Australian PHYSICS

March/April 2009 Volume 46 Number 2

A Publication of the Australian Institute of Physics

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

ORGANIC ELECTRONICS
The next technological revolution?

THE PHYSICS OF PLASMONS

SMART DIGITAL OPTICS
The business perspective

FASTS
An update

Australian Physics
A Publication of the Australian Institute of Physics

Contents

Volume 46 Number 2

Features

Regulars

Write an article for Australian Physics

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

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

Cover Image

Dew Drops on Spider's Web acting as convex lenses by Peter Firus from Swifts Creek Secondary College and the winning entry of the 2009 Victorian Physics Photo contest.

To learn more details on eligibility and entrance requirement for this contest see Branch News on page 34.

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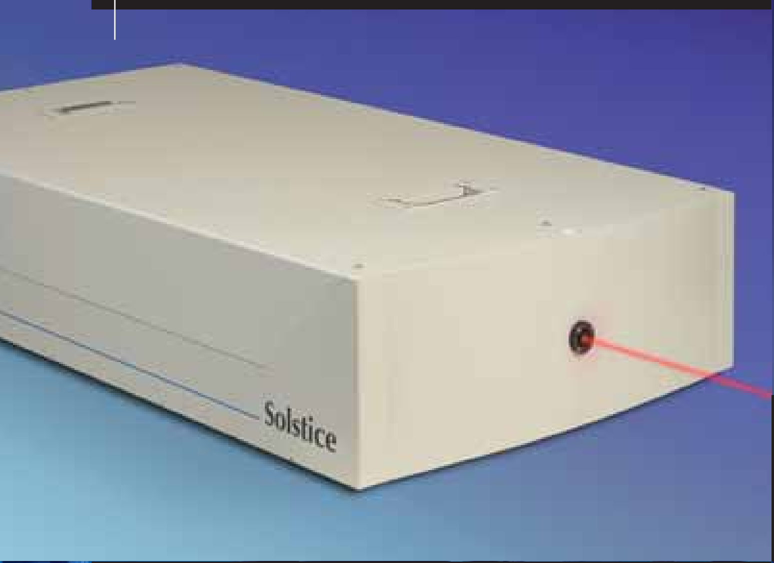

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Editorial

Editors of science journals, particularly physics journals, inevitably receive submissions proclaiming to have made a momentous discovery that will shake the world of science and quite possibly bring it to its knees. As Carl Sagan put it: Extraordinary claims require extraordinary evidence. Few of the claims made to *Australian Physics* ever satisfy that single potent criteria.

Nevertheless, there comes a time when, as a member's journal we should take a chance and print brief articles on a physics related topic, which may seem at first glance, to be risqué. Our new section called Quanta, is just such an avenue for you.

We're not talking about claims that Einstein got General Relativity all wrong by making an algebraic error that any high school student would know, nor are we willing to consider articles that purport to have scaled the heights of perpetual motion, now (evasively) called moto-continuum machines.

Our first Quanta article titled *Special Relativity Treatment of Stimulated Emission* by G.J. Troup et al (page 52) is a perfect example of what we're willing to consider.

No matter what the topic though, the decision to publish a submitted article rests with the Editor-in-Chief, who may consult the editorial board before making a final decision. As submissions to *Australian Physics* are not generally peer reviewed, this section does not provide an appropriate venue for publication of new results.

John Daicopoulos

Letters

Dear Sir,
Your Jan/Feb issue carries an interesting article on "Experiments with Antimatter". Having worked with antiprotons, antineutrons and even anti-hydrogen, I find the title of the article - and of the Centre of Excellence - mildly irritating, seeing that it deals only with positrons.

It is just too pretentious and misleading, in my humble opinion, shared by many others in the profession!
Tony Klein
University of Melbourne

Steve Buckman replies:
Thanks for the opportunity to respond to the (above) comment on our recent article, on the new Australian positron facility.

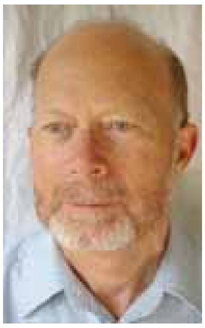
As you know, our brief from Australian Physics was to describe the new facility and discuss what plans there are for it. We were not asked, nor would we be qualified, to cover or review the wealth of other work on 'antimatter' - some of it by Australian colleagues and a considerable amount by Prof. Klein.

Our facility is one of just a few high flux, high-energy-resolution positron beams in the world. We have no pretensions to anything other than establishing a unique Australian facility for Australians to conduct experiments with these exotic particles on our own shores and, if we have irritated anyone in the process, then that is indeed unfortunate and unintended.
But, positrons ARE antimatter and we are working with them right here in Australia. Do I detect a form of 'scientific cringe' here - that in the world of antimatter physics one can only contribute if one works on particles that, by definition, are only available at offshore laboratories. That would be a shame.

We would be happy and delighted to provide Professor Klein with a tour of our facility when next he is in Canberra. I would hope that we can convince him that our program is active and worthwhile, even if it is 'only' involved with positrons - the most abundant form of antimatter.
Steve Buckman
The Australian National University

Submission deadline for the May/June 2009 issue is 11 May
Submission deadline for the July/August issue is 29 June

President's column: The path ahead



As I start my term as President, I reflect upon my last two years as a member of the national executive in the position of Vice-President. The highlight has been taking on the role of Editor-in-Chief[1] in order to create a stronger link between the executive and Australian Physics. This included overseeing the transition to a new Editor, John Daicopoulos, and with his help working to improve content and production values. I hope the results are obvious to members!

The 61st annual AIP Council Meeting was held in Melbourne 12-13 February, with a noticeable focus on operational issues. It is a testing time for professional societies: most are asking themselves in what ways they need to change to remain relevant to members; what services do members want and how are these changing. A slow decline in membership, which appears, at least in part, due to a reluctance of younger scientists to join societies like the AIP, suggests that the traditional model of a professional society is no longer relevant. Joining the AIP is not seen as an obvious part of describing oneself as a physicist.

Change does not always come smoothly. As members will be well aware, our change to web-based membership administration has had teething problems, but there can be no doubt that it is a move in the right direction. If anything, we have lagged in this regard. The next step is to further develop our website. I see it as serving a number of purposes: a resource for the broader community on physics-related topics, a location for resources for students and teachers; and also, via a members–only section, a means of providing more specific professional information, such as career advice. In achieving this we will have access to material prepared by fraternal societies such as the UK Institute of Physics. I would like to see our website become one that students, teachers, professional physicists, and perhaps even members of the general public would have reason to visit frequently.

