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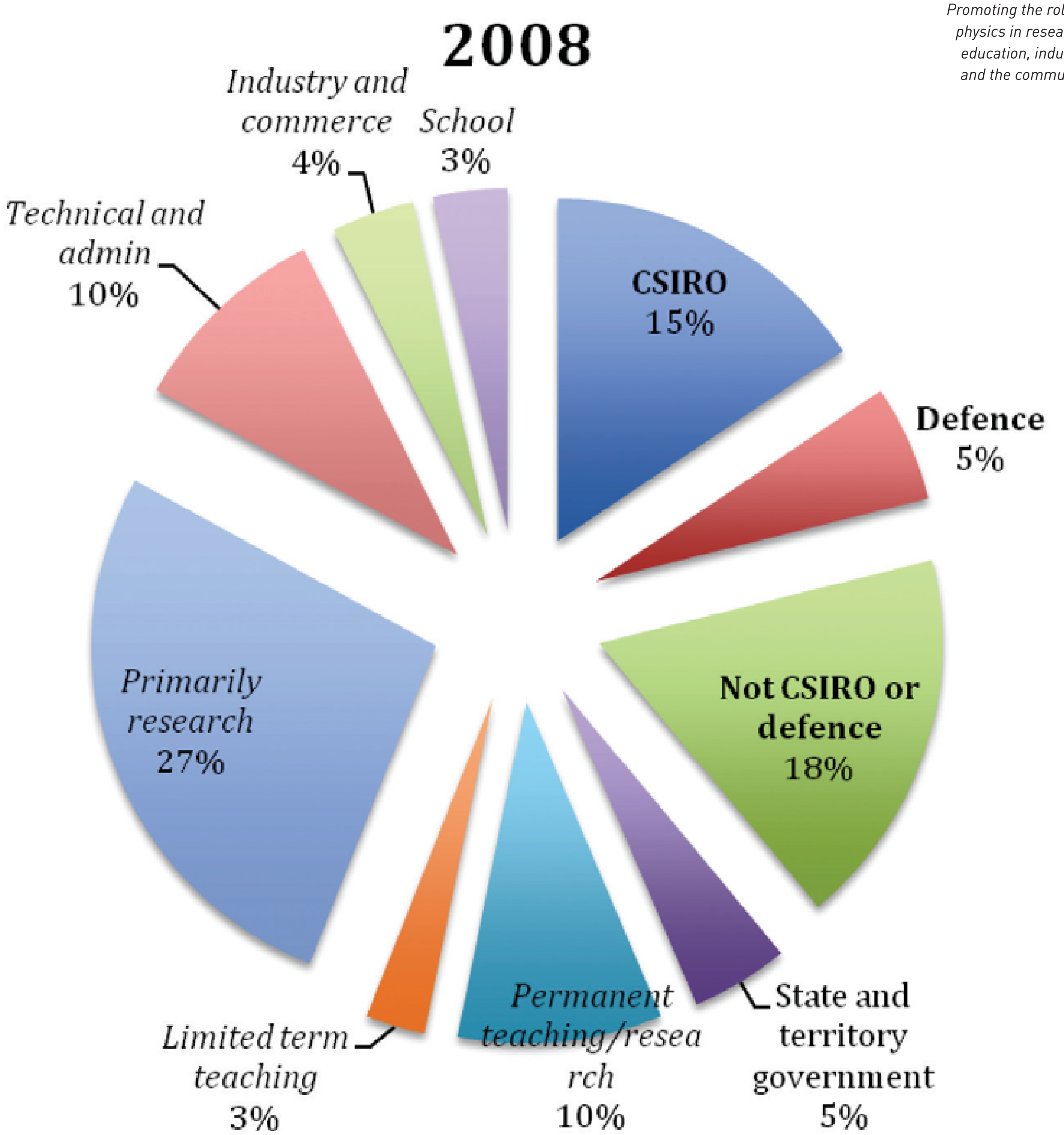
Promoting the role of physics in research, education, industry and the community



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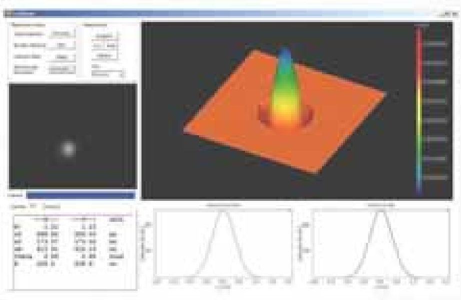

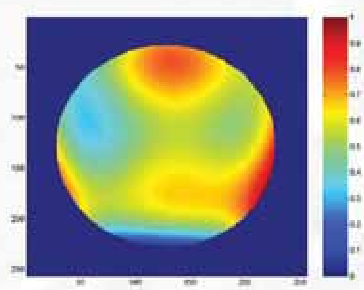

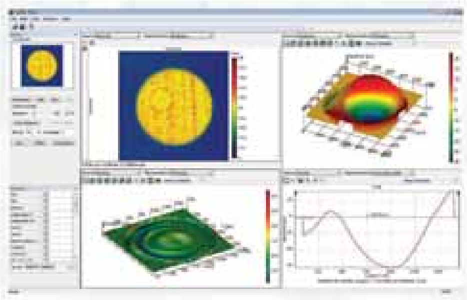

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Australian Physics
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Volume 46 Number 5

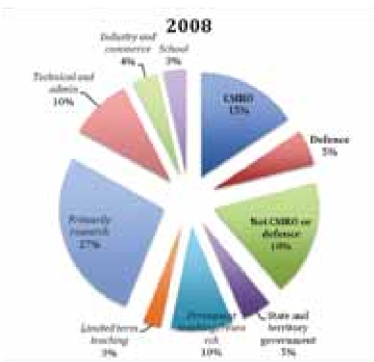
Features

Regulars

Write an article for Australian Physics

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

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



Cover Image

Who's hiring physicists? The chart shows the break down of where physicists were going in 2008. Similar data from 2003, and an analysis of what it all means is detailed by John Prescott who, for 25 years, kept an eye on employment prospects for physicists. The full story on page 146. Image credit: John Prescott

Submission deadline for the January/February 2010 issue is 20 December

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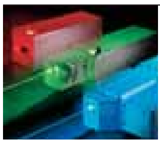

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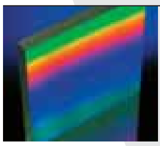

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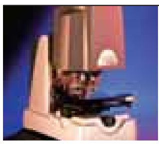

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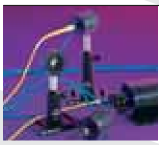

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Articles for submission to Australian Physics should be sent in electronic format. Word or rich text format are preferred. Images should not be embedded in the document, but should be sent as high resolution attachments in eps, tiff or jpg. Authors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

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Editorial

I am not surprised when teachers complain about the drive to add more content to a syllabus, in fact I am quite sympathetic to their grievance since more factual content tends to crowd out the equally necessary time that should be spent on conceptual content like problem solving and experimental skills; however, when it comes to ancillary content like the history and application of physics, or the employment prospects of physicists, I have little tolerance for griping over the addition of this material into the curriculum.

In our efforts to itemize all that should be taught in a physics class, the educational community, teachers and bureaucrats together, often confuse the process of itemizing the essential information with the compulsion to compartmentalize that information into the syllabus. Obviously, when developing a syllabus, topics such as mechanics, optics or acoustics need to be addressed piece by piece with a keen eye to covering all that is fundamental to the syllabus. From that itemized list a teacher can devise a set of course of study that weaves all of the essential information into lesson plans. A period on Newton's 1st Law, two on the Lens Equation, whatever is required.

Unfortunately, when teachers hear that ancillary content such as the application, history, or career aspects of physics have been added, they tend to confound teaching this supplementary material by adding in a period (or project) on Newton's life, one on how physics applies to a specific job, another on car safety, etc… The usual refrain from teachers is: "*That extra content takes time out of teaching the rest of the material. I can't fit it all in. Tell me what material you want me to remove.*"

And therein lies my issue with compartmentalizing content; this ancillary content should be taught through the narrative of teaching… while teaching the content, not in place of the content. It is the story, the life, and the depth behind the content.

To complement this narrative is the abundance of resources available. Every textbook has elements of each scattered throughout – it should take little effort for any teacher to find something to add into the conversation that is teaching as an aside, something to bide a student's time while digesting a new equation or theory. In an ideal system, every teacher should have these ancillary features imbedded in their psyche.

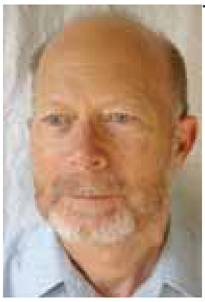
If you are in need of specific examples, then consider five of the articles in this issue of Australian Physics. Dr. Richard Walding looks at both the application, and history, of physics behind the efforts of William Bragg and Alexander Crichton Mitchell's antisubmarine detection loop considered towards the end of WWI (page 140). More instances of the application of physics, are covered in articles by Dr. Jim Lovell (AuScope, page 136) and Prof Hans Bachor (New Inventors, page 139). AuScope is a project that strives to further improve modern navigation systems using celestial observations; while Prof Bachor details how the Quantum Imaging team at ACQAO was invited by the ABC's New Inventor's show to explain their success in multimode entanglement – not your typical New Inventors category.

As for employment prospects read John Prescott's recent survey results of who was hiring physicists in 2008 and who might be doing so right now (Jobs 2009: Who Wants Physicists? page 146) and finally, but first up to bat in the issue, is the grand news of Dr. Tamara Davis winning this year's L'Oréal Women in Science Award for her contribution to astrophysics (page 133).

Students need to see and hear our passion for physics in each and every lesson. To be fair, passion does not necessarily equate with exuberance; however, our students need to know that we eat, sleep, and breathe physics and that maybe, just maybe, there's a reason to listen to the narrative behind physics, and not just the content.

John Daicopoulos

President's column
Climate change: the public debate



Climate change, its causes and consequences have not been far from public attention in recent years. This is particularly true at the moment with the approach of the UN Climate Change Conference in Copenhagen in December, and while various legislatures, including in Australia, consider introduction of emission reduction programs.

Although there are many excellent articles in the popular media, attention often concentrates on an apparent conflict between those who believe that human activity is the ultimate driver of our current rapid climate change and those who do not. Unfortunately this tends to give the impression that just because there are two views they are of equal standing. Evidence, however, must be the arbiter, and it is not surprising therefore that there is a broad scientific consensus that the present rapid climate change is predominantly due to human activity. Physicists, owing to their good understanding of relevant issues, are, in general, part of this broad scientific consensus.

Articles in the popular media purporting to dismiss the idea of human influence on climate change often latch on to simplistic ideas: climate is always changing so why should we be concerned, measurements of one parameter are seemingly inconsistent with model predictions, so the model must be wrong in its general predictions. Others, confusing short turn fluctuations, with long-term trends by judicious choice of a reference year claim that the world has been cooling in recent times.

The popular debate about climate change is often indicative of a poor understanding of the operation of scientific enquiry and in particular of the role modelling plays as a result of recent increases in computing power. Some take the fact that effects of human activity on climate are predicted by complicated models that attempt to take account of many phenomena and also achieve a degree of spatial resolution over the surface of the earth as reasons to dismiss the conclusions ("they are only computer models"). Such attitudes fail to appreciate that modelling is the only way we can predict the consequences of global changes in atmospheric composition.

Models have their problems, of course. Some mechanisms may be incorporated, initially, in an approximate way only. Some mechanisms are not well understood, maybe not even be identified yet. The use of models is, however, subject to the normal scientific practices: there is free debate, deficiencies are detected and over time inadequacies are addressed [1]. The view sometimes promulgated of a monolithic community with a single model, conspiring in order to maintain funding, is an ideologically driven point of view that cannot be supported by any evidence.

As the world focuses on achieving a global agreement about the introduction of carbon reduction schemes, the political difficulties become more apparent and alternatives gain more attention. An example is geoengineering, which has been the subject of a recently released report by the Royal Society [2}. There are two categories: carbon dioxide removal (reafforestation is only one example) and, more desperately, solar radiation management (e.g. simulating the effects of a large volcano by seeding the stratosphere with small particles).

The climate change debate provides an ideal example of progress in understanding due to science. It confirms that the only way to obtain a reliable understanding of climate change, and gain the knowledge needed to drive global action is through the scientific method. It also shows that science is not dogmatic, it is open to review; all that is required is evidence.

1. The content of successive reports by the Intergovernmental Panel on Climate Change are a good example: see *http://www.ipcc.ch*.

2. J.G. Shepherd, Geoengineering the climate: science, governance and uncertainty. The Royal Society (London, 2009)

Editor's Note: David Karoly reviewed Ian Plimer's book *Heaven and Earth* in the July/August 2009 issue of *Australian Physics*.

Branch News

Western Australia

The John De Laeter Youth Lecture was held at the Octagon Theatre at the University of Western Australia (UWA) on August 20 this year. The lecture is named in honour of Professor John De Laeter and is intended not only to recognise him for his eminent status but also for all his work towards the development of high quality science education in Western Australia.

A minor planet was been named after Professor De Laeter in recognition of his research in astrophysics and, in 1992, he was awarded the Officer of the Order of Australia (AO) for his contributions to science, education and industry. John has been given a Eureka Prize in 2005, a Clunies Ross Science and Technology Award in 2006, and was recently recognised by a Premier's Science Awards for his lifelong dedication to science in WA.

The title of the address this year was "Are We Alone?" and was delivered by Professor Charley Lineweaver who holds a joint appointment with the Australian National University's Planetary Science Institute and Research School of Earth Sciences. Charley obtained his PhD in astrophysics from the University of California at Berkeley, supervised by George Smoot (2006 Physics Nobel Prize for the discovery of temperature fluctuations in the cosmic microwave background radiation).

He has been published Science, Nature, the Astrophysical Journal, Astrobiology, Scientific American and the American Journal of Physics in his fields of cosmology, exo-planetology and astrobiology. The purpose of the talk was to tell us about the scientific evidence for life in the Universe as well as addressing questions about the probability of it being similar to us (functionally equivalent humans) and why no contact has been made.

The subject matter necessitated a remarkably wide ranging talk covering questions such as what is life and its origins on earth, the origin of the Universe and the solar system, whether intelligence is a guaranteed feature of evolution. The talk was introduced by the Pro-Vice Chancellor of UWA, Robyn Owens, and was attended by more than 320 school kids from across

Professor John de Laeter (left) with Jackie Davidson (right).
Image credit: Chris Perrella, UWA.

the metropolitan area of Perth. As one might have expected with such a provocative topic the audience were emotionally engaged and listened intently to Charley's every word. Charley demonstrated bravery in taking questions from the floor at any time in the lecture and he managed to field these with great aplomb.

As part of the talk Charley commented on some of the especially ancient rocks in Western Australia, research work in which John De Laeter had played a key role in his earlier career. Professor De Laeter attended the lecture and thanked Charley for his lecture - Professor De Laeter even got asked by one of the students the name of his minor planet. A measure of the intellectual stimulation was evident in the question session which continued on until we were all forced to leave the venue.

The WA Branch of the AIP would like to kindly thank Charley for putting on such a great lecture, which he performed after also giving two lectures in celebration of the International Year of Astronomy: one in Geraldton earlier in the week and a second public lecture at UWA the night before.

