 2010 Barry Inglis Medal

Quantum Mechanics in the 21st Century

by Ken Baldwin

The importance of precision measurement is a hallmark of a modern technological society. Better measurement techniques lead to new understanding of the world around us, which in turn leads to novel technological advances. The devices that arise from new technology can further improve our ability to measure precisely, and so the measurement cycle continues.

There is perhaps no better example of this than the measurement science which underpins the Global Positioning System (GPS). Each GPS satellite (Figure 1) relies on precise timing information that is derived from its own internal atomic clock, based on the microwave frequency of the caesium atomic ground state splitting. This is the same transition that since 1967 has provided the international definition of the second:

"The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom... This definition refers to a caesium atom at rest at a temperature of 0 K." (*1*)

Fig. 1. GPS satellite with on-board atomic

The adoption of a time and frequency definition based on an atomic transition was the culmination of many decades of precision measurement of atoms which led to a detailed theoretical understanding of atomic structure. It is this continuing interplay between fundamental science and precision measurement that yields many benefits to modern society such as the GPS.

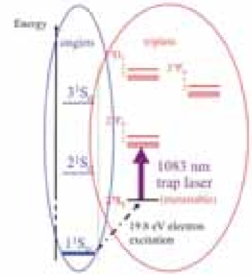

Fig. 2. Helium energy levels, showing both singlet and triplet manifolds.

Ongoing advances in the use of atomic frequency standards have enabled physicists to move beyond the current accuracy of the Cs standard (~1 part in 10^{12}). The next generation of atomic clocks will most likely be based on optical (rather than microwave) electronic transitions in atoms isolated in a virtually unperturbed environment, either in ion traps or optical lattices formed by intersecting laser beams. This will enable accuracy at the 1 part in 10^{18} level – the most accurate measurement of any physical quantity.

New areas of physics will be thrown open for investigation as a result of this unprecedented accuracy and precision. More rigorous tests of general and special relativity will be possible, and even more stringent limits will be placed on the variation in the fundamental "constants", which in turn will test the validity of various models of the universe. And no doubt such advances will lead to new technologies that may themselves further improve precision, thus continuing the measurement cycle.

Central to these developments is an improved understanding of the structure and dynamics that underpin our knowledge of atoms. This understanding has led to the theory of quantum electrodynamics (QED) which provides a near complete knowledge of atomic properties across the periodic table. Since its genesis in the 1940's, following on from the early advances in quantum mechanics, QED has stood the test of time and is

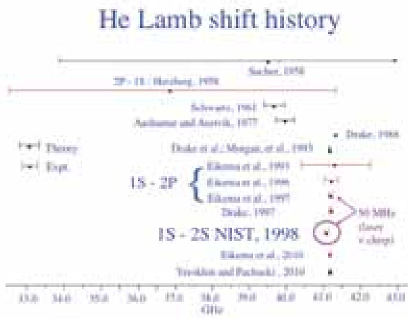

Fig. 3. Experimental apparatus for triplet manifold transition rate measurements.

now one of the most rigorously validated theories in modern physics – thanks to precision measurement.

Considerable attention has been paid to testing QED predictions for helium since it is the simplest multi-electron atom, and this is where my contribution to precision measurement has been most keenly focused. The energy levels of helium are shown in Figure 2 where the atomic structure is categorised by the states for which the two electron spins are opposed (the singlet states) or parallel (the triplet states). The triplet states have slower decay rates to the ground state because the spin of one of the electrons has to flip in the process, thus giving rise to the "forbidden" character of these transitions.

The first triplet state – the 2^3S_1 state – is doubly forbidden, since quantum mechanical selection rules prevent S -> S transitions. Hence its lifetime is even longer – around 8000 seconds – the longest lifetime of any neutral atomic or molecular state yet measured. This long lifetime means that the 2^3S_1 "metastable" state (as it is known) can act as an effective ground state for transitions to the higher energy levels in the triplet state manifold (*2*). For the same reason the metastable state cannot be readily populated by a photon transition from the ground state, so consequently it has to be excited by electron collisions e.g. in an electric discharge.

The metastable state is extremely important not just because of its long lifetime, but also because of the large amount of stored energy it contains – some 20 electron volts (eV) which again is the largest of any neutral atomic or molecular species. The electron scattering cross-section of the metastable state is also very large (*3*). This makes the metastable state an important species in discharges, light sources and atmospheric physics because of its role as an energy reservoir.

Metastable helium is also important in atom optics – the matter wave analogue of light optics where atoms can be laser-cooled, manipulated and trapped at very low temperatures. Ultracold atoms can behaviour either

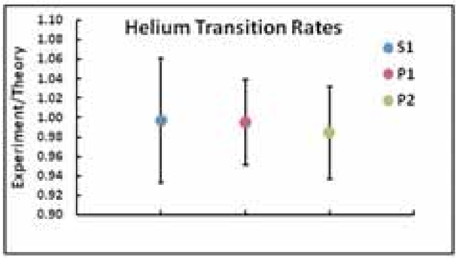

Fig. 4. Ratio of experimental to theoretical values for the transition rates shown, with experimental error bars.

as waves or as particles, because the lower the temperature, the larger the de Broglie wavelength λ_{dB} (= h/mv , where h is Planck's constant and mv the atomic momentum) allows wavelike processes such as beams splitting (for interferometry) to occur. The laser cooling transition used to reduce the atomic velocity by photon momentum transfer usually starts from the atomic ground state, but for helium this transition is in the extreme ultraviolet (XUV at ~58.4 nm). However, because the metastable state can act as an effective ground state, this allows the use of infrared laser-cooling in the 2^3P manifold *via* a 1083 nm transition which is accessible to a number of laser systems.

"New areas of physics will be thrown open for investigation as a result of this unprecedented accuracy and precision."

This mechanism is used to efficiently laser cool metastable helium, thereby creating an excited state species for use in atom optics. The large stored energy of metastable helium provides an additional advantage, since the metastable atoms are easy to detect using charged particle detectors. The stored energy is released on impact, with the metastable helium atoms acting as "nanogrenades" that enable single particle detection.

In the metastable helium atom optics laboratories at ANU we have exploited these unique characteristics to perform atom optics experiments, and to create Bose-Einstein condensates (BECs) of ultracold atoms whose de Broglie wavelengths overlap to form a macroscopic quantum state. These studies – in which the atoms are isolated in an unperturbed, ultra-high vacuum environment – also offer excellent opportunities to undertake precision measurements on the triplet state helium atoms.