Another topic that produced lively discussion at Council was branch activities. There is a general consensus that the old style branch meeting, where an invited speaker gives a talk on his or her special topic, does not attract the audience it used to. There are possibly several reasons for this: there is more competition for our time outside work hours; finding a 'good' time and venue to hold such a meeting is problematic, especially in the big cities; and many members have frequent other opportunities to hear such talks. The most successful branch events are more likely to be special events rather than regular meetings: industry days, outreach activities, meetings organised jointly with other organizations on topical issues (the Nobel Prize for Physics, the Large Hadron Collider….). The success of an event will be judged on attendance, but it is also likely to be something that would not have occurred if the AIP had not organised it or had not contributed to its organization. It will be something where the AIP has made a difference. Branches took note of each other's successful activities; I am sure that branch chairs went away with new ideas and renewed enthusiasm.

My background is academia but I have had frequent interactions with government research institutions. I am, however, less familiar with the activities of physicists, and physics-trained professionals, outside these institutions. In particular I believe the AIP needs to serve better its members working in industry. A first step is better recognition. As editor-in-chief of Australian Physics I sought articles about physics in industry and career profiles of physicists working outside academia and government research laboratories. I had some success with the latter, less with the former. Although the large industry research laboratories have all but disappeared, there is much more small-scale entrepreneurial activity, often growing from research in universities and government laboratories. Physicists working in small, often recently established, companies are likely to have more pressing matters to deal with than writing articles for Australian Physics. Nevertheless, I invite such members to consider writing an article. Feel free contact me with ideas about how the AIP can help with your specific needs.

I have been a member of the AIP since student days, and it is an honour to find myself now President. I have been proud to be a member of the executive over the last two years as it undertook initiatives, under Cathy Foley's leadership, to better serve the membership. The new executive will continue the process. I look forward to a wider engagement with the physics community that is afforded by the position of President. Finally, I invite members to contact me to express their views about 'what the AIP should be doing'.

[1] *This role, which is part of the vice-president's portfolio now passes to incoming vice-president Marc Duldig.*

Branch News

Victoria

2009 Physics Video Clip Contest

Open to students and science teachers in Victorian schools.

Content: The video clips should demonstrate physics in action and explain the physics ideas in the action shown. They will be evaluated on their suitability for instructional use.

Two Categories: Teachers and Students
The production of a video may involve a number of people. If the production has substantial teacher input, even if those in front and / or behind the camera are students, then the submission should be in the teacher category. If a group of students produce a video as a class assignment set by the teacher, but without any further input from the teacher then it can be entered in the Student category. Videos can only be submitted by individuals or a team of two people.

Entry: The video clips can be submitted as an email attachment or on DVD. Entrants may submit more than one, however each entrant can receive only one prize. Limit of 10 entries per school. Videos must be in MP4 or Quicktime format, or a format suitable for video streaming. The video may not be longer than three minutes in length. Professional editing is not required. Please note: Unsafe practices will not be accepted. An explanation of the Physics in the video should be either on the audio or in a supporting 250 word statement.

Guidelines for a better video clip:
Check the contrast between any text and the background. Readability is crucial. Do not let the background music overtake any voice-over messages. If audience can't hear the message, they will not understand the lesson. Relating the physics lesson to a story line is effective. Humor is good, bad physics doesn't 'make the cut'. Credits at the end of the video are useful but should not be very long.

Viewing: Entries will be placed on the AIP website as they are received. They will be available as streamed video.

Judging: The best three entries in each category will be selected for judging at the annual Physics Teachers Conference in February. Videos will be evaluated on their suitability for instructional use. A student report to camera of a practical activity is unlikely to be of significant value.

Prizes in each category
1st Prize: $600
2nd Prize: $300
3rd Prize: $150
4th and other prizes: $50

More details about the Contest Rules and Entry Agreement can be found at *www.vicphysics.org/videocontest.html*.

Closing Date:
Videos will be accepted until the 30th October, 2009.

2009 Physics Photo Contest

The contest is open to students in Victorian schools. Entrants must submit their photos by email attachment. In addition entrants must print out, complete, sign, and mail the Contest Rules and Entry Agreement, which is available on the AIP website, *www.vicphysics.org/Photocontest.html* Failure to submit this form will invalidate the contest entry.

Both the email and the hard copy must contain a statement of 250 words or less describing the physics in the photo. The statement should have a title and must be written by the entrant. Entries are limited to 10 per school each year.

The photos can involve everyday situations that may demonstrate a variety of physics concepts or a set up to show a particular physics concept or related set of concepts.

Prize Pool: $1000

Judging:
Upon receipt each photo will be placed on the AIP website. Photos will be accepted until the first day of Term 4, 2009.

Judging will be by a panel experienced in scientific photography and it will be based on the quality of the photo and the accuracy of the physics statement.

The rules and conditions of the AIP Photo contest are based on those of the photo contest of the American Association of Physics Teachers. Previous winners of their photo contest are displayed at *http://www.aapt.org/Contests/photocontest.cfm*.

Professor Aspect

Professor Alain Aspect (CNRS Senior Scientist at Institut d'Optique and Professor at Ecole Polytechnique, Palaiseau) was invited to Australia for the 2008 AIP Congress and as part of his visit on December 10, 2008, he presented an exciting public lecture on the EPR paradox, quantum entanglement and experimental evidence he, and others, have undertaken to demonstrate these effects. Professor Aspect's lecture, "From Einstein's intuition to quantum bits: a new quantum age?", was given at Melbourne University as the final of the Victorian Branch's 2008 lecture series.

The talk was preceded by the presentation of the 2008 Third Year Physics Practical Award to Mr Jayden Newstead of Monash University. The award is sponsored by Gottfried Lichti and Technology Outcomes Pty Ltd, a continued supporter of experimental physics at an undergraduate level. Mr Newstead undertook a mini-project as part of his third year laboratory activities, the outcomes of which are intended to be written up as an article, with his supervisor Dr Lincoln Turner, for submission to the American Journal of Physics.

Professor Alain Aspect prepares to give his lecture "From Einstein's intuition to quantum bits: a new quantum age?"

News

ERA timeframe

The Minister for Innovation, Industry, Science and Research, Senator Kim Carr, announced the timeframe for the Excellence in Research for Australia (ERA) trial, which will evaluate the Physical, Chemical and Earth Sciences (PCE).

