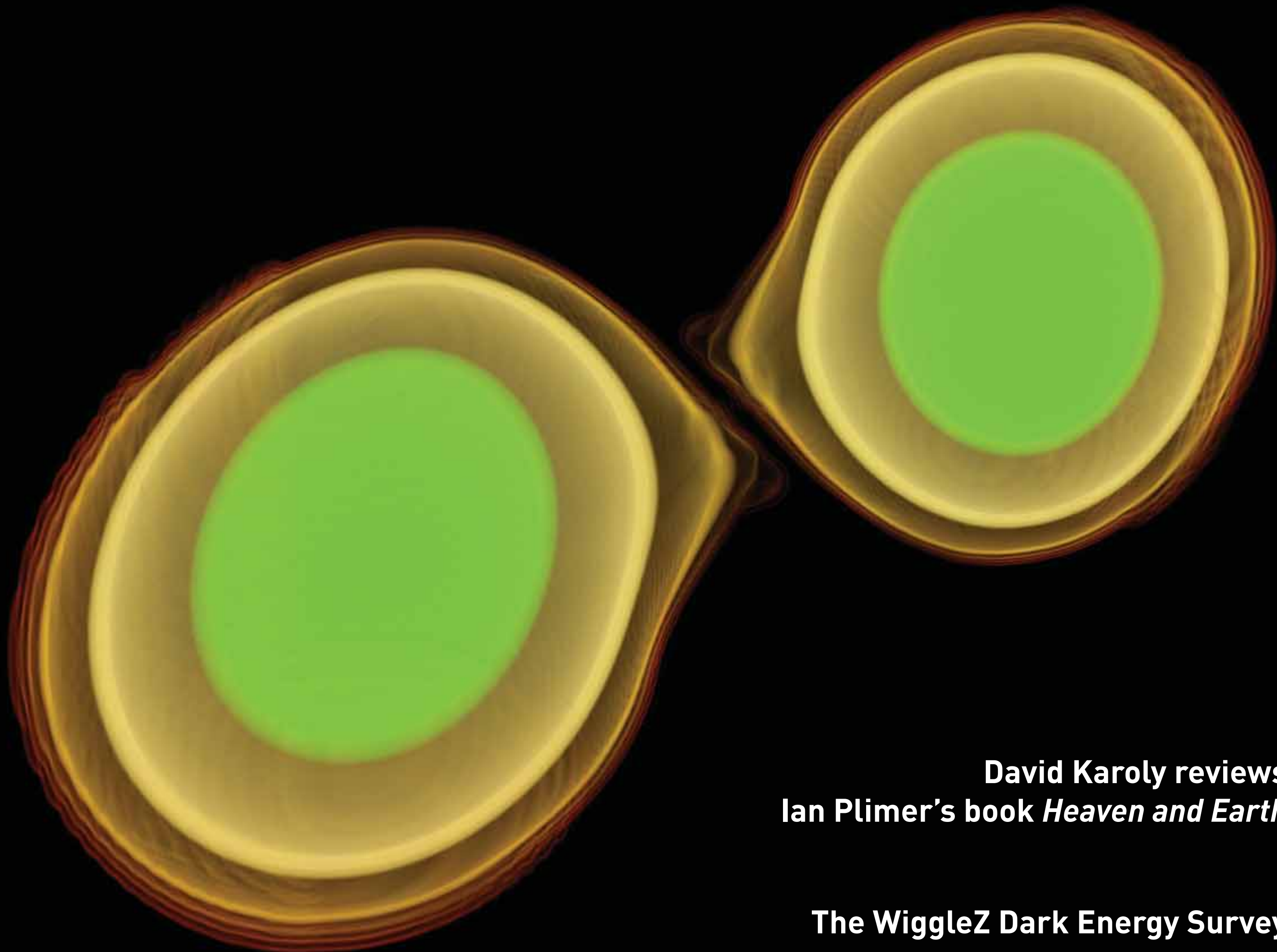
Australian PHYSICS

July/August 2009 Volume 46 Number 4

A Publication of the Australian Institute of Physics

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

The Australian International Gravitational Observatory



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Australian Physics
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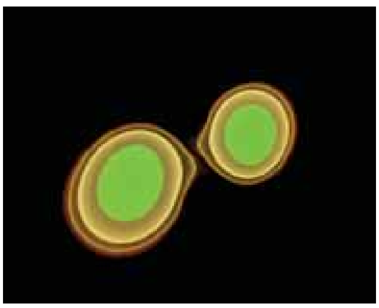
Write an article for Australian Physics

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

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



Cover Image

The image shows a snapshot of the inspiral of a neutron star binary. The two stars have equal masses of 1.46 solar masses. Eventually the binary system will merge because of the loss of angular momentum and energy, leading to a single neutron star that is too massive to resist gravity. This hypermassive neutron star therefore collapses after about 16 ms, leading to a Kerr (rotating) black hole surrounded by a torus of hot matter.
Image credit: Kaehler (ZIB/AEI), Rezzolla (AEI)

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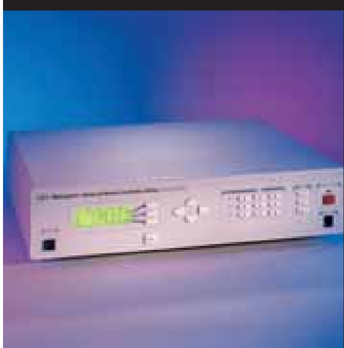

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Submission Guidelines
Articles for submission to Australian Physics should be sent in electronic format. Word or rich text format are preferred. Images should not be embedded in the document, but should be sent as high resolution attachments in eps,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

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Editorial

My earliest memories of an interest in physics always take me back to exploring the starry night – or more exactly to discovering the lunar surface. I grew up in a large city where my interest in astronomy led me outside frequently to battle with the light pollution, small as it was then. With my small telescope I chose to focus, forgive me, on the planets and moon so the light pollution would pose an insignificant detriment to my pleasure. My family was indifferent to my pursuits so I had to stay close to the safety of home, quite literally on the driveway, to do my observing. Therefore the moon was a recurrent companion.

I was only four years old when Apollo 11 landed on the moon and, as sure as I can be, the TV was set for the great moment. Obviously my age precludes any memory of a single image, thought or emotion when Armstrong stepped off the ladder; however, as my astronomical habit grew, the image of that boot print inset on the lunar dust was my inspiration. From foot prints on the sand, eventually we sailed the oceans – where will a boot print on the moon take us?

If all goes well for everyone concerned, myself included, we will get another chance to see a fresh boot print inlaid upon the lunar surface around 2020. After that it may be yet another generation before humans lay a boot print upon the Martian dust; but to Mars we must go. Robotic exploration can never take the place of human discovery. A pedestal, wheel or tractor print can never replace a boot print. The ability for humans to tweak, amend and adapt our surroundings and technology in order to overcome unexpected situations is crucial for future exploration. Indeed, it is exactly the reason we are who, and where, we are today.

There are many costs and risks involved in this class of adventure, not to mention that virtually all of the risks are to the lives of the explorers themselves; but humans not only take risks, we ask others to take them on our behalf. I am reminded of Galileo's character in Bertolt Brecht's *Life of Galileo*, when he denounces hesitation and incremental progress:

> *"Who takes big steps is given big boots. No hugging the coast; sometimes you must put out to sea."*

The sea awaits us.

John Daicopoulos

Correction

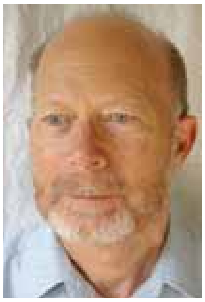
The Letter by Graham Day, which appeared on page 64 of the May/June 2009 issue, was incorrectly typeset. It implied a comment was written by Graham Day when in fact a quote, entirely attributable to T. Rothman, should have read:

... there is no mention of antiparticles in the two famous 1928 papers; those are devoted entirely to the fundamentals of the theory. The "prediction" comes two years later, in a 1930 paper Dirac titled "A theory of Electrons and Protons." Protons? ... When Dirac found his negative-energy solution, he realized that it could be described by a positive charge. The only particles around with positive charges were protons, and in his paper he quite clearly states "the holes...are the protons. He never says anything about antielectrons or antimatter."

[1] T. Rothman, Everything's Relative and Other Fables from Science and Technology, John Wiley and Sons, Inc., Hoboken, New Jersey, 2003

The Editor apologises for the error.

President's column



For many years I maintained a noticeboard on which I displayed job advertisements for physics students. Although the jobs were ones that I believed physics graduates (major, honours or PhD) were appropriately qualified to apply for, the advertisements frequently did not mention *physics*. In deciding whether or not to display a particular advertisement, I took account of my understanding of the generic skills and expertise of a physics graduate. When asked what aspects of a physics education enhance employability, most physicists will mention attributes such as problem solving ability and an analytic approach that can be applied widely, including outside the field of training. The American Institute of Physics captures these ideas when, in answer to the question, 'Why study Physics?' it proposes that[1]

> *a physics education equips a person to work in many different and interesting places …… where their problem-solving abilities and analytical skills are great assets.*

In a recent campaign to convince employers that, in contrast to a supposedly common belief that physics graduates are only suitable for working in laboratories (Physicists. Think.[2]), the UK Institute of Physics offered the following:

> *Physics is about solving problems and understanding how the world works and so physicists are brilliantly equipped to deal with all sorts of issues, from technological challenges to complex strategic planning.*

If, however, you ask a chemist or engineer about graduates in their fields you get fairly similar answers. In other words problem solving and analytical skills are seen as attributes of a sound scientifically based training, not peculiar to physics. If we want to distinguish physics from other disciplines we need to be more specific. Perhaps the AIP's accreditation program[3] can assist here: we require that an accredited degree, in addition to physics content, includes a specified minimum amount of mathematics. This is, in general, not required for the other sciences (although degree programs are often sufficiently flexible to allow such choices). Physics graduates are expected to not only be numerate, but to have a significant mathematical ability since the use of mathematics is fundamental to the practice of the discipline.

It helps explain why physicists have achieved much success outside physics: it is much easier for a physicist to apply these skills in another field than it is for a person trained in another field to acquire these skills. Physics graduates working in other fields are often involved in modeling, which, of course, requires not only quantitative skills but also an ability to apply them to the real world. With the ready availability of computing power, and generic computational tools, it is rare now for a physics PhD thesis, including largely experimental theses, to not include substantial modeling. As such skills are highly transferable it is not surprising that it is via modeling that many physicists enter a different field. This is not the only route, however: physics graduates also understand the principles of measurement and their application in a wide range of contexts, data analysis techniques and, importantly, how to assess the reliability of the results of measurements. These are also skills that are readily transferable, but not necessarily core parts of other science disciplines. While there is no justification for arrogance or claims of exceptionalism, I believe if is fair to claim that it is these core attributes of a physics education that distinguish it from other science disciplines.

So when I am asked 'what is physics?' or 'what does a physicist do? I start with a fairly standard response: physics is the study of the universe at its most basic and fundamental level, and as such it forms the basis of all science. But I go on to add that physicists are good at problem solving, have an analytical approach and are at ease in using mathematical techniques; they understand measurement and are alert to the issues of reliability of measurements. It would probably kill a social conversation, but I feel satisfied that I have given an answer that goes some way to distinguishing physics from other sciences.

1. *http://www.aps.org/programs/education/whystudy.cfm*
2. *http://www.iop.org/activity/careers/page_26755.html*
3. *The information for universities seeking accreditation indicates that the accreditation panel 'expects to see evidence of sequential development of physics and mathematics knowledge and skills'.*

AIP Web site:

www.aip.org.au

Branch News

Victoria

The May meeting of the Victorian Branch held at Swinburne University of Technology in Melbourne showcased the research of three early career researchers, Marcus Kitchen, Guangyong Zhou and Michael Mark. All three are current ARC Australian Postdoctoral Fellows.

Marcus Kitchen (Department of Physics, Monash University) reported on the 'Determination of lung morphology from X-ray phase contrast radiographs'. The lung's complex structure makes it difficult to detect minor morphological changes associated with early lung disease when using conventional clinical imaging. However, novel phase contrast imaging techniques can now provide high contrast images of the lung, with sufficient spatial resolution to detect the smallest respiratory micro-structure.

Experimental data, combined with numerical modeling, are being used to decode this information as a way of detecting respiratory disease. New phase contrast imaging methods are being trialed that enable two different images of the same object to be acquired simultaneously. The main benefit is that images can be segmented into separate thorax images of either bone or soft tissue, and thus make it possible to enhance disease detection within the lung tissue.

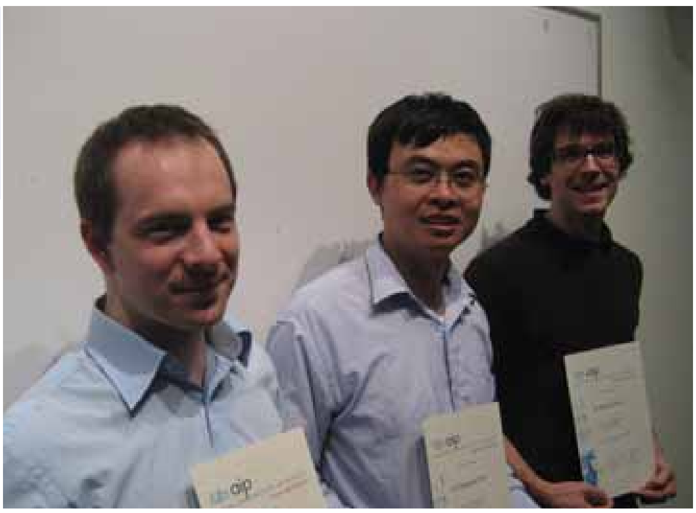
Guangyong Zhou (Centre for Micro-Photonics, Swinburne University) described his work on 'Nonlinear photonic crystal fabrication in a high refractive index lithium niobate crystal'. The speed of current silicon-based information and communication technology is approaching fundamental physical limits. To further increase the speed and capacity of computing and communication will require replacing electrons with much faster photons as the information carrier. To this end, artificial 'crystals' for photons - known as photonic crystals - with a periodicity in the micrometre range will need to be fabricated.

Recent work at the Centre for Micro-Photonics has led to the fabrication of micron-sized void structures inside nonlinear lithium niobate crystals, using a femtosecond pulsed laser. By using a method involving adaptive optics, the fabrication process can be improved leading to high-quality photonic crystals that have been demonstrated to be able to affect the radiation of light from it.

Michael Mark (Centre for Atom Optics and Ultrafast Spectroscopy, Swinburne University) reported on 'Fermionic superfluidity in lower dimensional quantum gases'. Research with ultracold quantum gases may provide answers to some of the key questions in modern physics, such as understanding exotic fermionic superfluids. Gases cooled to quantum degeneracy can be confined in a variety of geometries and are readily imaged using laser light. The interactions between particles can be widely tuned using magnetic field Feshbach resonances.

In ultracold gases the dimensionality of the system is crucial and leads to intriguing phenomena. Superfluidity in two-dimensional quantum gases - known as Berezinskii-Kosterlitz-Thouless (BKT) superfluidity - is different from three-dimensional gases. At Swinburne, laser-cooled lithium atoms are used to produce fermionic quantum gases in a two-dimensional environment. These gases in the Bose-Einstein condensate can be used to investigate the Bardeen-Cooper-Schrieffer crossover regime. Ultimately, our findings on BKT superfluidity may shed light on related fermionic phenomena such as superconductivity.

Marcus Kitchen (Monash), Guangyong Zhou (Swinburne) and Michael Mark (Swinburne)



NSW

The May meeting of the NSW branch was held at the University of Sydney on 26 May and featured a public talk by Professor Barry Allen. Professor Allen is the Director, Centre for Experimental Radiation Oncology at St George Cancer Care Centre where he runs the Targeted Alpha Therapy (TAT) project for developing new therapeutic agents for the treatment of melanoma, breast, prostate, pancreatic and other cancers.

Professor Allen, having published research papers extensively in fields as diverse as neutron physics, stellar nucleosynthesis, in vivo body composition and targeted cancer therapy, was in a position to provide a unique talk that successfully linked the creation of the elements in the early universe to cancer therapy.