We have focused on measuring the transition rates to the ground state of both the metastable state and the helium 2^3P manifold (Figure 2), whose energy intervals have been measured with great precision (1 part in 10^7) (*4 - 6*). However, the experimental results were at considerable variance with theory (*7, 8*) - by several factors of ten times the experimental uncertainty - which appeared to provide a significant challenge to QED. Very recently, this discrepancy has been partially resolved by new calculations (*9*) which reduce the discrepancy to several standard deviations.

The discrepancy with QEC theory prompted us to ask the question – do the transition rates from these states to the ground state also provide a sensitive test of QED? Interestingly, the energy intervals are known to a high level of accuracy (1 part in 10^7), whereas the transition rates were either not known at all (in the case of the 2^3P manifold), or to at best to within 30% for the metastable state (*10*).

We used the isolated environment provided by our BEC experiments (Figure 3) to measure the transition rates. We first directly measured the fastest transition from the 2^3P_1 level to the ground state [~180 s^{-1} (*11*)] by measuring the decay of the atomic cloud when illuminated with 1083nm light (P_1) from the metastable state. The decay rates of the metastable level (~7900 s lifetime) (*12*) and the 2^3P_2 level (~0.3 s^{-1} transition rate, excited by P_2 light) (*13*) were then determined by measuring the XUV photon decay flux using a channeltron detector, relative to the P_1 flux decay. The expected 2^3P_0 level decay rate – predicted to be zero – was also confirmed (*13*).

The results of the helium triplet state

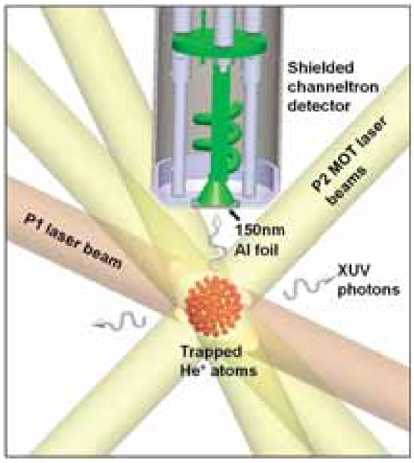

Fig. 5. Theoretical and experimental determinations of the helium ground state Lamb shift with uncertainty levels shown.

lifetime measurements are shown in Figure 4, together with the experimental uncertainties. The rates for the 2^3P manifold were determined for the first time, while the accuracy of the metastable state was improved to ~6%. In all cases the experiments were in excellent agreement with theoretical predictions, once again confirming the validity of QED.

The singlet manifold also presents an opportunity to use helium as a test bed for QED theory. In an experiment in which I participated in at the US National Institute of Standards

Fig. 6. Professor Ken Baldwin (Centre) discussing with Barry Inglis (left) and the Honorable Richard Marles (right), Parliamentary Secretary responsible for the NMI, on the occasion of the award of the Barry Inglis Medal.

"The encouragement that the Barry Inglis Medal provides... reflects the central role played by the National Measurements Institute in driving precision measurement in Australia..."

and Technology (NIST), we measured the transition interval from the 1^1S ground state to the first (2^1S) singlet excited state. This interval can then be used to determine the Lamb shift in the helium ground state – reflecting the effect of vacuum fluctuations on this state. We measured this transition for the first time, but other measurements of the helium Lamb shift using different transitions from the ground state had been undertaken with varying levels of precision (Figure 5) such as the experiments of the Amsterdam group (Eikema *et al. - 15*).

Our experiment aimed to improve on the most recent previous measurement by using a Doppler-free two-photon transition to measure this single-photon forbidden, ultra-narrow lineshape. We achieved a result (*14*) very close - within three (48MHz) standard deviations - from the other measurement, and in similar reasonable agreement with theory.

The precision measurement cycle continues however, and more recently together with my colleagues at Macquarie University we have created a new light source that overcomes the inherent frequency-chirp limitations of the original dye laser sources used in the NIST and Amsterdam experiments. We have developed an all solid state Optical Parametric Oscillator (OPO) -based system with well-characterised, near-zero frequency chirp characteristics (*16*). With this system, we hope to undertake a future measurement that will – along with the more recent Amsterdam experiments – challenge QED theory to better than 10 MHz.

In this way, better measurement techniques will enable more stringent tests of fundamental science, which will in turn allow better understanding to underpin development of new technologies, that will enable even more precise measurements. The encouragement that the Barry Inglis Medal provides to such investigations reflects the central role played by the National Measurement Institute in driving precision measurement in Australia, and it is with great pleasure that I humbly accept this award.

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Acknowledgements:

I would like to acknowledge the contributions made to this work by my many colleagues, in particular at the ANU, NIST and Macquarie University.

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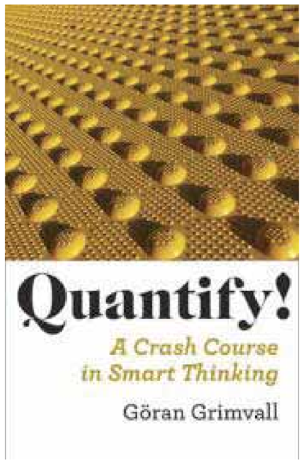
Book Reviews

"Quantify! A Crash Course in Smart Thinking " by Goran Grimvall, ISBN: 9780801897160, Johns Hopkins University Press.

Reviewed by Manoj Sidhar, Launceston College.



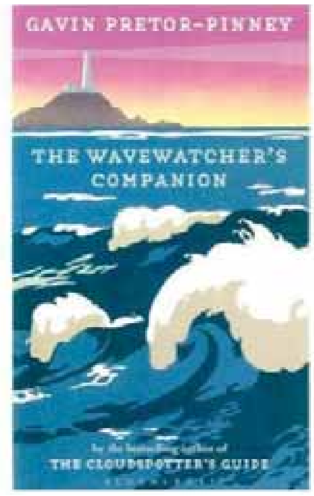
One of the most challenging tasks in science is communicating scientific concepts and methodologies to the average person. In his latest book, Goran Grimvall takes on this challenge and attempts to introduce basic quantitative analysis techniques to the average person. In this book, Grimvall engages readers with intriguing topics like "The Value of a Life", "The Age of the Earth", "Will your iPod make you deaf?" and "Galileo Galilei, Basketball and Table Tennis", a style somewhat similar to that used in the wildly popular Freakonomics book authored by University of Chicago economist Steven Levitt and New York Times journalist Stephen J. Dubner. The result is an interesting read that is bound to reveal some surprising and thought-provoking information to both scientific and nonscientific audiences alike. Grimvall discusses important concepts in quantitative analysis such as the need to measure quantities, like dimensions and weight for instance, relative to a suitable standard, the importance and implications of the accuracy of and errors involved in measured quantities, and the usefulness and limitations of developing simple models to analyse complex, real-world phenomena like resource depletion and taxation levels.