"The Australian Government is committed to the development of a world-class research quality and evaluation system that has the confidence of the sector," Senator Carr said.

"Recent feedback on the ERA Submission Guidelines and ERA–SEER Technical Specifications raised concerns about the proposed timing of the ERA trial.

To ensure universities are adequately prepared for the trial, submissions for the PCE cluster will now commence in June 2009.

The outcomes of these trials will inform the full ERA process in 2010."

Recent feedback also raised concerns about the scope of some of the data to be collected.

Following this feedback, esteem indicators will not be included in the ERA trial. I have asked the ARC to further investigate the collection of esteem indicators, which will be included in future evaluations.

The expert review and feedback that the ARC has received so far has been crucial in shaping ERA."

More information on the Excellence in Research for Australia is available on the ARC website.

ARC

Dr Matthew Hole appointed to the International Fusion Research Council

Dr Matthew Hole has been appointed by the Director General of the IAEA, Dr Mohamed Elbaradei, to the International Fusion Research Council (IFRC).

The function of the IFRC, a continuing Council within the framework of the IAEA, is to advise the IAEA on its controlled nuclear fusion research program, and promote international cooperation in this field.

The IFRC also proposes the Scientific Programme Committee of the biannual IAEA Fusion Energy Conference, the leading international fusion conference on the programmatic development of fusion power.

The Council, consisting of 10 to 15 expert members, comprises one member from each IAEA member state or international organisation having a substantial research effort in controlled nuclear fusion.

Appointment of an Australian to the IFRC, which occurred after consultation with the Australian government, is a recognition of Australia's research effort in this field, while selection of Dr Hole consolidates ANU's national research leadership in this field. The last Australian appointed to the IFRC was Professor Max Brennan AO FAA, who served as Chairman of the IFRC from 1987 to 1995. New developments in fusion research, support for international physics activities, and close collaboration with ITER and the OECD's Fusion Power Coordinating Committee, which supports ITER activities in OECD countries, will be among the future challenges for the IFRC.

ANU

Live streaming from the International Space Station

Live streaming video is now available every day of the week from the International Space Station. The video will show views of Earth and the exterior structure of the station, as seen from cameras mounted outside the ISS, and other times, activities going on inside the station. The Earth views will usually be seen during the crew's off-duty or sleep periods.

Image credit: NASA

During times when the shuttle is docked to the station, the stream will include video and audio of those activities. Whenever video isn't available, a graphical world map will be shown that depicts the station's location in orbit above the Earth using real-time telemetry sent to Mission Control from the station.

Since the station orbits the Earth once every 90 minutes, it sees a sunrise or a sunset every 45 minutes. When the station is in darkness, external camera video may appear black, but also may provide great views of city lights below.

The streaming video is being webcast as part of NASA's celebration of the 10th anniversary of the space station in orbit.

To find out when you can go outside and look back at the station overhead, check out NASA's page for sighting opportunities.

NASA

Organic Electronics

The Next Technological Revolution

by Paul C. Dastoor
Centre for Organic Electronics, University of Newcastle

Introduction

The development of plastic in late 1800s revolutionised manufacturing technology and led to the Plastics Age. These new materials were flexible, durable and formable in ways that natural materials were not. The first plastic material was developed by Alexander Parkes and was first revealed publicly at the 1862 Great Exhibition held at South Kensington in London. Parkesine, as the new material was dubbed, was cellulose-based material akin to celluloid that could be moulded when heated. In 1899, Arthur Smith patented the use of phenol-formaldehyde resins for use as an ebonite substitute in electrical insulation and this invention led to the development of Bakelite by Leo Baekeland in 1907; probably the best known early plastic. Further developments in the 20th century lead to the invention of Vinyl (polyvinylchloride) in 1926 by Walter Semon, Teflon (polytetrafluoroethylene) by Roy Plunkett in 1938 and Nylon by Wallace Carothers in 1939. These materials, and other related plastics, share many similar properties: they are inexpensive, flexible and easy to process. Another property that appeared to be systemic to plastics up until the 1970s was that they were all electrical insulators. Indeed, one of the first domestic applications for Bakelite was as electrical insulation.

This situation changed, however, in 1977 with the discovery by Alan Heeger, Hideki Shirakawa and the late Alan MacDiarmid that polyacetylene becomes a metallic conductor upon iodine doping. This discovery ultimately created an entirely new field of organic electronics and has lead to extremely rapid developments in the areas of organic light emitting diodes (OLEDs), organic photovoltaics (OPVs) and organic field effect transistors (OFETs) to name but a few. The rapid development of organic electronics as a research area has paved the way for the rapid development of commercial devices based on this new technology. The first applications have come from the commercialisation of OLED-based display technology with initially small screens for consumer products ultimately resulting in the development of the OLED based XEL-1 TV released by Sony in 2008. These new OLED based displays offer enhanced contrast ratios, wider viewing angles and much thinner formats that comparable LCD or plasma displays (Figure 1).

Figure 1

1 Organic Electronics: the plastic revolution

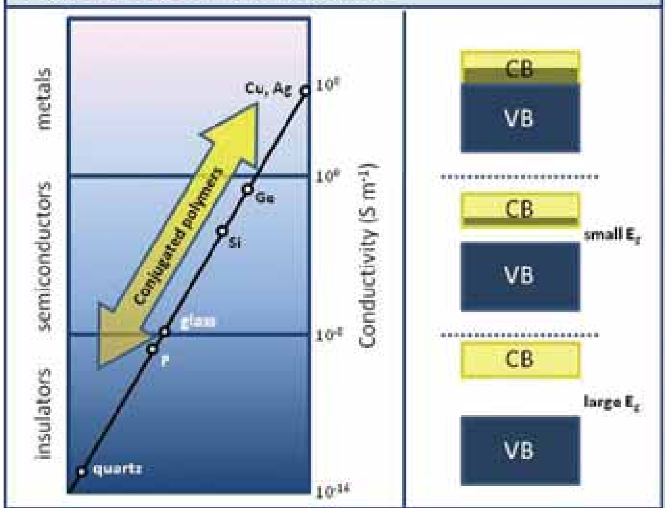
An OLED electronic display watch (**top left**) and mp3 player (**top right**). The new Sony XEL-1 OLED television (**bottom panel**).