His talk gave us an insight into how the creation of the elements, upon which all life forms are dependent, are due to a number of reactions. Charged particle reactions can produce elements up to iron, but we need the fast and slow neutron capture reactions to create the heavier elements.

Early in his career he studied the slow rate of nucleosynthesis of elements in stars by the sequential capture of keV neutrons up the valley of beta stability (s-process). His research group was able to validate this theory by the correlation of isotopic 30 keV neutron capture cross sections with solar system abundances, which showed the influence of the magic numbers across the periodic table over 5 orders of magnitude. The rapid neutron reaction process in supernovae (r process) created the neutron rich nuclides that decayed rapidly and led to the synthesis of the actinides.

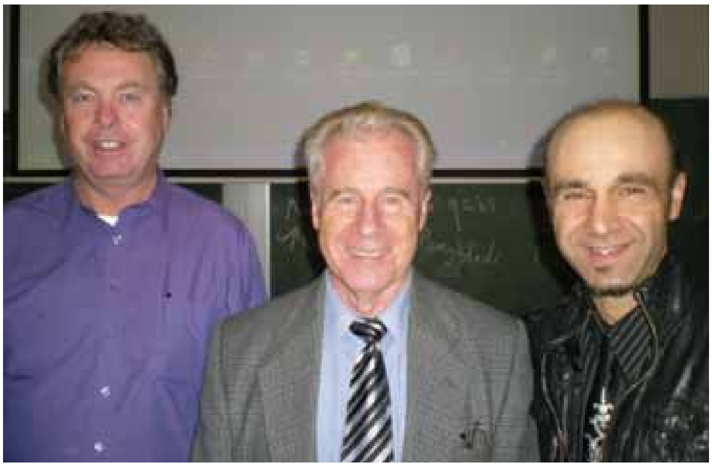


Photo: From left to right, Dr Graeme Melville (AIP Branch Secretary), Professor Barry Allen and Dr Fred Osman (AIP Branch Chair).

Professor Allen went on to explain how 40 years later (today), the products of the stellar nucleosynthesis are being used to kill cancer cells. With the development of monoclonal antibodies, a small band of biomedical scientists have brought these two Nobel prize winning achievements together to create targeted alpha therapy (TAT) for cancer. In spite of many setbacks, researchers at St George Hospital have taken TAT for metastatic melanoma from the test tube to the bedside.

Clinical trial results so far point to a very promising therapy. Things have been far from easy, however. A combination of a lack of funding and 'general disinterest or apathy' on the part of sections of the medical community, have threatened to halt the research program.

Despite the setbacks, the world first trials of intralesional and systemic TAT for melanoma have gone ahead. Some 40% of end-stage melanoma patients received a benefit in the ongoing systemic trial, without any evidence of adverse events.

Professor Allen told of how a very unusual result arose from their research. TAT was thought to be only useful on micrometastic tumours, however, solid tumours in patients also showed significant regression. The reason for this was at first unclear as targeted antibodies have not been known to rapidly penetrate a tumour mass, as required by the attached short lived radioisotope. However, it was found that the antibodies disrupted the capillaries leading to the tumour, thus indirectly attacking the tumour. This has led to a new approach to the regression of solid tumours which points to improved therapeutic efficacy for TAT.

The combination of Professor Allen's deep inside knowledge into these areas and sense of humour, meant the talk was highly entertaining from start to finish and well received by the audience. The Australian Institute of Physics thanks Prof Allen for an outstanding lecture!

The June meeting of the NSW branch was held at the University of Sydney on 23 June and featured a public talk by Professor Bryan Gaensler. Bryan Gaensler is a Professor of Physics at The University of Sydney, and is a Federation Fellow of the Australian Research Council. Prof.

Gaensler was awarded his PhD in Physics from The University of Sydney in 1999, and subsequently held positions at the Massachusetts Institute of Technology, the Smithsonian Institution and Harvard University, before returning to Australia in 2006.

Prof. Gaensler's current research interests focus on Cosmic Magnetism. A remarkable discovery made by 20th century astronomers was that the Universe is magnetic. These cosmic magnetic fields play a vital role in controlling how stars and galaxies form and evolve. This naturally occurring magnetism also regulates solar activity, protects the Earth from harmful particles, and is vital for the navigation of birds and other species.

He is currently working to open the window to this "Magnetic Universe" by exploiting an effect called "Faraday rotation", in which light from a background object is subtly changed when it passes through a cloud of magnetised gas.

Prof Gaensler and his team are carrying out detailed measurements using radio telescopes in Australia and in the USA. With these measurements, they can detect magnetic fields throughout the Universe! The observations that they are carrying out are resulting in three-dimensional maps of cosmic magnetism, which are revealing what these magnets look like and what role they have played in the evolving Universe.

His talk gave us an insight into the Earth's magnetic field as not just a curiosity or a handy navigation aid, but one that is vital for the existence of life. The Sun continually generates a stream of high energy charged particles that flow out in all directions as part of the solar wind. Exposure to this particle stream can cause serious damage to living tissue; any humans who one day travel to Mars will need heavy shielding around their spacecraft to protect them from this onslaught.

Just in the past 10 years a new class of stars, "magnetars", has been discovered. These bizarre beasts are only about 25 km across, and appear to be the most magnetic objects in the Universe, with magnetic fields up to 10^{15} times stronger than the Earth's! In comparison, the most powerful magnet ever constructed in the laboratory produces a field that is a mere million times stronger than the Earth's.

Prof Gaensler summarised that new discoveries will undoubtedly provide the answers to many long-standing problems, but at the same time they will raise a new set of magnetic mysteries for the next generation of astronomers to puzzle over.

The talk was very well received and geared to scientists and members of the public alike. The Australian Institute of Physics thanks Professor Gaensler for his outstanding lecture!

Dr Graeme Melville - AIP NSW Branch Secretary

Australian Institute of Physics

2009 Award for Outstanding Service to Physics in Australia

Background and Aim
The Australian Institute of Physics has several awards for excellence in some aspect of Physics. They are usually based on the research contributions of the individual or group concerned.

There are many individuals within the AIP who give great amounts of time and effort to the furtherance of Physics as a discipline. While some of these would also be contenders for one or other of the more research oriented awards, others would not. They tend to be quiet achievers, sometimes more devoted to teaching and its development than to research.

The AIP inaugurated an award for Outstanding Service to Physics in Australia in 1996.

Eligibility/Procedure
The award will be open to members of the AIP. Nominations may be made by a Branch Committee or by three members of the AIP. There will be no more than three awards nationwide in any one year and the Selection Committee, which will be appointed by the Executive, will reserve the right to make no awards in any one year.

The AIP Award for Outstanding Service to Physics will recognise an exceptional contribution on the part of an individual. Nominations should be accompanied by a clear one or two page citation describing the outstanding service given by the nominee.

Timelines
Nominations should reach the Hon. Secretary, at *aip_secretary@aip.org.au* or Olivia Samardzic, 205 Labs, EWRD, DSTO, P.O. Box 1500, Edinburgh, SA 5111 by 1 Sep 09.

The results of the decision of the judging panel will be announced in November of each year.

Previous winners
1996 Professor Rod Jory, ANU (among many other achievements, Prof Jory has organised the Australian Physics Olympiads teams)

2001 Professor Mike Gore, ANU (for development of Questacon Interactive Science Centre, now the National Science Centre in Canberra)

2002 Mr Dan O'Keeffe, Camberwell Grammar school (for work on Physics education, at the national level, especially the Switched on to Physics program)

2003 Ms Moira Welch (for her outstanding service to the AIP, including her role as NSW Branch Chair and AIP Honorary Secretary)

2003 Prof. J. Prescott (for many years of service, particularly in employment surveys and physics job advertisements)

2007 Prof. Colin Keay (for his contributions as editor for all versions of the publication of the AIP for many years)

2009 Walter Boas Medal

Background and Aim

The Medal was established in 1984 to promote excellence in research in Physics and to perpetuate the name of Walter Boas (University of Melbourne 1938-47, CSIRO 1947-69). The award is for physics research carried out in the five years prior to the date of the award, as demonstrated by both published papers and unpublished papers prepared for publication, a list of which should accompany the nomination.

Any AIP member may make nominations or may self nominate for the award.

Eligibility/Procedure

Nominees should be members of the AIP and Australian citizens and should have been residents of Australia for at least five of the seven years preceding the closing date for nominations. The Medal shall not be awarded more than once to any person.

The award shall be given for original research making, in the opinion of the examiners, the most important contribution to physics. This will be judged in papers published during the four years immediately preceding the date on which entries for the award close, supported where appropriate by unpublished papers or reports on work carried out during that period.

If a candidate considers that knowledge of work carried out prior to the four year period is necessary for the correct evaluation of the record of work submitted for the award, reference may be made to the work where published, or an unpublished account of such previous work may be submitted.

Supporting Information

Candidates for the award should provide the following:

- A brief curriculum vitae covering personal details, academic and professional qualifications, outline professional career history, and honours and distinguished awards. A full CV is not necessary.
- A short account of the research achievements of the candidate (or candidates if there is a joint submission) setting out the achievements on which the application rests and drawing attention to those articles that are important.
- A list of relevant publications, patents and reports by descriptive title and reference related to the achievements on which the application is based. Where heavy reliance is placed upon material not reasonably available, a copy of this material may also be submitted.
- Candidates are invited to provide the names of up to three internationally known referees who have the appropriate expertise to offer a critical appraisal of the candidate's achievements.

Timelines

Nominations should reach the Hon. Secretary, at *aip_secretary@aip.org.au* or Olivia Samardzic, 205 Labs, EWRD, DSTO, P.O. Box 1500, Edinburgh, SA 5111 1 Sep 09.

Presentation of the Award

The award is conditional on the recipient delivering a seminar on the subject of the award at a meeting of the Victorian Branch of the AIP in November. The recipient is also expected to provide a manuscript based on the seminar for publication in Australian Physics.

Previous winners

2005 Professor Yuri Kivshar, Nonlinear Physics Centre, ANU
2006 Professor Michael Tobar, University of WA
2007 Professor Derek Leinweber, University of Adelaide, SA
2008 Professor Peter Drummond, University of Queensland

The Australian International Gravitational Observatory

by David Blair and Jesper Munch on behalf of the Australian Consortium for Gravitational Astronomy

Building a single gravitational wave detector in Australia improves all the gravitational wave detectors in the world. It improves their sensitivity and their angular resolution, their ability to probe general relativity in the strong field limit at black hole event horizons, and to probe cosmological distances.

Normally scientific instruments stand on their own merits. They have a proposed scientific program and do as well as their performance allows; if one instrument is better than another, then it can do better science. So what can be the justification for building a new scientific instrument, rather similar to others in the world and with only one new feature - it's location being Australia? A sceptic might say it has already been done elsewhere, so there is no point. Another might say if it can only increase the quantity of data…there will be nothing qualitatively new.

In the field of gravitational wave detection nothing can be further from the truth. A new gravitational wave detector in Australia improves all the other detectors in the world. In this article we will outline how this can happen, but first we will summarise the development of the field, then outline the concept for AIGO, the Australian International Gravitational Observatory, and finally discuss the enormous advances this observatory can bring to our understanding of the universe.

Gravitational Wave Research in Australia and the World

The effort to build sensitive gravitational wave detectors began with the construction of big bars of metal, first at room temperature, then cooled to cryogenic temperatures, and all equipped with vibration sensors to pick up the tiny gravitational wave strains expected from the birth of black holes according to Einstein's General Theory of Relativity.

In Western Australia during the 1990s a detector called Niobe, consisting of a 1.5 tonne bar of niobium, participated in a worldwide network of 5 detectors (called the International Gravitational Events Collaboration) that placed significant limits on the rate of black hole births in our galaxy. In those days there were hopes that the missing mass might consist of a population of black holes, some of which might coalesce creating strong gravitational wave bursts. Such events now seem to be more rare than the early experimenters had hoped.

The next step in sensitivity was to construct large scale Michelson interferometers, which could measure the gravitational wave-induced spatial strains between widely spaced mirrors. Four huge detectors were constructed at three locations in the USA and Italy. The US LIGO detectors consisted of interferometers with 4 km long arms, while the French-Italian detector VIRGO had 3 km arms. Smaller detectors were constructed in Germany and Japan. Figure 1 shows one of these detectors from the air.

After several years of development, the LIGO detectors collected one year of data at high sensitivity. This landmark improved the sensitivity to known sources by an enormous factor. The sensitivity was sufficient to detect gravitational waves originating from far beyond our own galaxy, out to a distance of almost 50 million light years, sufficient to encompass on order of 10^3 galaxies. VIRGO achieved comparable results.

By the time approvals for building the LIGO and VIRGO detectors were received, there was a good theoretical understanding of at least one type of source for which the population was relatively well known. These sources are coalescing binary neutron stars such as the famous binary pulsar system, which was used by Hulse and Taylor to prove the existence of gravitational waves (Nobel prize 1993).

Unfortunately neutron stars coalesce relatively infrequently in our galaxy…maybe once every 10^4 years. That means that 10,000 Milky Way equivalent galaxies must be within range to detect an average of one event per year. Thus LIGO had a relatively small probability (~10%) of detecting an event in one year of observation, and so it is no surprise that events have not been reported.

The above statistics were well known at the time LIGO was proposed. The initial detectors were intended to be only the

Figure 1 The VIRGO gravitational wave detector near Pisa, Italy.

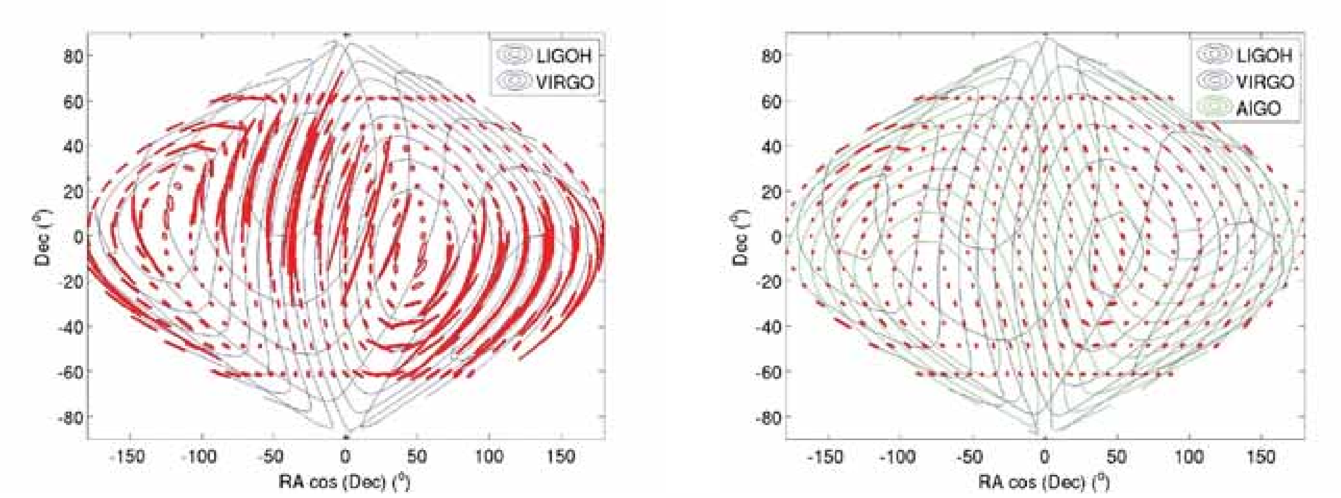


Figure 2: The angular resolution of the world array of gravitational wave detectors without and with AIGO. The ellipses represent the error box for a gravitational wave signal from each direction on the sky.

first step in a process that promised to open the gravitational wave spectrum to astronomy. They were intended to prove the technology and pave the way for a much-improved design called Advanced LIGO. VIRGO had similar development plans. The first step was essential because many scientists were sceptical that it would ever be possible to measure the very small gravitational wave strains required – strains at the 10^{-23} level corresponding to distance changes of ~10^{-19} m. The Advanced detectors have been designed to increase the sensitivity by one order of magnitude, in order to be certain of detecting signals, unless either gravitational physics was radically wrong or nature had unkindly located neutron star binaries in our galaxy alone. In either case, non-detection would be as significant as the missing neutrinos from the sun which eventually uncovered neutrino mass.