Particularly, his discussion of the uncertainties that may occur in sporting events due to variations in the length of running tracks or swimming pools is very captivating and is an example to which a number of people can easily relate. After dealing with a wide variety of topics such as the idiosyncrasies that exist in the ways we write and express the simplest numbers, the return on academic investment, the freezing of rain upon contact with the ground and the importance of the second

derivative in the context of economic growth, Grimvall provides a terrific summary of the key concepts of quantitative analysis in the epilogue which he calls “Seven Principles of Scientific Literacy”. Most importantly, he stresses that all our knowledge is only provisional and that we have to always keep in mind that future experimentation will provide us further insights that may alter our understanding of nature and ourselves. We must remain open to the possibility of such new knowledge, whilst being careful to thoroughly analyse any such new information, and learn from our past mistakes to further the boundaries of our knowledge. Certainly advice that we will do well to heed because it is becoming increasingly important for us to be able to analyse and evaluate the quality and validity of the massive amounts of information we receive on a daily basis from the various media pathways.
Manoj Sridhar

”The Wavewatcher’s Companion” by Gavin Pretor-Pinney, ISBN 978-0-7475-8976-1, Bloomsbury

Reviewed by Jason Dicker, Launceston College.



This book is a well-written, erudite and charming look at waves, their behaviour and ubiquity. The style is relaxed and humorous with no attempt at mathematical rigor but for all that accurate and careful with a beautifully selected prose to capture refraction, interference, beats, resonances and so on. All core wave behaviour is captured and described except, perhaps, polarization and solitons although tidal bores are described.

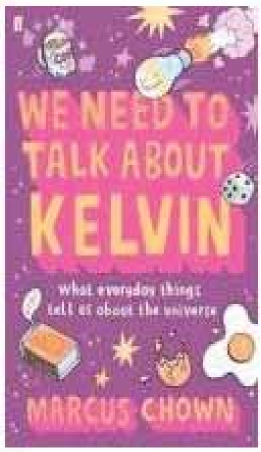
Being written for the general public, the natural focus is on water waves and sound but the author branches into atmospheric waves, earthquake waves, electromagnetic waves and briefly quantum waves. He also beautifully describes waves used by animals for locomotion, snakes, worms etc.

The author brings art and poetry into the book into the text to show how much waves mean to humanity and ventures into the possibility of sand dunes being waves given their similarity to ripples, a concept that is firmly rebutted. In doing this he reemphasizes the processes of wave generation that he then carries onto waves of car jams on motorways above a certain traffic density.

My only criticism of this enjoyable book was the use on a couple of occasions of jarring neologisms where softer expressions would have served better. Otherwise it can be thoroughly recommended to anyone with a love of natural phenomena.

“We need to talk about Kelvin: What everyday things tell us about the universe”, Marcus Chown, ISBN: 978-0-571-24402-7, Faber and Faber.

Reviewed by Jason Dicker, Launceston College.



Marcus Chown is a regular writer and consultant for New Scientist and has a radio astronomy background.

The target audience appears to be either educated non-physicists who feel they should know some modern physics or enthusiastic high school science students. Certainly I see some of my own Year 11 and 12 students enjoying this book then harassing me for weeks after.

I found this a curious book in that I learned quite a lot. I was very happy to see the work of Emmy Noether and Cecilia Payne described and acknowledged, while his description of Hoyle’s arrival at the nuclear processes of atom formation in the stars was new to me and intriguing, but I felt somewhat dissatisfied. It was not a book that I returned to easily.

I suspect it is the approach adopted deliberately by Chown that is its weakness and strength. This is a fast paced approach. Each chapter starts with a series of comments by notable individuals often, but not always physicists, followed by Chown’s discussion in terms of modern physics. Some times small errors appear and simplifications are made, for example Young apparently used monochromatic light on slits when I believe he used either sunlight from a pinhole or candle light, but no filters that I am aware of. These are distracting to a pedant (read “teacher”).

The basic theme, as befits modern physics, is probability, chance and randomness and with the frequently less publically discussed areas of quantum mechanics such as the Pauli Exclusion Principle shown as crucially important in our Universe.

Classical physics, Newtonian gravity and electromagnetism and even General Relativity, is virtually assumed so the book really starts with the turn of the 19th century. For Chown, modern physics starts with Young. He then rapidly progresses through Maxwell, with a scant wave of hand to Faraday, to Rutherford and Kelvin. At all times he keeps truly to a given subplot so most of the names mentioned make sense but sometimes skipping other important individuals.

We finish with the problem of the lack of aliens. This chapter, frankly, to me doesn’t really fit the earlier pattern of physical explanations even though Enrico Fermi is enlisted. While he strictly looks at the chances of aliens and the problems and chances of finding aliens as taken very seriously by SETI and other extremely respected groups, he manages to wangle in dark matter and wormholes but after the very concrete physics described earlier, this chapter finishes as it began – speculation.

Chown clearly has a wide and excellent knowledge of Physics and he has demonstrated a virtuosity in describing to the wider public the depth of physical understanding that we have now arrived at this Universe.

Send your book reviews to our Book Reviews Editor, Dr John Macfarlane at: john.macfarlane@csiro.au

Samplings

Water isomers separated by spin

http://physicsworld.com/cws/article/news/44845
http://www.sciencemag.org/content/331/6015/319.full

Physicists in Israel have used a modern version of the Stern-Gerlach experiment to separate out water molecules according to the relative spin of their constituent hydrogen atoms. This ability to generate a sample of water with a well-defined nuclear spin could, say the researchers, significantly increase the sensitivity, and hence applicability, of nuclear magnetic resonance (NMR).

Water molecules come in two varieties, or isomers, depending on how the spins of their two hydrogen atoms are oriented relative to one another. When the spins are parallel the molecules are known as "ortho" and when antiparallel they are called "para". Scientists would like to know more about how the two isomers differ physically and how they convert from one form to another. To do this, you must first separate the two isomers – something that has proven very difficult.

The latest attempt, carried out by Gil Alexandrowicz and colleagues at the Israel Institute of Technology in Haifa, instead uses the principle exploited by Otto Stern and Walter Gerlach in their pioneering experiment of 1921. Stern and Gerlach were able to separate a beam of silver atoms into two groups, according to what would come to be understood as the atoms' spin, or intrinsic angular momentum. To do this they passed the beam through a magnetic field whose strength varied along an axis perpendicular to the beam – being stronger on one side of the beam than the other – meaning that the atoms were forced to one side or the other depending on whether they were spin up or spin down.