The defining feature of organic electronics is that it allows us to combine the flexibility, formability and economy of plastics with the technological capability of electronics. We are now in the exciting position of being able to envisage a world where consumer electronics devices can be printed at such low cost as to be disposable, where every building has a flexible photovoltaic coating on its roof and where integrated bioelectronic sensors and transistors are routinely available.

Origins of Semiconductivity

Inorganic semiconductors, such as silicon, are crystalline solids with an electronic structure that can be described in terms of energy bands, where each energy band is actually an array of allowed energy levels (or states) that can be occupied by an electron. Just as audience members have to occupy seats in a theatre, electrons have to occupy states within the energy band. In the idealised case, the electronic structure consists of a higher energy conduction band and a lower energy valence band separated by an energy gap, the size of which depends upon the material. Indeed, one can stretch the theatre analogy a little further to think of the valence and conduction bands as corresponding to the stalls and upper circle seats respectively. This concept of an energy gap, which is entirely a consequence of quantum mechanics, is crucial to our understanding of conductivity in materials and its subsequent exploitation in a vast range of electronic devices. The high electrical conductivity of metals is a consequence of the fact that the highest occupied band is only half full and hence there are many empty states within the band that electrons can move to. In the case of insulators, however, the highest occupied band is full and thus for current to flow the electrons have to cross an energy gap of several electron volts and hence their conductivity is very low. Inorganic semiconductors tend to have band gaps typically in the energy range 0.1 – 2.2 eV. In the case of silicon, for example, the band gap is 1.12 eV, whereas for gallium arsenide it is 1.4 eV. It is energetically feasible, therefore, that there is sufficient thermal energy at room temperature to excite an electron from the valence band into the conduction band of the material thus producing two charge carriers: an electron in the conduction band and a so-called "hole" in the valence band. Although the hole that is produced is simply an empty electronic state, which can be occupied by other electrons in the valence band, it behaves to all intents and purposes as though it is an independent carrier of positive charge. However, to make practical devices, inorganic semiconductors typically need to be doped in order to increase their conductivity by making them rich in either electrons (n-type) or holes (p-type).

2 Conductivity and Band Structure Figure 2



Left hand panel: Electrical conductivity of conjugated encompasses the range of conductivities from insulators to semiconductors to metals. **Right hand panel:** The corresponding band structures for metals, semiconductors and insulators. In an insulator, the valence band (VB) is full and no electrons can cross the band gap (E_g) to occupy the conduction band (CB). For a metal there is no E_g and the CB is partially filled. In a semiconductor, E_g is small enough to permit thermally activated occupancy of CB.

Organic semiconducting materials are not limited to polymers but also encompass the small molecule systems such as the arenes, pthalocyanines and the vast range of organic dye materials. The common feature of all of these organic semiconductors is that they possess chains of alternating single and double carbon bonds, producing what is known as a conjugated p electron system that is delocalised over the entire molecular system. Effectively the extra electrons from the double bonds are only loosely held and can move along the polymer chain (intrachain transport) or between chains (interchain transport). More accurately, it is the characteristics of the p bonds that actually lead to the electronic properties of conjugated polymers. Firstly, the p bonds are delocalised over the entire molecule and secondly, the quantum mechanical overlap of p_z orbitals actually produces **two** orbitals, a bonding (p orbital) and an anti-bonding (or p* orbital). The lower energy p orbital produces the valence band while the higher energy p* orbital forms the conduction band, with the difference in energy between the two levels producing the band gap that determines the optical properties of the material. Interestingly, most semiconducting polymers appear to have a band gap that lies in the range of 1.5 – 3 eV, making them ideally suited as optoelectronic devices working in the optical light range.

Rather than the usual electron wave picture that is used to describe conductivity in crystalline inorganic semiconductors, electron transport, in the more amorphous conjugated polymers, is better described by a hopping transport model. As such, carrier mobilities in conjugated polymers are not as high as those observed in the best crystalline inorganic materials and thus it is unlikely that these organic materials will be able to truly compete with inorganic semiconductors in terms of speed or ultimate device miniaturisation. Indeed, the initial mobility values in these organic materials were very low (~10^{-5} cm^2 V^{-1} s^{-1}) in comparison with silicon-based inorganic devices (0.1 – 1 cm^2 V^{-1} s^{-1}). However, with the development of new organic semiconductors these mobilities have improved, with, for example, OFETs made from pentacene exhibiting mobilities in excess of 1 cm^2 V^{-1} s^{-1}. The vacuum deposition of short chain oligomers on the other hand tends to lead to polycrystalline or single crystalline films. These materials tend to assume p–p stacked structures parallel with the OFET substrate thus allowing efficient charge transport in the plane of the film. However, defect scattering occurs at the grain boundaries in these materials thus lowering the mobility of the polycrystalline films with respect to the single crystal materials. The polymers that show the most promise in this area are based on the polythiophene structure. Indeed, solution processed films of poly(3-hexyl)thiophene (P3HT) have high field effect mobilities of 10^{-2} – 1 cm^2 V^{-1} s^{-1} and hence are well within the range of amorphous silicon based devices. The mobilities of these more ordered thiophenes are much higher than those found in amorphous p-conjugated polymers such as polyacetylene and polythiophene and thus it appears that the degree of polymer crystallinity plays an important role in device performance. Thus, even considering their lower transport properties, solution processed polymers still offer the greatest potential for the production of low-cost so-called "soft electronics" since they can be easily processed as liquid, unlike the organic crystals and short chain oligomers which are typically vapour deposited.