The branch would also like to sincerely thank UWA's SPICE: Secondary teachers enrichment program, in particular Jan Dook, whose excellent publicity ensured such a large turn-out of students.

Andre Luiten

Tasmania

In December 2008 the Branch again ran its annual Professional Development seminar for Physics teachers. The aim is to keep participants abreast of some recent developments in physics and related areas. The majority of attendees are primarily responsible for year 11 and 12 studies, but some teachers of earlier grades also came. The two-day event was held in the Grote Reber Museum, located at the University of Tasmania's Radio Telescope site at Cambridge, near Hobart Airport. Participants were given a tour of the radio telescope facilities as well as the features in the museum.

The format followed that used in previous years, six or seven talks on various current aspects of physics research and related topics. Talks tend to run for 45 minutes or so, followed by ample time for discussion. On this occasion topics covered included "The 2008 Nobel Prize - Broken Symmetry", "Grote Reber and Radio astronomy at the University of Tasmania", "Antarctic Communications", "IYA, The International Year of Astronomy", "Radiation safety in medicine, science and industry" and "Solar Events and Variability".

A similar event is planned for 2009, to be held in Launceston.

This year's Branch public lecture programme is based around the IYA. Several of the talks are scheduled for late in the year but Professor Geraint Lewis from the University of Sydney presented the first in the series on 2nd July. His topic "Is the Universe made for me? The anthropic principle in Astronomy" provided a good insight into the various physical conditions in the universe that are required in order that life, as we know it can exist.

Our second event, on 13th August, was the annual Women in Physics lecture. This year's speaker is Associate Professor Christine Charles from ANU. Her topic, "To planets or just to the shops, Plasmas pave the path", enabled her to give a good introduction to plasmas (with the working assumption that some of the general audience would not know what a plasma is) followed by wide ranging discussion of the present state of some plasma applications. During her visit Christine also gave five lectures at Year 12 Colleges around the State.

On a very cold and wet 29th August the Branch ran the 15th Schools Physics Quiz, at the Australian Antarctic

Division at Kingston, just south of Hobart. The quiz is designed primarily for year 12 students but some year 11's also compete. We had hoped to hold the event simultaneously in Launceston and Hobart but, sadly, there were insufficient entries from the north. In view of the IYA some of this year's questions were based around astronomy, mainly to do with the solar system. The event was won by a team from Hutchins, with teams from Elizabeth College and The Friends School in 2nd and 3rd places.
John Humble

Victoria

July and August have been busy months for the Victorian Branch. The July branch meeting was the annual laboratory tour which this year was a visit to Scienceworks to attend *Star Wars: Where science meets imagination*. The exhibition included authentic costumes and props from the *Star Wars* saga. To help encourage a family friendly event, members were invited to bring up to two children with the branch covering their entry fee. The branch received some excellent feedback from members who attended.

In August there were several events that the branch helped to promote. They included a talk by Dr Sandra McLaren entitled 'The Earth's Natural Reactor – Options for our Energy Future' at the Royal Society of Victoria (RSV). The Victorian Branch has developed a good collaboration with the RSV and hopes to expand on this in the future. Another event that the branch helped to promote was a lecture by the well-known Professor Lawrence Krauss from Arizona State University as part of National Science Week 2009.

The August branch meeting was the annual Women in Physics public lecture given by Dr **Christine Charles**, a Research Fellow in the Space Plasma, Power & Propulsion Group (SP3) at the Australian National University. Her talk 'To planets or just to the shops: Plasmas pave the path' began with an introduction to plasmas and went on to discuss the phenomenon of a current-free electric double layer. Her studies of this layer have led to her invention of a new space engine known as the Australian Helicon Double Layer Thruster.

Victorian branch chair, Nicoleta Dragomir, presenting Christine Charles (ANU) with a certificate of appreciation following the 2009 Women in Physics public lecture

This revolutionary new thruster will be developed for launch into space within the next four years, as part of a prototype satellite. It will be the first time in seven years that a piece of Australian hardware will be sent into space and the first time a satellite with a plasma engine will be tested. The European firm EADS-Astrium, the world's largest aerospace and aeronautic company, approached Christine and colleagues in the SP3 Group to work in collaboration with the Surrey Space Centre at the University of Surrey (UK) to develop the prototype thruster.

Christine's visit to Victoria included the presentation of a number of talks and the Branch is grateful for her efforts.
Scott Wade and Peter Robertson

NSW

The July meeting of the Branch was held at the University of Sydney and featured a public talk by Dr Zdenka Kunic. Zdenka is currently Senior Lecturer at the School of Physics, University of Sydney, and coordinator for the postgraduate industry training initiative in Medical Physics. Zdenka's research interests include space plasma physics, theoretical astrophysics and radiation physics.

Dr Kunic explained that astronomy and medicine share many similar demands for increasingly sophisticated and diverse imaging techniques as well as associated cutting-edge instrumentation technologies and advanced software tools for multi-dimensional data storage, manipulation and processing.

Dr Kunic started the talk by comparing imaging in medicine and astronomy. In Medicine a radiation source such as X-rays mostly pass through bones leaving a shadow on a photon sensitive film (detector). The resulting image will be studied and a course of therapy may be undertaken. In Astronomy a similar process occurs where energetic photons from a far away source such as a galaxy passes through a number of intervening mediums (such as dust and gas) to land on a another type of detector on earth where an analysis is done.

Dr Kunic then went on to link both astronomy and medicine in a historical context. It was once believed that body functions, and the contraction of diseases, were influenced by the sun, moon, planets and signs of the Zodiac.

Dr Kunic also talked about a number of other connections between astronomy and medicine such as using similar imaging techniques. Astronomy uses interferometry, direct photon detection and spectral imaging, with medicine using CT, magnetic resonance and ultrasound. There is also much common ground in data handling and analysis. Astronomy uses detection, vertification and interpretation of spectral data, with medicine using a similar detector and accelerator verification, with a calculation of absorbed dose.

Astronomy and medicine come closely together in space radiation dosimetry. Dr Kunic concluded by emphasizing

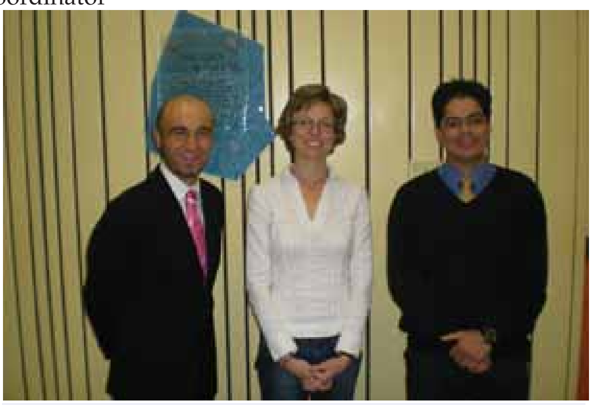


Photo: From left to right, Dr Fred Osman (AIP Branch Chair), Dr Zdenka Kunic and Dr Scott Martin (AIP Deputy Branch Chair).

the opportunities for knowledge and technology transfer across the two disciplines. This cross-disciplinary research initiative in Astronomy and Medicine is currently being established at the School of Physics, University of Sydney.

The August meeting of the NSW Branch was held at the University of Sydney and featured a public talk by Dr Tony Farmer. Dr Farmer is the Deputy Chief of Operations at the CSIRO. Tony's research interests include spectrophotometry/radiometry, gas discharges/plasma spectroscopy, sub-surface radar, sensing systems/intelligent networks and, most recently, high-power ultrasonic's which his talk was based on High-Power Ultrasonic's and its Applications.

Dr Farmer explained that a small sonochemistry group at the CSIRO Division of Materials Science and Engineering has been investigating the applications of ultrasound at high power levels. Ultrasound process technology is a unique method for the activation and acceleration of processes in chemistry, petrochemistry, and biotechnology. In chemical synthesis, ultrasound supports organometal intermediary products and promotes most types of catalytic processes.

Tony outlined some of the intriguing effects produced by high-density ultrasonic fields in liquids and gases and in particular in a wide range of applications for this technology covering areas as diverse as mining, energy, health and food. Pouring beer or soft drink slowly so it does not foam up over the top of your glass is something with which we are all familiar. Foaming overflow is a much bigger problem in commercial bottling plants. The idea of using sound waves to destroy bubbles is not new, but getting it to work is far from easy. The most difficult part is getting enough energy across the air gap between the source of the noise and into the foam. Tony explained that CSIRO is developing a compact unit to be mounted above bottles on the production line. As bottles are filled, they pass under this unit that generates pulses of high-power ultrasound. The sound is at the right frequency to destroy the bubbles and it has enough intensity to cross the air gap and get into the foam.
Dr Frederick Osman

Executive News

AIP Executive meetings so far this year have been held at Swinburne University (29 April), CSIRO Material Science and Engineering, Sydney (30 June) and DSTO Edinburgh (2 September), and there have been several telephone conference calls. It is our intention, within the constraint of keeping costs as low as possible, to vary meetings among states and institutions - in 2008 meetings were held at University of Melbourne, University of NSW, University of Queensland and university of Western Australia.

The Astronomical Society of Australia proposed a series of national lecturers to tour Australia during the International Year of Astronomy. It selected a number of presenters and topics for the lectures and agreed to cover the interstate airfares of the speakers. The AIP collaborated in the venture with AIP Branches selecting speakers for lectures in their region and with the AIP allocating central funds to cover the local costs. The lectures have been highly successful and well attended.

The Executive is seeking expressions of interest for a person to take over as Editor of Australian Physics when John Daicopoulos leaves next year. The Executive has been particularly appreciative of the high standard John has achieved during his period as Editor.

The AIP President continues to represent the physical science societies at the FAST Board. The Executive was particularly pleased to congratulate immediate past present Cathy Foley on her election as President-elect of FASTS. Cathy becomes President in November this year.

Issues at recent Executive meetings included:

• An award of $400 to the Solar Terrestrial and Space Physics group for a postgraduate student publication prize.

• A new national postgraduate travel support scheme to replace the schemes presently operated at branch level.

• A small rise in membership fees for 2010 and improvements to the online membership system and the AIP administration in general.

• The award of Medals for Outstanding Service to Physics to John O'Connor (University of Newcastle) and Hans Bachor (Australian National University).

• Redesign of the AIP website. This will include use of the URL www.physics.org,au, which has been allocated to the AIP, as a portal for Physics in Australia,

• Preparation of new membership material in order to undertake a membership drive before the end of 2009.

• Award of the 2009 AIP Honours Scholarship to Sophie Underwood, University Adelaide,

• Planning for a ceremony in conjunction with the ACT Branch and the ANU to present the Bragg Medal to Christian Rosberg and an Award for Outstanding Service to Physics to Hans Bachor.

• Discussion with AIP Congress organising committee co-chairs Andrew Peele and Ann Roberts about arrangements for the Congress to be held in Melbourne 6-10 December, 2010

• Consideration of applications for AIP to support by limited underwriting of the conferences STATPHYS 24, the XXIV International Conference on Statistical Physics (Cairns, 19-23 July, 2010) and the IQE /CLEO Pacific Rim Conference (Sydney, 28 August - 2 September 2011)

• Approval of accreditation reports on Physics courses at Macquarie University, Australian National University, University of Technology, Sydney, Flinders University, University of Tasmania, James Cook University and University of New South Wales.

• The first Asia-Europe Physics Summit, to be held in Tsukuba, Japan, 24-26 March 2010. For costs reasons the AIP did not send a representative to a preparatory meeting in Shanghai in July, but kept in touch via a telephone link.

L'Oréal Women in Science Award for 2009

An astrophysicist from The University of Queensland's School of Mathematics and Physics has been awarded the prestigious L'Oréal Women in Science Award for 2009. Dr Tamara Davis has been acknowledged for her contribution to astrophysics through her hunt for dark energy. Dr. Davis aims to continue the hunt using a new Australian telescope that has grown out of the ashes of the 2003 fire that destroyed Mt Stromlo Observatory.

Dr Davis hopes to use the Australian National University's new telescope "Skymapper" at the Mt Stromlo Observatory to track the movement of supernovae to understand dark energy.

"We know that stars, planets, galaxies and all that we can see makes up just four per cent of the Universe," Dr Davis said. "About 23 per cent is dark matter. The balance is thought to be dark energy, which we know very little about."

"Supernovae are extremely bright stellar explosions," Dr Davis said. "Because we know how bright they are we can use them as 'standard candles' to accurately measure distance and motion across the Universe."

The SkyMapper telescope offers some unique opportunities for mapping the Universe that makes her hunt even more exciting.

"SkyMapper takes images that are 25 times larger than the full moon. This allows us to scan the southern sky once every four days," Dr Davis said. Until recently, the best telescopes would take a year to cover the same area.

"Using Skymapper allows us to look at a much bigger region of the nearby Universe, rather than zeroing in on single objects or distant galaxies," she said.

Using the data generated over the next couple of years, Dr Davis hopes to detect invisible dark matter by observing the effects of its gravity on the motion of supernovae. However, for such an ambitious project, Dr Davis needs an all-star team of scientists, with expertise in various areas from observational analysis to theoretical physics.

She plans to use her $20,000 L'Oréal Australia For Women in Science Fellowship to help assemble an international team of scientists to work on this project. Dr. Davis is no stranger to working with leaders in the field including Nobel Laureate George Smoot, and Shaw & Gruber prize winners Brian Schmidt, Adam Riess and Saul Perlmutter.

A leader in her own right, Dr Davis has written numerous journal articles and reviews, including two in Nature, and two book chapters, that in total have over 1000 citations.

As a team member in the ESSENCE and SDSS supernova surveys, Dr Davis and colleagues have discovered over seven hundred supernovae. In 2007 Dr Davis led the ESSENCE collaboration in a paper that ruled out two of the leading alternative cosmological models, based on quantum theories of gravity. This became one of the top-ten most highly-cited astrophysics papers of that year and gained her the Astronomical Society of Australia's 2009 Louise Webster Prize.

Now with the Australian team WiggleZ making the largest ever three-dimensional map of the distribution of galaxies in the Universe, Dr Davis is well placed to test new cosmological theories that explain dark energy.

2009 Awards were also presented to Zenobia Jacobs, University of Wollongong and Marnie Blewitt, The Walter & Eliza Hall Institute of Medical Research, Melbourne.

For more information on L'Oréal Women in Science Awards, visit *http://www.scienceinpublic.com/loreal/*. This site also contains video footage of Dr Davis talking about her research and the award.


Photo credit: timothyburgess.net

Tamara Davis

Using Skymapper allows us to look at a much bigger region of the nearby Universe, rather than zeroing in on single objects or distant galaxies

News

ARC invites comment on peer review processes

Australian Research Council (ARC) Chief Executive Officer Professor Margaret Sheil released a consultation paper on the ARC peer review processes.

"Peer review underpins the management of the National Competitive Grants Program, enabling the delivery of quality funding outcomes that maintain researcher confidence," Professor Sheil said.

"It is therefore vital that ARC peer review processes are efficient and effective, and up-to-date with the changing research environment.