This latest experiment is a little more sophisticated, because the spin states of water molecules are slightly more complex than those of silver atoms. The spins of the two hydrogen atoms in each nucleus can combine in four different ways, leading to an ortho "triplet" with total spin 1 and a para "singlet" with total spin 0. To distinguish between these different states, the Israeli group sent a beam of water molecules through a "hexapole" magnetic field, whose gradient, instead of becoming gradually stronger across the beam, goes to zero in the middle of the beam and increases linearly with radius. This arrangement works like a lens, focusing molecules with a total spin of 1 and a "spin projection" of 1 to a point a finite distance from the magnet while leaving the others (those with either a total spin of 1 and a spin projection of 0 or –1 or a total spin of 0) to follow diverging paths.

According to Alexandrowicz, this filtering of water molecules according to their spin could make NMR much more sensitive. Making measurements of a water sample in which almost all of the nuclear spins lie in the same direction would result in a far stronger signal. This, says Alexandrowicz, could expand the use of NMR, allowing it, for example, to be used in surface science – currently, only bulk water contains enough molecules to generate a measurable signal.

Strain and spin could drive ultralow energy computers

http://physicsworld.com/cws/article/news/44910

Tiny layered magnets could be used as the basic processing units in highly energy-efficient computers. So say researchers in the US who have shown that the magnetisation of these nanometre-sized magnets can be switched using extremely small voltages that induce mechanical strain in a layer of the material. The resulting mechanical deformations affect the behaviour of electron spins, allowing the materials to be used in spintronics devices, which are electronic circuits that exploit the spin of the electron as well as its charge. Hybrid spintronics/straintronics processors made from such magnets would require very little energy and therefore could work battery-free by harvesting energy from their environment. As a result they could find a host of unique applications, including implantable medical devices and autonomous sensors.

Kuntal Roy and colleagues at the Virginia Commonwealth University claim that they can switch the magnetization of their nanomagnet-based devices with less than 0.4 attojoules of energy, a figure that is four orders of magnitude smaller than that for conventional transistors. "The energy requirement is so low that processors built with this technology could run by harvesting energy from their environment without needing a battery," said Roy.

Roy's team designed a basic computer processing unit from a multiferroic nanomagnet consisting of a piezoelectric layer and a magnetostrictive layer in contact with each other. Magnetostrictive materials change shape when magnetized. When a voltage (around 10 mV) is applied to the piezoelectric layer, it generates a mechanical strain in the material. This strain is then transferred to the magnetostrictive layer, in which it causes stress, so flipping its magnetisation.

Holographic video comes up to speed

http://physicsworld.com/cws/article/news/44885

Researchers at Massachusetts Institute of Technology (MIT) have demonstrated the highest frame rate yet for a dynamic hologram that can recreate evolving 3D scenes. The breakthrough means that holographic television is now tantalizingly close to industry frame rates at a time when 3D cinema is fully back in vogue.

In November, a group of researchers based at the University of Arizona and Nitto Denko Technical Corporation in California made the headlines when they unveiled the world's first "telepresence" system capable of reproducing a changing 3D scene every 2 seconds. The system worked by surrounding an object with 16 cameras and writing these images into a polymer-based screen, which can project when illuminated with LEDs.

Now, a group at MIT's Media Lab under the leadership of Michael Bove Jr has raised the bar once again by creating a system that can reproduce a 3D scene 15 times every second. And the MIT system uses a novel design that requires only one camera – a commercially available range-finding camera that can record both the luminance and depth of a scene.

Bove's team takes this footage and sends it via the internet to a PC that has been fitted with three graphics processing units. The units have been programmed with an algorithm that can compute the diffraction patterns needed to reproduce the moving 3D images. These patterns are then recreated on a projection screen using arrays of components known as "wafels", which can control the intensity of light emitted in all directions.

Bove is confident that his team can boost the frame rate even higher to the 24 frames per second of feature films or the 30 frames per second of television. He believes that, within the next few years, his group's method of creating dynamic holograms could become available commercially at the scale of standard laptop screens. The group is looking to develop alternative versions of the diffraction screen at lower costs, and is seeking to design a laptop-scale screen that retails at around $200. More difficult, however, will be scaling up the devices to the size of cinema screens, because it is difficult to generate complicated diffraction patterns on larger scales.

Carbon nanotubes spin a yarn

http://physicsworld.com/cws/article/news/44732
http://www.sciencemag.org/content/331/6013/51.full

Researchers in US are the first to produce electrically conducting yarns from webs of carbon nanotubes and various powders and nanofibres. The yarns, made by a technique called biscrolling, are very strong and can be woven, sewn, knitted and braided into a variety of structures. They could find applications in energy storage and harvesting,

structural composites, photocatalysis and intelligent textiles.
Current methods to transform powders with useful properties into yarns involve using polymer binders to fix the powders in place, a technique that has significant problems. Now, Ray Baughman and colleagues at the Nanotech Institute at University of Texas in Dallas have developed a new approach that exploits carbon nanotube (CNT) sheets, or webs, instead of polymers to transform nano- or micron-sized powders into electrically conducting, sturdy yarns.
CNT sheets are ideal for making such yarns; its sheets are nearly as light as air (they have a density of around just 1.5 mg/cm3) but are stronger than steel, with a specific strength that can reach 560 MPa cm3/g when densified. The yarns can also happily be washed in an ordinary washing machine without suffering any measurable damage.
The biscrolled yarns can be made from a variety of powders that can be chosen according to the final application. For example, Baughman and colleagues made superconducting yarn by biscrolling a mixture of magnesium and boron powders (up to 99 wt.%) as the guest on CNT sheets, and then thermally annealing the biscrolled yarn. The technique has the added bonus in that it avoids the 30 or more drawing steps needed in conventional powder-in-tube methods to produce millimetre-sized, iron-clad, superconducting wires from a magnesium/boron/CNT precursor.
The team also made biscrolled yarns containing up to 98 wt% graphene oxide nanoribbons that were then converted to graphene nanoribbon yarn by reducing the graphene oxide. These yarns could be used to make weavable anodes for flexible lithium-ion batteries, says Baughman. The researchers showed that they could make electrodes for lithium-ion batteries using $LiFePO_4$ (an environmentally friendly, inexpensive, high-performance lithium-ion battery cathode) as the guest powder.
The batteries perform well, with a high gravimetric electrical conductivity of 8 S cm^2/g, are flexible and mechanically robust. These properties mean that they could be used in applications like energy storage and energy-generating clothing – so-called intelligent textiles.
And if that wasn't enough, Baughman and co-workers also fabricated highly catalytic fuel cell cathodes by biscrolling nitrogen-doped carbon nanotube guests. These devices are promising for future applications because they do not contain any of the expensive platinum found in conventional fuel cells.