Developing Solar Paint - Organic Photovoltaics

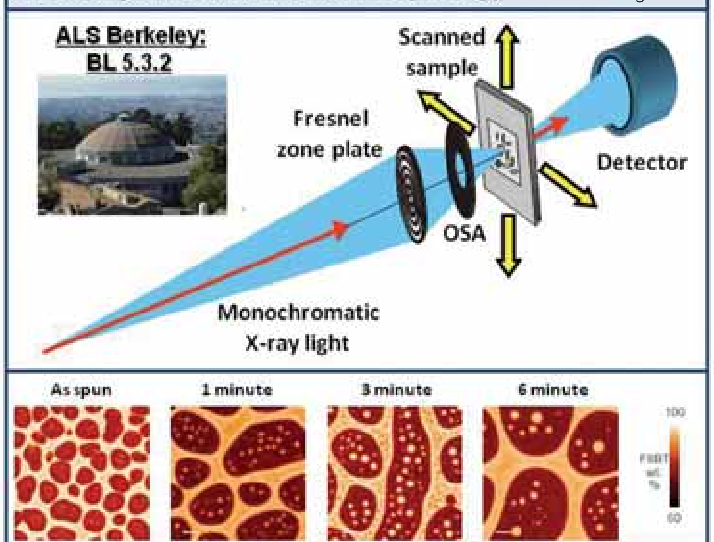
The development of novel photovoltaic (PV) devices based on conducting polymers is one of the most rapidly developing areas in the field of organic electronics. The increasing demand for energy coupled with the rapidly increasing world population provides a significant driver for the expansion of global energy resources. Moreover, the constraints of climate change and sustainability mean that meeting this so-called "Terawatt Challenge" will only be possible using non-CO_2 energy generating technology. Indeed, ever since their first discovery, conducting polymers have been used to form the active elements of PV devices. The motivation is clear: of all the non-traditional renewable energy resources currently available arguably only solar power has the potential to provide the world with the increased electrical generating capacity that it requires in a sustainable manner. Moreover, within the more specific area of solar photovoltaic devices, solar cells made from polymers can be printed at high speeds across large areas using roll-to-roll processing techniques thus creating the tantalising vision of coating every roof and other suitable building surface with photovoltaic materials at extremely low cost.

Basic Operation

The photocurrent generation mechanism for inorganic semiconductors, such as silicon, is well established.
In a conventional inorganic photovoltaic device, the photocurrent is generated across junctions between n-type and p-type semiconductors with the photo excited electron and hole being separated by the strong internal electric fields that exist at the junction and thus becoming free to migrate to the opposite electrode, whereupon they can

do useful work. In the case of semiconducting polymers, however, the photocurrent generation mechanism is more complex than for inorganic semiconductors. Although the action of an incident photon upon a conducting polymer excites an electron from the valence band into the conduction band the low relative dielectric constant of organic materials (typically 2 – 4) means that the electron and hole that are produced are bound and their motion through the material is coupled. These coupled moieties are known as **excitons** and are responsible for many of the electronic properties found in the most common and efficient polymer-based electronic devices.

3 Probing OPV Structure and Morphology Figure 3



Upper panel: Scanning transmission X-ray microscopy (STXM) is a powerful synchrotron based technique for quantitatively mapping the chemical composition of OPV polymer blends. By rastering the X-ray beam across the surface an X-ray absorption spectrum can be collected at every pixel. Chemical contrast is obtained from the different absorption strength of each component at different X-ray photon energy. **Lower panel:** Evolution of morphology and chemical composition of poly(9,9´-dioctylfluorene-co-bis-N,N´-(4,butylphenyl)-bis-N,N´-phenyl-1,4-phenylene-diamine) (PFB) and poly(9,9´-dioctylfluorene-co-benzothiadiazole) (F8BT) for increasing film drying times following spin coating (scale bar = 2μm).

How then, can we obtain any useful work from a conducting polymer if the electron and hole are not separated? It turns out that the bound exciton can be split at interfaces with the simplest interface being created at the junction between the electrode and the conducting polymer. Under open circuit conditions, holes are collected at the high work function electrode (which is typically made of indium tin oxide (ITO) which is a transparent conductor) while electrons are collected at the low work function electrode (which is typically a metal electrode such as aluminium). Indeed, the open circuit voltage generated by these devices depends upon the work function difference between the two electrodes. Unfortunately, the exciton splitting process that occurs at a conducting polymer/electrode interface is not very efficient and was one of the causes of the low quality of early polymer photovoltaics. Another cause of the very low efficiencies of early devices was the effect of impurities, such as oxygen, which acted as traps to the migrating charge carriers.

Attempts to improve the efficiency of the exciton splitting process led to the development of new conducting polymer species that contained electron-donating and electron-accepting species. By creating interfaces between conducting polymer molecules of differing electron affinities it is possible to enhance the probability of electron transfer between molecules. This process (photo excited charge transfer) causes the bound charges to separate and the junction formed at the donor-acceptor interface is analogous to a semiconductor heterojunction. These heterojunctions work well at separating excitons that arrive at the junction. Unfortunately, the lifetime of excitons is short such that only excitons formed within about 10 nm of the junction will ever reach it. This short exciton range clearly limits the efficiency of these photovoltaic devices. In an attempt to develop more efficient photovoltaic structures, interpenetrating networks of electron-accepting and electron-donating polymers were produced by blending electron-donating and electron accepting materials together. With these materials, the number of heterojunctions within the polymer blend is greatly increased and so is the probability that an exciton will encounter a junction and be separated.

Progress Towards Organic Solar Coatings

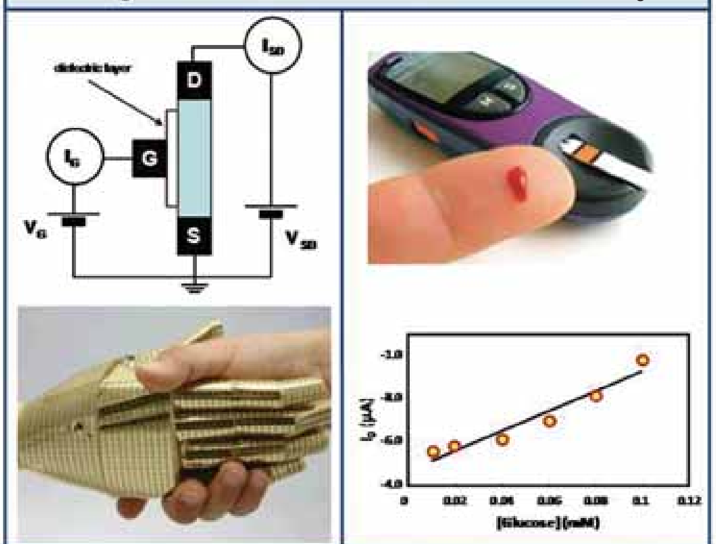
Photovoltaic devices made from organic semiconductors have come a long way since the first devices, using organic crystals such as anthracene and perylene were reported in 1959. These early organic electronic devices were typically sandwich-type structures, with films or single crystals of thickness between 1 to 100 mm arranged between two conducting electrodes.