"I welcome your comments on the Consultation Paper, and will take them on-board to ensure that the revised processes instil confidence and allow the ARC to continue achieving its mission to deliver policy and programs that advance Australian research and innovation globally and benefit the community."

The ARC Peer Review Processes Consultation Paper includes a number of proposed changes to existing ARC peer review processes, including the:
- implementation of a revised assessor structure;
- introduction of new processes for assigning proposals to assessors, and;
- development of alternative mechanisms for ranking proposals.

"I look forward to reading your comments, which will help the ARC in its continued support of the Australian Government's investment in high-quality fundamental and applied research that produces benefits for all Australians."

To view the Consultation Paper visit: *www.arc.gov.au/general/peer_consultation.htm*.
ARC

Teaching Award

Congratulations to Associate Professor David Paganin, from the School of Physics, on winning a 2009 Australian Learning and Teaching Council (ALTC) Citation Award for outstanding contributions to student learning. Monash received four of these national awards this year.

As a sidelight, the Faculty of Science has so far attracted only one of these awards each year since their inception. The ALTC citation (value: $10,000) was presented to David at an awards ceremony at the National Gallery of Victoria International, Melbourne.

The citation reads: "For inspiring, enthusiastic and innovative research-led Physics teaching that equips the Physics students of today with the skills to thrive as working scientists of tomorrow."
Monash

Australians help to listen for the Big Bang

University of Adelaide researchers are among a large international team of physicists taking part in one of the most challenging scientific endeavours ever undertaken: the attempt to directly detect vibrations in space called gravitational waves.

The international team's latest research findings, published in the journal *Nature*, are considered to be a small but significant step forward in the quest to better understand the nature of the universe after the Big Bang.

Gravitational waves, which previously have only indirectly been shown to exist, are believed to be emitted whenever mass is accelerated.

Physicists expect these waves to provide a whole new method for observing and understanding the universe, including gathering information about the Big Bang.

Current detectors operate in the audio frequency range, which in simple terms means that scientists are trying to detect gravitational waves by "listening" to the universe.

"One of the goals of the team's research is the direct detection of black holes - to listen to their births and the 'ring-tones' produced by their vibrations," says Professor Jesper Munch, Chairman of the Australian Consortium for Gravitational Astronomy (ACIGA) and Professor of Experimental Physics at the University of Adelaide.

"Another goal is to listen to the birth of the universe itself, called the 'stochastic background', which should sound a bit like wind in the treetops."

ACIGA includes research groups at the University of Adelaide, ANU, Melbourne, Monash, UWA and Charles Sturt University. Researchers from these six Australian universities are working with a large international team from more than 70 universities in the United States, Europe, Australia and Asia, using the huge detectors of the Laser Interferometer Gravitational Observatory (LIGO) and the Italian-French VIRGO.

The detectors use powerful lasers, and mirrors suspended at the ends of multi-kilometre scale vacuum pipes, to sense the tiny vibrations of gravity waves. The LIGO observatories are located in Washington State and Louisiana in the US and VIRGO close to Pisa in Italy. In its Nature paper, the international team has announced its first significant observations relating to waves from the Big Bang.

LIGO staff installing a mode-matching mirror and suspension into a vacuum chamber during the construction of LIGO. Photo courtesy of LIGO and Caltech

"Although the team reports that the stochastic background has not yet been discovered, this result itself is significant, because it sets new limits on the strength of the waves we're trying to detect," says Dr David Ottaway, Lecturer in the University of Adelaide's School of Chemistry & Physics.

"The measurements taken so far rule out some possible theories for the early universe. This result will help the team to fine tune what we're looking for, which in turn will help us to pin down the details of the Big Bang in which the universe was born."

In trying to detect gravitational waves, the international team of physicists kept three ultra-sensitive detectors in operation for two years, from 2005 to 2007.

Australian physicists contributed to the design of the instruments and were among a number of teams who operated the supersensitive instruments around the clock to gather the data.

"The measurements obtained over the two years pave the way for new measurements with improved detectors over the next few years," says David Hosken, Research Associate in the Univ of Adelaide's School of Chemistry & Physics, who was involved in observation runs in Louisiana, and is among those currently working on high-power lasers for this purpose.

"The improved detectors are almost certain to be able to detect gravitational waves from colliding stars and black holes," he says.

Physicists from the University of Adelaide working on this project also include Associate Professor Peter Veitch. Together with physicists from ANU, they are in a partnership with LIGO and the international community to develop the next generation of detectors.

Some of the Australian team are also working on designs for the large-scale Australian International Gravitational Observatory, which is planned to be built in collaboration with the US, Germany, France and India.

http://www.nature.com/news/2009/090819/full/news.2009.844.html

University of Adelaide

Measuring the Australian Continent with AuScope

by Jim Lovell[1], Christopher Watson[2], and John Dickey[1]

For centuries, navigators used the stars to determine their location. This has been replaced by radio transmission of time signals from spacecraft, culminating in the 1990s with the US Global Positioning System (GPS) and similar Global Navigation Satellite Systems (GNSS). These systems offer much better positional accuracy than classical celestial navigation, with precisions of modern geodetic quality GPS time series at the sub-cm level. However, unknown to most users, these modern navigation systems still rely on astronomical observations for their fundamental reference frame, and hence their accuracy.

A worldwide array of radio telescopes coordinated by the International VLBI Service (IVS) are regularly observing the distant quasars that define an inertial celestial reference frame, which is in turn used to define the terrestrial reference frame. Consequently, in order to further improve coordinate quality from GNSS techniques, it is vital that the IVS continue to observe and improve observations made to astronomical sources in the sky.

The IVS network was established in the 1990's based on VLBI techniques of astrometry developed in the 1970's and 1980's. The system includes 27 radio telescopes operated by 14 nations, of which all but a handful are in the Northern Hemisphere1. The University of Tasmania (UTAS) 26m dish has been a regular participant in VLBI astrometry since the 1980's, and UTAS has been a member of the IVS since its inception, contributing 60 days per year to IVS observations.

Data from the telescopes is processed at correlation facilities in Germany, Russia, the US, and Japan, and interpretation of the results is done at Analysis Centres in 12 countries.

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[2]School of Geography and Environmental Studies, University of Tasmania

Geoscience Australia operates the only IVS Analysis Centre in the Southern Hemisphere. Collectively, this infrastructure is dedicated to maintaining and improving the precision of geodetic measurements of positions on the Earth's crust.

AuScope

In 2007 the National Cooperative Research Infrastructure Strategy (NCRIS) initiated program 5.13, "Structure and Evolution of the Australian Continent", which is funded by the Department of Innovation, Industry, Science and Research and managed by AuScope Ltd. (*www.auscope.org.au*). A major component of this project is the establishment of a national geospatial framework, including satellite laser ranging, ultra-precise gravimetry, a network of ~100 of GPS receivers and VLBI (Figure 1). Total federal funding for this undertaking is $15.8M, together with $21M from Universities, State governments and Geoscience Australia.

AuScope VLBI

As part of this effort, UTAS is constructing three new radio telescopes, located near Hobart, Yarragadee (WA), and Katherine (NT); all three will be installed and operational by mid-2010. The Hobart antenna was assembled in April this year and is currently undergoing acceptance testing (Figure 2). Foundations have recently been poured at Katherine in readiness for an October 2009 assembly, and preparations at Yarragadee are well advanced. In a coordinated international effort in New Zealand, Auckland University of Technology (AUT) has purchased a similar radio telescope, now completed and in the testing phase.

These new telescopes will double the number of IVS stations in the Southern Hemisphere. They will allow the extension of astrometric VLBI solutions to radio sources south of declination -40°, an area of the sky that has been severely under-sampled by the existing array because so few telescopes are available in the South. They will observe for 180 days per year, increasing the number of geodetic VLBI observations in Australia by a factor of nine. In addition to

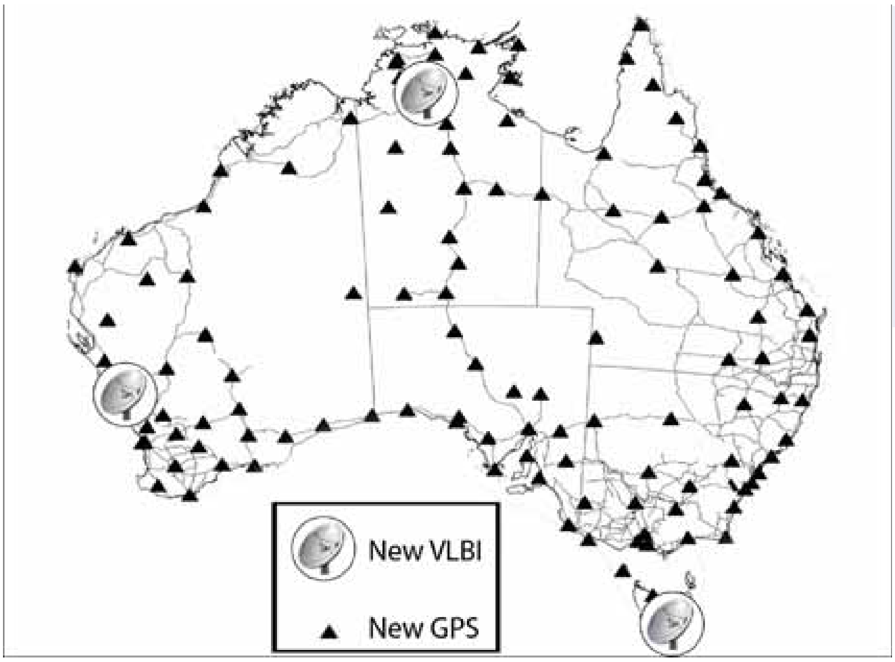

Figure 1. The geographical distribution of VLBI and GPS infrastructure for AuScope. New VLBI stations will be established at Yarragadee (WA), Katherine (NT) and Hobart (Tas) with co-located GPS receivers. An additional ~100 GPS receivers will be distributed across the continent.

contributing to the IVS, the new VLBI array will have time available to undertake stand-alone geodetic and astronomical research. The AuScope and AUT telescopes closely follow the draft IVS VLBI2010 specification for the next generation of telescopes for geodesy. We are therefore extremely well placed to lead the development of observational and analytical techniques that will enable millimetre-precision absolute position determination. A high priority in this area is to further improve the catalogue of reference sources in the southern sky.

The Astronomical Reference Frame Sources

Although classical celestial navigation was based on observing the positions of nearby stars, modern geodetic VLBI uses compact radio sources in distant galaxies, most are billions of light years away. Active Galactic Nuclei (AGN) are extremely compact and luminous objects, in some cases outshining their host galaxies by more than four orders of magnitude. In most bands of the electromagnetic spectrum, the sky is dominated by AGN. They are associated with super-massive black holes that accrete surrounding material and, in some cases, emit relativistic jets of plasma that can extend far beyond the stellar boundaries of the host galaxy.

The most extreme type of AGN is the blazar, where the jet is aligned close to our line of sight so that its emission is highly boosted by relativistic Doppler effects. Blazars are therefore apparently highly luminous and variable, and emit energy across the entire electromagnetic spectrum, from radio to TeV gamma-rays. AGN are the only known laboratories for many aspects of physics at the limits of gravity, temperature, matter density, velocity and acceleration.

About half of all AGN radio sources are extremely small, with angular sizes of ~10^{-5} arc-seconds (the angle subtended by 1mm at a distance of 21 million kilometres). These sources show rapid variability caused by inter-stellar scintillation. Scintillation at centimetre radio wavelengths is caused by the propagation of the radio waves through turbulence in the interstellar medium (ISM) of our Galaxy. The turbulence acts like a number of small lenses moving across our field of view, which in turn magnify and de-magnify the background light. The scale size of the turbulence is the Fresnel scale, defined as the scale where phase changes of one radian are introduced into the wavefront (Macquart & de Bruyn 2007, Rickett et al. 2002.) Background objects must have an angular scale similar to or smaller than the Fresnel scale in order to scintillate. Because of the large distance to the ISM screens (10s to 100s of parsecs), the Fresnel scale is typically a few tens of micro-

Figure 2. The new AuScope VLBI 12m antenna at Hobart (photo: Jim Lovell)

arcseconds. Therefore, any object that scintillates at radio wavelengths must have an angular size of this order or smaller. These objects make the very best calibrators for geospatial VLBI because their small angular size allows their position to be measured very accurately.

In 2002 and 2003, a yearlong observing program with the Very Large Array telescope (USA) was carried out to search for interstellar scintillation (ISS) in a sample of over 700 AGN in the northern sky. The Micro-Arcsecond Scintillation-Induced Variability (MASIV) survey (Lovell et al 2003, 2008) conducted observations over four epochs of three or four days duration at 4.9 GHz. The aim of the survey was to obtain a large catalogue of AGN that vary on timescales of hours to days with which to provide the basis of detailed studies of the ISS phenomenon. The MASIV survey found that 56% of the sources showed scintillation-induced variability (Lovell et al 2008).

Follow-up imaging with VLBI showed a strong connection between ISS and compact milli-arcsecond scale structure (Ojha et al. 2004), making scintillating AGN ideal celestial reference frame candidates. At UTAS we will exploit this technique again, this time to develop a catalogue of geodetic position calibrators in the Southern Hemisphere. As a side

The consequences of crustal hazards in Australia are not insignificant and collectively transcend the individual economic, environmental and cultural impacts that face us today.

benefit, these objects are important in their own right as examples of very bright radio emission from near the event horizon of the giant black hole in the centre of the AGN.

AuScope GPS

For around two decades the Global Positioning System (GPS) has been used to study geophysical phenomena that manifest as temporal changes in the position of the Earth's crust. The most significant early results related to plate tectonic motion, notably continental drift and earthquake deformation (e.g. Davis et al., 1989 and Bock et al., 1993). Improvements in analysis strategies have led to improved accuracy - particularly in the vertical component - which now permits GPS to be used to study glacial isostatic adjustment (e.g. Milne et al., 2001; Sella et al., 2007), tide gauge motion (e.g. Snay et al., 2007), elastic deformation caused by atmospheric pressure loading (e.g. Tregoning and van Dam, 2005, Tregoning and Watson, 2009) and atmospheric remote sensing (e.g. Bevis et al., 1992).

The NCRIS funded array of continuously operating GPS receivers (Figure 1) has the potential to provide an unprecedented insight into the crustal stain and deformation over the Australian continent. The GPS technique is however limited due to a range of systematic errors that have recently been highlighted in the literature. Mis-modelled geophysical signals such as the solid Earth tide, ocean tide loading and the tidal component of atmospheric pressure loading have been shown to induce aliased signals at frequencies of geophysical interest (Penna et al. 2007, Watson et al., 2006, King et al., 2008, Tregoning and Watson, 2009). Further, near field multipath and time dependant geometry effects have recently shown alarming impacts on long GPS time series, inducing both periodic and abrupt offsets in addition to secular rates (King and Watson, 2009). Independent time series such as that provided by VLBI are likely to provide the next significant leap in understanding and mitigating these error sources. VLBI also offers the potential to significantly improve the underlying reference frame that is critical in order to further advance the accuracy of the GPS technique.