Thunder storm radiation surprises

http://physicsworld.com/cws/article/news/44722

The radiation produced during a lightning storm is more energetic and potentially threatening to aircraft than previously thought, claim researchers in Italy. Studying this radiation in closer detail could help scientists to probe some of the big unanswered questions in the study of thunder storms, such as how lightning is triggered in clouds.
Scientists have known for a long time that the large electric fields and currents produced during thunder storms can also generate X-rays and gamma rays in the vicinity of clouds (see also X-ray vision tracks lightning bursts, http://physicsworld.com/cws/article/news/44595). But in the early 1990s a rare type of lightning event was discovered that can produce extremely bright, energetic gamma rays – known as terrestrial gamma ray flashes. So far, however, it has been difficult to determine specific details about this phenomenon such where the radiation originates from and its energy range.
Now researchers involved with the Italian Space Agency's AGILE mission have been able to home in on terrestrial gamma ray flashes. Launched in 2007, this satellite is dedicated to observing gamma rays originating from terrestrial and cosmic sources. Its silicon-based gamma ray detector has recently been fitted with new software that enables the satellite to take snapshots of the radiation at sub-millisecond time intervals.
The AGILE team led by Marco Tavani gathered data collected from 130 terrestrial gamma ray flash events occurring in the past two and a half years. Reporting its findings in Physical Review Letters (**106**, 018501 (2011)), Tavini's team noted radiation emerging in all directions from the upper atmosphere, covering a wide range of energies. In some cases gamma rays were up to 100 MeV – more than twice as energetic as previous measurements.
While the specific details of lightning initiation are not yet known, scientists do know that it requires large potential differences to be established within thunderclouds. This can transform the clouds into particle accelerators where electrons can be rapidly accelerated, producing an avalanche of particles as they liberate more electrons along the way. These "runaway electrons" are believed to be the source of gamma rays, and they may be involved in producing the initial spark for bolts of lightning.

3D magnetic domains imaged for the first time

http://physicsworld.com/cws/article/news/44707
http://www.nature.com/ncomms/journal/v1/n8/full/ncomms1125.html

Physicists in Europe are the first to obtain 3D images of magnetic domains – regions within a material in which all the magnetic moments point in the same direction. While 2D magnetic domains on surfaces can be imaged using several different techniques, 3D images have eluded scientists since such magnetic domains were first proposed over 100 years ago. As well as providing better insight into how domains form and evolve, the technique could also help to improve hard disks – which store data in magnetic domains.
While physicists have been able to study the effect of domains on the magnetic properties of materials, they had not been able to make 3D images of domains deep within the bulk of a material. Instead they had to settle on destructive techniques such as imaging domains near the surface of the sample and then shaving off a thin layer and repeating the measurement.
But now Ingo Manke and Nikolay Kardjilov of the Helmholtz Centre Berlin and colleagues in Germany, Switzerland and the UK have created the first 3D images using a new technique called Talbot-Lau neutron tomography. They did this by firing a coherent beam of low-energy neutrons at a sample of an iron-silicon alloy. A small number of the neutrons are deflected slightly when they cross a boundary between two domains. This deflection occurs because the index of refraction of the material changes abruptly at the boundary. A diffraction grating with a detector behind it is scanned across the beam of deflected neutrons to determine the angle of deflection.

This measurement is repeated many times as the sample is rotated through 360°. The data are then fed into a computer program developed by the team, which produces a 3D image of the domains. The images have a spatial resolution of about 35 μm, which Manke and Kardjilov say could be improved to about 1 μm by using a neutron detector with a better spatial resolution and a higher neutron flux.

More on self-assembly through molecular recognition

Structures up to centimetres long have been created by the self-assembly of gel particles that 'recognize' each other at the molecular level. Such molecular recognition has previously been used to self-assemble molecules at the microscopic scale.

Akira Harada of Osaka University in Japan and his colleagues prepared acrylamide-based 'host' gels bearing cyclodextrin rings, and other gels with smaller 'guest' hydrocarbons. The rings and the guest molecules bound to each other, allowing small pieces of gel to self-assemble in specific ways. See Nature Chemistry:

http://www.nature.com/nchem/journal/vaop/ncurrent/full/nchem.893.html

Rule Brittania

The Cavendish Laboratory, Cambridge University, 1932

by Peter Robertson

Photo: courtesy of Professor Woody Sullivan, University of Seattle. Text: Peter Robertson, School of Physics, University of Melbourne. My thanks to Professors Rod Home and Tony Klein for their comments.

Nine Nobel Laureates in one staff photo! The front row is (left to right): Jack Ratcliffe, Peter Kapitza (Nobel Prize physics 1978), James Chadwick (1935), Rudolf Ladenburg, J. J. Thomson (1906), Ernest Rutherford (chemistry 1908), Charles Wilson (1927), William Aston (chemistry 1922), Charles Ellis, Patrick Blackett (1948) and John Cockroft (1951). The photo was taken in the same year that Chadwick discovered the neutron.

There are four Australian postgraduate students in the photo. Joe Pawsey is in the back row in the sports blazer. After Cambridge, Joe helped to develop the first television system for the BBC. He returned to Australia, joined the CSIRO Radiophysics Lab and took part in the secret wartime development of radar. After the war Pawsey became the founding father of Australian radio astronomy. Each year the Australian Academy of Science awards the Pawsey Medal to a talented physicist under the age of 40.

In the second row (second from left) are Courtney Mohr, Harrie Massey and Mark Oliphant. At Oliphant's left is Ernest Walton, the ninth Nobel Laureate, but who was relegated to the second row for this photo. Walton shared the 1951 prize with Cockroft for their development of the first linear particle accelerator.

Pawsey, Mohr and Massey were graduates from the School of Physics, University of Melbourne, and Oliphant from the University of Adelaide.

Courtney Mohr became an expert on the theory of atomic collisions, as did his close friend Massey. After a period in South Africa, Mohr returned to Australia where he later became the inaugural professor of theoretical physics at the University of Melbourne. Unlike Mohr, Harrie Massey stayed in England and became a mover and shaker in the British science establishment. The Massey Medal is awarded jointly every two years by the British Institute of Physics and the Australian Institute of Physics.

Mark Oliphant had arguably the most illustrious career of the four Australians. He rose to become Rutherford's right-hand man, before moving to the University of Birmingham. In 1948 he returned to Australia where he was the inaugural director of the Research School of Physical Sciences at the Australian National University. Oliphant became one of the most powerful figures in Australian science. He ended his career as governor of South Australia.