Unfortunately, these molecular semiconductor based devices tended to show low photo-voltages (typically less than 500 mV) and poor energy conversion efficiencies. These poor efficiencies were attributed to difficulties in achieving efficient ionisation of the photo-generated excitons together with inherently poor electron or hole mobility in these materials. However, different device architectures were devised to circumvent some of these limitations. In 1986, Tang demonstrated that exciton dissociation could be made more efficient in molecular photovoltaic devices by creating a heterojunction of two organic layers with different electronegativities (namely CuPc (copper phthalocyanine) and PV, a perylene tetracarboxylic derivative. This was the first heterojunction structure and showed that efficiencies could be improved by bringing the electron donor (D) closer to the electron acceptor (A) material. In 1992, Sariciftci showed that by combining a semiconducting polymer (D) with C_{60} (A) then ultrafast D – A electron transfer occurs and demonstrated for the first time the potential for fullerenes (and their derivatives) to act as highly efficient electron acceptors in these devices. In 1995, Yu showed how the bulk heterojunction (BHJ) concept could be used to increase massively the number of excitons reaching an interface by intimately blending the donor and acceptor components. Moreover, the soluble fullerene derivative phenyl-C_{61}-butyric acid methyl ester (PCBM) material that was developed as part of this work has gone on to become the mainstay electron acceptor material in OPV devices for more than a decade. In 2001, Shaheen showed

how surface morphology was a critical determinant for device performance and that the choice of solvent system could have a profound effect upon OPV efficiency. Since then, OPV devices based on polythiophene derivatives have gone onto achieve routine efficiencies around 4 %. More recently, the importance of controlling the light distribution in these devices has been recognised and in 2006, Heeger's group showed how the use of a TiO_2 spacer layer could be used to enhance device performance by ~50% through maximisation of the light field within the very thin active layer. Further efforts to improve efficiency have focussed upon the development of tandem cells; combining two OPV cells with complimentary absorption characteristics in series. This architecture increases the open circuit voltage of the overall device and enables broadband absorption over the solar spectrum. Combined, these improvements have lead to the most efficient OPV device so far with efficiencies as high as 6.5% reported for tandem cells involving two polythiophene derivatives combined with PCBM.

Australian research in this field is very strong and coherently organised, with over a hundred researchers engaged across six universities and two divisions of the CSIRO, with a record of achievement that is highly competitive by global standards. The International Consortium for Organic Solar (ICOS) was established in 2006 with federal government support and brings together the major OPV research groups at the Universities of Melbourne, Monash, Newcastle, Queensland, Sydney, Wollongong, together with CSIRO groups in Melbourne and Newcastle to coordinate the activities of the Australian groups across a common set of milestones and also to provide Australia with access to the experience of major international research groups in the US, UK and Singapore. The ICOS consortium has been an outstanding success in demonstrating the ability of geographically distributed research teams to focus on a common goal. Each partner in the consortium brings complementary strengths to the group across activities ranging from modelling and synthesis of new organic molecules, through to the physics of solar cell design and the characterisation of OPV systems. For example, the Centre for Organic Electronics (COE) at the University of Newcastle has been contributing expertise in device physics and fabrication to the consortium and has developed new state-of-the-art synchrotron-based techniques for studying the influence of surface morphology upon device performance (Figure 3).

4 Building OFET Sensors and Devices Figure 4



Left panel: (Upper) In an OFET device, the current flowing between the drain (D) and source (S) electrodes is controlled by the voltage applied to the gate (G) electrode, with very small changes in the gate voltage leading to large changes in the drain-source current. (Lower) E-skin hand device comprising OFET arrays embedded in carbon-rubber flexible sheet. **Right panel:** (Upper) Conventional blood glucose meter requiring needle stick extraction of blood sample. (Lower) Prototype OFET enzyme-based glucose sensor response showing response at glucose concentrations that are comparable to salivary levels (0.008 – 0.2 mM) and considerably lower than the corresponding blood glucose levels (3.5 – 7.8 mM).

Developing Disposable Integrated Circuits – Organic Transistors

The first OFET was demonstrated by Tsumura and co-workers in 1986 using polythiophene as the semi-conducting layer with a similar device being reported by Burroughes et al. in 1988. In an OFET, the current between the source and drain electrodes (I_{SD}) is controlled by a voltage (V_G) applied to a third electrode known as the gate. The gate electrode is separated from the source-drain region by a thin insulating dielectric region and thus is capacitively coupled to the semiconductor. By altering the bias voltage applied to the gate region the source-drain region can be altered from conducting to insulating and hence the device can be turned on or off. Importantly, the presence of a relatively small number of charges on the gate electrode alters the flow of a great many charges between the source and drain electrodes and thus, as well as acting as a *switch*, the FET acts as an *amplifier*.

A common feature of these early organic thin film transistors (OTFTs) was the use of silicon as the substrate material. These hybrid devices were not truly all-polymer electronic devices and did not offer all of the advantages of organic materials such as flexibility. However, patterning conducting and insulating regions on silicon is a well-established technology and fabrication of these devices was relatively easy to implement. Subsequently, the first all-polymer FET was reported by Garnier et al. in 1994 and was fabricated by a printing technique.

As discussed, the mobility of the charge carriers is a key to determining the performance of conjugated polymers in organic electronic devices and this parameter is particularly relevant in the case of organic transistors. As such, a great deal of OFET research has focussed upon developing and optimising the charge carrier mobilities of existing and new organic materials. Traditionally, hole carriers (p-type materials) dominated the organic electronic landscape but advances in material design and synthesis have led to an increasing number of n-type molecules where electrons are the dominant charge carrier. A variety of semiconducting organic materials are now commonly available ranging from small molecule systems based around the acenes to conjugated polymer systems (such as polythiophenes) to larger macrocycles with further intense effort aimed at improving morphology, processing, and reliability through modification of side chain functionality, etc.

One of the most active areas of current OFET research is focussed on the application of these organic electronic devices as sensors and detectors. Research into OFET-based sensors encompasses a number of areas, including large area detectors, transducers and biosensors. In the case of large area detectors such as pressure sensors, the OFETs are typically used to form active-matrix structures or other electronic circuits for reading data out from each sensing unit. As such, the OFET structures are simply used as electronic switches and are actually designed to be insensitive to their environment. Indeed, research at the University of Tokyo has shown how robots of the future could be endowed with the sense of touch using sensors based on organic electronics. Takeo Someya's group has built high-mobility organic transistors with pentacene as the channel layer that were fabricated into a flexible sheet made of carbon and rubber. Upon flexing the electrical resistance of the carbon-rubber sheet is changed locally and this change in resistance operates on the nearest OFET. Using this so-called e-skin (Figure 4), the robot's control system could be made to "feel" with a sensitivity of about 10 g/cm^2 that is independent of the OFET array. The initial 16 x 16 sensor devices built by the University of Tokyo team were limited by the response time of the pressure-sensitive rubber (~500 ms) but for larger arrays the overall frequency response is currently limited by the response time of the OFET devices (~30 ms).