The consequences of crustal hazards in Australia are not insignificant and collectively transcend the individual economic, environmental and cultural impacts that face us today. Large uncertainties in motion of the land around the Australian continent are hindering the development of mitigation and adaptation strategies for phenomena such as sea level change. Refined positioning techniques such as those enabled by AuScope are therefore required. The VLBI component of AuScope will drastically improve the fundamental building blocks of our reference frame. This in turn will enable improvements in the allied technique of GPS that provides the ability to observe crustal behaviour at far greater spatial densities and therein provide a future window into the crust that is unavailable at present.

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Footnotes

[1]*http://ivscc.gsfc.nasa.gov/about/org/components/ns-list.html*

Dr Jim Lovell is the AuScope VLBI Project Manager. His research background is in high angular resolution studies of Active Galactic Nuclei, with a particular interest in using inter-stellar scintillation to probe sub-parsec-scale structure.

Each of us probably has some special "trick of the (physics teaching) trade." You may think your is too obvious, or well known, or trivial to justify a full note, but it may be just the sort of technique others would find useful. If you will send us a brief description of such practices along with any diagrams or images, we'll use them from time to time as space permits.

A meeting of two parallel worlds

by Prof Hans Bachor and Damien Hughes. The ARC Centre of Excellence for Quantum-Atom Optics

Public culture such as mainstream TV programs and fundamental research are normally two worlds that hardly mix. It is not only a challenge to explain what we are doing in our labs, but also why are we doing it. Recently there was a great opportunity for these two worlds to meet: An invitation from the ABC New Inventors show to a research team from ACQAO to present their work on Multimode Entanglement.

The Quantum Imaging team from ACQAO, by accepting the invitation to appear on the ABC New Inventors show, found that it proved to be an unlikely and interesting opportunity that became a successful outreach exercise.

Professor Hans Bachor tells the story…

When the call came in the initial reaction was, "NO WAY, you have the wrong people!" But the producer insisted that this was just the stuff they were looking for. They wanted to promote a different perspective on what they defined as 'invention'. At that point I do not think either of us knew what we were in for. With some caution we accepted the invitation and so began an experience in science communication that challenged our team to look at what we do in an entirely new way.

For fundamental scientists communicating what we do is relatively easy when we are with our peers. However, put us in a room with those outside our field and you hit a fundamental barrier (excuse the pun). The common problem for fundamental scientists has always been finding ways to communicate something that is so far removed from your audience.

How do you explain entanglement? Should we take the line of the quantum weirdness, the famous spooky action at a distance that is discussed in popular science books? For us working with the concept everyday, entanglement has become a real thing. The uncertainty principle has become real noise that we detect in our optical experiment.

In our approach we can link two modes, sometimes two beams, and see correlation within the quantum noise. Entanglement has become a measure of the quality of the correlation.

When the call came in the initial reaction was, "NO WAY, you have the wrong people!"

We are convinced we need good entanglement for any future application, however we can only guess what the application of that will be. Entanglement will be like oil during the age of steam engines (thanks Ben for the metaphor), it is necessary to make quantum technology work. And we just had a great success in simplifying our machine to make it more useful (*Nature Photonics*, *Vol.3*, *2009*, *p 399-402*).

With this background we approached the production team: We needed big props to show the concept and a couple of thick towropes did the trick. Each strand a mode, wriggling independently, when linked together they became 'entangled'. Finally we tied them up, to show how we could have entanglement in one beam.

This all worked well and the response has been very encouraging. Most importantly a debate started about the practical value of quantum physics. The judges realised that such esoteric machines might be necessary to keep our technology evolving at the rate we have become used to. This has started discussion amongst the viewers.

Hopefully this is the beginning of similar events in the future. The ABC team was extremely professional and supportive, the judges' questions were most interesting and the time in the production studio was certainly fun – the ABC would like to create more of this.

It was all achieved with entertainment, good humour and in fast pace. We learned a lot and are pleased that such a diverse audience watched our fundamental physics, even if only for a brief moment in time.

Photo credit: The Canberra Times and the photographer, Melissa Adams.

Bragg and Mitchell's Antisubmarine Loop

by Dr Richard Walding

Abstract
Towards the end of World War 1, antisubmarine harbour defences developed by the British physicist William Bragg were being trialled in the English Channel. They were called "Indicator Loops" but were more commonly known as "Bragg Loops" in honour of the man who had recently become a Nobel laureate. However, their origin can be traced to another physicist – a Scot – Alexander Crichton Mitchell some years earlier. Mitchell was ignored by the English physicists in London who in turn were treated with disdain by naval officers and as a result German submarines roamed the English Channel undetected for longer than otherwise would have been. This article presents a review of the events surrounding the invention of the Indicator Loop and the lessons learnt.

Introduction

The discovery of the third 'missing' WW2 Japanese midget submarine off Sydney Heads in 2006 ended 60 years of speculation about its location and, for a while, its very existence. During the time of the attack in May 1942, the antisubmarine defences in Sydney Harbour became somewhat confused. Of particular concern in this article are the defences known as "indicator loops" and why their signals went unrecognised and misinterpreted for so many days, even months.

'Indicator loops' are long lengths of cables laid in precise patterns on the seabed and form part of the underwater defences of a harbour, anchorage or shipping channel. The presence of steel-hulled vessels – both surface craft and submarines – is indicated by the electromagnetically induced swing of a galvanometer needle at a nearby shore station. Anti-submarine vessels are stationed nearby to attack the submarines, usually with depth charges, if they were detected by the loops.

Professor A. C. Mitchell
Courtesy of Eskdalemuir Magnetical Observatory, Scotland.

In May 1942 there were six large 'outer' loops in a defensive semi-circle across the harbour entrance, as well as two miniature 'inner' loops within the harbour. The outer loops were out of action but the inner loops did detect all three submarines, however, interpreting the 'signatures' on the paper charts was problematic. Watchkeepers at Sydney Heads had never experienced a loop crossing by an enemy vessel and there was enough electrical noise near the loops from nearby trams to confuse matters. This was one of the first times that indicator loops were put to the test under hostile conditions in WW2 and their performance - failure or otherwise - was of enormous interest to the British Admiralty.

The Admiralty had invested a huge amount of time and money in loop research since 1915 when it became very obvious that there was almost nothing standing in the way of the dreadful loss of allied shipping to German submarines. But two physicists rose to the occasion and loop defence research was born in that year. A little history is needed to set the scene before we get down to the physicists and the physics.

War is declared

On the 3rd August 1914, Germany declared war on France and by the next day Britain had declared war in response. The Royal Navy was making attempts in early 1915 to develop antisubmarine devices and most effort and money was concentrated on Commander C. P. Ryan, RN, and his hydrophone research at the Admiralty Experimental Station station at Hawkcraig in the Firth of Forth near Edinburgh. By 1915 his primitive hydrophones could detect British submarines exercising off Leith – the port for Edinburgh.

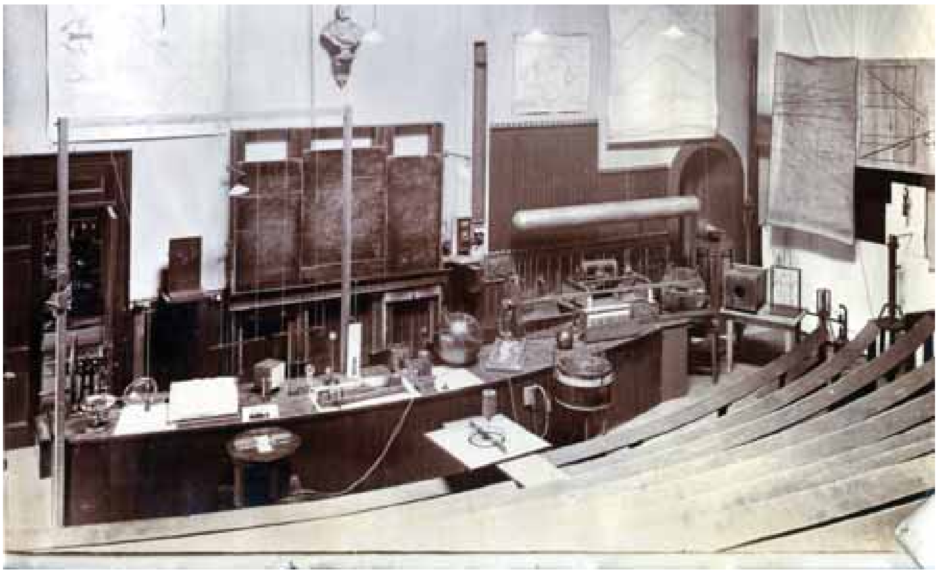
The war in France had bogged down by March 1915 and the British public had begun to accept that the war would not be over in a few weeks, or even months, as promised. British scientists – physicists in particular – were twiddling their thumbs waiting for their offers of help with the U-Boat menace to be taken seriously and wondering why the Government was so reluctant to accept their offers. But this was about to change.

H. G. Wells - Mobilisation of Invention

Of all people to get scientific research underway, it was the seminal call by science fiction writer and inventor H. G. Wells who really made the British government take notice. On the 11th June 1915, Wells had a letter published in *The Times* under the heading "Mobilisation of Invention". Wells was more concerned by the fact that the scientists of Britain were sitting around wringing their hands wanting to make a contribution but not being called to do so. He suggested a committee of "scientifically and technically competent men for this highly specialised task".

However, unbeknown to the Admiralty, a Scottish couple whose two sons had volunteered to join the army had already taken direct action; and before H. G. Wells made his call for mobilisation of scientists. In May 1915 they wrote to their solicitor in Edinburgh to let it be known that they were "strongly of opinion that in the present state of affairs very special steps ought to be taken by scientific men and organisations to assist the British government generally and the Admiralty and War Office in particular". The couple offered £300 to the Royal Society of Edinburgh (RSE) on 7 June 1915 for "better methods of detecting and locating the presence of submarines". By the 21st June the RSE had convened a War Committee that contacted Professor Alexander Crichton Mitchell – a recently retired physics and mathematics professor who had returned to Scotland after 24 years in India – to ask if he would be prepared to undertake research using these funds. Mitchell agreed and on the 25th June 1915 he visited West Pier at Leith to reconnoiter the site and order equipment for his experiments. This was the start

of the research the Scottish couple had funded to shorten the war and bring their sons home safely but, sadly, their two boys were to be dead within a month: one at Gallipoli and the other in France.



Tait's lecture theatre at Edinburgh University. Mitchell's thermal conductivity apparatus is just to the right of centre. Courtesy of University of Edinburgh Physics Department.

Board of Investigation and Research formed

On the same day Mitchell began his experiments in Leith, there appeared in *The Times* newspaper a list of war deaths of Cambridge men; the brightest scientists of Britain were dying in the trenches of France. It was obvious this calamitous situation could not continue. On the 5th July 1915, the Board of Investigation and Research (BIR) was set up in London comprised of a Central Committee of civilian scientists such as physicist J. J. Thompson FRS, engineer Charles Parsons FRS (inventor of the steam turbine for ships) and chemist George Beilby FRS. The role of the Board was to evaluate problems, propose solutions and organise research schemes, at the same time sifting, assessing and, as appropriate, developing the inventions and ideas the public were submitting. A Consulting Committee was also formed and included the eminent physicists Ernest Rutherford, Oliver Lodge, William Strutt (later Lord Rayleigh) and former Professor of Physics at Adelaide University - William H. Bragg. The Committee was divided into six sections with Section II (Submarines and Wireless Telegraphy) receiving by far the largest government grant. The wheels of government turned slowly and it was to be some time before the scientists got underway.

Alexander Crichton Mitchell - Magnetician

Before we consider Mitchell's experiments, we should look at the man himself. Alexander Crichton Mitchell was born in 1864 in Leith, Edinburgh. He undertook a degree in experimental physics under the supervision of Professor P. G. Tait at Edinburgh University. By the late 1880s Mitchell had graduated and worked as Tait's research assistant for two years working on the thermal conductivity of ice and various steels. This is where his accuracy and attention to detail were forged. In 1890 Mitchell accepted a job as Professor of Mathematics and Physics at His Highness The Maharaja's College in Trivandrum, in the erstwhile state of Travancore, now Kerala, Southern India. Mitchell became Principal of the College and voluntarily took over supervision of the government magnetical observatory nearby. On furlough in Edinburgh in 1896, while measuring temperatures inside a block of ice at midnight in winter on the roof of the Physics laboratory he noticed a large swing on his thermocouple's galvanometer. This coincided with a brilliant flash of the Northern Lights (Aurora) and he was most peeved that his data had been spoilt for the night. However, the effect of magnetic disturbances and electromagnetic induction in a loop of wire made a strong impression on him. Mitchell had a remarkable career in Travancore and when he left in 1912 he was given great honours by the government.

The Admiralty had invested a huge amount of time and money in loop research since 1915 when it became very obvious that there was almost nothing standing in the way of the dreadful loss of allied shipping to German submarines. But two physicists rose to the occasion and loop defence research was born in that year.

He returned to Edinburgh and began thinking about working again in a magnetical observatory. But that would have to wait, for the war had intervened and the RSE project had begun.

Mitchell's antisubmarine work

On 1st August 1915 Mitchell took a loop of bell wire and hung it vertically off the end of Leith Pier as a trawler passed by.[1] The deflections on the galvanometer were "very good" but not good enough for Mitchell. He then placed the loop horizontally on the harbour floor and obtained dramatic results. The galvanometer was far too sensitive and was picking up variations in both vertical and horizontal components of the geomagnetic field which overwhelmed the signals from the passing ships. Mitchell's solution was to put a figure-of-eight twist in the loop so that he had two loops in opposition. Terrestrial fluctuations and 'industrials' from motors nearby cancelled each other out as they created opposite polarities at the galvanometer, but allowed ships' induction to show up. By the 19th August he had completed quite an insightful and extraordinary piece of work.

Mitchell at Hawkcraig

Mitchell wanted to repeat his experiments on a much larger scale with real submarines. On August 20th he contacted Commander Ryan at Hawkcraig and requested assistance in trialling his loops. Ryan, a forceful, obstinate, abrasive and difficult Irishman was surprisingly happy to help. Mitchell may not have been a naval officer but, like Ryan, at

West Pier Leith in July 1916. Mitchell conducted experiments off the end in the same month this photo was taken. Courtesy of Peter Stubbs, Edinburgh

least he was not English and, most importantly, he would be under Ryan's command. They began work the next day – a Saturday. Cables were laid in the shipping channel in the Firth of Forth and over the next few weeks Mitchell observed large ships of Admiral Beatty's Battle Squadron steam out to sea. They passed over his loop and gave superb galvanometer deflections. He reported his great success to the RSE on October 19th and they subsequently wrote to the BIR with his findings.

Bragg's background

The first general meeting of BIR had taken place in London on the 29th July 1915, one day before Mitchell collected his first data from the Leith loop.[2] Bragg was soon to be involved.

William Henry Bragg is generally regarded as one of Australia's most respected and influential physicists. Although he remained a British citizen for his 17 year stay in Australia, his adopted country loved him and he loved her. It is no wonder then that the AIP devised the Bragg Medal in his (and his son's) honour for the best PhD thesis in physics at an Australian university.