Product News

Lastek

Lowest Profile 3-axis Nanopositioners from Mad City Lab

The Nano-LPQ is the lowest profile high speed XYZ nanopositioner available and offers 75 x 75 x 50µm travel with picometer position noise under closed loop control. The Nano-LPQ features equal millisecond response

times in XYZ, an integrated sample holder, analog and digital control with added scan synchronization features, and compatibility with major image and automation software. Designed to minimize the moving mass, lightweight sample holders are integrated into the stage and represent the only moving component. This unusual design allows the three axes of motion to have matched resonant frequencies and step response times. Equal 3-axis speed is particularly useful for applications like 3D particle tracking. The Nano-LPQ uses internal position sensors utilizing proprietary PicoQ™ technology to provide absolute, repeatable position measurement with sub-nanometer resolution under closed loop control. The Nano-LPQ is LabView™ and C++ compatible and is supplied with Mad City Labs' Nano-Route™3D software, for ease of use.

Features:

- Low profile, high speed, XYZ motion
- Built-in sample holders
- Equal speeds on all three axes
- Closed loop control

Typical Applications:

- Optical microscopy, easy to retrofit
- Optical trapping experiments
- Fluorescence imaging
- Particle tracking
- Single molecule spectroscopy

The Nano-LPS Series is the lowest profile 3 axis piezo nanopositioning systems suitable for applications such as super resolution (SR) microscopy and force microscopy. The Nano-LPS series continues the innovative design approach originally introduced by Mad City Labs. At only 20mm tall and an 83mm wide center aperture, the Nano-LPS series is designed for practical microscopy users interested in nanoscale phenomena. The Nano-LPS series features up to 300 microns of motion per axis and picometer precision under closed loop control. The low height of the Nano-LPS Series allows it to be easily integrated into existing inverted optical microscopes. Like the related Nano-LP Series, the Nano-LPS Series is ideal for demanding microscopy applications which require long range travel, fast scan rates, and three axes of motion.

Mad City Labs proprietary PicoQ™ sensors enable picometer position noise with ultra high stability, which is important for demanding applications such as SR microscopy techniques.

Features:

- Lowest profile 3-axis nanopositioner available
- Large aperture for standard 3" slides
- 100 µm, 200 µm, and 300 µm ranges of motion (XYZ). Closed loop control

Typical Applications:

- Optical microscopy, easy to retrofit
- Optical trapping experiments
- Fluorescence imaging
- Alignment
- Single molecule spectroscopy

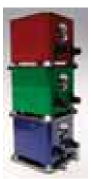
Ocean Optics acquires Sandhouse Design

Ocean Optics extended its product family after acquiring Sandhouse Design, LLC.

Sandhouse developed a unique line of high-powered LED light sources for research and spectroscopic applications.

These products have been widely used in biotechnology, process control and industrial applications.

LED Light Sources



These ergonomic and smartly designed fiber-coupled LED light sources are ideal for fluorescence, spectroscopy and general fiber illumination applications. The Ultra LED high-power light sources can be operated in continuous or external trigger

modes. Available in UV, VIS and Infrared.

SIR Scanning Spectrometers

The SIR Scanning Spectrometer Series from Ocean Optics provides you a range of fiber-based spectral data collection in a detection instrument that is built to last and always reliable.

These SIR Scanning Spectrometers feature USB 2.0-compliant interfaces that provide fast data transfers. Plus, the included software can be used to control all of your SIR spectrometer's functions as well as analyse data.

The SIR spectrometer family includes:

- SIR-1700: 400-1700 nm
- SIR-2600: 0.9-2.6 µm
- SIR-3400: 1-3.4 µm
- SIR-5000: 2-5 µm
- SIR-6500: 3.0-6.5 µm

Deep UV LEDs

Sandhouse Deep UV LEDs are available in a wide range of wavelengths and package sizes. These devices are manufactured using AIGaN/GaN technology, which enables a new generation of high band-gap energy opto-electronics devices, able to perform down to 240 nm.

Latest News from Toptica Photonics

Multi Color Systems - Multi Laser Engines and Tunable VISible Lasers

Three exciting new systems are now available from Toptica:

iChrome MLE-L: Multi Laser Engine with up to three diode lasers and one DPSS Laser fully integrated in one compact box.

- Multi-line laser with up to 4 laser lines
- Wavelengths diode lasers: 405 nm, 445 nm, 488 nm, 640 nm (375 nm, 473 nm, 660 nm, 785 nm and others on request)
- Wavelengths DPSS laser: 532 nm, 561 nm (505nm, 515nm, 594nm and others on request)

iChrome MLE-S: All-diode Multi Laser Engine with up to four diode lasers fully integrated in one compact box.

- Multi Line Laser with up to 4 diode laser lines
- Available wavelengths: 405 nm, 445 nm, 488 nm, 640 nm (375 nm, 473 nm, 660 nm, 785 nm and others on request)
- High free-space and fiber coupled output power levels

Common to both MLE models:

The individual lasers are efficiently combined and delivered free beam or via an all-in-one PM/SM fiber output. The microprocessor controlled system enables flexible OEM integration. High speed analogue and digital modulations allow fast switching of laser wavelength and intensity. TOPTICA's ingenious COOL^{AC} technology automatically aligns the system with a single push of a button. This feature ensures a constant optical output level even under strongly varying ambient conditions and completely eliminates the need for manual realignment - making the iChrome MLE the most advanced multi-line laser system on the market.

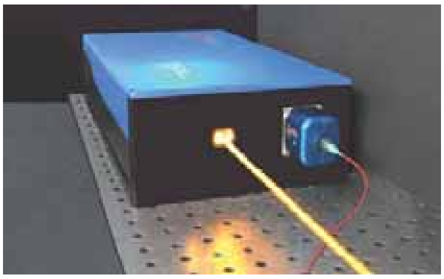
- Single mode, polarization maintaining fiber output or free beam COOL^{AC} technology for highest coupling efficiency, ultimate stability and drop-shipment capability
- Direct modulation and fast switching between wavelengths
- True one-box solution with integrated electronics
- Unique features: COOL^{AC}, FINE and SKILL technology
- Most compact and cost effective solution for multicolor biophotonic applications

iChrome TVIS: Ultrachrome Picosecond Laser - continuously tunable in the visible: 488 nm – 640 nm

- Continuously tunable in the visible range (488 - 640 nm)
- Fiber coupled output (single-mode)
- Fully automated operation
- Pure color, narrow emission bandwidth (< 3 nm)
- Perfectly suited for fluorescence lifetime imaging microscopy (FLIM) or optical testing of components

The iChrome TVIS laser system 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. The coherent laser output ensures that the visible light exhibits the best intensity noise performance and the use of polarization maintaining optical components a stable linear polarization of the fiber coupled output beam is achieved. The entire laser system is extremely user friendly: No alignment procedures of any optical components distract the user from the main task – to produce results.

DL-RFA-SHG pro @ 589nm 2 Watt, single line for sodium cooling



The new DL RFA SHG pro is a narrow band, tunable continuous wave laser for Sodium cooling.