OFET devices are also attractive as candidates for sensors in the own right. In particular, the fact that OFETs are fabricated from a material system that can be made liquid soluble and is carbon-based means that they are much more compatible with other organic systems, such as biomolecules, than transistors built from conventional inorganic materials. Research in the author's group at the University of Newcastle is focussed upon developing new biosensors based on integrating biomolecules (such as enzymes) directly into the OFET structure to create highly specific and highly sensitive detectors that can be printed at low cost using conventional inkjet printing technology (Figure 4). The ultimate vision for this work, which is at an advanced stage, is the development of a sensor that responds to the much lower salivary glucose levels instead of the usual blood glucose levels. Such a development would open the door for a non-invasive glucose meter for diabetes sufferers that would only require a very small amount of saliva to determine glucose level as opposed to current devices that require the patient to provide blood samples via needle stick.

The Organic Electronic Age

Although the fabrication of devices and machines based on organic electronics is still in its infancy, this exciting new field is developing rapidly and this development is accelerating. It is widely anticipated that electronic devices based on organic materials will gradually replace those based on conventional inorganic semiconductors and metals, driven primarily by the material properties of plastics, which allow for the production of arrays of devices on flexible substrates using extremely low cost printing and coating techniques. Indeed, rapid advances are already being made with organic electronic materials offering enormous potential across many technologies ranging from new sources of low cost renewable energy to arrays of biosensors for medical applications. These materials also open up the prospect for new technologies that not accessible by current materials by providing the interface between biological systems and electronic systems. It is possible to envisage bionic devices based on organic electronics that could be readily interfaced with biological systems and potentially directly linked to a patient's muscles and nerves. Perhaps we will see, in our own lifetime, a world where organic electronics provides both the photovoltaic coating on our roof and the glucose sensor that we printed at home on our inkjet printer.

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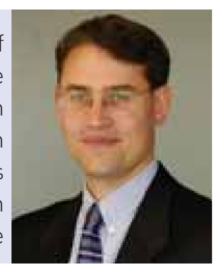
Professor Paul Dastoor is Professor of Physics at the Univ. of Newcastle. He received his B.A. in Natural Sciences in 1990 and his PhD in Surface Physics, both from the Univ. of Cambridge, in 1995. His research interests encompass the growth and properties of thin films, surface



More Branch News

Queensland

byJoel Corney

As the 2009 Chair, I'd like to introduce the other committee members that I will be working with to promote physics and the role of physicists in Queensland.
They are:

Dave Kielpinski, Secretary
(Griffith Univ.)
Tom Stace, Treasurer
(Univ. Qld)
Josh Bartlett
(Student rep, Univ. Qld)
Brad Carter
(Univ. Southern Qld)
Matthew Davis
(Univ. Qld)
John Wilkinson
(Forest Lake College)
Mark Young
(Anglican Church Grammar School)

FASTS Federation of Australian Scientific and Technological Societies

FASTS – update on Australia's peak science body

You are a member of the Federation of Australian Scientific and Technological Societies (FASTS), Australia's peak science body, through your AIP membership.

FASTS represents 60 professional societies and 60,000 scientists, with professional staff who serve you, the AIP and the Australian scientific community in a number of ways.

FASTS ongoing activities include 'Science meets Parliament'—FASTS' annual flagship event, where more than 200 scientists have face-to-face meetings with politicians on key science issues.

Other work includes:

- Highlighting science with the Prime Minister and the Cabinet through the Prime Minister's Science, Engineering and Innovation Council (PMSEIC)
- Organising forums and workshops on key science issues
- Developing science policy at a high level and providing input to Parliamentary Committees, Government Departments and Government reviews and inquiries
- Assisting member societies to raise and develop issues, and distributing information to member societies weekly, and receiving feedback.

Highlights of 2008 included:

- Forums on 'Rights and Obligations of Scientists and Researchers' and 'Supporting Risk-Aware Research'
- A national roadshow to gather inputs to FASTS' submission to the Cutler Review
- Submissions to reviews on Higher Education Research Training, Future Fellowships, Defence, Higher Education Endowment Fund, ERA journal ranking, Questacon, CRC
- Continuation of FASTS' successful request for release of ARC grants in early October
- FASTS' statement on Climate Change – reported in 145 media outlets
- FASTS' Taxonomy paper highlighting this endangered species at SmP 2008.

In 2009 FASTS will:

- Holds 'Science meets Parliament'
- Provide to Parliament examples of science success stories from FASTS' members
- Present 'On the Radar' briefings on upcoming issues in science that need to be addressed by government, industry and the media – contact FASTS with your ideas
- Contribute to the development of National Curricula in science and mathematics
- Investigate whether science graduates have sufficient industry-ready practical skills.

In addition to its continuing and prospective activities FASTS will:

- Establish an expert list of FASTS members for media commentary – via your society
- Hold a forum on Governance of Science – how can science self-organise better?

FASTS seeks your help to keep science at the forefront of the national agenda in these challenging times.

For more information visit the FASTS' website *www.fasts.org*

President: Professor Ken Baldwin **Executive Director: Bradley Smith**

‘Plasmonics’ demystified

by Michael Cortie and Adel Rahmani
Institute for Nanoscale Technology
University of Technology Sydney

plasmon → ***noun*** *(Physics)* a quantum or quasiparticle associated with a local collective oscillation of charge density. from plasma + -on

1956 D. PINES in *Rev. Mod. Physics* **28** 184/1 “The valence electrons in the solid…are capable of carrying out collective oscillations at a high frequency... The valence electron collective oscillations resemble closely the electronic plasma oscillations observed in gaseous discharges. **We introduce the name ‘plasmons’ to describe the quantum of elementary excitation associated with this high-frequency collective motion**”
[Oxford English Dictionary]

‘Plasmons’ have been under scrutiny since at least 1956, when David Pines of Princeton coined the term[1] in a review article, and there have been some seminal texts on the subject in the interim[2, 3]. However, the field of ‘plasmonics’ - the exploitation of plasmons for useful or potentially useful technological objectives - is a more recent phenomenon, which emerged around the late 1990s. Since about 2003 there has been a significant rise in the number of both scientific papers and meetings devoted to plasmons and plasmonics. To illustrate this point, (Figure 1) a meta-analysis of the literature, where we have used the search terms ‘plasmon*’ and ‘optic*’ as proxies for papers on ‘plasmonics’ and ‘optics’ generally and applied them to the ISI Web of Science database. While the numbers of papers on general optics are roughly in line with the overall growth of content in the ISI database, those addressing some aspect of plasmonics have shown a marked increase in both relative and absolute numbers.