Advanced LIGO is now under construction and by 2014 should be approaching design sensitivity. Before these detectors and Advanced VIRGO come on line a run at intermediate sensitivity is planned by LIGO. In this run there is about a 50-50 chance of detecting a neutron star inspiral signal in one year of data.

Thus gravitational radiation is getting tantalisingly close to the first direct detection. The community is focussed on the imminent opening of this new spectrum for observing the secrets of the Universe and the enormous scientific opportunities it will bring.

How can one detector improve all the other detectors?

Gravitational waves are transverse waves of gravity gradient. They come in two polarisations 45 degrees apart and travel at the speed of light. With current technology they must be located flat on the earth's surface. Individual gravitational wave detectors have poor directional sensitivity – comparable to that of a single human ear. They are also susceptible to interference from electromagnetic, seismic or acoustic sources. One detector alone cannot be certain of having detected a signal because interference can be indistinguishable from a signal. The probability of interference glitches occurring accidentally in a network of detectors reduces as the power of the number of detectors. Each additional detector makes an enormous contribution, allowing the network to dig out events that otherwise cannot be separated from the noise. In addition, widely spaced detectors can use triangulation based on signal arrival times to determine the source direction. It is thus reasonable to think of the single detectors as relatively unimportant by themselves, but as essential components of a single global observatory.

Gravitational wave detectors are L-shaped to match the displacement pattern of a plane-polarised gravitational wave: when one arm of the L is stretched the other arm shrinks. The detectable part of the spectrum using ground based interferometers occurs at audio frequencies between 10 Hz and a few kHz, which correspond to signals expected from both neutron star and 1-50 solar mass black hole coalescence events. Ideally each observatory would have pairs of detectors located at 45 degrees to each other, to give sensitivity to both polarisations. However even this is not sufficient because gravitational waves are transverse waves and detectors are constrained to be flat on the earth's surface for practical reasons.

Why care about polarisation?

If you can measure both polarisations of a binary coalescence event, the signal carries with it a *complete description of the system*, including both the masses of the binary pair and the orientation of the source. When you measure both polarisations the system is so well constrained that the signal basically carries with it a message about its distance. The sources are true standard candles, or as gravitational wave physicists like to say, standard sirens. Like a siren, the frequency rises in a chirp as the coalescence proceeds. (You can hear and view such signals at the Black Hole Hunter website.)

The best way of obtaining polarisation coverage is to spread detectors around on the spherical Earth. This is fine if you have enough detectors, but if you have only two or three locations this solution could be very dangerous, because the signals can be so different from each other that you

may interpret them as noise: you can lose the advantage of coincidence detection.

Thus three detectors focussed on initial confirmation of gravitational wave signals are best if they are co-aligned as well as possible. But once detection is achieved there is a strong benefit in adding another one that is able to sample the orthogonal polarisation. If the additional detector is maximally distant from the others, and if it is out of the plane, it has the added advantage of being able to combine polarisation coverage with time of flight phase delay to both locate the source on the sky and determine its distance.

Analysis of signals from an array can be undertaken coherently. Effectively we can think of detectors sampling part of an incoming wavefront, and like Very Long Baseline Radioastronomy, the combined signal is equivalent to that from an enormous telescope with angular resolution set by the spacing of the detectors. The source location can be defined to quite high precision, limited, like electromagnetic telescopes, only by the diffraction limit. Because the detectable range of wavelengths is quite large (typically a few hundred kilometres) the angular resolution is a few arc minutes.

One way to represent array sensitivity is to plot the error circles for sources uniformly distributed on the sky. Figure 2 shows the angular resolution of the current large-scale detectors, compared with how it is improved by adding a detector in Australia. The results are dramatic: the error ellipses that were tens of degrees long have turned into sub-degree sized uncertainty regions.

If you can locate gravitational wave sources to reasonable precision it becomes possible to use gravitational wave signals to direct optical and radio telescopes to image the region of the outbursts. With an Australian detector the directional resolution of the global array matches well to the field of electromagnetic telescopes.

One of the main candidates is gamma ray bursts. It is thought that some gamma ray bursts are neutron star coalescence events. The bursts that are detected from space at a rate of one every few days, appear to be strongly beamed so that only observers in the line of sight can see their direct emission. Out of the line of sight there should be a very weak afterglow that would normally be very difficult to detect. However a gravitational wave beacon can make all the difference: it allows deep electromagnetic imaging so that events can be correlated across two separate spectrums – electromagnetic and gravitational.

What can we learn from such correlated observations? First it allows a completely independent measure of the Hubble law. The luminosity distance is measured by the gravitational wave signal. The red shift is measured from electromagnetic

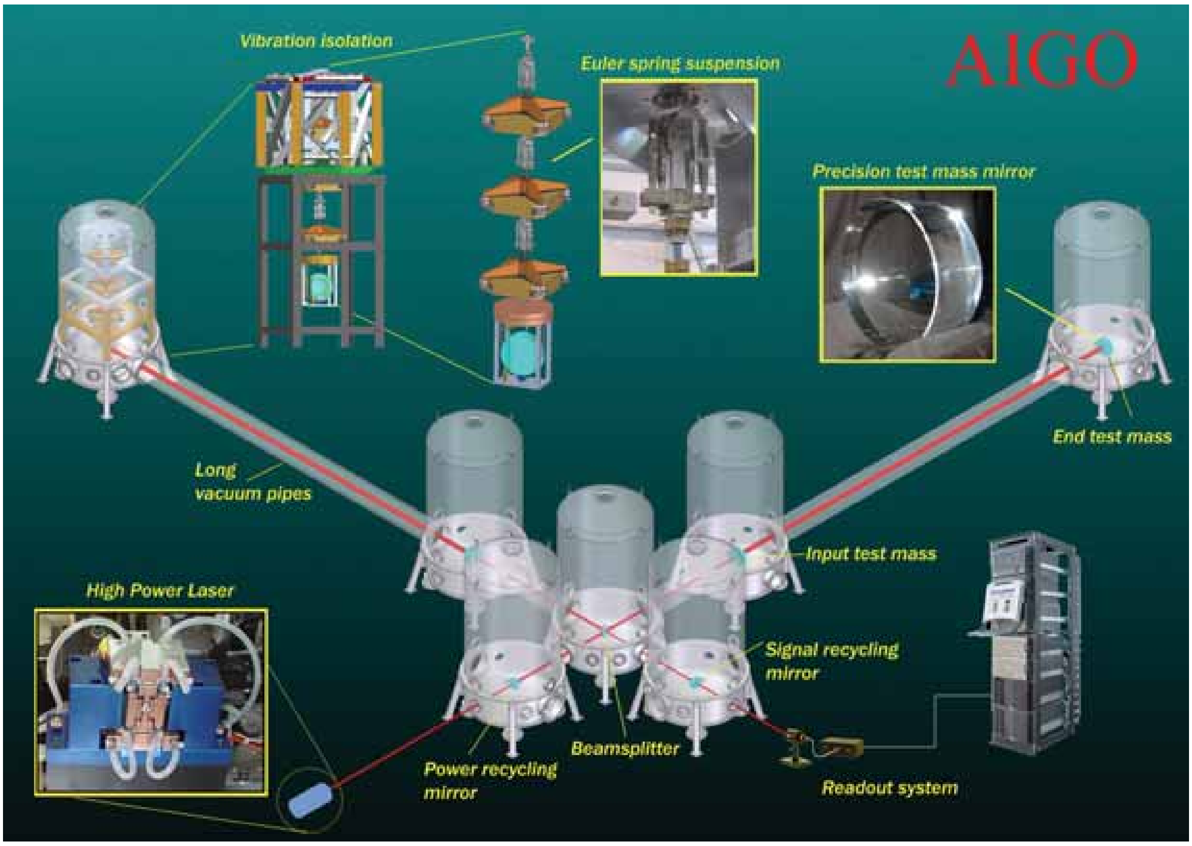


Figure 3: The design concept for AIGO. Powerful laser beams traverse two 4km vacuum arms that form a high sensitivity, high optical power Michelson interferometer. Fabry-Perot arm cavities, plus additional power and signal recycling cavities combined with high performance vibration isolation and precision low acoustic loss test masses create a system capable of detecting time varying strains in space with dimensionless amplitude ~ 10^{-24}.

observations of the afterglow, or if this is not observed, then the red shift can be measured for the host galaxy of the event. This allows direct determination of the Hubble Law and cosmic acceleration. Second, by comparing the arrival time of electromagnetic waves and photons we can make an accurate measure of the velocity of gravitational waves, which currently is only known as a theoretical prediction. Third, with gravitational waves describing the internal dynamics of the source, and electromagnetic waves describing the external structure and processes in the sources, we should finally be able to explain how these prodigious outbursts of energy occur.

The coalescence of binary black holes is another very likely source of gravitational waves. Stellar evolution theory predicts binary black hole coalescence events occurring at a rate of a few to a few hundred detectable events per year. Coalescing black holes may not have an electromagnetic signature. However because they are also standard candles, a detector array can locate them three dimensionally (angular position and distance) which in many cases can enable their host galaxies to be identified. Once this is done we can again use them for probing cosmology.

The case of black hole coalescence is one of the most exciting targets for gravitational wave detectors. This is because black hole signals allow a very clean observation of the physics of spacetime at the extremes of strong field gravity where two event horizons merge into one. These observations will constitute very deep tests of general relativity. It will be possible to test predictions of general relativity such as the black hole surface area theorem (the surface area of black holes must always increase) the no hair theorem (black holes are entirely characterised by their mass, charge and angular momentum) and the cosmic censorship conjecture (singularities must always be clothed by an event horizon).

Most of the above science is dependent on an improved gravitational wave detector array that allows accurate localisation and description of sources. The detector in Australia does this better than any other location in the world.

The Plan for AIGO

Australia currently has very strong participation in the US LIGO project. Three experimental groups and two theory and data analysis groups constitute about 50 scientists who are all actively involved.

The world community of about 1000 gravitational wave researchers is naturally enthusiastic that a detector be built in Australia. The LIGO project has offered to help Australia build a detector very similar to Advanced LIGO. The experimental research groups at ANU (Centre for Gravitational Physics), Adelaide (Laser Physics Group) and UWA (Australian International Gravitational Research Centre) have extensive expertise in key research areas, while data analysis and theory groups at Melbourne, Monash and Charles Sturt University as well as ANU and UWA contribute to the massive worldwide gravitational wave data analysis effort. The Australian Consortium for Gravitational Astronomy (ACIGA) has developed a High Optical Power Facility in Gingin, Western Australia, on a potential site for AIGO 80 km north of Perth.

If you can locate gravitational wave sources to reasonable precision it becomes possible to use gravitational wave signals to direct optical and radio telescopes to image the region of the outbursts.

Two Australian groups (ANU and Adelaide) are supplying key components for Advanced LIGO, while the UWA group is researching aspects of high optical power technology which is the essential enabling technology to allow Advanced LIGO to achieve its planned sensitivity.

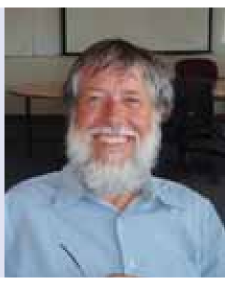
Currently ACIGA has created a roadmap and a business plan for AIGO and is working towards an international / national collaboration to build the $150M AIGO. Two advisory committees have been assisting nationally and internationally in creating the plan for AIGO. Currently the plan involves constructing a detector nearly identical to Advanced LIGO, but making use, where preferable, of Australian developed vibration isolation technology, Australian lasers and Australian optics created by the Australian Centre for Precision Optics in the CSIRO. A major part of the AIGO project will be 8 km of high vacuum pipe used for the interferometer beams. Fortunately Australia has an innovative company STM Duraduct with expertise and experience in such UHV fabrication. Figure 3 shows a concept cartoon for AIGO showing the massive vacuum system and internal components. The AIGO site has not been formally chosen yet, but the Gingin site is a strong candidate.

Thus Australian scientists are poised and ready to build this exciting international science project. We in the team believe that it "ticks all of the boxes" – jobs, industry relevance, local manufacture, boosting education and training, encouraging young people to take up science careers, international significance and international investment.

Further reading

Ground-based gravitational-wave detection: now and future: Stanley E. Whitcomb 2008 *Class. Quantum Grav.* 25, 114013
Ripples on a Cosmic Sea. David Blair and Geoff McNamara 1997 Australian edition Allen and Unwin, US Edition: Addison Wesley

David Blair is Director of the Australian International Gravitational Research Centre, a WA Centre of Excellence. He has been working in the area of gravitational waves for many years, and is a member of the team proposing to build the Australian International Gravitational Observatory, AIGO. He was WA Scientist of the Year in 2007.



The WiggleZ Dark Energy Survey

by M.J. Drinkwater[1], C. Blake[2], K.A. Pimbblet[1], T.M. Davis[1], S. Brough[2], M. Colless[3], W.J. Couch[2], S. Croom[4], K. Foster[5], K. Glazebrook[2], R.J. Jurek[1], B. Madore[6], D.C. Martin[5], G.B. Poole[2], M. Pracy[2], R. Sharp[3], D. Woods[7], T. Wyder[5]

Abstract

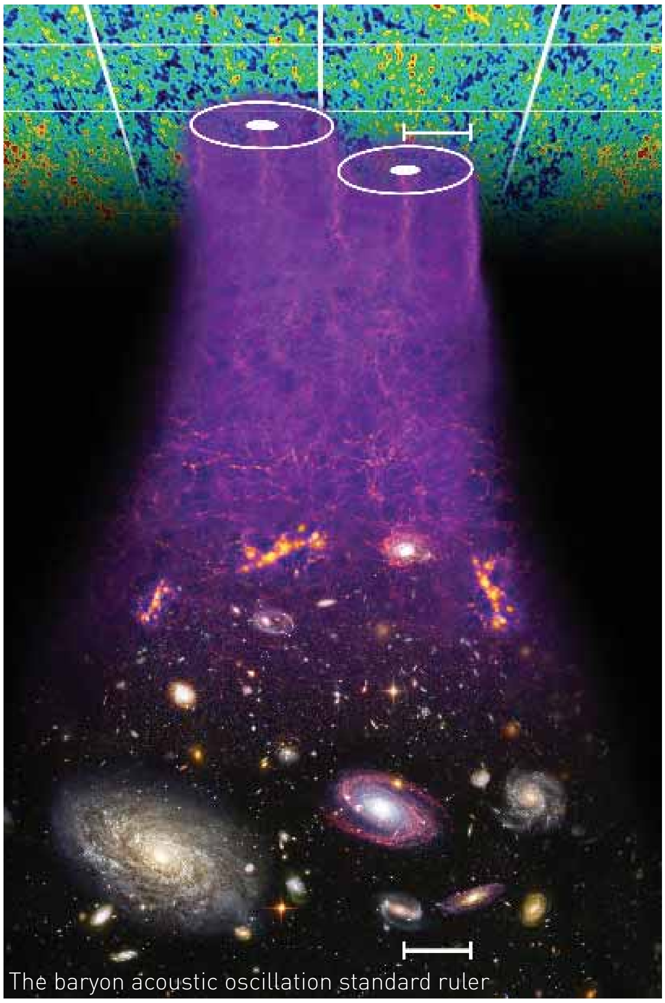
The WiggleZ Dark Energy Survey is an Australian-led project, which will measure some 240,000 spectroscopic redshifts of distant emission-line galaxies with the AAOmega spectrograph of the 3.9-metre Anglo-Australian Telescope. The aim of the project is to measure the scale of baryon acoustic oscillations (BAO) imprinted on the spatial distribution of the galaxies. The BAO scale can be used as a standard ruler to measure cosmic distances. Our BAO measurement will be accurate to 2 per cent and will constrain theories of dark energy. In this article we describe the design and initial results of the project, which started in 2006 and is scheduled to finish observations in 2010. The target galaxies are selected by detecting the Lyman break in ultraviolet photometry from the Galaxy Evolution Explorer satellite. We show that our selection process is very effective in choosing galaxies with strong emission lines and high redshifts; the strong lines allow reliable redshift measurements in relatively short exposures on the telescope.