Bragg's history is well known and hardly needs restating here, but a few points are worth noting as they impinge on his work in WW1. Bragg was born in England in 1862 and arrived in Adelaide in 1886 after a short period in the Cavendish Laboratory. Many of his biographies quote two rather offhand comments by Bragg: one, that he had never studied physics at Cambridge and two, that he would have to read his *Deschanel* aboard the ship on his way to Adelaide. 'Deschanel' refers to the popular physics text *Elementary Treatise on Natural Philosophy*[3]. A more nuanced biography by physicist John Jenkin from La Trobe University suggests that "Bragg grossly overstated his ignorance"[4]. Bragg had emerged Third Wrangler for his performance in the Cambridge Mathematical Tripos which included the topics of statics, dynamics, hydrostatics, optics and astronomy. But of interest to his work in WW1, Bragg was not familiar with electricity and magnetism and he would come to rely on his good friend Richard Threllfall at Sydney University. Threllfall had taken the less-fashionable Natural Sciences Tripos at Cambridge and was with Bragg at the Cavendish laboratory. Threllfall was rated by J. J. Thompson as "one of the best experimenters I ever met"[5]. Both Bragg and Threllfall arrived in Australia in 1886.

It would be foolish to suggest that Bragg ended up at the Board of Inventions and Research with a deficit in knowledge in electricity and magnetism. Far from it; Bragg quickly educated himself in E & M as this topic had been introduced into all three years of undergraduate physics at Adelaide University by his predecessor Horace Lamb. It is quite clear that Bragg was well versed in E & M.

But it is not only Bragg's theoretical knowledge in this topic that grew during these years; his laboratory skills and research methodology were also developed. Bragg himself gives the impression that he did not begin research until quite late in his stay in Australia: "For seventeen years I worked

steadily in Adelaide. It never entered my head that I should do any research work."[6] While it is true that Bragg undertook most of his experimental work (on radioactivity) in the period 1903-1909, he began laboratory investigations in 1892, the first being for a London-based electrical engineering company and he continued from thereon. In essence, it is the intention here to show that Bragg had a thorough background in both theoretical and experimental electricity and magnetism by the time he left Australia for Leeds University, making him a wise choice for work on electromagnetic anti-submarine devices in 1915. The final piece in the puzzle is Bragg's familiarity with electrical cables.


Professor W. H. Bragg. Courtesy of The Nobel Foundation 1915

While he may not have experimented on overhead telegraph and undersea telegraphy cables, he became familiar with the successes and problems of this technology by his very relationship with his wife's father, Charles Todd. Todd, Government Astronomer, Postmaster-General and Superintendent of Telegraphs, was responsible for telegraphy in South Australia at this time and the two of them are known to have discussed its introduction into Australia. The effects of lightning strikes on telegraph cable and short circuits (sea-cells) in the London-Australia underwater cable provided stimulating evening conversation between Bragg and Todd on the verandah of the Todd residence in Victoria Square in Adelaide.

It is clear that reliance on civilian consultants employed by the Navy as the source of its only expertise was a dismal failure at the start of WW1.

Bragg's Stresses

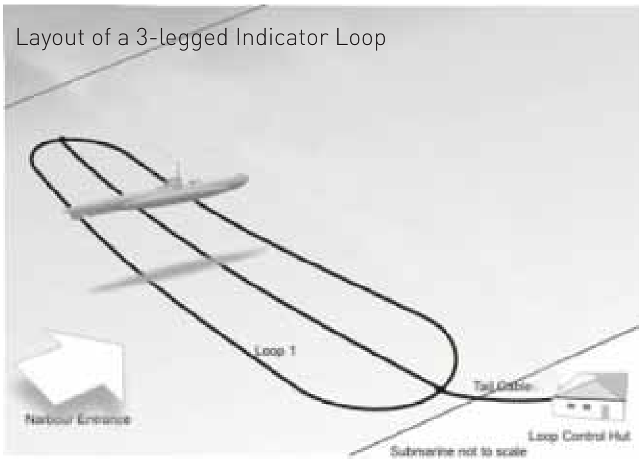
William Bragg's youngest son Robert had volunteered for army service well before the outbreak of the war. Here he was now, on the 9th August 1915, as an officer in the 58th Brigade Royal Field Artillery, about to land at Gallipoli to begin the disastrous "August Offensive" against the Turks. He had three weeks to live. The following day – the 10th – a few kilometers north of Anzac Beach, one of the brightest physicists of a generation was killed by a sniper during the failed offensive. Henry Moseley - the Oxford scientist and a colleague of Rutherford – had joined the Royal Engineers as part of his war effort. Unquestionably, had the BIR been set up earlier Moseley would have been a certain appointment, as certain as being awarded Nobel Prize for his work.

It was a terribly stressful time for William Bragg: taking up the appointment as Quain Chair of Physics at University College, Robert in Gallipoli, his older son Lawrence an officer in France developing sound ranging techniques for the artillery, and the pressure to come up with war-shortening strategies for the BIR. He heard of Robert's death on the 4th September, just 3 days after he started his new job. Nevertheless, Bragg was deeply committed, and the BIR's work had to continue. They had invited and received suggestions from scientists, naval personnel and members of the public about strategies to defeat the enemy. Tens of thousands of suggestion poured in and staff were quickly overwhelmed. For detecting submarines, most submissions envisaged arrays of magnets in the water ready to clonk on to the steel hulls of submarines. This was quickly discounted as impractical but the BIR wanted the methods examined by a competent scientist. William Duddell FRS, President of the Institution of Electrical Engineers was such a person. He had become quite famous for developing the oscillograph (a precursor to the CRO) and a variety of galvanometers. In September 1915 Duddell reviewed the theoretical work undertaken by the National Physical Laboratory in London for the Admiralty some years earlier[7]. The NPL considered the magnetic field of a submarine 100 metres underwater and concluded that it would be about one-ten-thousandth of the Earth's magnetic field strength making it undetectable with the equipment available at the time.

Rather than question the assumptions on which this advice had been given, Duddell merely reiterated the findings: "the detection of a submarine by this method appears to be ruled out". He further considered various other measures such as changes in conductivity, attraction to electromagnets, and use of magnetised coils were also all ruled out. The BIR took his advice and moved on to other methods, particularly acoustic methods such as the hydrophone.

I was puzzled by Duddell's willing acceptance of the NPL conclusion and asked a physicist at Griffith University to give me a back-of-envelope calculation of the voltage induced in a cable by the presence of a submarine. Associate Professor Evan Gray has expertise with magnetic alloys and his logic went thus: *First calculate the remnant magnetisation of the steel hull. The initial permeability of steel in a low field such as the Earth's magnetic field could be up to 1000, say 200 as a conservative estimate. Considering the submarine as a cylinder say 3 m in diameter, it will be magnetised by the Earth's field (0.05 mT max) and if the hull is parallel to the Earth's field the value of B at the metal/environment interface at the bow or stern would be in favourable cases 0.05 x 200 = 10 mT (the normal component of B is continuous across the interface). The total flux through the bow/stern could then be of order 0.01 T x 10 m^2 = 0.1 Wb. This flux spreads through the surrounding space and re-enters the vessel at the opposite end (or side); think of a bar magnet.*

Now consider a detecting loop lying on the sea floor a few tens of metres away. As the submarine passes over it, the flux through the loop changes by an amount that depends on orientation and distance, and at a rate that depends on the vessel's speed. In a favourable case, perhaps 10% of the total flux emanating from the vessel could cut the loop as the submarine passes. Say the sub takes 10 seconds to pass. Then the voltage induced in the loop is V = d□/dt = 0.1 Wb x 10%/10 s = 0.001 V = 1 mV. This should have



Layout of a 3-legged Indicator Loop

been been quite detectable in 1915, when radio receivers sensitive to microvolts were around.

Readers may be able to spot the difference between Duddell's and Gray's estimates: the depth of water. If Duddell had been given advice on what depth of water he should consider, the outcome may have been very different, and possibly a much earlier end to the war. Why the Navy chose not to make its needs clear to scientists at the NPL or BIR can only be guessed, but Commander Hall, perhaps representing the Navy did say 'the only information necessary to be given [to civilian scientists] was that the enemy submarines were in the sea, and that means were required to detect their presence'.[8]

The BIR had accepted Mitchell's report in late October 1915 on his successful loop trials in Scotland but replied that "no use could be found for this method". It is not clear if Bragg was aware of the report. It would seem likely that he was, being on the panel for that very issue – but we cannot be certain because hundreds of suggestions were arriving at the BIR daily regarding anti-submarine measures. Nevertheless, it was read and filed away.

Duddell had sniffed at the prospect of detecting submarines and no-one was about to disagree. But we should follow the exploits of the BIR antisubmarine researchers. Rutherford visited Hawkcraig in mid-October to see if the BIR would be well placed to use its facilities. In November 1915 he sent a group of BIR scientists there to work at the Admiralty Research Station under the watchful eye (but not leadership) of Commander Ryan. Two scientists of interest are Albert B. Wood the research assistant from Liverpool University and Harold Gerrard, a lecturer in electrical engineering at Manchester. Also that month - on the 12th November 1915 - the Royal Academy of Science in Stockholm announced that Bragg was awarded a Nobel Prize in Physics in conjunction with his son Lawrence currently serving in France.

Civilian vs. Navy science

There were, from the start, tensions between the Royal Navy and civilian scientists, exacerbated by the BIR's independence from naval control, by the abrasive character of the Chairman of the BIR, Lord Fisher, who was not universally liked in the Royal Navy and who wanted to exert an influence in the conduct of the war, and by the reluctance of the Royal Navy to countenance involvement by civilians in the solution of problems it saw as its own responsibility. In early May 1916 Bragg, as one of the Consulting Committee of the BIR, arrived at Hawkcraig to be Resident Director overseeing research and to join Wood and Gerrard. Within months Bragg lamented in a letter to his daughter 'We are practically cut off from all contact with the navy, except such part of it as is hostile to BIR.'[9] Commander C. P. Ryan RN, as the resident technical expert at Hawkcraig, insisted that the only work to be done in earnest by the BIR would be on improving the (near-useless) hydrophones he had developed. Ryan had never heard of Rutherford and had little formal scientific training. Work was not progressing well despite the increasing U-Boat attacks by the Germans.

Merchant shipping losses increase

Losses of British, neutral and allied mercantile gross tonnage from submarine and (to a much lesser extent) mine attack was beginning to rise quite dramatically. Bragg had tried to work with Ryan at Hawkcraig during this time but he just had to admit defeat against the closed shop that was the Royal Navy, wary of outsiders, especially civilians, and especially smart ones, not under their direct control. On the 26th November 1916 Bragg took the BIR to the Experimental Station at Parkeston Quay, Harwich, down on the Devon coast east of London. He was desperate to get his work moving again.

With the pressure on him to come up with a solution for the U-Boat question, Bragg made excellent progress on echo ranging – known to the BIR scientists as Asdic (for anti-submarine detection). Less progress was being made on magnetic field detection using loops. However, Bragg suggested that Wood should review Professor Crichton Mitchell's work from 1915 "which led to revival of loop idea".[10] On 19th November 1917 Bragg reported that with loop experiments there had been "great progress in the last few weeks". Bragg envisaged two types of loops: one, a small 'mine loop' used with a group of mines which could be fired when the loop detected the passage of a submarine across the loop; and two, a bigger 'indicator loop' used just to detect the passage of a vessel. Progress on indicator loops was still slow but by mid-1918 the loops were sensitive enough to detect enemy submarines. As well, about a dozen mine loops had been installed at Scapa Flow in the Orkney Islands – home of the Royal Navy's Grand Fleet.

William Henry Bragg is generally regarded as one of Australia's most respected and influential physicists.

War's End

By 1 October 1918 the war was ending. On October 25th 1939 *U-16* was returning home after having laid mines off Dover when it was detected on a Dover Indicator Loop and sunk. A few days later German submarines were sighted off the Orkneys and one of them - *UB116* - was tracked into Scapa Flow where the Royal Navy Grand Fleet was at home. When the galvanometer spot indicated the submarine was over the 'Bragg' loop, the mines were fired and *UB116* sunk with

no survivors. These were the last submarines to be sunk in WW1. The Indicator Loops had worked and two weeks later – on 11th November 1918 – the war ended.

The Interwar Period

The main theme of this article is how Mitchell's work on indicator loops was dismissed and how his results took so long to resurface. But it is interesting to see how loop research fared in the interwar period and how they were deployed in World War 2. In brief, as far as loop research is concerned, the establishment of the Underwater Detection Establishment (UDE) at the shore station HMS *Osprey* (Portland Naval Base) in 1927 was of great importance. The indicator loop developed by UDE envisaged a pattern of three parallel cables spaced about 200 metres apart (or about the length of the ship they are trying to detect) and about 4000 metres long.

As the world was plunged into WW2, the indicator loop laying program began in earnest. Loops were laid in Britain and the Dominions and in the US. The major ports of Australia were protected by loops, including Sydney, as we saw in the introduction. The fascinating wartime use of loops is outside the scope of this article and details can be found elsewhere[11].

It is clear that reliance on civilian consultants employed by the Navy as the source of its only expertise was a dismal failure at the start of WW1. The lack of trust and the lack of confidence in each others' methods were highly problematic, and efforts to make this work also failed. There was remarkably quick progress made once a professional scientific service in the Navy had been set up; one that could properly involve industry and the universities in naval scientific research.

Footnotes

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11 See author's webpage at *indicatorloops.com*

Dr Richard Walding (FAIP) is a Research Fellow at Griffith University. His area of research is in the history and development of antisubmarine harbour defence system known as Indicator Loops. He recently travelled to Southern India to follow up his research and give lectures on India's unusual involvement in indicator loop history.

James V Allaby 1936–2009

Jim Allaby, a well-known figure at the CERN laboratory near Geneva, and in the international particle physics community, died on 7 April. He was a good friend of the HEP community in Australia. Jim went to CERN in 1965 and worked on many leading experiments over some 30 years.

Later in his career he was also put in charge of relations with CERN's non-member states, including this country. In this context he made a considerable number of visits here, and was often involved with meetings in Canberra, for example with Barry Jones (then Minister for Science) and with senior members of the ARC.

This led to the signing in November 1991 of the CERN/ Australia Cooperation Agreement. Although essentially an umbrella agreement, it allowed our physicists to sign Memoranda of Understanding to participate in experiments there.

Credit: CERN

Two outstanding examples are the NOMAD experiment, which searched for neutrino oscillations, and the ATLAS experiment, one of two large experiments currently active at CERN's Large Hadron Collider, the LHC. In both cases physicists from the Universities of Melbourne and Sydney helped to build parts of the experiments, and participated fully.

Jim played a major role in making all this possible, and his friends here will sorely miss him.

Stuart Tovey
School of Physics
The University of Melbourne

Jobs 2009: Who Wants Physicists?

by John Prescott

For 25 years John Prescott kept an eye on employment prospects for physicists. The annual surveys were published by the Australian Institute of Physics in Australian Physicist. Six years on, he returns to the surveys.

I was prompted to start the employment surveys in 1978 by the comment of one of my honours students that he was doing physics because he liked it although he knew that, "*there were no jobs available in physics*". This did not square with my own observation that our graduates had little trouble finding jobs and it prompted me to read the pages of the newspapers to see what was actually on offer. This was duly reported for 1979 in *The Australian Physicist* and was then continued on an annual basis for 25 years. If you want to read about how things were in the year at the end of the surveys, and the way in which jobs for physicists changed over the years, you can find it in Prescott (2004).