The system is based on a near-IR diode laser in the successful "pro design" (DL 100 / pro design, 1178nm), with a subsequent Raman fiber amplifier (RFA) and a resonant frequency doubling stage (SHG pro).

The DL RFA SHG pro features a spectral linewidth below 1 MHz and 20 GHz modehop free tuning. For system operation, no water cooling and no external pump is required. The power scalable approach of the DL RFA SHG pro also offers solutions for other high power applications such as sodium LIDAR, medical therapy or super resolution microscopy. Customized systems with higher output powers up to 10 W are available on request. Wavelengths between 560 and 620 nm will soon be available as customized solutions.

FemtoFiber pro – the product family gets expanded

After the successful introduction of the FemtoFiber pro IR, NIR and SCIR models, TOPTICA is now doing the final step to also

include the remaining system variants such as tunable visible (TVIS), tunable near-infrared (TNIR) and tunable ultra compressed pulse (UCP). Options like variable repetition rate (VAR) and a phase-locked loop Laser Repetition rate Control (LRC) by TOPTICA's well-established PLL-electronics are rounding up the FemtoFiber pro product family.

The first and fastest of the new models, UCP, shows shortest pulses in the range down to 13 fs, the fastest one can get on the market from a turnkey SAM modelocked fiber laser system.

The TVIS expands the supercontinuum generation (SCIR) by a tunable second harmonic generation and allows transferring femtosecond pulse generation into the visible wavelength range from 490 to 700 nm.

The TNIR variant finally adds a new feature to the FemtoFiber pro family. Opposite to the TVIS, it uses the high band continuum (>1560nm) for second harmonic generation. This continuum part is a solitonic pulse and therefore needs no pulse compression. The output wavelength can be tuned from 800 to 1100 nm. This variant was not available in the FFS product family.

For synchronization purposes, the FemtoFiber pro options VAR and LRC are established. With a more than 200 kHz wide repetition rate modulation it allows to electronically synchronize two laser systems with lowest residual RMS jitter.

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

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web: www.lastek.com.au

Lightweight Benchtop Vibration Isolation

Warsash Scientific is pleased to announce a new lightweight benchtop vibration isolation system from Kinetic Systems, Inc. Specifically designed for portability, the ELpF can be easily repositioned on the benchtop, even with a load and in float. Its unique, self-contained design provides this without causing damage to the vibration isolators.

An economical alternative to heavyweight models, the Ergonomic Low-Profile-Format platform provides vibration isolation for sensitive devices. It features a load capacity of 100 or 300 lbs. in a lightweight, ergonomic system.

The platform has a low profile (only 3" high), uses a small tabletop (16" x 19" standard), and weighs 40 lbs., making it very portable. Ergonomic features include gauges tilted upward for easier viewing and recessed handles for easy carrying.

Designed for use in laboratories and Class 100 cleanrooms, the ELpF platform is ideal for supporting atomic force microscopes, microhardness testers, analytical balances, profilometers, and audio equipment.

Self-leveling and active-air isolation give the platform low natural frequencies (1.75 Hz vertical, 2.0 Hz horizontal) and typical isolation efficiencies of 95% (vertical) and 92% (horizontal) at 10 Hz.

Other tabletop sizes can be customized per specifications. The top, which can be ordered with or without mounting holes, can be aluminum plate, ferromagnetic stainless steel, plastic laminate, or anti-static laminate.

For more details on this or other vibration isolation equipment, contact sales@warsash.com.au

Real-Time Operating System for Systems Integration

Real-Time Operating System for Systems Integration by Physik Instrumente

PI (Physik Instrumente), the leading manufacturer of piezoceramic drives and positioning systems, offers a real-time module as an upgrade option for the host PC and also the connection of the GCS (PI General Command Set) software drivers. The module is based on Knoppix-Linux in conjunction with a pre-configured Linux real-time extension (RTAI).

The use of real-time operating systems on the host PC allows it to communicate with other system components, *e.g.* a vision system, without time delays with discrete temporal behavior and high system clock rate.
A library which is 100% compatible with all other PI GCS libraries is used for the communication with the real-time system. All PI GCS host software available for Linux can be run on this system.

The real-time system running in the real-time kernel can be used to integrate PI interfaces and additional data acquisition boards for control. Open functions to enable you to implement your own control algorithms are provided. Data, such as positions and voltages, is recorded in real time, and pre-defined tables, with positions, for example, are output in real time to the PI interface and to additional data acquisition boards.

You can program your own real-time functions in C/C++, MATLAB/SIMULINK and SCILAB.

The system includes a PI GCS server, which allows the system to be operated as a blackbox using TCP/IP, via a Windows computer, for example.

The system can be installed on a PC or booted directly as a live version from the data carrier. A free demo version with restricted functionality is available.

For more information on the real time operating software or other PI positioning equipment, contact sales@warsash.com.au

E-618: 3.2 kW Peak Power for New Piezo Amplifier

Available from Warsash Scientific is the new

PI (Physik Instrumente) E-618 high power amplifier for ultra-high dynamics operation of PICMA® piezo actuators.
The amplifier can output and sink a peak current of 20A in the voltage range between -30 and +130V. The high bandwidth of over 15kHz makes it possible to exploit the dynamics of the PICMA® actuators. This type of performance is required in active vibration cancellation and fast valve actuation applications.
The E-618 also comes with a temperature sensor input to shut down the amplifier if the maximum allowed temperature of the piezo ceramics has been exceeded. This is a valuable safety feature given the extremely high power output.

The E-618 is available in several open-loop and closed-loop versions with analogue and digital interfaces. For more information on these and the range of other PI products, contact sales@warsash.com.au

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New Sensors Improve Precision of S-340 Tip/Tilt Mirror

New Sensors Improve Precision of S-340 Tip/Tilt Mirror

Warsash Scientific is pleased to announce the release of the new S-340 piezo tip/tilt mirror platform from PI (Physik Instrumente),

equipped with new high-resolution strain gauge sensors. The S-340 now achieves a resolution of 20nrad at angles of 2mrad about both orthogonal axes. This large mirror platform is used for optics with diameters of up to 100 mm (4 inches) and achieves a resonant frequency of 900Hz for a mirror of 50 mm diameter.

The S-340 can be operated by the new, low-cost E-616 controller. Together, they form a compact, high-performance solution for beam control and image stabilization as employed in astronomy, laser machining or optical metrology, for example.

For more information on the S-340 Tip/Tilt Mirror platform or other Positioning equipment from PI, contact

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Coherent

Princeton Instruments

PI-MAX3 Intensified CCD Cameras

Princeton Instruments' PI-MAX series of intensified CCD cameras has set the standard for time-resolved imaging and spectroscopy for almost a decade. Now Princeton's PI-MAX3 takes ICCD performance to a new level with order of magnitude speed improvements and a host of new features to allow easier and more accurate time-resolved imaging.