1 Introduction

One of the major triumphs of modern cosmology in recent years is the extraordinary precision with which the key properties of the universe can now be measured. The age, expansion rate, geometry, matter and energy content of the universe are now determined to a precision of better than 10%; we have entered the era of "precision cosmology" [1].

Paradoxically, our success in measuring these "cosmological parameters" has revealed an enormous gap in our knowledge of the underlying physics of the Universe. This was already noted in the early 1990s as it became clear that the Universe was geometrically flat, but the matter density was well below the critical value, requiring an additional (large) contribution from a non-zero cosmological constant term [2]. The need for this additional term was confirmed when studies of distant supernovae revealed that the expansion rate of the universe is accelerating [3,4]. This was perhaps the most startling breakthrough in cosmology since Hubble's demonstration of the expansion itself. Despite initial scepticism, the conclusion that the universe is accelerating has strengthened to the point where few doubt its accuracy, because of the strong agreement between different measurement methods [5-8].

The problem is that we cannot explain this acceleration. It requires new physics: either gravity must be fundamentally different from the vision put forward by Einstein, or the cosmic energy budget must be dominated by a new form of matter which has a negative pressure—"dark energy" [9]. The U.S. National Academies' Board on Physics and Astronomy has identified the nature of dark energy as one of the key "Science Questions for the New Century" [10]. In response to this challenge, several large, high-redshift, galaxy surveys have been proposed to test models of dark energy.



The distribution of galaxies contains the imprint of a standard ruler that will be measured by the WiggleZ project. In this illustration time runs from the top to the bottom. At the top, the two bulls eyes represent the imprint of baryon acoustic oscillations on the distribution of matter, detected in the cosmic microwave background radiation. Galaxies later form preferentially at the centres and edges of the bulls eyes where there are higher matter densities. This creates a preferred separation scale or "standard ruler" in the final distribution of galaxies at the bottom, that cosmologists can use to measure cosmic distance. [Image credit: Sam Moorfield, Swinburne University.]

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Figure 1. The 3.9-metre Anglo-Australian Telescope, situated at Siding Spring Observatory in central New South Wales, Australia.

The first of these to commence is the WiggleZ survey, made possible by the availability of the highly sensitive multi-object AAOmega spectrograph of the Anglo-Australian Telescope. In the rest of this article we describe the design of the survey, our current progress and our expected results.

2 Survey Design

There are three major features in the design of the WiggleZ survey, described in this section. The first is our use of a geometrical measurement to make an independent test of dark energy. Then we use ultra-violet imaging data to select high-redshift emission line galaxies and, finally, we use the highly efficient AAOmega spectrograph to confirm the galaxy identifications and measure their redshifts.

2.1 Measuring Dark Energy with Baryon Acoustic Oscillations

A powerful and independent way to measure the effects of dark energy is to use geometrical relations between distance and redshift, as these are a function of the cosmological parameters, notably the nature of the dark energy contribution. For such tests we require a “standard ruler”, a known physical scale whose observed angular size can be measured as a function of redshift. Fortunately, such a standard ruler scale does exist: the baryon acoustic oscillation (BAO) scale imprinted on the distribution of baryonic matter at recombination in the early Universe. The BAO signal has been measured in the cosmic microwave background [11] (i.e. at recombination) and, more recently, in the present-day galaxy distribution [12, 13]. These galaxy samples are too close to measure dark energy, but they establish the feasibility of the BAO method. Measurement of the BAO scale in the galaxy distribution at high redshifts will give a powerful test of the dark energy models [14]. The name of our WiggleZ survey is based on the wiggles imposed on the galaxy power spectrum by the baryon acoustic oscillations and the redshifts (z) we measure.

2.2 Target Selection

Our galaxies are primarily selected using ultra-violet photometry from the Galaxy Evolution Explorer (GALEX) satellite [15] in two ultraviolet bands, the FUV from 135–175 nm and NUV from 175–275 nm. We detect galaxies in the NUV filter and then use the NUV/FUV ratio of their fluxes to select high-redshift galaxies. This works because the observed FUV flux of a galaxy drops rapidly as the redshift increases past $z=0.5$ as the Lyman break[1] in the (rest wavelength) galaxy spectrum shifts into that filter. We use additional optical photometry to further improve the fraction of galaxies with high redshifts.

2.3 Spectroscopic Observations

The WiggleZ survey would not be possible without the Anglo-Australian Telescope’s new multi-object spectrograph AAOmega and the existing robotic fibre positioner 2dF (named after the two-degree diameter of the field of view on the sky). We show an external view of the AAT in Fig. 1. The two key properties of the system are the efficiency of the new spectrograph and the multiplex advantage obtained by using optical fibres to simultaneously observe up to 392 targets in the focal plane at the same time.

The AAOmega spectrograph consists of two arms (blue and red) split by a dichroic. The dispersing elements are volume phase holographic gratings, improving the efficiency by a factor of about 2 compared to the previous system using reflection gratings. The spectrograph is bench mounted (for mechanical stability) in a thermally stable room. For more details about the performance characteristics of AAOmega see [16].

The spectrograph is fed by 392 optical fibres, providing a 38-metre long link to the focal plane of the telescope. The fibres are terminated with small prisms mounted in magnetic buttons attached to the focal plate. The buttons are positioned automatically for each observation by the 2dF robotic positioner. There are two interchangeable focal plates (each with its own set of fibres), so during one observation, the robot can configure the other fibres for the following observation. This means that minimal changeover time is needed between successive observations, so we can typically observe 7–8 observation sets, for a total of some 2500 spectra per night[2]. This high efficiency is essential to complete the WiggleZ survey in a reasonable allocation of telescope time. The arrangement of fibres on the focal plate and the robotic positioner are shown in Fig. 2.

Figure 2. The robot positioner placing optical fibres on the field plate of the AAOmega spectrograph.

The WiggleZ survey will have a major scientific impact beyond the primary BAO scale measurement

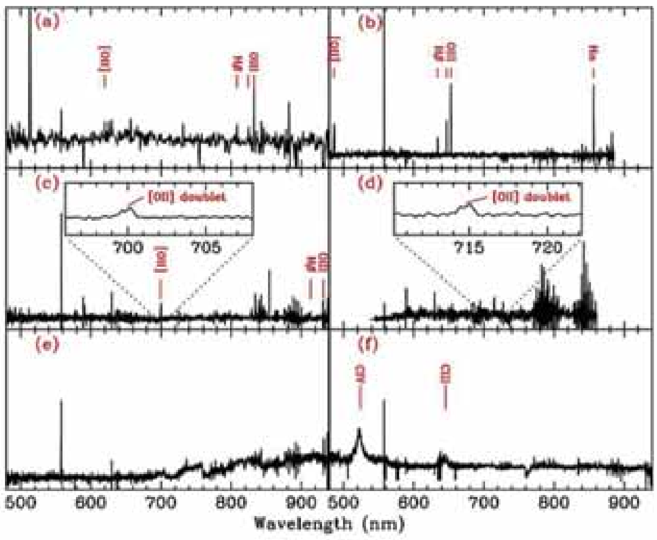

Figure 3. Example spectra from the survey: (a) Galaxy with a high quality redshift (z = 0.6628) determined by multiple emission lines. (b) Galaxy with a high quality redshift (z = 0.3048) determined by multiple lines, at a lower redshift than (a). (c) Galaxy with fewer confirming emission lines but a confident redshift (z = 0.8775) based on the [OII] doublet feature. (d) Galaxy with a redshift (z = 0.9173) based solely on the [OII] doublet. (e) Galactic star at z = 0. (f) Quasar with a high quality redshift (z = 2.370).

3 Initial Results from the Survey

At the time of writing we have completed half the allocated 220 nights for the survey, having measured some 100 000 galaxy spectra. We will not be able to measure the BAO scale until this survey is complete, but we have already obtained several important results.

The key result in terms of the feasibility of the project is that we can efficiently measure large numbers of redshifts of the selected galaxies with the AAOmega spectrograph in relatively short 1-hour exposures. The galaxies are extremely faint (optical R magnitude around 22), so we rely on strong emission line features in the spectra for the redshift measurement. Sample spectra of six different objects are shown in Fig. 3. The figures shows two galaxies identified by multiple emission lines, as well as two where the main feature is a double oxygen line. We also show a Galactic M-dwarf star: these are expected to appear as contamination in most galaxy surveys because they are so extremely numerous. However they are very rare in the WiggleZ survey, as they do not emit significant amounts of UV radiation.

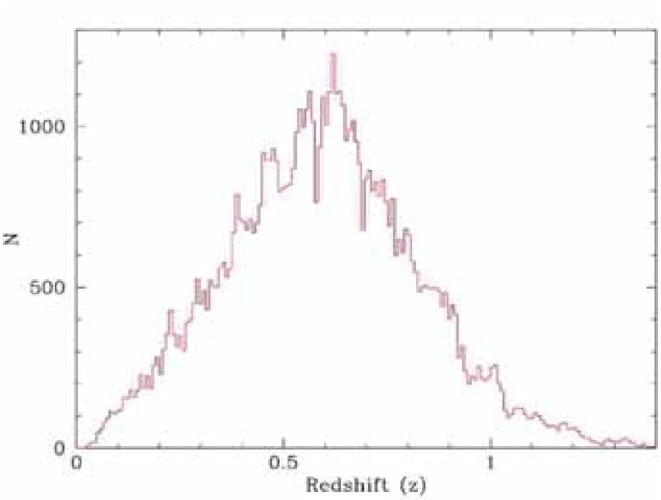

Figure 4. Redshift distribution of the WiggleZ galaxies. The high fraction of galaxies with redshifts z>0.4 demonstrates that our selection criteria are very effective at selecting high-redshift galaxies.

The success of our approach in selecting galaxy targets is demonstrated in Fig. 4. This shows the redshift distribution of galaxies with measured redshifts: some 70 per cent of the measured galaxies have redshifts higher than *z*=0.5, so we are able to sample the key redshift range of 0.25 < z < 1 where we are most sensitive to the effects of dark energy.

Some indication of the extent of the survey is given in Fig. 5, a "cone" diagram representing the distribution of measured galaxies in one half of the survey. When the survey is complete, the data will reveal the weak large-scale BAO signal, but even from this early data set the small-scale clustering of the galaxies can be measured: these galaxies are strongly clustered which makes them good tracers of the large scale matter distribution [17]. The full survey will obtain redshifts for some 240 000 high-redshift (0.25 < z < 1) galaxies in a volume of about 1 cubic Gigaparsec^3. This is by far the largest ever galaxy survey at these redshifts.

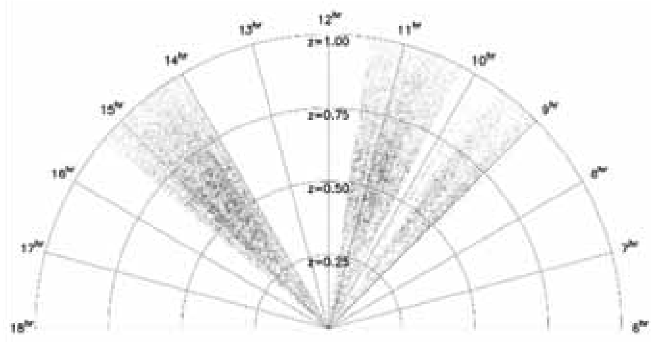

Figure 5. The distribution of galaxies currently observed in the three WiggleZ Survey fields located near the Northern Galactic Pole. The observer is situated at the origin of the co-ordinate system. The radial distance of each galaxy from the origin indicates the observed redshift, and the polar angle indicates the galaxy right ascension. The faint patterns of galaxy clustering are visible in each field.

4 Results to come: the BAO Measurement

When our observations are complete, the WiggleZ survey will measure the BAO scale at an effective redshift of z=0.7 to a precision of 2 per cent. This will allow an independent measurement of dark energy to a similar precision to that of the supernova data.

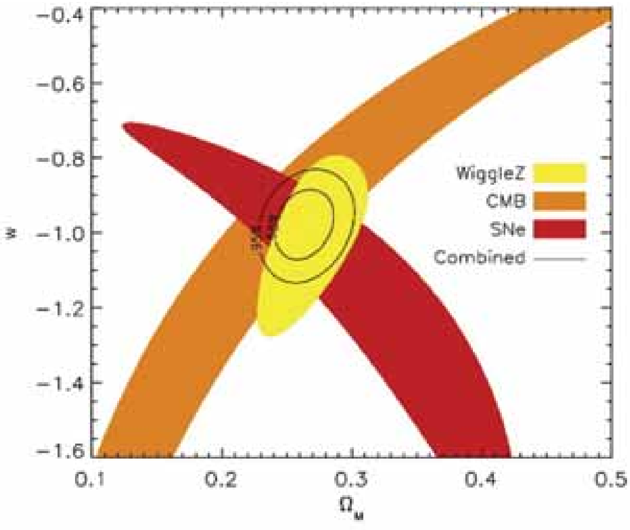

Figure 6. Simulated cosmological parameter measurements using baryon oscillations in the final WiggleZ Dark Energy Survey. This figure focuses on measurements of the matter density, Ω_M, and the equation of state of dark energy, w. We assume a fiducial cosmological constant model with $\Omega_M = 0.27$ and $w = -1$. The yellow ellipse indicates the 68% confidence region for measurement of these parameters using the WiggleZ Survey baryon oscillations combined with the CMB "acoustic scale parameter" l_A, which calibrates the baryon oscillation preferred scale. The orange band indicates the confidence region obtained from WMAP measurements of the CMB "shift parameter". The red region displays the confidence region for latest supernova measurements. When the WiggleZ Survey is complete, the baryon oscillation data will measure the properties of dark energy with a similar precision to the supernova data, providing a detailed crosscheck of the two techniques. The central confidence circles illustrate the dark energy measurements obtained by combining all the datasets.

One of the major triumphs of modern cosmology in recent years is the extraordinary precision with which the key properties of the universe can now be measured.

In Fig. 6 we simulate the results of the WiggleZ survey to compare it with other surveys. The figure displays contours describing the joint uncertainty in measuring the two key parameters of matter density[4] (Ω_M) and the dark energy equation of state[5] (w) from each survey. For the purpose of the simulations we assume a canonical model with $\Omega_M = 0.27$ and $w = -1$ and calculate the uncertainties each study would have in the joint measurement of the two parameters. Note in particular how the uncertainty in the WiggleZ BAO measurement is orthogonal to the uncertainty from the supernova data in the two parameters shown in Fig. 6. If we detect any inconsistency between the two techniques, this would be the first strong evidence of systematic errors or new physics. Indeed, existing comparisons of the two methods already suggest some disagreement [19].

The WiggleZ survey will have a major scientific impact beyond the primary BAO scale measurement, especially in the three following areas:

- We will accurately measure the shape of the galaxy clustering power spectrum on large scales. This depends on the relative amounts of baryons and dark matter in the early Universe, and can be combined with the CMB to provide more accurate estimates of the composition of the Universe. The shape of the clustering power spectrum also traces massive neutrinos.
- We will measure the rate of structure growth in the universe, allowing us to test theories of gravity. Galaxies falling into growing structures have coherent velocities that distort their measured redshifts. This leads to a signature we will detect in the measured clustering spectrum.
- Finally, we will obtain the largest ever sample of distant star forming galaxies. Measurement of the internal properties and environments of these extreme galaxies will provide valuable information about galaxy evolution. We will answer questions such as is this star formation triggered by the merging of massive galaxies and is it enhanced or suppressed in dense environments?

The WiggleZ project represents a very large investment of telescope time from the Anglo-Australian Telescope. We are very grateful for the allocation of this time and for the initiative of the Anglo-Australian Telescope Board in encouraging large projects such as this one.