In 2008, to see how things had been going in the five years since the last survey, I went back to my scissors-and-paste reading of newspaper advertisements. The present piece reports on the results. All of the jobs reported were real jobs for which real people were being sought. They are not hearsay, they are hard data. My interpretation of their significance, on the other hand, is my own; it does not necessarily represent the views of the Australian Institute of Physics, which has had a close interest in the results.

JOBS 2009	2003	2008
Total	425	440
	%	%
Commonwealth Government		
CSIRO	7.5	15.5
Not CSIRO not Defence	20.8	17.9
Defence	3.4	5.5
State and Territory Government	10.5	4.6
University		
Permanent Teaching/Research	7.3	9.6
Limited term Teaching	4.8	2.8
Primarily Research	35.8	27.0
Technical and Administrative	3.2	9.6
Industry and Commerce	4.1	3.9
School	2.6	3.5
Total	100	100

In the present survey the data are taken from advertisements in The Weekend Australian and The Australian Higher Education Supplement on Wednesdays. Past experience has shown that this picks up almost all the positions for which an honours degree or postgraduate qualifications are called for. Positions for which an ordinary degree or diploma in physics are suitable are mostly found in the capital city press. This is a long-established pattern. Most jobs for teachers of physics are found there. Over the years, there have been about the same numbers of jobs advertised in each of these two locations. A significant number of jobs now appear in various places on the Internet; that location also provides easy access to the international advertisements. Geophysics is commonly grouped with earth sciences and is not included in the job count, although it also qualifies as physics.

The table above shows the data for the various categories of positions advertised; for comparison, the corresponding data from the previous (2003) survey are included. It starts with government agencies, almost all in the Commonwealth sphere. Overall, Commonwealth appointments, in CSIRO, defence and "other", account for about one-third of all advertised positions, as they have over many years.

University positions of all sorts come next and are close to half of all positions. State government, commerce and industry and school teaching make up the balance.

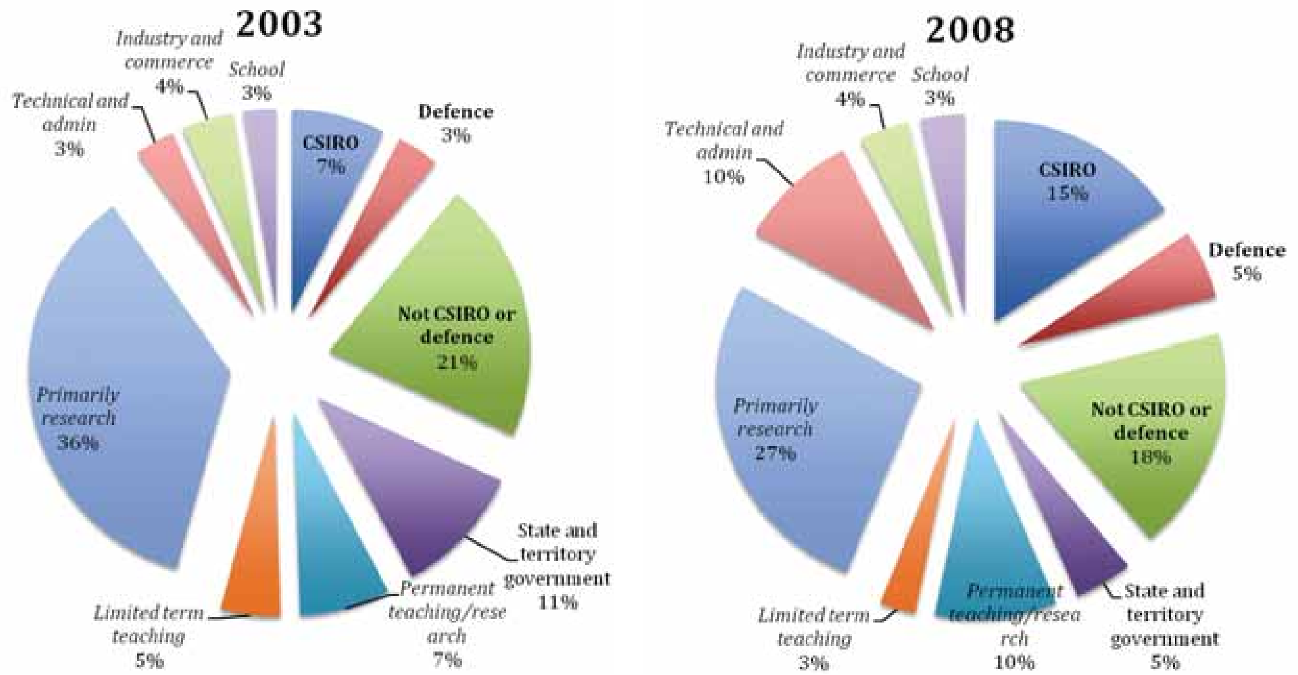
Looking back over the past 30 years, a perhaps surprising feature of the demand for graduates in physics has been stability, at somewhere between 400 and 500 jobs. This remained true even in the recessions of 1983 and 1991–93. Within the overall total, however, the proportions in the various categories have varied and there have been some big changes in the pattern.

In 1989 the distinction among universities and colleges of advanced education was removed. This resulted in an inexorable fall in the number of new teaching staff being sought in the higher education sector. Although the redefinitions/mergers were not of themselves the cause of all of the fall, the financial changes that went with them were. By 1998/1999 fewer than a dozen teaching positions were advertised in either year, permanent or temporary. Between 1995 and 1999 only one tenurable professorship was advertised in a physics department anywhere in Australia.

Things have improved since then. Since 2003, about 50 teaching appointments have been offered in universities each year and this was maintained in 2008. This having been said, the opportunities for tenured university positions are necessarily limited. If you reckon that the average academic teaches for 30 years and that the students take three years for their first degree, then staff members teach 10 student generations and only 10% of those students are needed to replace them. Students with ambitions to teach in academe should value their chances accordingly. I am indebted to the late Professor Tommy Gold for this piece of mathematics.

The universities are, of course, the places where postgraduate students are trained to do research. About 60% of physics honours students go on to postgraduate studies of some sort. It is good advice for job seekers to add to their first qualification since it opens up a much broader prospect of opportunities. Students and not commercial gains are the main product of the universities.

For quite some years now, the number of research-only positions in universities has been significant in both absolute



Jobs in physics compared: for 2003 and 2008.
Bold and italic denote Commonwealth government and university positions, respectively.

numbers and as a percentage of physics jobs on offer. In 2008 there were 120 research-only positions advertised: 27% of physics jobs. This includes jobs advertised by individual universities and 32 appointments identifiable as physics in the annual report of the Australian Research Council. The ARC offers a range of fellowships in competition to individuals and these are almost all taken up in universities.

The ARC deserves credit for establishing and expanding their fellowship program. It retains PhDs in the workforce (even though for limited terms) and it provides a career structure for some. Nevertheless, physicists on limited term fellowships continue to be faced with insecurity and the question of where to go next; and a significant number are in their second or even third limited term appointment. In their commentary on the science provisions in the most recent federal budget, the Australian Academy of Science points out that Australia differs from most other countries in this respect and that more could have been done in the budget to correct this. This has been a constant theme in my own previous job surveys.

Very late in 2008, the ARC announced 200 Future Fellowships, at three salary levels, with support for the institution where they are held. Described as intended for outstanding mid-career researchers, the intention is to attract applicants from overseas and retain Australians in the country. They can be held at any research organisation, not only at universities. Some of these will undoubtedly go to physicists. They are not included in the 2008 count. The current federal budget adds 100 Super Science Fellowships.

Another feature of the statistics for universities is the relatively large number of positions for technical and administrative staff. More than half of them are to manage scientific laboratories, or specialised equipment. The new Melbourne node of the Australian National Fabrication Facility, located at Monash, was offering both managerial and technical officer posts. The Anglo-Australian Observatory was seeking an operations manager. Several positions were on offer in various places to run atomic beam lithography. These are at the professional officer level and it is encouraging to see increased opportunities in this type of appointment. In passing, it should be remarked that university physics departments are having increasing difficulty in persuading Deans to provide enough money to maintain workshops staffed at the level of toolmaker or electronic technician. These are not appointments requiring physics qualifications per se but, in my view, no physics department can function effectively without strong supporting workshops. At least there is now some evidence of opportunities at the middle level.

A major change in the employment patterns in industry and commerce (commonly referred to as Business) set in about 1990. From year to year, a smaller number of positions suitable for physicists have been offered. In the 1980s some hundred firms advertised at least one post for which a physicist would be suitable. I checked this: I wrote to them all in 1980. Eighty per cent replied and said that physics qualifications were either what they had in mind or were satisfactory. In 2003 the number of jobs had fallen to 12 and it is not much better in 2008, at 14. For two decades, successive federal governments have recognised this as a problem and devised a variety of encouragements to business to expand their research and development. For whatever reason, they have been unsuccessful. This is recognised in Powering Ideas, the White Paper of the present government, but the details of what is to be done about it have yet to be worked out.

Over the years tax incentive schemes have clearly not been effective in encouraging innovation. One of my cynical

colleagues, with an ear to the commercial world, commented that the reaction of industry to these incentives was to say, "*Ask the accountants what we are doing now that looks like R&D.*" A large fraction of the money actually claimed as R&D has gone to the motor vehicle industry. This is a legitimate claim but it underlines the relatively poor performance of other parts of the sector.

If I read the OECD publications correctly, in 2006–07 Australia stood 10th of 29 countries in its expenditure by government on R&D but 18th of 29 in expenditure by business. Allowing for new additions to the OECD, this is pretty much where Australia has stood for a couple of decades.

The previous government made it clear they expected university research groups to devote significant effort to commercialising their work. It could arguably be interpreted as an attempt to make up for the shortcomings of business. When you are contemplating how to maintain your student services and equip undergraduate laboratories, it is difficult to resist the pressure of this thrust. To be effective, more money needs to be allocated to universities for research infrastructure and operational costs. There is some indication the present government knows this and will do something about it.

So far as employment is concerned, Commonwealth Government agencies contribute 39% of all advertisements. This is much the same as it has been for many years, although the breakdown within government agencies has varied over fairly wide limits. After a period when CSIRO was not looking for many physics graduates, they advertised for 68 in 2008. Most of these were continuing appointments, including a quite unusual advertisement in September for no fewer than 23 scientists or engineers in the division of Materials Science and Engineering. A physicist could fill every one of these! Not that every post would be filled in this way and applicants would have to compete; nevertheless these are positions for a physicist to aspire to.

Defence includes the Defence Science and Technology Organisation (DSTO), which was looking for a new chief scientist (a physicist was appointed); Defence Signals Directorate; Defence Imagery and Geospatial Organisation (DIGO) and a few other small groups. DIGO is a young organisation, describing itself as "safeguarding Australia's interests through geospatial intelligence products". It was recruiting fairly vigorously throughout the year and accounts for more than half the positions advertised in defence.

Leaving out CSIRO and Defence, a wide range of Commonwealth organisations make up 17.9% of jobs. Among them, the Commonwealth Bureau of Meteorology (which was also advertising for a director), the Australian Nuclear Science and Technology Organisation, the Australian Radiation Protection and Nuclear Safety Agency, the Department of the Environment (also advertising for a chief scientist) and the Department of Climate Change were those most active. Some dozen other departments or divisions also advertised a position or two. It is clearly possible to see a growth in activity in environment and security among the more recent additions to the Commonwealth payroll.

State and Territory Governments are also active in the environmental field, for what might be described as bread-and-butter tasks: clean air, radiation monitoring and so on. As the Commonwealth government does, at least three states have programs on climate change, expressed in those words. These direct activities are government programs.

One feature of state government activity that does not appear directly in the advertisements for positions is their support for specific research projects on topics likely to lead to commercial activities in the state. This is a relatively recent development. In my own university, for example, the South Australian Government has given support to university-based research programs on fibre optics and photonics. In Victoria the Synchrotron received substantial financial support from the state government. There are similar examples in other states.

School teaching is included if "physics" appeared explicitly in the advertisement. All the 15 positions were in independent schools. As noted earlier, the state school system advertises in the local papers for preference. It is generally recognised that there is a serious shortage of teachers of mathematics, physics and chemistry and that this is reflected, at least in part, in a fall in demand for student places in science degree programs. This is a worldwide phenomenon and such demand has been much reduced for a decade at least. Some would say that part of the problem lies in the perception that physics (like languages) is difficult and that there are easier ways to make one's fortune. In the absence of mentors who are able to incite their interest, students will therefore look elsewhere. This having been said, the situation has turned around and enrolments in physics degrees have been increasing. In Australia, the survey by Jennings et al (2008) shows that enrolments in honours physics and postgraduate degrees have now recovered to about where they were 10 years ago.

I started this piece with the comment of one of my students that " *… he knew there were no jobs in physics but he was doing it anyway.*" That was not true then and it is not true now.

Acknowledgements

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The author thanks Sally Woollett for editorial assistance.

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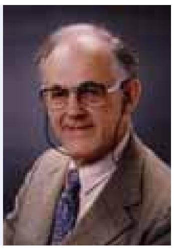
1. Prescott J. R. (2004) Jobs in Physics in 2003: an unusual year. The Physicist, 41, 44-49
2. Jennings P., de Laeter J., Zadnik M. & Lloyd B. (2008) Physics Enrolments – more good news Australian Physics 45, 166-174

Professor Emeritus John Prescott is nominally retired and holds a position of Honorary Visiting Research Fellow in the School of Chemistry and Physics at the University of Adelaide. He continues to carry our research in Physical Archaeometry, which is the application of physics to archaeology and Quaternary geology.



Caught in the Act:
Andromeda Galaxy and neighbouring Triangulum Galaxy hook up

by Katynna Gill

Caught on film for the first time ever, paparazzi to the stars - astronomers - have captured images of our nearest large galaxy, Andromeda, hooking up with its neighbour, the Triangulum Galaxy. Just like any good star gossip, the liaison was suspected previously, but these images are the first to reveal the connection between the two.

Published in the journal Nature on 3 September 2009, the research shows how large galaxies grow by incorporating stars from surrounding smaller galaxies. This popular model of galaxy evolution, called the 'hierarchical model', predicts that large galaxies such as Andromeda, which can be seen with the naked eye from the northern hemisphere, should be surrounded by relics of smaller galaxies it has connected with.

Now astronomers have the images to go with the hierarchical model - a close liaison between the Andromeda and Triangulum galaxies.

The discovery was made by a team of international astronomers, including Professor Geraint Lewis from the University of Sydney's School of Physics. The team was led by Dr Alan McConnachie, from the National Research Council of Canada's Herzberg Institute of Astrophysics, and included astronomers from universities in Canada, Australia, France, Germany, the UK and the USA.

"The Andromeda Galaxy is our closest giant neighbour, located more than 2.5 million light years from the Milky Way. Our new survey charts an area with a diameter of nearly a million light years, centred around Andromeda - it's the broadest and deepest image of a galaxy ever made," said Professor Geraint Lewis.

"We mapped Andromeda's unexplored outskirts for the first time and found stars and giant structures that are remnants of smaller galaxies, which have been incorporated into Andromeda as part of its ongoing growth," explained Professor Lewis.