PI-MAX3 is available in formats of 1024 x 1024 pixels for imaging and 1024 x 256 pixels for spectroscopy. Video frame rates can be achieved in the imaging format and spectral rates of thousands of spectra per second can be achieved. Most importantly, the camera allows sustained gating rates up to 1MHz, a 20-fold improvement over previous designs.

The camera includes the improved SuperSynchro timing generator, SyncMaster clock output, a compact "one-box" design, convenient GigE interface and much, much more. For further information please contact Paul Wardill on sales@coherent.com.au
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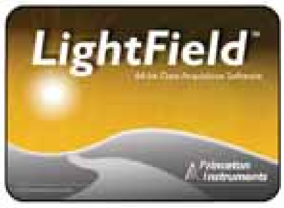

Princeton Instruments

Light-Field 64-bit Acquisition Software

From the world leaders in optical spectroscopy and CCD/EMCCD/ICCD technology comes LightFieldTM, an all-new 64-bit data acquisition platform for spectroscopy and imaging. LightFieldTM combines complete control over Princeton Instruments' cameras and spectrometers with easy-to-use tools for experimental setup, data acquisition and post-processing.

LightfieldTM ensures data integrity via automatic saving to disc, time stamping and retention of both raw and corrected data with full experimental details saved in each file. LightFieldTM works seamlessly in multi-user facilities, remembering each user's hardware and software configurations and tailoring options and features accordingly. The optional, patent-pending IntelliCal package is the highest-performance wavelength calibration software available, providing up to 10X greater accuracy across the entire focal plane than competing routines.

Features include:

- Immediate data acquisition upon launch
- Progressive disclosure - contextual menus ensure that only relevant options appear
- Graphical hardware configuration builder ensures that system elements work exactly as the end user expects
- Dark gray GUI reduces monitor brightness; monitor dims automatically during acquisition
- All experimental parameters are saved to data file headers - no more searching old notebooks for data acquisition settings
- Automatic light saturation warning with pseudocolour
- Multiple regions of interest can be defined in a single window
- Save and reload experimental settings and share between multiple users
- Configurable setting dock holds preferred commands
- Control multiple cameras via multiple instances of LightField
- Drag-n-drop data into Excel, Paint and Notebook or export to TIFF, FITS, CSV etc.
- Peak find function works with both narrow and broad lines
- IntelliCal provides up to 10X improved accuracy

Princeton Instruments

eXcelon...CCD and EMCCD sensitivity redefined

Princeton Instruments and Photometrics are pleased to announce the launch of new eXcelon back-illiminated charge-coupled device (CCD) and electron-multiplication CCD (EMCCD) detector technology that will revolutionise scientific imaging and spectroscopy.
New eXelon sensors provide excellent photon-detection capabilities across a wide spectrum, from 200nm to 1100nm, and are particularly beneficial for applications requiring enhanced sensitivity in the blue and near-infrared (NIR) region, as illustrated below. In addition, eXcelon back-illuminated sensors significantly reduce etaloning (the problematic appearance of fringes).
When eXelcon technology is applied to EMCCD devices, the result is a detector with sub-electron read noise, superb sensitivty, low dark current, little (if any) etaloning and high frame rates.
New eXcelon technology will be featured in Princeton Instruments' PIXIS and ProEM deep-cooled cameras and is available in several pixel-array formats:
1340 x 100 and 1340 x 400 CCD cameras for spectroscopy
512 x 512 and 2048 x 2048 for imaging
The technology is also available in 512 x 512 and 1024 x 1024 ProEM EMCCD cameras.
These new eXcelon-enabled cameras will target a wide variety of applications in both the life and physical sciences. Examples include astronomy, Raman spectroscopy, live-cell imaging confocal imaging, Total Internal Reflection Fluorescence Microscopy (TIRFM), Forster Resonance Energy Transfer (FRET), Bose-Einstein Condensate (BEC) imaging, solar cell inspection, as well as super resolution techniques such as STORM and PALM.

For further information please contact Paul Wardill on sales@coherent.com.au
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Conferences

February 1 - 4, 2011
35th Annual Condensed Matter and Materials Meeting
Charles Sturt University, Wagga Wagga

February 6-11, 2011
2011 Schools, Advanced Workshops, Conference, and Exhibition
AXAA 2011 - Australian X-ray Analytical Association
Darling Harbour, Sydney

March 1 - 3, 2011
Astronomy with Radioactivities VII
Phillip Island, Victoria

March 20-25, 2011
12th Int. Conference on Accelerator Mass Spectrometry (AMS-12)
Te Papa, Wellington, New Zealand

April 4 - 8, 2011
Greenhouse 2011
Cairns Convention Centre, Queensland
http://www.greenhouse2011.com

April 5 - 8, 2011
4th IUPAP International Conference on Women in Physics (ICWIP 2011)
Western Cape, South Africa

April 10 - 15, 2011
34th International Symposium on Remote Sensing of Environment
Sydney Convention and Exhibition Centre

April 11 - 16, 2011
1st GEANT4 Australian School and User Workshop
University of Wollongong, NSW

May 29 - June 3, 2011
4th Int. Conference on Chaotic Modeling, Simulation and Applications
Agios Nikolaos, Crete, Greece

June 6 - July 8, 2011
XXV International Union of Geodesy and Geophysics (IUGG)
General Assembly: Earth on the Edge
Melbourne Convention & Exhibition Centre, Victoria
Register your expression of interest on the website to receive updates

June 28 - July 1, 2011
IUGG Earth on the Edge: Science for a Sustainable Planet
Melbourne, Victoria
http://www.iugg2011.com

July 1 - 3, 2011
Astronomical Society of Australia's Harley Wood Winter School
Adare House, Victor Harbor, SA

July 4 - 8, 2011
Astronomical Society of Australia's Annual Science Meeting
University of Adelaide, Adelaide, SA

July 19 - 22, 2011
15th Int. Conference for Women Engineers and Scientists (ICWES15)
Adelaide Convention Centre, SA

August 22 - 31, 2011
XXII General Assembly and Congress of the
International Union of Crystallography (IUCr)
Madrid, Spain

August 13 -20, 2011
URSI General Assembly and Scientific Symposium of
International Union of Radio Science
Istanbul, Turkey

August 28 - September 1, 2011
IQEC/CLEO Pacific Rim 2011
Sydney, NSW

September 7 - 9, 2011
Deadline for abstracts is 30 April 2011; early bird registration before 30 June
Int. Conference on Nanoscience & Technology (ChinaNANO 2011)
Beijing, China

February 25, 2012
2012 Queensland Astronomy Education Conference (QAEC)