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Footnotes

[1] Virtually no flux is received from any distant galaxy at rest wavelengths less than 92 nm as photons shortward of this Lyman break limit have sufficient energy to ionise the abundant atomic hydrogen along the line of sight and are thus absorbed.
[2] In practice not all fibres are available for targets as several are used to measure the sky background light and a few are faulty at any given time.
[3] One parsec is equal to 3.26 light years or 3.09×10^{16} m.
[4] The matter density parameter Ω_M is defined as the ratio of the matter density to the critical density required for a flat universe. Our best current data suggest that the universe is flat so that the total density parameter (normal matter, plus dark matter plus dark energy) is $\Omega=1$.
[5] There is no accepted theoretical model for dark energy, so a general dark energy equation of state, $P = w\rho$, relating pressure P to density ρ has been proposed [18]. An accelerating universe is produced if $w < -1/3$, and constant dark energy is described by $w = -1$.

Acknowledgements

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Professor Michael Drinkwater trained at the University of Sydney, the University of Cambridge (PhD 1988), and was postdoctoral fellow at the Université Laval, Canada. He returned in 1991 as a staff astronomer at the AAO and was appointed to the Univ. of Queensland in 2002 where he is Head of Physics and co-leads the WiggleZ Dark Energy Survey.

Nuclear Energy without Radioactivity

by Heinrich Hora and Jak C. Kelly
School of Physics, University of New South Wales

A fusion reaction of light hydrogen with boron-11 (HB11) generates less radioactivity per gained energy than burning coal. With the usual spherical laser compression scheme, the deuterium-tritium (DT) ignition may be demonstrated with the NIF laser, but the use of HB11 requires exorbitant compressions precluding this option; however, in contrast, the new petawatt-picosecond laser pulses, based on a recently discovered extreme anomaly, may permit a side-on ignition of uncompressed fuel differing from the spherical compression scheme. In this case the HB11 reaction is only about 10 times more difficult than for DT and is in the next available range.

Energy topics

The mix of energy sources required for preventing a climatic catastrophe includes the nuclear option at a reasonable level of contribution despite its known problems and the advanced solutions required. There is no question that the emission of CO_2 has to be drastically reduced. 4 Billion tons per year, which was the level at 1950, are tolerable; nevertheless, even this limit guarantees that a large volume of Australian coal will still be mined in one hundred years. However, if CO_2 emission continues at more than 24 Billion tons per year, then ice will melt from Greenland, the Antarctic and glaciers. Melting half of the present Greenland ice, estimated to be equivalent to 500 meters depth over the whole island, will result in more than a 3 m increase in the level of the oceans.

Conversion of motorcars or aircraft to be driven by electricity, hydrogen or alternative fuel sources needs many years of research and development; however, mobility cannot be abolished in modern life. Energy waste can be reduced in lighting by using photodiodes increasing the efficiency by a factor ten while emitting the same light compared with conventional sources. Other methods of energy conservation are being developed. Alternative energy is coming from advanced solar-thermal power generation, and solar cell technology may drastically overcome the ongoing high price gap e.g. by using electron beam technology [1]. Wind energy is now economical since the French AREVA nuclear reactor producer has started investing money into offshore wind generators in the Baltic Sea.

Nuclear fission energy is the second largest producer of energy worldwide after fossil fuels. The most advanced EPR (European Pressure Reactor) dominates the market for new installations. A further question still open is whether fusion energy – different to fission - may be an important component as a future energy source. After more than 50 years development, magnetic confinement fusion is still being tested by the international ITER project aimed beyond 2015 at a cost of more than 10 Billion Euro. Critical problems need to be addressed such as wall erosion (disruption by Razumova effect) and many other challenges need to be overcome.

Laser driven fusion, using the largest laser NIF completed in early 2009 [2], aims to produce up to 10^{19} fusion neutrons from deuterium and tritium (DT) reactions with pulses of 1.1 MJ (gain 24) by the end of 2009; following this, the historic first controlled ignition of a fusion reaction on earth. The spherical laser compression of DT fuel may well reach the needed 2000 times solid-state density that had been measured in 1991; however, Steve Bodner [2] has predicted that the experiment "will fail to work". The critical solid-state density may occur using the complicated scheme of spark ignition, but the more simplified volume ignition [3] – discovered in 1977 in Australia – may work as confirmed in 1988 in underground reaction experiments. This alternative may even better fit the strategic goal of laboratory scale conditions for secondary fusion stage reactions with NIF [2,3].

Australian contributions to fission energy, apart from our domination of uranium resources, were highlighted by Dr. Selena Ng [4]. She first mentioned the Synrock method for storing long-lived nuclear waste where the use of ceramics is better than the French vitrification. Ng also highlighted the Silex isotope separation which is more advanced compared with other methods and is expected to be on the market in 2011.

Alternative scheme for fusion energy with lasers

The invention of the laser in 1960 led to the hope that it may ignite exothermal nuclear fusion reactions beginning with DT and resulting in neutrons and helium with a reaction energy about ten million times higher than from chemical reactions

$$D + T = n + {}^4He + 17.6\ \text{MeV} \qquad (1)$$

To ignite this reaction in DT plasma, it normally requires a temperature above 40 Million °C (about 4 keV). By 1969, lasers of a few Joules produced 1000 fusion neutrons and by 1996 100 Billion more were measured using about 10,000 times more energetic laser pulses (Soures et al 1996:[5] - references are in [5, 6]). The laser had to generate a spherical compression of the DT fuel and the design of the $3.5 Billion experiment NIF [2] followed along these lines of spherical compression for the next expected first manmade controlled ignition of fusion.

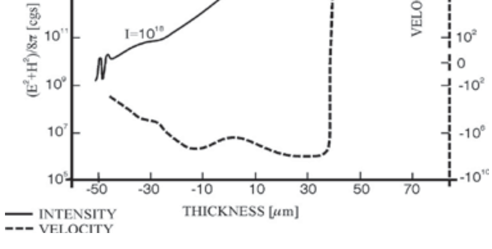

Fig. 1. Neodymium glass laser irradiation of 10^{18} W/cm^2 intensity from the right hand side on a deuterium plasma initially with low reflectivity bi-Rayleigh density profile located between 50μm and +50μm and initial temperature 100eV for plane geometry hydrodynamic very general computation. Result after 2 ps for the velocity (more than 10^9cm/s block with 18 vacuum wave length depth moving against the laser) and laser field energy density with dielectrically swelled field vectors, whose negative gradient determined the nonlinear (ponderomotive) force (from Figs. 10.18a and b of [10]). Negative velocity shows the block moving into the plasma interior.

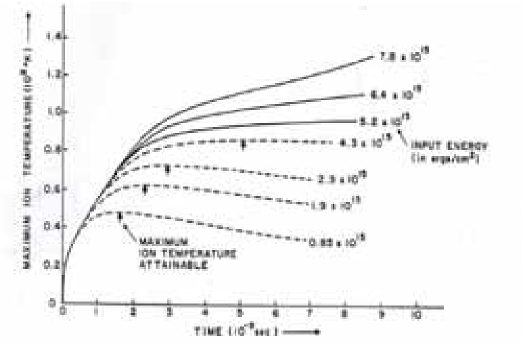

Fig.2. Characteristics of the maximum temperature T on time t for parameters E* of energy flux density in ergs/cm^2 for side-on fusion ignition of solid state DT from Fig. 2 of Chu [11].

Another scheme is called "fast ignition". When Azechi et al. (1991) demonstrated compression to 2000 times solid-state density with the then highest neutron gains of 10^{13}, the temperature of 3 Million degrees was disappointingly low. In this situation it was decided by E.M. Campbell (summarized in his Doctor of Science thesis at the University of Western Sydney: [6]) to use a laser pulse of picoseconds (ps) duration and petawatt (PW) power into the centre of the compressed DT plasma to generate the necessary ignition temperature. Based on the schemes to produce ps laser pulses of TW and finally PW power by 1999, experiments were followed up; however only 10^8 neutrons were gained by fast ignition due to complicating relativistic effects such as pair production of electrons, GeV ions, bursts of many 100 MeV electrons, and nuclear transmutations due to bursts of gamma radiation.

A modification of fast ignition, proposed by John Nuckolls et al. in 2002 [7], uses a very intense 5 MeV electron beam to ignite a larger volume of low density DT, compressed to only 12 times the solid-state, producing a fusion gain of 10^4. A laser of several PW needs to be fired into a plasma of high pre-compression produced prior by ns laser pulses.

Our new scheme is working alternatively without the need of a preceding plasma pre-compression. It uses extremely intense ion beams instead of the electron beams of Nuckolls et al. [7]. The new scheme is therefore a single step interaction PW-ps laser irradiation process and works with uncompressed DT fuel or with modest compression as in the scheme with electron beams.

The new scheme is based on measurements observed as an extreme anomaly at the interaction of ps or shorter laser pulses of more than PW power. This could be understood from much earlier numerical results for laser plasma interaction showing in one dimension (Ph.D. thesis of V.F. Lawrence, University of New South Wales, 1978:[6]) the action of the nonlinear (ponderomotive) force due to dielectric plasma effects [8]. The exact measurement of this acceleration was not discovered prior to Sauerbrey 1996: [5] because in all preceding measurements the plane of the geometry was violated by relativistic self-focusing [9] appearing in all relevant experiments before 1996. The very first time that relativistic self-focusing did not destroy the plane geometry was at the very anomalous experiment of Sauerbrey where the cut-off of any laser prepulse (contrast ratio 10^8) until less than 50 ps before the main pulse was used. This prevented the generation of a plasma cloud in front of the target that usually generates relativistic self-focusing, such that no beam filamentation could occur. The agreement of Sauerbrey's measurements with the nonlinear force theory was shown [5]. One example of the plane geometry computation with the dominance of the nonlinear force is seen in Fig. 1 extracted from the thesis of Lawrence:[10].

Measurements of the ions by Badziak et al 1999:[5] under the same anomalous conditions resulted in maximum energies of 0.5 MeV while relativistic self-focusing usually produced 22 MeV ions. The anomalous effect was shown also in the experiment by Zhang et al. 1998: [5] from x-emission. The explanation in 2002 [5] was the nonlinear force acceleration of the dielectrically enlarged skin layer as later confirmed in many details experimentally and numerically [5]. The highly directed ions were in space charge neutral plasma blocks with ion current densities above 10^{10} Amps/cm^2. The use of such ion beams for igniting laser driven fusion was formulated in 2002 by the first author (Hora) and was declassified when a similar case with electron beams was disclosed [7].

The use of the nonlinear force driven plasma blocks from PW-ps laser-plasma interaction permits a come-back of the side-on ignition of uncompressed DT as studied with hydrodynamics by Chu [11] and fully confirmed in 1974 by Bobin 1974:[6] including the losses by bremsstrahlung emission. A typical result is shown in Fig. 2. Irradiation by ps pulses with an energy flux density E* (in ergs/cm^2) results in a time dependence of the triggered detonation wave. If the temperature decays after a few ns, no ignition happens. The result is that ignition appears for higher temperatures T than the ignition temperature T_{ign} where the curves do not decrease in time with a threshold E_{th}^* if

$$E^* > E_{th}^* = 4.3\times10^8\ \mathrm{J/cm^2}\ \text{for temperatures}\ \ T > T_{ign} = 7.4\ \mathrm{keV\ (DT)} \quad (2)$$

This extremely high ignition threshold for E* prevented the side-on ignition of uncompressed DT in 1972 and laser fusion followed the scheme of spherical compression of the fuel by lasers for ignition.

With the now available nonlinear force driven plasma blocks using PW-ps laser pulses the situation was changed [6]. The conditions of the side-on ignition of uncompressed DT now appear to be an option for laser fusion after the NIF experiment (Moses 2008:[6]) confirms ignition. Chu's computations were fully reproduced (Ghroanneviss, Malekynia et al.:[6]) and the effects of thermal conduction inhibition due to the double layer and the collective stopping power following Denis Gabor 1952:[6] (not known to Chu [11] in 1972) resulted in a 20 times lower threshold E* for ignition [12]. It was estimated [6] that this one step side-on ignition of solid density DT should be possible with ps laser pulses of several PW subject to further detailed research. This is close to the present capacity of lasers after 2 PW pulses of about ps duration were realized in 1999 (Cowan et al:[5,6]).

The dream fusion reaction of light hydrogen with boron-11

From the beginning of fusion research, a dream reaction is

$$p + {}^{11}B = 3\ {}^4He + 8.8\ \mathrm{MeV} \quad (3)$$

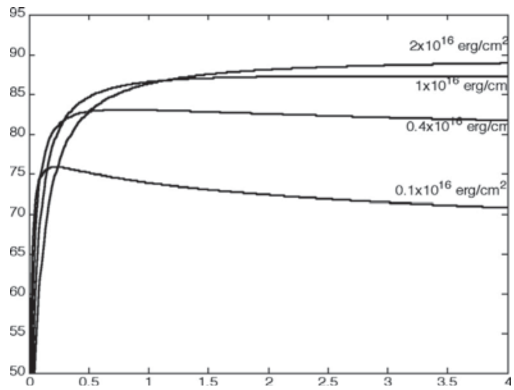

Fig. 3. Side-on ignition characteristics for HB11 at the same conditions as in Fig. 2 resulting in Eq. (4).

because no neutrons are produced and the resulting alpha particles are mono-energetic of 2.9 MeV being ideal for high-efficient direct conversion into electricity or after redirecting with magnetic fields for space propulsion (Miley et al 2008:[6]). Secondary reactions lead to radioactivity but this is less per produced energy than burning coal due to its natural contents of 2 ppm uranium and may be considered as negligible (Weaver et al 1973:[13]). However, it was evident from the beginning that this fusion reaction is more difficult than using deuterium-tritium fusion fuel, as seen from the spherical laser compression of HB11 needing densities of 100 000 times the solid-state (Hora 1975:[13]) and input laser pulses of some 10 MJ energy to produce modest energy gains per laser energy of less than 25 (Scheffel et al 1997:[13]). These conditions are exorbitant and have excluded any hope for laser driven HB11 fusion by spherical compression.

This situation changed, when instead of the spherical laser compression scheme, the side-on ignition with Petawatt-picoseconds laser pulses was studied following the DT results [6]. To be consistent with the results of Chu [11] with DT fuel, computations were first performed based on his assumptions. Using the HB11 fusion cross-sections, the hydrodynamic calculation resulted in the time dependence of the plasma temperature shown in Fig. 3 in analogy to the characteristics plots of Fig. 2 for DT. The parameter of the curves is the energy flux density E*. The aim is to find the value of E_{th}^* of the ignition threshold where the plasma temperature T merges into a constant value in the dependence on time t. The determination of the threshold conditions needs a very detailed and highly precise numerical evaluation following up on the detailed curves of Fig. 3 to exclude the very slight time decay. This value is found to be for HB11, with ignition temperature T_{ign}, given by the curve in Fig. 3 with the parameters

$$E^* > E_{th}^* = 1\times10^9\,\mathrm{J/cm^2} \quad \text{at} \quad T_{ign} = 87\,\mathrm{keV} \quad \text{(HB11)} \qquad (4)$$

These results are remarkably modest compared with the values for DT in Eq. (2) and within a factor of only ten more difficult than the DT fusion, Eq. (2). In view of the exorbitant difference between DT and HB11 for volume ignition using spherical pellet compression, it is surprising how much easier the ignition of HB11 works with a side-on generated thermonuclear reaction front.

Bremsstrahlung emission is automatically included in the hydrodynamic computations following the treatment of Chu [11]. Separate outputs of the bremsstrahlung have confirmed this result. The side-on ignition is a kind of shock wave process and is practically two dimensional in difference to the three dimensional processes at spherical compression. This fact requires that the temperature for DT needs to be larger than 4 keV and for HB11 larger than 60 keV, as confirmed by the results (2) and (3). Electron and ion temperatures and many further details are evaluated separately.

Acknowledgement

More than 30 years of cooperation with Prof. G.H. Miley, Uni. of Illinois, and with the co-authors of references [5] and [12], especially with the Ph.D. students Babak MelkyNia and Nader Azizi is gratefully acknowledged. The work with the I.A.University Tehran was partially supported by the Coordinated Research Program C.R.P. Nos. 13011 and 13508 of the International Atomic Energy Agency (IAEA) in Vienna.