"The big surprise in the data was finding that Andromeda is interacting with its neighbour, the Triangulum Galaxy, a galaxy which is also visible in the Northern Hemisphere using a small telescope. Millions of Triangulum's stars have been pulled in by Andromeda as part of the encounter."

Just like any good star pairing, the paparazzi are predicting a more solid union between the two will result.

"The two galaxies may eventually merge together entirely," explained Professor Lewis.

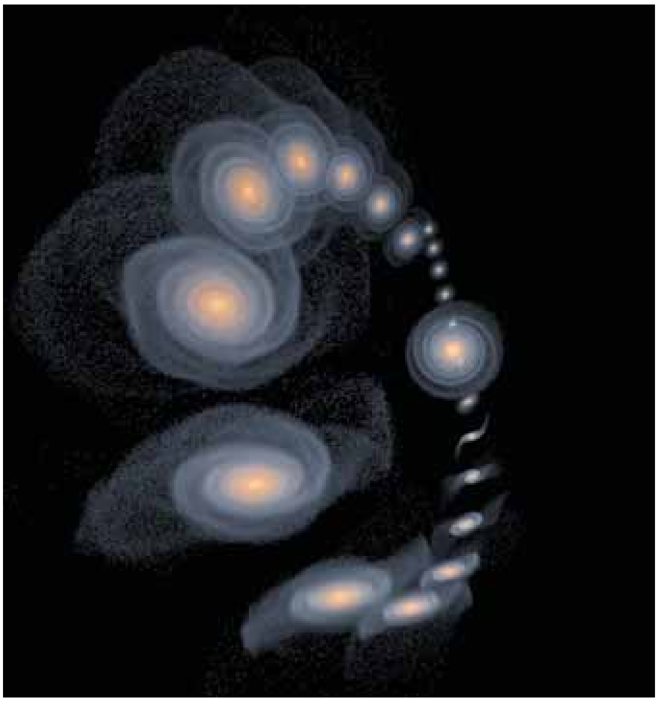
In addition to the affair between the two galaxies, the new survey has shown that galaxies may be much larger than previously thought, with their gravitational influence stretching well beyond stars near the centre of the galaxy. "We've found coherent structures and star formations over the entire survey area, showing that galaxies are much bigger than we originally thought. Andromeda is considered by astronomers to be a typical galaxy, so it's surprising to see how vast it really is. We found loosely bound stars at distances up to a hundred times the radius of the large galaxy's central disk."

The team used the Canada-France-Hawaii Telescope, located on the summit of Mauna Kea on the island of Hawaii, to probe the faint outer reaches of Andromeda with unprecedented sensitivity. Their surprising results, reported in Nature, set the stage for a more detailed reconstruction of the formation of Andromeda, a process that appears to be continuing to this day.

Watch a movie of the Andromeda and Triangulum Galaxy affair at: *www.nature.com/nature/journal/v461/n7260/extref/nature08327-s2.mov*

Read the journal article in Nature at: *www.nature.com/nature/journal/v461/n7260/full/nature08327.html*

A simulation of how Triangulum will eventually join its massive neighbour Andromeda, contributing to the ongoing formation of the Andromeda Galaxy. The image is a stroboscopic projection of a high resolution numerical simulation of a possible orbit of the Triangulum galaxy around Andromeda, that reproduces much of the observed details of these galaxies.



Samplings

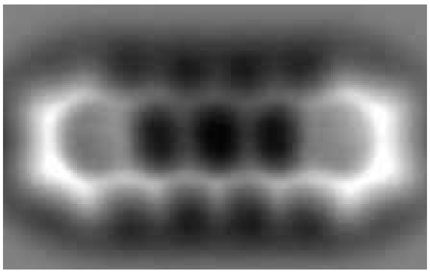
Molecules revealed in all their glory by microscope
http://www.sciencemag.org/cgi/content/full/325/5944/1110
http://physicsworld.com/cws/article/news/40250
Physicists in Switzerland and the Netherlands have designed a new form of atomic force microscopy (AFM) capable of revealing the identity of individual atoms within a molecule for the first time. The result is a key breakthrough in surface microscopy and could yield important insights into chemical reactions as well as the development of single-electron devices, say the researchers.

AFM – invented some 20 years ago – gives scientists the best view for examining atoms on the surfaces of both insulators and conductors. The basic process is to scan a sharp metal tip across a sample to generate images based on the balance of tiny forces between the tip and the sample.

To improve AFM to even higher resolutions, however, researchers need to move the microscope's tip to within 1 nm of the sample and at this range a number of technical challenges arise. Now, a team led by Leo Gross of the IBM research laboratory in Zurich, Switzerland, has overcome these problems to resolve individual atoms and bonds within a single molecule. Gross realized that the atom or molecule at the very tip of the AFM probe governs the contrast and resolution of the microscopy. For this reason, they replaced the metal tip of conventional AFMs with a single molecule of carbon monoxide (CO), which is very stable as well as being subject to significantly smaller van der Waals forces when in close proximity to a sample.

To demonstrate their new tool the researchers applied their AFM tip to a well studied hydrocarbon known as pentacene ($C_{22}H_{14}$), which consists of five fused benzene rings and measures just 1.4 nm in length. They produced an image showing all five carbon rings as well as the individual carbon and hydrogen atoms within the molecule.

The observed spacing between individual atoms was only 0.14 nm – the best resolution yet for an AFM.



The delicate inner structure of a pentacene molecule imaged with an atomic force microscope. For the first time, scientists achieved a resolution that revealed the chemical structure of a molecule. The hexagonal shapes of the five carbon rings in the pentacene molecule are clearly resolved. Even the positions of the hydrogen atoms around the carbon rings can be deduced from the image. (Image courtesy of IBM Research, Zurich)

See also the following related articles in Nature Nanotechnology:
http://www.nature.com/nnano/journal/v4/n8/full/nnano.2009.215.html
http://www.nature.com/nnano/journal/v4/n8/full/nnano.2009.154.html

Breath-testing for cancer using gold
http://physicsworld.com/cws/article/news/40263
http://www.nature.com/nnano/journal/vaop/ncurrent/full/nnano.2009.235.html
Researchers in Israel have invented a new type of breath test for detecting lung cancer in patients using sensors built with gold nanoparticles. Although the analysis of breath particulates is not a new tool in cancer diagnosis, this is the first technique that could detect cancer without the need to pre-treat the exhaled breath, say the researchers.

Breath testing is an established, non-invasive method for testing for lung cancer that works by linking "volatile organic compounds" (VOCs) with specific forms of lung cancer. The drawback at present is that it requires collecting samples and analysing them using techniques such as mass spectrometry and infrared spectroscopy.

Hossam Haick at the Israel Institute of Technology and his colleagues have now developed a new device for detecting cancer in breath, which could provide an almost instant diagnosis of a patient's health, they say. At the heart of the new device is a carbon-based sensor with embedded gold nanoparticles.

When a patient breathes into the device, particulates in the breath accumulate on the carbon layer and the sensor swells pushing the gold nanoparticles further apart, which, in turn, alters the resistance of the film. Each type of particulate has a unique effect on the resistance which can be measured by having a current flow through the sensor.

'Artificial trees' to reduce CO_2: is "geoengineering" part of the solution?
http://physicsworld.com/cws/article/news/40254
Constructing a forest of 'artificial trees' is one of the most promising technologies to remove carbon dioxide (CO_2) from the atmosphere, according to a report published by the Institution of Mechanical Engineers in the UK.

The report also calls for a national UK programme for research and development into "geoengineering" projects that could provide a better understanding of the risks and costs of manipulating the climate.

Geoengineering is deliberate intervention into the climate system to counteract man-made global warming. The new report, Geoengineering – Giving us Time to Act?, looks at different geoengineering options for tackling climate change, including adding iron to the oceans to produce phytoplankton blooms that then absorb CO_2. A separate report on geoengineering by the Royal Society is due to be published soon.

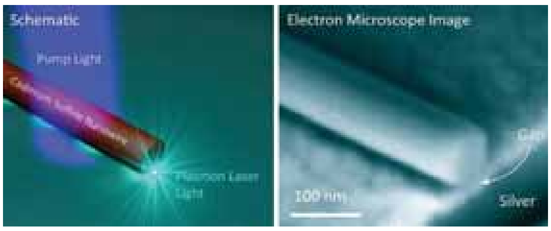
'Gigantic jets' caught on camera
http://physicsworld.com/cws/article/news/40239
Ever since the American polymath Benjamin Franklin braved electric storms with his scientific kites, the study of lightning has been associated with the Romantic explorer in search of scientific answers. The latest Romantics to shed light on this spectacular natural phenomenon are a team of physicists in the US who have managed to capture the most detailed images yet of a "gigantic jet" – a rarely seen form of high-altitude lightning that shoots upwards towards the heavens.

Gigantic jets are believed to initiate from the electric coupling between the lowest part of the atmosphere, known

as the troposphere, and the upper atmosphere at altitudes of 90 km where lots of free ions and electrons exist. This form of lightning has been observed previously from the ground and from orbit. But, because it happens so high up in the atmosphere, no one has yet managed to get close enough to study its electric properties during a strike. However, in this case the researchers established the exact location and dimensions of the bolt using low-light photography, and quantified the transfer of electric charge by observing the lightning's radio signal using a series of ground-based radio sensors.

Plasmonic laser puts the squeeze on light
http://physicsworld.com/cws/article/news/40258
Researchers at the University of California at Berkeley claim to have created the smallest semiconductor laser ever. The new nanoscale device can generate light in a space just 5 nm in size, which is 100 times smaller than the spot produced by conventional lasers. The feat could pave the way for a host of applications, including optical computers that use light instead of electrons to process information, biosensors and nanometre-sized photonic circuits.

Normally, light cannot be focused to a spot smaller than half its wavelength – something known as the diffraction limit. However, in recent years, scientists have succeeded in compressing light down to the nanoscale by coupling it to the electrons that oscillate collectively at the surface of metals – called surface plasmons. The resulting excitations of light and electrons are known as "surface plasmon polaritons" or SPPs.



The schematic on the left illustrates light being compressed and sustained in the 5 nm gap between a nanowire and underlying silver surface. To the right is an electron microscope image of the hybrid design shown in the schematic. (Courtesy: Xiang Zhang, UC Berkeley)

Previous attempts to exploit SPPs to make nanoscale plasmonic lasers failed because the inherent resistance of metals absorbs the SPPs, causing them to dissipate almost immediately after they are generated. This effect becomes worse the tighter the light is bound to the surface.

Now, Xiang Zhang and colleagues have overcome this problem by constructing a hybrid device consisting of a cadmium sulphide semiconductor nanowire separated by a 5 nm thick insulating layer from a metallic silver surface.

This structure – dubbed a "hybrid plasmonic waveguide" by the researchers – can concentrate light into an area as much as 100 times smaller than a diffraction-limited spot. And, because it is non-metallic, it poses little resistance so that SPPs can survive for longer.

The researchers can then amplify the SPPs present by shining light onto the structure, and the nanowire essentially acts an amplifier for nanoscale light. The result is all the more exciting because it has been demonstrated with semiconductor materials, which are fully compatible with modern electronic device engineering.

The new device follows hot on the heels of another nanolaser, the "spaser", developed by researchers from Purdue, Cornell and Norfolk State universities. (See *http://www.nature.com/nature/journal/v460/n7259/full/nature08318.html*). In this case, a dye coupled to gold spheres just 44 nm across immersed in solution generates surface plasmons when exposed to light.

Producing tiny inorganic LEDs in bulk
http://www.sciencemag.org/cgi/content/full/325/5943/977
http://physicsworld.com/cws/article/news/40161
A team of researchers in the US has developed a new technique to shrink the size of inorganic LEDs so they can be used as pixels in display screens. The novel process could allow these tiny light sources to be easily mounted on a range of materials – such as glass, plastic and rubber substrates – for the first time. This breakthrough could lead to affordable and eco-friendly applications, including computer screens and flexible displays, claim the researchers.

Inorganic LEDs are bright, reliable and last a long time, which is why they are used as back-lights in a range of applications from watches to advertising boards. The production of inorganic LEDs, however, is laborious because manufacturers must saw up wafers, remove the diodes and then relocate the diodes into specific applications. Producing displays that feature small inorganic LEDs arranged in parallel is a tough challenge, but the US team led by John Rogers at the University of Illinois, Urbana-Champaign, has managed to do just that. The hope is that these tiny lights could eventually be produced en mass in parallel to act as the pixels of a display screen, rather than just forming the back-light.

Green laser diodes
http://www.nature.com/nphoton/journal/v3/n8/full/nphoton.2009.118.html
Powerful, green laser pointers (now, thankfully, banned) are really frequency-doubled infra-red laser diodes. These are limited in efficiency, cost, and are difficult to miniaturize and integrate. When a true green laser diode becomes available, combined with the already-available red and blue laser diodes, and a MEMS scanner, full-colour displays for televisions, mobile phones etc. would take a significant step forward in quality and brightness. Researchers at the Japanese company Nichia have fabricated an InGaN semiconductor laser diode that operates at a wavelength of 515 nm and emits milliwatt-level powers in continuous-wave mode at room temperature. This news offers renewed hope that a practical commercial green laser diode may be close to fruition.

The not-so-large hadron collider
http://www.nature.com/news/2009/090807/full/460784a.html
The Large Hadron Collider (LHC) should yield its first data by Christmas, smashing protons at energies high enough to begin pushing back the boundaries of particle physics. But the world's largest particle accelerator will

only be operating at half the energy that it was originally designed for, and may not reach that peak until 2011, if at all. During repairs this spring, a new set of problems related to faulty magnet connections was discovered.

Although CERN officials believe they now have the problem in hand, they are being cautious in ramping up the beams' energies. Well may they be cautious: they have found 80 bad copper welds so far, but a further 10,000 similar welds around the LHC have not yet been inspected.

Smaller circuits
http://www.physorg.com/news169796309.html
and
http://www.nature.com/nnano/journal/vaop/ncurrent/abs/nnano.2009.220.html

IBM scientists are using DNA origami to build tiny circuit boards; in this image, low concentrations of triangular DNA origami are binding to wide lines on a lithographically patterned surface. Image: IBM

Scientists at IBM Research and the California Institute of Technology have announced a scientific advancement that could be a major breakthrough in enabling the semiconductor industry to pack more power and speed into tiny computer chips, while making them more energy efficient and less expensive to manufacture.

They have combined lithographic patterning with self-assembly to rearrange DNA structures on surfaces. This may enable structures smaller than the present feature size limit of about 22 nm to be constructed on circuit boards.

Samplings by Don Price and Andy Scott

Quanta: The geometry of crystalline objects in high dimensions

by Neville Fletcher

Most physicists will be familiar with the expression, put forward by Euler in about 1792 and later proved in detail by Legendre and by Cauchy, giving the relationship between the number of vertices, the number of faces, and the number of edges for an object with crystal-like habit, such as a geometrical polyhedron or a faceted gemstone, namely

$$\text{vertices} + \text{faces} = \text{edges} + 2 \tag{1}$$

or, with a more compact notation,

$$N_V + N_F = N_E + 2. \tag{2}$$

The general validity of this result can be established for any polyhedron by noting that it is correct for the case of a tetrahedron, where $N_V = 4$, $N_F = 4$ and $N_E = 6$. Adding another point vertex near the centre of a face increases N_V by 1, increases N_F by 2 since the original face is removed, and increases N_E by 3. The relation therefore continues to apply. The extra vertex could be lifted above the original face plane, making a completely convex structure, or depressed to make a concave structure, without changing the relationship.