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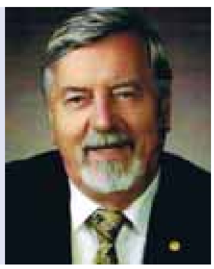
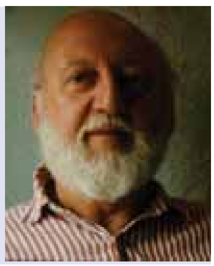
Professor Heinrich Hora was founder and Head of the Department of Theoretical Physics at the University of New South Wales from 1975 and is Emeritus since 1992. He is known for his work on the theory for fusion energy with lasers. He has published 10 books and co-edited 14 including Dirac's "Directions in Physics" and the "Edward Teller Lectures".



Professor Jak Kelly was Head of Physics and Chairman of the Science Faculty at the University of New South Wales. He is a former editor of the Physicist. Kelly has published extensively on ion optics and applications of laser beams for fusion energy. He was recently President of the Royal Society of New South Wales and edits the RSNSW Journal.



Manufacturing Gold Nano-Jewellery

by Neville Fletcher, Robert Elliman and Taehyun Kim
Research School of Physics and Engineering
Australian National University

Jewellery is an important feature in the life-style of humans worldwide, but what market for nano-jewellery? A typical element in a necklace is a few millimetres in size compared to a typical human at about two metres in height, so something like a factor of 1000 emerges. If we start from something that is a few tens of nanometres in size, an application of the same ratio suggests we should look for things a few tens of micrometres in size, and what do we find? Bacteria – and there are trillions not just billions of them! So if we can make nano-jewellery that is the right size for bacteria, the potential market is immense.

Recent work reported in an article by us in the journal *Nanotechnology*[1] shows how we can manufacture strings of gold nano-beads encased in a thin transparent filament of glassy silica – just the thing for nano-jewellery and made from gold as well. Products derived from this technology could really take off in the world of microorganisms, unfortunately though they will not greatly enhance the profits of gold mines.

The technology involved is itself quite simple. We start with a crystalline silicon wafer of the sort used in semiconductor devices and deposit on its surface a very thin film of gold. Another bare silicon wafer is then placed at a very small distance above the coated wafer and the whole sandwich heated to a temperature of about 1100 °C for 60 minutes in an atmosphere consisting of nitrogen or argon with about 3 to 5 parts per million of oxygen. The first thing that happens is that the gold film breaks up into tiny drops because of the influence of surface tension and at the same time the oxygen in the surrounding atmosphere attacks the surface of the upper wafer to create a vapour concentration of silicon monoxide SiO. This SiO then dissolves in the gold drops, along with some of the oxygen from the vapour, and the two combine to form silica (SiO_2) molecules. Because silica is not very soluble in gold, it tends to precipitate at the interface

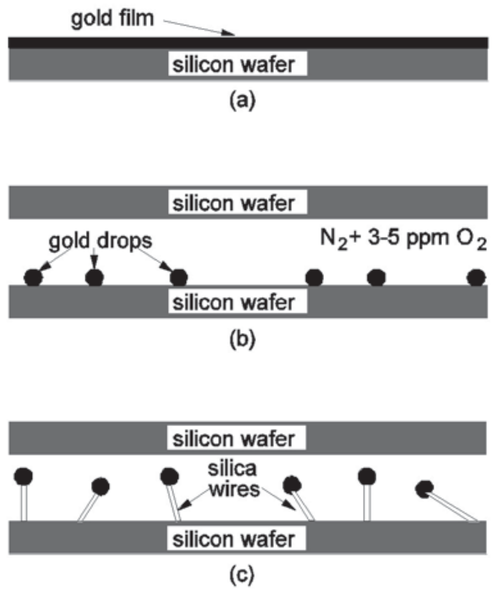
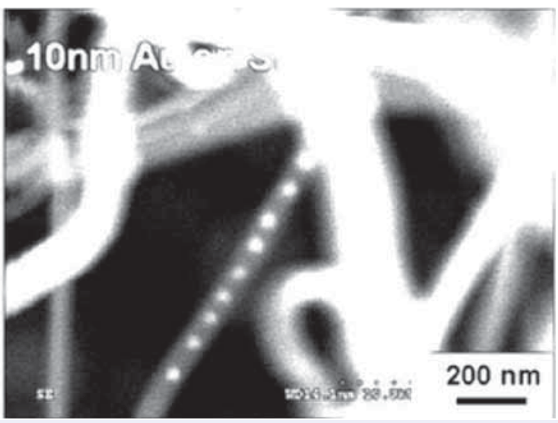


Figure 1. The growth technique described here for silica nanowires: (a) a gold film is deposited onto a silicon wafer; (b) the wafer is capped by another bare wafer and heated in an inert gas atmosphere with 1 to 5 ppm of oxygen and the gold film condenses into a distribution of small gold drops; (c) silica wires grow from the base of the gold drops, bearing them aloft.

between the gold and the silicon substrate and the gold drop is lifted up on a column of amorphous silica. This results in the growth of a population of silica whiskers, or wires as they are often called, each capped with a liquid gold drop which continues the growth process as shown in Figure 1.

So far there is nothing very special about this process, but then something strange happens: in a proportion of the growing wires ranging from 1% to 80% the gold drop begins to leave behind it a trail of small gold droplets with nearly regular spacing, the diameter of each droplet being about one fifth to one half of the wire diameter but more like one tenth of the diameter of the main growth drop at the end of the wire. Examples are shown in Figure 2, some irregularity being introduced by the presence of neighbouring wires.



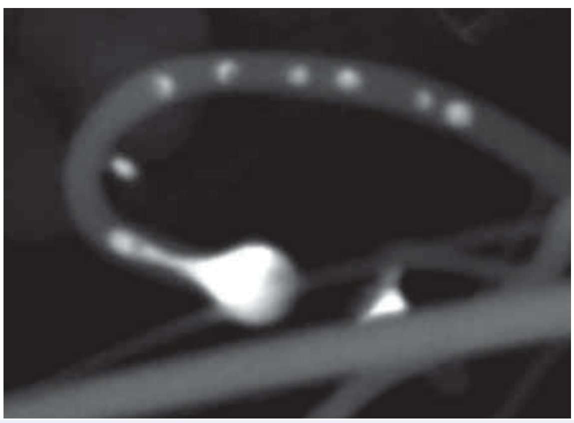


Figure 2. (a) Typical nearly-regular growth of gold bead strings within the silica nanowires;
(b) the diffusive pinch-off effect behind the gold drop at the end of the silica wire. The image width in each case is about 2μm so that the diameter of the main drop is about 300 nm and that of the droplets or beads about 30 to 100nm.

So there we have the ready-made gold bead-strings for our nano-jewellery. All that remains is to seek publicity (this article!) to advertise it to the bacterial community – except that, being scientists, we would like to understand how the process works. A clue to this may be seen in Figure 2(b), in which the main gold drop seems to be dragging a gold tail behind it in the wire and this tail is pinching off to form a droplet. Indeed this is just what happens in a regular fashion, and the question is "Why?"

Products derived from this technology could really take off in the world of microorganisms, unfortunately though they will not greatly enhance the profits of gold mines.

As we saw before, the large gold drop absorbs SiO and oxygen from the surrounding atmosphere and the SiO_2 that is produced diffuses through the drop to deposit at its interface with the growing wire. Because the concentration gradient is larger near the edges of this circular interface than at the centre, the edges grow more rapidly and the interface develops an almost conical depressed shape. After this has reached a moderate depth, its top opening begins to close under the influence of diffusion and ultimately seals off, leaving a small volume of liquid gold within the wire. The enclosed liquid gold volume then gradually becomes a spherical droplet under the influence of its interfacial free energy. This process then repeats in a regular manner if the gas environment remains stable, giving a chain of gold droplets with a short length of solid silica separating them from each other. These two stages of simple diffusion processes have automatically self-assembled the gold droplet string which later becomes the bead-string of our nano-necklace.

It may be true that we are being unduly hopeful in conjecturing a huge market for the sale of these necklaces to bacteria – perhaps they are much too busy infecting humans and other animals to worry about their appearance. But a regularly spaced string of gold beads may have other applications in the area of nanoelectronics or nanophotonics. We can but hope and meanwhile refine the processes involved.

1. "Gold bead-strings in silica nanowires: a simple diffusion model" N.H. Fletcher, R.G. Elliman and T-H. Kim Nanotechnology 20, 085613 (5pp) (2009)

Neville Fletcher is an Emeritus Professor of Physics of the University of New England and former Director of the CSIRO Institute of Physical Sciences. Robert Elliman is Professor and Head of the Department of Electronic Materials Engineering at ANU where Taehyun Kim is a PhD student and Neville Fletcher a Visiting Fellow.

Both Neville and Rob have been Presidents of the Australian Institute of Physics.

AUSTRALIAN INSTITUTE OF PHYSICS

Editor for Australian Physics - expressions of interest invited.

John Daicopoulos will be leaving the position of Editor in 2010. Accordingly we are seeking a new Editor to take up the position in early 2010 to allow for some overlap.

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- **in consultation with the editor-in-chief, seek material for publication**
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- **prepare layout for the printer using appropriate software (knowledge of currently used 'Indesign' is desirable but not essential)**
- **check printers proofs**

Remuneration for this part-time activity is by means of an honorarium, the amount of which is subject to negotiation. Expressions of interest, including a CV should be sent to: Editor-in-Chief, Dr Marc Duldig: *Marc.Duldig@aad.gov.au* by 30 September 2009.

David Karoly reviews *Ian Plimer's Heaven + Earth*

This review by David Karoly was first heard on The Science Show, ABC Radio National

Ian Plimer's new book Heaven + Earth claims to shed new light on the science of climate change. It states that 'human-induced global warming has evolved into a religious belief system', that 'atmospheric carbon dioxide does not create a temperature rise' and that 'global warming and a high CO_2 content bring prosperity and lengthen your life'.

Are these claims justified and based on science? They are in marked contrast to the scientific understanding of the causes of recent climate change reported in the assessments of the Intergovernmental Panel on Climate Change (IPCC), as well as by other scientific bodies including the US National Academies, the British Royal Society and the Australian Academy of Science. They have all reached the same conclusion; the observed increase in global-average surface temperature since the mid-20th century is mainly due to the increase in greenhouse gases in the atmosphere, caused by human activity.

Heaven + Earth claims that this conclusion and almost all the conclusions of the IPCC are wrong. It suggests that there is a conspiracy amongst climate scientists to hide the 'truth' and that the learned scientific societies of many countries have been hoodwinked. He implies that this conspiracy involves all the hundred-plus national governments that unanimously approved the conclusions of the IPCC assessments. Not surprisingly, the book has attracted attention from the media, politicians and some scientists, as well as the public. Nothing sells like a good conspiracy story.

But is this book the story of a conspiracy, or even a good read? Is it about science or is it science fiction? The book is impressive and possibly interesting, but very disappointing. Impressive because of the time and effort that must have been spent writing the 500 pages with 2,000-plus footnotes. Interesting because it seeks to link many aspects of geology, astronomy, biology, glaciology, oceanography and meteorology to explain climate change over the Earth's multi-billion-year history, including the last hundred years. It's disappointing because a senior professor should not have produced such a book with so many errors, so many internal inconsistencies, and with no sources for its graphs.

The average reader will find it difficult to sort the fact from the fiction, to disentangle the inconsistencies, and separate the personal opinions and interpretations of the author from the well-established science. The book is built around six sections that consider history, the Sun, earth, ice, water, and air. In these, 18 questions are considered, and many scientists would agree with some aspects of the answers presented. However, there are major errors in many of the answers, making the conclusions invalid. The best description of the problems with the book is provided by Plimer himself. He writes, 'Trying to deal with these misrepresentations is somewhat like trying to argue with creationists, who misquote, concoct evidence, quote out of context, ignore contrary evidence, and create evidence ex nihilo.'

There are some sensible things in Heaven + Earth. Yes, it is important to 'look at climate over geological, archaeological, historical and modern time'. Throughout Earth's history there have been natural climate variations driven by many factors, including variations in the Earth's orbit, volcanic eruptions, tectonics, and changes in greenhouse gas concentrations.

For most of Earth's history, global temperatures and carbon dioxide concentrations in the atmosphere have been higher than present. Plimer is wrong to claim that 'the IPCC has essentially ignored the role of natural climate variability', as natural climate variability is carefully considered in all four of the IPCC's comprehensive assessments since 1990. In its 2007 report, a whole chapter on palaeoclimate focuses on natural climate variations over Earth's history. Yes, water vapour is the most important greenhouse gas in the atmosphere. However, as Plimer states, 'Water vapour tends to follow temperature change rather than cause it,' so water vapour changes cannot initiate climate change.

Now let me address some of the major scientific flaws in Plimer's arguments. He claims 'it is not possible to ascribe a carbon dioxide increase to human activity' and 'volcanoes produce more CO_2 than the world's cars and industries combined'. Both are wrong. Burning fossil fuels produces carbon dioxide enriched with carbon isotope ^{12}C and reduced ^{13}C and essentially no ^{14}C, and it decreases atmospheric oxygen, exactly as observed and as Plimer states on pages 414 and 415. Scientists have estimated emissions from volcanoes on land for the last 50 years and they are small compared with total global emissions from human sources.

Plimer even argues that the recent sources must be underwater volcanoes. This is not the case, because the net movement of carbon dioxide is from the atmosphere to the ocean, based on measurements that the concentration of dissolved carbon dioxide in the ocean is less than in the atmosphere. In addition, measurements show the concentrations of two other long-lived greenhouse gases with human-related sources, methane and nitrous oxide, have increased markedly over the last 200 years, at the same time as the increases in carbon dioxide. This is not possible due to sources from underwater volcanoes.

Next, he states that CO_2 does not drive climate and then contradicts himself by writing 'CO_2 keeps our planet warm so that it is not covered in ice'. There is ample geological evidence of increased CO_2 causing climate change, such as the Palaeocene-Eocene thermal maximum about 55 million years ago. He writes 'land and sea temperatures increased by five to ten degrees with associated extinctions of life' when methane was released into the atmosphere due to geological processes and rapidly converted to CO_2.

Plimer writes repeatedly that global warming ended in 1998, that the warmth of the last few decades is not unusual, and

that satellite measurements show there has been no global warming since 1979. He is correct that on time scales of the last 100 million years, the recent global-scale warmth is not unusual. However, it is unusual over at least the last 1,000 years, including the Medieval warming. Plimer makes the mistake of using local temperatures from proxy evidence rather than considering data from the whole globe at the same time. The report of the US National Academy of Sciences in 2006, cited by Plimer, states 'Presently available proxy evidence indicates that temperatures at many, but not all individual locations, were higher during the past 25 years than during any period of comparable length since AD 900.'

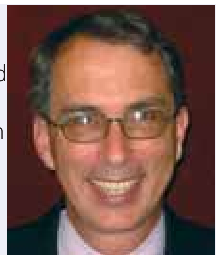
We do not expect significant warming to always occur for short periods, such as since 1998. Natural climate variations are more important over short periods, with El Nino causing hotter global-average temperatures in 1998 and La Nina cooler global temperatures in 2007 and 2008. Global-average temperature for the current decade from surface observations and from satellite data is warmer than any other decade with reasonable data coverage. Plimer is wrong to write 'Not one of the IPCC models predicted that there would be cooling after 1998'. Actually, more than one-fifth of climate models show cooling in global average temperatures for the period from 1998 to 2008.

Plimer writes that solar activity accounts for some 80% of the global temperature trend over the last 150 years. This doesn't fit the observational evidence. Increases in solar irradiance would cause more warming in the daytime, in the tropics and in summer, as well as warming in the upper atmosphere, and these are not observed. Changes in solar irradiance and cosmic rays show a large 11-year sunspot cycle and negligible trend, but observed global temperatures show a large warming trend and small 11-year cycle.

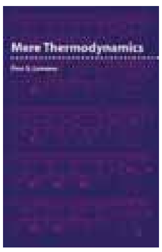
Plimer is wrong again when he writes 'An enrichment in atmospheric CO2 is not even a little bit bad for life on Earth. It is wholly beneficial.' This is contradicted when he writes that the Palaeocene-Eocene thermal maximum was associated with mass extinctions. There are many other errors, both large and small, including volcanoes emitting CFCs and that the Sun consists mainly of the same elements as the rocky planets. Many of the figures have mistakes, either in the caption or in the data, and have no sources provided.

Given the errors, the non-science, and the nonsense in this book, it should be classified as science fiction in any library that wastes its funds buying it. The book can then be placed on the shelves alongside Michael Crichton's State of Fear, another science fiction book about climate change with many footnotes. The only difference is that there are fewer scientific errors in State of Fear.

Professor Karoly is an internationally - recognised expert in climate change and climate variability. He was heavily involved in preparation of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007) in several different roles. Professor Karoly is Chair of the Premier of Victoria's Climate Change Reference Group.



Reviews



Mere Thermodynamics

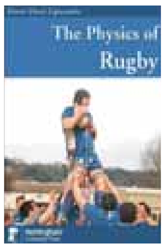
Don S.Lemons
Johns Hopkins University Press, 2009
xi + 207 pp.,
US$ 30 (paperback)
ISBN: 978-0-8018-9015-2

Thermodynamics has such a profound impact in so many areas of science and technology that it stands out as an essential component in any course of study in Physics. That said, the number of students who actually understand and develop an appreciation for the topic is a small subset of those who enrol.

Don Lemons has written a very readable and engaging book on thermodynamics that really does allow the reader to develop an appreciation for the topic. It delivers all of the information and develops understanding in an easy style that reflects the author's deep understanding and love of the topic.

In the Australian context this text would suit a second or third year course to follow a partial differential equation course in maths. I would recommend a copy of this book in your institutional library for the benefit of students and one on your shelf if only for some neat end of chapter problems.

John Holdsworth
University of Newcastle



The Physics of Rugby

Trevor Lipscombe,
Nottingham University Press Nottingham UK, 2009. Paperback £20
ISBN: 978-1-904761-17-4

Over the years there has been a steady stream of book titles starting with "The physics of..", including specific sports. This one, on Ruby Union, will appeal primarily to physicists with a passion for that particular football code. It also contains many interesting examples of elementary physics useful in the classroom. For example, if a player is running forwards at 10 m/s and passes the ball backwards at 9 m/s, will the referee blow his whistle?

Despite the fact that the prose is eloquent and entertaining, I found it was often hard to follow due to the rugby jargon. Early on, for example, we learn that "Isaac Newton tells the pack that good binding is vital, especially in the tight five."

There are several unfortunate mistakes mixed in with good, entertaining physics. The author claims the ball will bounce with a coefficient of restitution of unity only if it bounces off a hard surface. He claims that the bounce is chaotic since there is no way that the simple laws of physics can deal with something as complex as a rugby ball. This reviewer has measured the bounce, it is not chaotic, the physics is simple and the COR is less than unity even on concrete.

Rod Cross
University of Sydney

Quanta: The Gravity of Time

By Sam Drake

Einstein was struck by the fact that gravity is different to all the other forces of nature in that it accelerates all particles by the same amount in the same direction regardless of their size, weight or charge. By contrast the acceleration of a particle in an electric field depends on both its charge and mass. Einstein hypothesised that the reason gravity affects all particles the same way is that gravity is not a force at all.

One way to visualise the effect of gravity is to imagine ball bearings being rolled on a trampoline, with the bearings representing satellites and the trampoline our universe. When the trampoline is completely flat the ball bearings roll in a straight line, like a satellite in deep space far from the gravitational pull of any planet or star. Imagine now that a heavy iron ball (a planet) is placed in the middle of our trampoline, pulling it down. In the language of relativity the trampoline is now said to be a curved space. If we now roll the ball bearings (ignoring any slowing down caused by friction) they trace paths like the orbits of a satellite that comes close to a star. The path of the ball bearings depends on their initial speed and direction but is completely independent of their mass.

Time as a dimension measured with a moving ruler (a clock)

Most people consider the spatial dimensions like east and north as nothing like time. Physicists, on the other hand, treat time as just another dimension. The reason for considering time separately is completely intuitive. I cannot take a step back in time the same way I can step back from the footpath. I cannot see forward in time whereas I can easily look ahead to the north.

To a physicist any event must have both a spatial and temporal coordinate. There is no point in making arrangements to meet at the Adelaide railway station if I do not know when to meet you. In addition, we are quite happy to consider both space and time as equivalent measures of distance, if we had a race and at the end I am running at 10 metres per second you could equally say that you won by half a second or by 5 metres. The idea that you can see into the distance but not into the future is not correct. When you look into the distance what you are seeing light that was emitted from the object in the past.

What gives us the impression that time is very different to space is that we measure time with a clock as opposed to a ruler, and we can not move through time like we move through space.

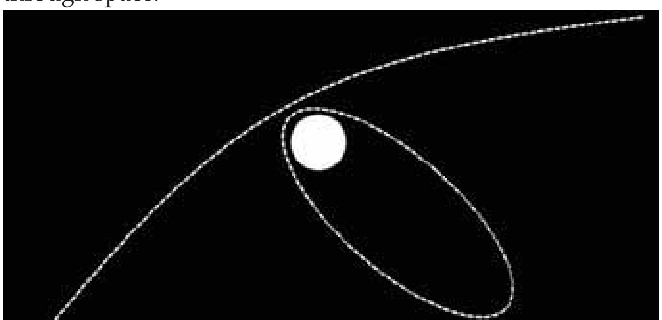


Figure 1: The motion of ball bearings on a trampoline can be used to describe the motion of satellites near a planet.

The fact that time always moves forward is known as time's arrow and is a direct consequence of there being many more disordered states than there are ordered ones. Imagine you are watching a film of somebody shuffling a deck of cards; the film can be run forwards or backwards but I don't tell you which. The film starts with an ordered deck (ace to king in suits) and as the cards are shuffled they become more disordered until eventually there doesn't appear to be any pattern to the distribution of cards. I run the film a second time but this time the cards are randomly distributed but as the cards are shuffled they become more ordered until they are completely in order (ace to king in suits). If I were to ask you in which of the screenings was the film run backwards you would say the second because you know intuitively that the probability of shuffling a deck of cards into order is so small that it is considered impossible. Hence you are able to determine the direction of time from your knowledge that systems (such as a deck of cards) tend to disorder not order.

A deck of cards only has 52 elements so you can imagine that for a much more complex system (such as a human being) the probability of going from a disordered state to an ordered one is so small as to be considered impossible, which gives us the impression that time always moves forward.

A clock ticks once per second regardless of what we are trying to measure. This means that if there is a stationary ball on a flat trampoline at every instant we measure its position time has increased, even though the spatial coordinates remain unchanged and nothing has happened. The similarity between space and time would be more apparent if we constructed a ruler that moved to the left 300 million metres every second. With this ruler everything would move to the right regardless of the speed or direction it was travelling (because nothing can travel faster than light) and we would say that you cannot travel to the left in the same way that you cannot travel to the past.

Matter stretches time

I would now like to draw together the two concepts already described, namely that matter warps space and time is a dimension just like space, to conclude that matter stretches time. If the satellite shown earlier in Figure 1 had a clock on it the general theory of relativity predicts that the clock ticks slower when it is closer to the planet than when it is further away because time is more curved closer to the planet.

An example of how this rather abstract theory is used in practice is found in the global positioning system (GPS). Accurate timing is crucial to the operation of GPS; the timing required is so accurate that the general relativistic effects of time delay need to be included. Despite general relativity already being a well established and tested theory there were some engineers in 1977 that were not convinced that gravity affected time. When NASA launched the initial GPS satellites they were equipped with extremely accurate atomic clocks. These clocks were equipped with a frequency synthesizer that could be controlled from Earth enabling the engineers to change the clock frequency if the relativistic predictions were not correct. The initial predictions were correct and no adjustments were required, thereby demonstrating that matter does indeed stretch time.

News

2009 Gruber Cosmology Prize
The University of Melbourne Department of Physics is delighted to announce that the 2009 Gruber Cosmology Prize has gone to Wendy Freedman, Robert Kennicutt and our Jeremy Mould.

This outstanding team led the Hubble Space Telescope Key Project on the Extragalactic Distance Scale, a painstaking ten-year-long effort that resolved the decades-long dispute about the value of the Hubble constant, one of the most important measurements in astronomy.

The project's findings have not only effectively determined the age of the universe (about 14 billion years), but have also enabled scientists to more accurately investigate other profound questions about the birth, evolution, and composition of the universe.

Freedman, Kennicutt, and Mould will receive the Prize on August 4, 2009, at the opening ceremony of the International Astronomical Union's General Assembly in Rio de Janeiro, Brazil.

More information may be found at:
http://www.gruberprizes.org/GruberPrizes/Cosmology_PressRelease.php?awardid=49
University of Melbourne

WA scientist measures up on World Metrology Day
West Australian scientist Professor Michael Tobar has been awarded the Barry Inglis Medal for Excellence in Practical Measurements by an Individual in Australia.

The Minister responsible for Australia's National Measurement Institute, Dr Craig Emerson, made the announcement while in WA.

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

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

"In particular, his work with oscillators forms the basis for the next generation of radar, telecommunications and precision measurement applications."

The Barry Inglis Medal was created in honour of the first Chief Metrologist and CEO of the National Measurement Institute.

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

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

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

Adelaide physicist wins national Science honour
University of Adelaide physicist Professor Tanya Monro has been judged Australia's top 'emerging' leader in Science.

Announced at a lunch with Prime Minister Kevin Rudd in Canberra, Professor Monro is the winner of The Weekend Australian Magazine's Next 100 Emerging Leaders series in the Science category.

The national newspaper chose 100 young leaders in 10 key areas of national life, and profiled them in the newspaper over 10 weeks starting in April. The top 10 leaders - the winners in each category - will be profiled in the paper this weekend.

Professor Monro, 36, is the Director of the University of Adelaide's new Institute for Photonics and Advanced Sensing and Director of the Centre of Expertise in Photonics. This is the latest in a number of prestigious awards and recognition she has received since starting at the University of Adelaide in early 2005 as the inaugural Chair of Photonics.

Last year she was named Physical Scientist of the Year - one of the five Prime Minister's Science Prizes - after earlier in the year being awarded one of the 2008 Australian Research Council Federation Fellowships.

Professor Monro has created a new class of optical fibres with innovative potential applications in medical research, defence, industry and environmental science. She is regarded as one of the world's leaders in optical fibre technology.

This new class of optical fibres, containing air holes and made from soft glass, is broadening the role of optical fibres from communications to areas such as diagnostics - detecting trace quantities of chemicals or biomolecules - and a variety of medical and defence applications.

Professor Monro's work has received support from both state and federal governments, as well as the Defence Science & Technology Organisation.

The University's new Institute for Photonics and Advanced Sensing brings together research in optical fibres, lasers, luminescence, chemistry, proteomics and virology to develop new technologies focusing on some of the big problems in health, the environment, industrial processes and defence. With the specialised laboratories under construction later this year, the Institute's facilities will be unrivalled in the world.

Professor Monro is a member of the South Australian Premier's Science & Research Council, a founding steering member of the Royal Institution of Australia, and member of the 2008 community consultation panel for the Defence White Paper. In 2007, she was awarded the `Women in Physics Lecture' by the Australian Institute of Physics and, in 2006, a Bright Spark award for Australia's Top 10 Scientific Minds under 45 by Cosmos Magazine.
University of Adelaide

Product News

Warsash

NEW Versatile 10 Channel Multiplexed Digital Joulemeter for Pulsed Lasers from Warsash Scientific.

Warsash Scientific is pleased to unveil the latest product from Spectrum Detector…the MDJ10, a 10 Channel Multiplexed Digital Joulemeter. It is the first of its kind, designed to make pulse energy measurement of a single laser at 10 places, or 10 lasers synchronized to one trigger.

The MDJ10 was originally designed to measure the spatial distribution of a single high energy pulsed laser, but can readily be used as a 10 channel pulsed laser test set for burn in and life test. It currently features the use of 10 Pyroelectric Joulemeter probes mated to flexible cables for unique positioning (shown in a linear pattern in the above photo). It can easily be adapted to take Joulemeter probes of any size, and based on Silicon, InGaAs or Pyroelectric detectors. With a variety of energy detectors it can measure from DUV to Far IR, nJ to mJ, and 1 pulse to 400 pps.

Each MDJ10 includes 10 detector channels, featuring a smart interface box that includes an EPROM for individual probe calibration data, fixed range amplifiers, a microprocessor and D to A for handy analog output. The MDJ10 comes with a basic stand alone LabView Applications program that displays the pulse energy of the 10 individual channels. It also includes LabView Drivers that support customer driven test software.

For additional information on this and other Spectrum Detector products, contact:
Warsash Scientific Pty Ltd
Tel: +61 2 9319 0122
Fax: +61 2 9318 2192
sales@warsash.com.au
www.warsash.com.au

High resolution, high force PiezoWalk® Linear Actuator from PI

Warsash Scientific is pleased to present the N-380 series of linear actuators from Physik Instrumente (PI).

The compact N-380/N-381 linear actuators are ideal drives and micro manipulators for biotechnology and nanotechnology applications with rapid accelerations, velocities of 10 mm/s and forces up to 10 N to enable high-dynamics and throughput for automation tasks. The N-380 open-loop version is intended for high precision applications where the absolute position is not important or is controlled by an external loop (video, laser, quadcell, etc.).The N-381 model is equipped with a high-resolution position sensor, allowing sub-micrometer repeatability in closed-loop operation.

The NEXACT® PiezoWalk® technology replaces conventional stepper-motors or DC servo-motors providing several advantages. Due to the direct linear drive, there is no loss of precision as a result of converting rotational to linear motion. The position is securely clamped when switched off. The drive does not need to be powered and does not heat up. The working principle allows very high resolutions within one step. In open-loop operation, motions can be resolved to about one nanometer.

Applications include cell manipulation, biohandling, micromanipulation, laser tuning, and for motion in strong magnetic fields.

Further information on this and other motion control products is available from:
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www.warsash.com.au

High resolution, high force PiezoWalk® Linear Actuator from PI

Low-cost PI Drives for Automation and Handling

Low-cost solutions with micrometer range positioning accuracies are required for tasks such as setting valves, adjusting components for further processing, and pick-and-place.

Warsash Scientific is pleased to present the cost-optimized M-228 and M-229 linear drives from Physik Instrumente (PI) who have taken up the challenge posed by industry's requirements.

The M-228 and M-229 have travel ranges of 10 or 25 mm and use classic stepper motors as drives – with either a compact or cubic configuration. Despite the low price, the user need not forego useful features such as mechanical position display, a non-rotating spindle or safety limit switches.

PI low-cost linear drives are available with a variety of motors and have accuracies of a few micrometers and below.

Further information on this and other motion control products is available from:
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Tel: +61 2 9319 0122
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www.warsash.com.au

Editor's note: 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 as fillers from time to time.

Coherent

Quantel Brilliant EaZy Q-Switched Nd:YAG Laser

Brilliant EaZy from Quantel is a compact, lamp pumped Nd:YAG laser combining a new compact power-supply with the proven Brilliant laser head.

The new power-supply/heat exchanger (14kg) occupies half the space of previous versions and allows mounting vertically or horizontally. Quick cable disconnects and an easy carrying handle allow the head and power supply to be separated for ease of transport.

The coolant reservoir is back lit and will flash to alert the user of a low water condition. Inside, a heating element in the coolant loop actively temperature stabilises the head and reduces warm up time. Just plug into nearly any available wall plug outlet, 240Vac, and the Brilliant EaZy is ready to use.

The oscillator produces 300mJ @ 1064nm, 5ns, with a high quality beam profile (M2<2). The Brilliant EaZy has excellent energy stability (<2%), proven field reliability and features the same harmonic modules and wavelength separation optics as the Brilliant.

Features

330mJ in 5ns @ 1064nm
Compact power supply
Detachable cables
Prompt set-up and warm-up times
High quality beam profile
High pulse-to-pulse stability
High pointing stability
1 year full warranty, including optics
Remote control box

For further information please contact Gerri Springfield or Paul Wardill at *sales@coheren.*
Coherent Scientific
116 Sir Donald Bradman Drive
Hilton SA 5033
Ph: (08) 8150 5200
Fax: (08) 8352 2020
www.coherent.com.au

Intensified CCD cameras with broad spectral response

Princeton Instruments has introduced the new Unigen™ II intensifier for use with the PI-MAX range of intensified CCD cameras.