There is a topological restriction applying to (2) in that the space enclosed within the polyhedral surface, as well as the space outside, must be simply connected, by which we mean that it must be possible to shrink any closed curve drawn within this space to zero size without crossing any faces or edges. This rules out objects in which the enclosed space is toroidal, or polygonal tubes with both ends open.

An extended formulation

The primary aim of this note is to show the simple relation (2) can be extended to apply to crystal-like objects in a space of any number of dimensions. It could well be that this question has already been investigated and resolved by mathematicians, but I have no citations to make. Instead I rely upon the approach of the philosopher Ludwig Wittgenstein, who wrote "*I give no sources, because it is indifferent to me whether what I have thought has already been thought before me by others.*"

As a first step, equation (2) can be rewritten:

$$N_V + N_F = N_E + N_S + 1\,, \tag{3}$$

where N_S is the number of unconnected spaces contained within the object. For all the cases we have considered so far, $N_S = 1$, but it is easy to construct an example with a higher value of N_S. Suppose we begin with a simple cube, for which $N_S = 1$, so that it clearly satisfies (2). Now insert a partition parallel to one of the square surfaces of the cube. Because this partition divides each of the edges and faces that it intersects into two parts, this increases N_V by 4, N_F by 5 and N_E by 8, and, because the interior volume is now divided into two sections, increases N_S by 1. The relation (2) is still satisfied, and further divisions of the interior volume have similar results, provided they do not result in any torus-like structures.

If we examine the dimensionality of the objects referred to by terms in equation (3), we see that those on the left-hand side have dimension 0 and 2 respectively, while those on the right-hand side have dimensionality 1 and 3, omitting consideration of the final numerical term. This observation leads us to propose a generalization of (3) of the form

$$\sum_{n=0}^{\infty} N_{2n} = \sum_{n=0}^{\infty} N_{2n+1} + 1 \tag{4}$$

where N_n is the number of elements in the structure with dimensionality n, all elements being assumed to have simple geodesic form — points, straight lines, planes, etc.

It is straightforward to check this relationship in spaces with a small number of dimensions, since $N_n = 0$ if n exceeds the dimensionality of the space. For a zero-dimensional space only point vertices can exist and an object can have only one, so that $N_0 = 1$ and $N_n = 0$ for $n > 0$, thus satisfying (4). Such a zero-dimensional object can, of course, also exist in any space of higher dimensionality. For a one-dimensional space, and neglecting the case of a zero-dimensional object, a simply connected object with m point vertices must have $N_0 = m$, $N_1 = m - 1$ and $N_n = 0$ for $n > 1$, again satisfying (4).

Two-dimensional objects in two-dimensional space become more complex, since they may or may not enclose two-dimensional spaces. A simple cross has $N_0 = 5$, $N_1 = 4$ and $N_2 = 0$, satisfying (4). A square has $N_0 = 4$, $N_1 = 4$, $N_2 = 1$, again satisfying (4), and if we add a line joining two opposite edges then $N_0 = 6$ and $N_1 = 7$, since each of these edges is split into two separate one-dimensional objects, and $N_2 = 2$, again satisfying (4). The familiar three-dimensional case has already been discussed using the notation of equation (3).

Extension to objects and spaces with dimensionality higher than three remains a conjecture, but a steady progression through dimensionality exists. To convert from an object of dimensionality zero to a dimensionality of one in a space of dimensionality one or higher, we must add another point not lying in its zero-dimensional space and join them with on object of dimensionality one (a line). To convert from an object of dimensionality one (a line) to a minimal object of dimensionality two (a triangle), we must connect its vertices to a point not lying within its one-dimensional space. To convert from a triangle to a minimal object of dimensionality three, we must connect its vertices to an additional point not lying in its plane, thus making a tetrahedron. This leads us to surmise that, in order to create a minimal object of dimensionality four, we must take a tetrahedron and connect its vertices to an extra point not lying in the three-dimensional space that it occupies. Unfortunately it is nearly impossible for us to visualize such an object! Once again, following the discussion of three-dimensional objects, the applicability of the result must be restricted to objects with compact topology, eliminating those with the analog of toroidal structure.

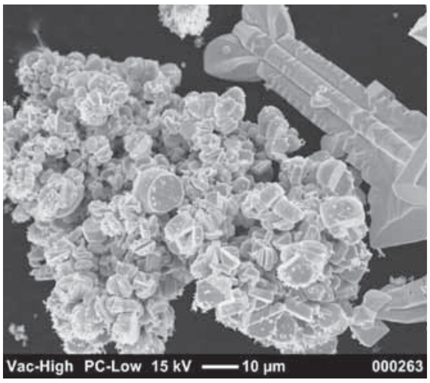
Conclusion

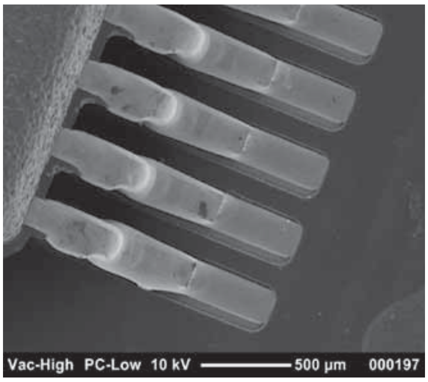
This short note takes a well-known theorem relating to the geometry of polyhedral crystalline forms in three dimensions, expresses it in a notation that is applicable in any number of dimensions, and conjectures that this extended version, which is demonstrably correct for objects in spaces of dimensionality three or less, can also be applied to similar objects of higher dimensionality embedded in spaces of higher dimension. With theoretical physics expanding into spaces with dimensions higher than twelve, this conjecture is perhaps worthy of further attention and could even prove useful. (Perhaps string theorists already know all about it!)

Product News

Coherent

NeoScope – Benchtop SEM





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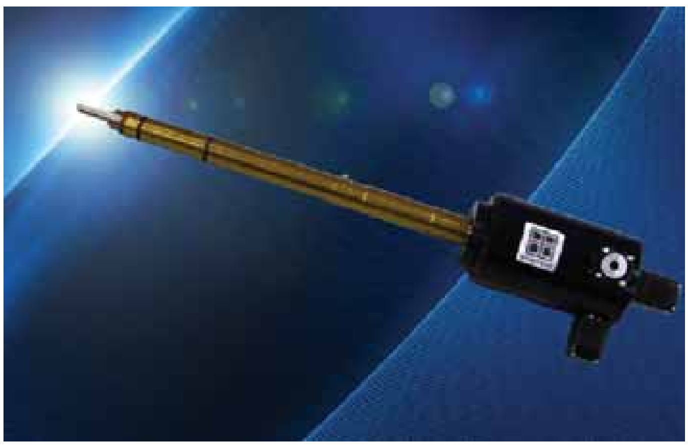

NewSpec

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Newport / Spectra-Physics have released the SCAN series OPO family, engineered by their partner firm GWU to offer superior performance in a compact, rugged package. With three series to choose from—the entry-level basiScan, versatile versaScan and premier premiScan—the Scan series will meet a wide range of budgets and needs.

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For more information contact Graeme Jones: *graeme.jones@newspec.com.au*

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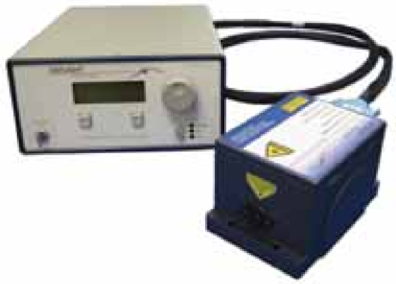

NewSpec are delighted to have signed an exclusive distribution agreement with Daylight Solutions. Daylight Solutions is the world's leading expert in tuneable, mid-IR lasers. Their products integrate Quantum Cascade Lasers (QCLs) in miniature external tuneable cavities, and use telecom-style packaging to deliver extremely small, high power, tuneable sources.

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» Extreme Sensitivity & Discrimination
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» Low Cost for Multiple OEM Applications

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Conferences 2009

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

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

December 7 - 9
AINSE/ANBUG Neutron Scattering Symposium, AANSS 2009
AINSE, Lucas Heights
http://www.ainse.edu.au/

December 14 - 16
ASTROMED09: The Inaugural Sydney International Workshop on Synergies in Astronomy and Medicine.
Sydney, Australia
www.physics.usyd.edu.au/astromed09

December 14 - 16
APSPT 2009: The Sixth Asia-Pacific International Symposium on the Basic and Application of Plasma Technology (APSPT-6)
Hsinchu, Taiwan, R.O.C
http://apspt6.must.edu.tw

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

2010

January 23 - 28
LASE 2010 – Part of SPIE Photonics West
San Francisco, USA
http://spie.org/lase.xml?WT.mc_id=Cal-PWL

February 14 - 18
EOS Topical Meeting on Diffractive Optics 2010
Finland
http://www.myeos.org/events/koli

February 15 - 18
Biology and Synchrotron Radiation
and
Medical Applications of Synchrotron Radiation
Melbourne, Australia
http://www.bsr2010.org
and
http://www.masr2010.org

February 22 - 25
META10, 2nd International Conference on Metamaterials, Photonic Crystals and Plasmonics
Cairo, Egypt
http://meta10.lgep.supelec.fr

March 10 - 14
EPC' 10: 4th Environmental Physics Conference
Hurgada, Egypt
http://www.physicsegypt.org/epc10/

March 22 - 25
European Conference on NanoFilms
Liege, Belgium
http://www.ecnf.eu

March 24 - 26
Asia-Europe Physics Summit: Physics towards Science Innovations
Tsukuba, Japan
http://aseps.kek.jp/ranst_en.html

May 24 - 26
Debris Flow 2010
Milan, Italy
http://www.wessex.ac.uk/10-conferences/debris-flow-2010.html

June 8 - 11
Recent Developments in Gravity
Ioannina, Greece
http://neb14.physics.uoi.gr/

June 14 - 16
Heat Transfer 2010
Tallinn, Estonia
http://www.wessex.ac.uk/10-conferences/heat-transfer-2010.html

June 22 - 25
Western Pacific Geophysics Meeting
Taipei, Taiwan
http://www.agu.org/meetings/wp10/

June 24 - 26
The International Symposium on Photonics and Optoelectronics (SOPO 2010)
Chengdu, China
http://www.scirp.org/conf/sopo2010/

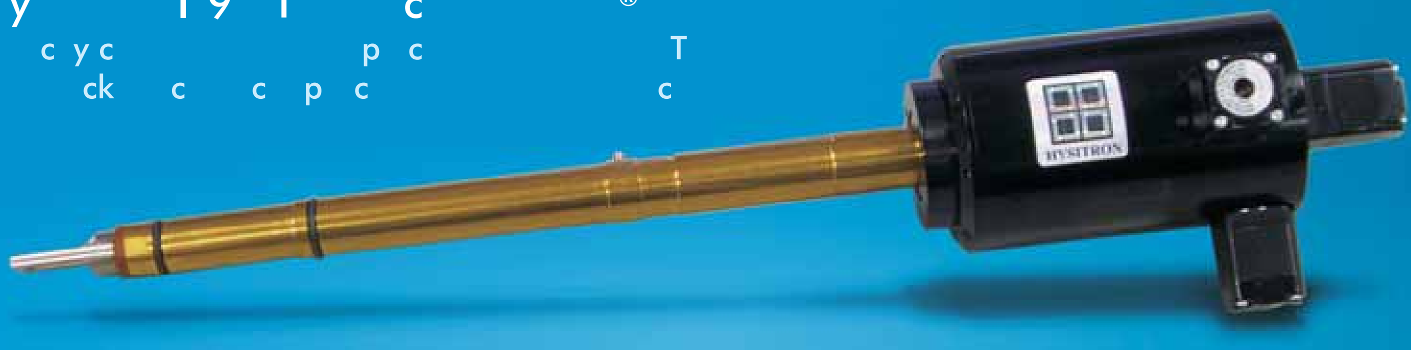
July 19 - 23
STATPHYS 24: The XXIV International Conference on Statistical Physics of IUPAP
Cairns, Queensland
http://www.statphys.org.au/

July 28 - 31
3rd Conference on Nonlinear Science and Complexity
Ankara, Turkey
http://nsc10.cankaya.edu.tr/

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

Direct Observation of Nanomechanical Processes

HYSITRON



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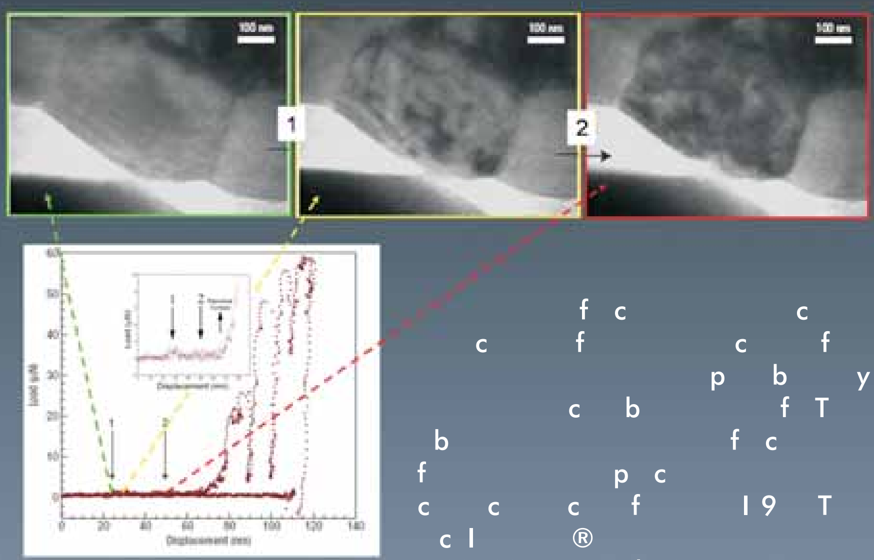
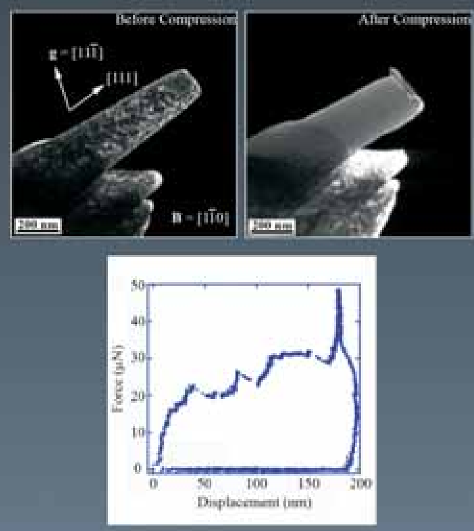


A.M. Minor et al., Nature Mat. 5, 697 (2006)



Z.W. Shan et al., Nature Mat 7, 115 (2008)