The new intensifiers are based on a proprietary UV-enhancing technology from Princeton Instruments and offer the best overall UV-NIR response, while maintaining fast gating and excellent spatial resolution. They provide a significant performance improvement in time-resolved imaging and spectroscopy applications such as laser induced fluorescence (LIF) and laser induced breakdown spectroscopy (LIBS).

The intensifiers offer excellent sensitivity over 200-900nm, minimum gating speed of <2nsec and sustained repetition rate of 50 kHz (500 kHz in burst mode).The combination of gate speed, repetition rate and high quantum efficiency over a broad wavelength range is unequalled in the market today.

The Unigen™ II intensifier coupled with Princeton's PI-MAX camera is an ideal choice for time resolved imaging and spectroscopy applications requiring low noise and wide dynamic range. The cameras are equipped with built-in programmable timing generator (PTG) for easy setup of complex time resolved experiments. Princeton's Acton range of high-performance spectrometers is available for spectroscopic experiments, with fully integrated control of camera and spectrometer provided by the WinSpec software package.

For further information please contact Paul Wardill at *sales@coherent.com.au*.
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TMC: Vibration control supplier of choice for the world's highest energy laser system.

TMC has officially been recognised as a key industrial partner and critical contributor for the supply of 552 (!) high performance anti-vibration control tables to the Lawrence Livermore National Ignition Facility (NIF) – the world's highest energy laser system.

TMC manufactures a wide range of high performance optical table tops, including clean-room and vacuum compliant tops, laboratory tables, pneumatic isolators and advanced vibration isolation and vibration cancellation systems and floor isolation platforms, and was selected by NIF on the basis of unmatched table performance, build quality, cleanliness, price and on time delivery.

Bring the benefit of multi-billion dollar facility technologies and expertise to your research laboratory today. Contact us on sales@coherent.com.au to assist with your vibration control requirements – big or small.

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First Announcement

ASTROMED09
The Inaugural Sydney International Workshop
on Synergies in Astronomy and Medicine.
14-16 Dec. 2009, Sydney, Australia
www.physics.usyd.edu.au/astromed09

Second Announcement and Call for Papers

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

Lastek

Aerotech ANT Series nano-Motion Technology Systems

Aerotech has met the nanotechnology motion challenge and is already producing products that provide nanometer accuracy, resolution, repeatability, and in-position stability. Aerotech focuses exclusively on high performance motion control. Key components such as motors, drives, control software, and of course the stage mechanics, are designed and manufactured in-house. Together they provide the extreme performance required by nanotechnology and photovoltaic research, as well as positioning applications requiring nanometer accuracy in a 24/7 manufacturing environment.

For example, Aerotech's NanoTranslation (ANT95-L, ANT95-L-H) cross-roller stages are the best-in-class in combining speed, accuracy, resolution, repeatability, reliability, and size, and are offered in two accuracy grades. As an evolution of the popular ANT stage family, these linear stages exhibit enhanced motion performance over Aerotech's first generation ANT series. Product improvements such as 5 g acceleration, 500 mm/s velocity, enhanced load capacity, and standardized, universal base mounting patterns allow the use of this flexible stage family in a wide range of multi-axis configurations.

Features

- Integrated low profile linear motor stage
- Available in X, XY, XYZ, and many other combinations
- Noncontact, non-cogging, frictionless directdrive – zero backlash or hysteresis
- High resolution (1 nm), repeatability (50 nm), and accuracy (250 nm)
- In-position stability of 3 nm
- Anti-creep cross-roller bearings
- High dynamic performance

For more information please contact:
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Sensors Unlimited's SWIR Cameras Ideal for Photovoltaic Inspection

Concerned About PV Cell Efficiency? Sensors Unlimited announces that high resolution, shortwave infrared (SWIR) area and linescan cameras are being used to improve the manufacturing yield of photovoltaic cells. SWIR technology is well suited to monitor the quality of solar thin films, concentrated PV, and crystalline cells, to maximize efficiency of the solar cell manufacturing process through final assembly of the completed modules.

Electroluminescence from PV cells captured with a Goodrich SU320KTS InGaAs SWIR camera (left). This illustrates cell non-uniformity within and between the cells. Colour camera image of the same set of cells is shown on the right.

The InGaAs-based SWIR cameras, which operate between 0.9 to 1.7 microns, are ideal for inspecting silicon boules and wafers due to the material's transparency beyond 1.2 microns. The Goodrich cameras reveal voids in silicon boules, bricks, and ingots before they are sliced into wafers to produce mono- and multi-crystalline solar cells. They can also detect hidden cracks by mapping stress in raw wafers, finished cells, and thin-films made for solar electricity generating panels. SWIR cameras can also spot saw marks on the opposite side of a silicon wafer and/or defects inside the material.

In addition, by applying forward bias to cells to generate electroluminescence, the SWIR cameras are used to gauge cell efficiency and uniformity. This aids improvement of cell manufacturing processes, and aids matching cells with similar efficiencies for assembly into modules. The latter step prevents the loss of energy from the stronger cells which would be lost in heating the inefficient cells.

Sensors Unlimited, Inc., part of Goodrich Corporation, based in Princeton, NJ, has pioneered the design and production of NIR and SWIR cameras and systems utilizing advanced Indium Gallium Arsenide (InGaAs) imaging technology for industrial, commercial, military, agricultural, and scientific markets.

For additional information on InGaAs-based shortwave infrared imaging detectors, arrays, and systems, please contact:
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Adelaide U - Thebarton Campus
10 Reid St, Thebarton, South Australia
Australia 1800 882 215; NZ 0800 441 005
T: +61 8 8443 8668 ; F: +61 8 8443 8427
sales@lastek.com.au
www.lastek.com.au

LaVision now introduces a new generation of soot characterization with the LII 300 system

Laser induced incandescence (LII) is an optical technique for accurate, non-intrusive and temporally resolved measurement of soot concentration, specific surface area and primary particle diameter. LaVision GmbH, now partnering exclusively with Artium

Technologies PDI and LII systems, is now presenting the advanced LII 300 system which is mainly configured for quick set up and unattended operation to measure soot in many applications, among Diesel engine exhaust, Gasoline engine exhaust, Diesel particulate filter performance, Gas turbine particulate emissions.

Laser Induced Incandescence (LII) involves measuring the thermal emission (incandescent light) emitted from particles heated by a pulsed laser to temperatures in the 2500 K to 4500 K range. LII is highly selective, responding only to the presence of black carbon, making it decidedly appropriate for measuring the nonvolatile particles produced as a combustion emission. At LII temperatures, all volatile components that may have been condensed on the BC particles will be promptly evaporated, and most other nonrefractory particles will have also evaporated or undergone sublimation.

Due to this selectivity, LII does not measure the total particle mass. Black carbon is the primary and most stable constituent of particulate matter emissions from combustion.

Features

• Top-hat laser beam profile for uniform heating
• Two-color pyrometry for measuring the soot temperature
• Auto-compensating
• Does not require precise conditioning of the sample
• Real-time measurements
•Convenient for laboratory testing
• Vehicle onboard monitoring
• Very large dynamic range

Applications

On-road mobile emissions
Diesel engine exhaust
Gasoline engine exhaust
Diesel particulate filter performance
Advanced and alternative fuels, including biofuels
Urban air quality
Ambient air monitoring
Atmospheric black carbon levels
Gas turbine particulate emissions
Carbon black production
For engine emissions, LII 300 may be reliably applied directly to raw exhaust or to dilute exhaust.

For more information please contact:
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10 Reid St, Thebarton, South Australia
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NewSpec

Magnetic Beam Block / Tool Holder

The BB-L is a multi-function accessory for the lab, combining the features of a beam block and beam aligner with a ball driver tool holder. The front surface of the BB-L has a grid pattern of 0.25-in squares which can be used as a reference for aligning or levelling an optical beam. Numbers are printed on the edge of the grid pattern indicating height, in inches, above the table surface. Promoting eye safety, unused or stray beams can be easily blocked using the BB-L. Two sets of four holes (eight in total) are provided in the top for mounting various sizes of ball drivers either English or metric.

Made from black-anodized aluminium alloy its design also incorporates a 3-element magnetic base to allow quick and stable placement on to the stainless steel surface of an optical table. The base also includes a slot for bolting securely to an optical table. Metric and English ball driver wrench sets are available separately.

Please contact NewSpec for further details: *sales@newspec.com.au*

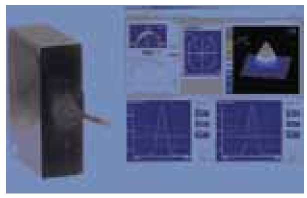
Reference Solar Cell

The Newport Oriel® Reference Cell, which is an integral part of solar simulator calibration and solar cell I-V characterisation, consists of a readout device and a 2 x 2 cm calibrated solar cell made of monocrystaline silicon. The cell is also equipped with a thermocouple assembled in accordance with IEC 60904-2.

The Reference Cell comes with calibration data and an accompanying certificate. It reads solar simulator irradiance in “sun” units; one sun is equal to 1000 W/m2 at 25 °C and Air Mass 1.5 Global Reference. This tool’s primary use is the testing of photovoltaic cells under standard conditions. The Readout Meter includes two BNC connectors for analogue outputs for the sun irradiance and the temperature.

Please contact NewSpec for further details: *sales@newspec.com.au*

Scanning Knife-Edge Laser Beam Profiler



The KEP Series Laser Beam Analysers are an extension to Newport’s LBP series CCD based laser beam profiler range. The KEP produces the same detailed 3D intensity profiles as the LBP products but also is capable of measuring very small spots at high resolution and huge dynamic range.

The measurement technique is based on a multiple scanning knife-edge technology, combined with a tomographic image reconstruction for the creation of the 2D/3D display. When the drum spins, the knife-edges cut across the beam in an orthogonal plane to the direction of propagation. A stationary large detector inside the spinning drum measures light intensity.

For attenuation, when needed, a built-in distortion free optical filter is inserted between the spinning drum and the detector. Each scanning knife-edge is oriented at a different angle on the drum and moves across the beam path in a different direction as the drum rotates. Consequently, during a single

Product News continues on page 124

Samplings

Nano-lamp illuminates quantum-classical boundary

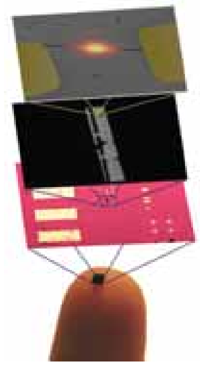
http://physicsworld.com/cws/article/news/39039

With just a single carbon nanotube for a filament, the world's smallest incandescent lamp has been made by physicists in the US. The team is using the tiny light to study the murky boundary between quantum mechanics and thermodynamics — and to their surprise, they have found that Planck's theory of blackbody radiation, which should only apply to large objects, is also relevant at the nanoscale.

Planck's blackbody radiation law describes thermal radiation emitted by large objects — including light bulbs, the Sun, and the early universe. The law was developed over a century ago using thermodynamics principles, plus one revolutionary new postulate — the idea that light was quantized. This led to the development of quantum mechanics, which works best when describing just a few tiny particles. Conversely, thermodynamics concerns systems with many particles.

The new incandescent bulb was made by Chris Regan and colleagues at the University of California at Los Angeles. The filament is a single carbon nanotube just 100 atoms wide and as such straddles both classical and quantum regimes thanks to its small size. With less than 20 million atoms, the nanotube filament is both large enough for statistical thermodynamics to apply, and small enough to be a molecular, or quantum mechanical system.

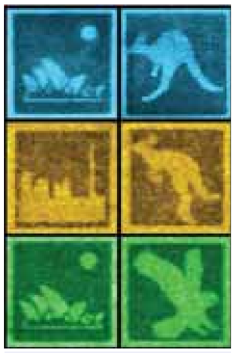
The team studied the light emitted by the carbon nanotube filament using an optical microscope with various colour filters. "Planck's law tells us what light intensity to expect as a function of wavelength and temperature," said Regan. "By changing the colour filter and the applied electrical current, we can alter both the wavelength and temperature respectively. This allows us to compare Planck's prediction with what we detect coming from the carbon nanotube lamp." (*Phys. Rev. Lett. 102, 187402 (2009)*)



Images of the world's smallest incandescent lamp at progressively increasing magnification. (Courtesy: Regan Group, UCLA).

Data storage enters the '5th dimension'

http://physicsworld.com/cws/article/news/39146



Six of the 18 patterns encoded in the same area using two laser polarizations and three different wavelengths. (Courtesy: James W. M. Chon).

The first DVD–sized discs with storage capacities well over one terabyte could be available in as little as five years, according to researchers at Swinburne University in Melbourne who have invented a new storage technique. The concept, which the researchers have already demonstrated on test media, uses layers of gold nanorods to achieve 'five–dimensional recording'.

Optical discs, such as CDs and DVDs, store data as a spiral track of microscopic pits etched onto their surface. To read the data, light from a laser diode is reflected from the surface and the reflected light drops in intensity every time the beam hits a pit. With just one layer of pits the storage is two dimensional, and with multiple layers — a method employed in the highest capacity DVDs, providing capacities up to about 17 Gb — the storage is 3D.

For higher capacities, above 1 Tb (10^{12} bytes) per disc, scientists believe they will need to record in even more 'dimensions'. Recently there has been success in adding one dimension in the form of sensitivity to either the polarization or colour of the laser, a technique called multiplexing. The Swinburne team led by James Chon has combined both types of multiplexing for five–dimensional recording.

Recording consists of polarization- and wavelength-dependent melting of nano-rods by laser irradiation, and reading is achieved by measurement of plasmon resonances. In tests using media with three layers of gold nanorods, Chon and colleagues achieved a data storage density of 1.1 Tbit per cubic centimetre, which would equate to 1.6 Tb for a DVD–sized disc. The researchers think that by using thinner spacers between layers the capacity could be increased to 7.2 Tb. Moreover, they say that recording speeds could be as fast as 1 Gbit/s, and the discs would be compatible with existing technology.

Samplings by Don Price and Andy Scott

Product News continued from page 123

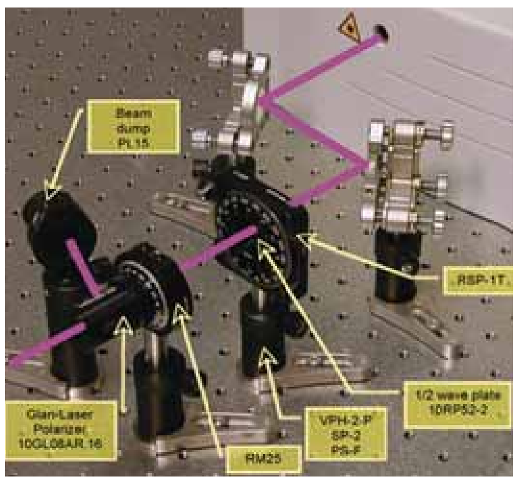
rotation of the drum, the instrument generates a set of profile curves, each representing the intensity profile of the beam from a different direction. This data is the input for the tomographic reconstruction algorithm to generate the 2D/3D intensity profile of the beam.

Please contact NewSpec for further details: *sales@newspec.com.au*

Variable Attenuator Kit

The Newport Variable Attenuator (MVA) Kit is an easy to use kit for the continuous attenuation of laser output power. Often times the output power of a laser is fixed at full power and users are not able to adjust the power coming out of the laser directly. This kit allows the user to assemble pre-selected off-the-shelf components for a cost effective, manual, continuous power control solution for linearly polarised lasers. A motorised variable attenuator kit is also available.

Please contact NewSpec for further details: *sales@newspec.com.au*



Conferences 2009

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

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

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

October 26 - 30
International Conference on Quantum Communication and Quantum Networking (from Satellite to Nanoscale)
Vico Equense, nr. Naples, Italy
http://www.quantumcomm.org

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

November 19
AIP Physics in Industry Day 2009
Sydney, NSW
http://physics-industry.com

November 23 - 27
Atomic Physics 2009
Dresden, Germany
http://www.mpipks-dresden.mpg.de/pages/veranstaltungen/frames_veranst_en.html

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

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

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

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

December 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
Registration will open in March 2009
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 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

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