But first, before we discuss ‘plasmonics’, we had better investigate what exactly the field encompasses. This simple question immediately leads to an interesting bifurcation in views, with two nearly disparate lines of work laying claim to the title. There is a large body of work devoted to propagating oscillations of the electric charge density and a second large body of work devoted to stationary (i.e., spatially localized) oscillations, with overlap between the two phenomena in the same paper being rather rare. It is helpful to go back in time to get some perspective. Certainly, as defined by Pines, the definition of the term ‘plasmon’ applies to both kinds of phenomenon. More recently, however, it has become recommended practice[4] to differentiate between the two types by referring to the propagating oscillation as a ‘surface plasmon polariton’ (SPP), and to the stationary one as a ‘localised surface plasmon’ (LSP). And, yes, they are both part of ‘plasmonics’.

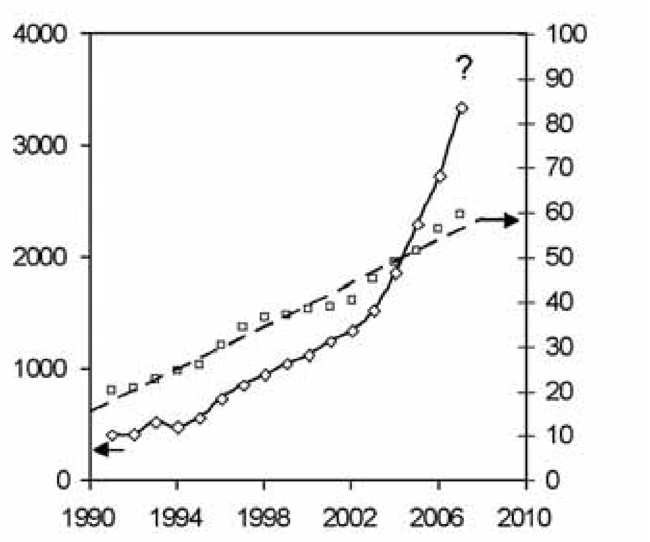


Figure 1. Number of papers per year on the ISI database that contain the term ‘plasmon*’ in their topic descriptor versus papers that contain the term ‘optic*’. Arrows denote which vertical axis to use.

Surface plasmon polaritons

The idea that an electric charge oscillation of this type can propagate along a suitable metal/dielectric interface predates Pine’s review in 1956, but was placed on a modern footing in an important paper by Kretschmann and Raether in 1968[5]. Of course, the oscillation is strongly confined to the immediate vicinity of the interface, but can travel long distances laterally, as we will see. This has led to the phenomenon being explored for potential application in waveguides, optical circuits and sensors, and it is already, of course, the basis of surface plasmon resonance spectroscopy which is an important analytical technique in the biosciences. The main problem to overcome is that the momentum of a photon in free space is normally insufficient to couple into an SPP, which is a TM electromagnetic wave trapped at the metal/dielectric interface. It can be shown[4] that the dispersion relationship for a SPP is

$$k_{SPP} = \frac{\omega}{c}\sqrt{\frac{\varepsilon(\omega)\varepsilon_m}{\varepsilon(\omega)+\varepsilon_m}} \tag{1}$$

where k_{SPP} is wave vector, ω and *c* are the angular frequency and velocity of the light (in vacuum), e_m is the dielectric constant of the insulating medium, and e(ω) the wavelength-dependent dielectric properties of the metal.

This relationship is plotted in Figure 2 using the e(ω) for gold and silver. The velocity of the propagating electromagnetic wave is less than *c* for all but the very lowest of ω values. (Since *k*=2p/l , the value of l *decreases* from left to right along the horizontal axis of this plot). Also important is that the dispersion curve for the SPP lies on or to the right of the light line, a factor caused by the mismatch in momentum mentioned earlier. As a result, a Kretschmann prism or some other scheme is needed to achieve phase matching between light and the SPP mode[6]. As shown here, the dispersion curve can be quite complex in shape. For example, the peculiar ‘zig-zag’ at the edge of the ultra-violet frequencies seen for silver[4] is due to the onset of strongly absorptive interband transitions in the metal, with the precise shape and depth of this feature being very sensitive to experimental conditions or values assumed for the dielectric constants [7].

Once excited, the SPP will propagate, decaying in intensity at a rate that is largely controlled by the level of absorption

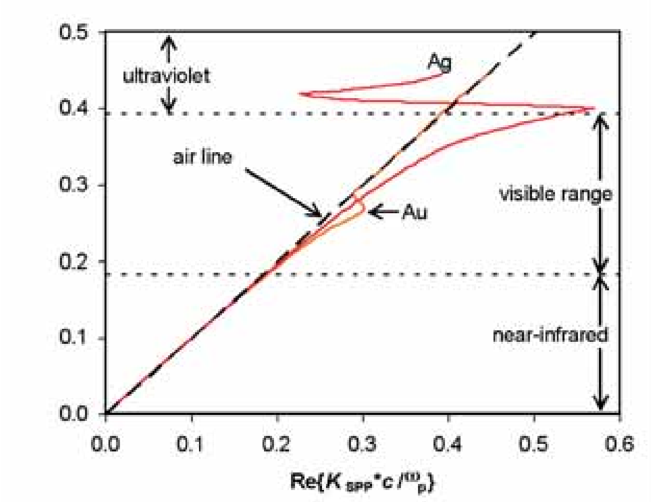


Figure 2. Dispersion characteristics of gold and silver, plotted using dimensionless parameters.

in the metal. Different materials may be compared with reference to their characteristic SPP propagation lengths, L_{SPP}, given by[8]

$$L_{SPP} = \left[2 \,.\, \mathrm{Im}\left(K_{SPP}\right)\right]^{-1} \qquad (2)$$

which is obviously also a function of the wavelength of light through K_{SPP} which is the wave number associated with the SPP. Some characteristic propagation lengths are shown in Figure 3.

Localised surface plasmons

As with the SPP, interest in localised surface plasmons goes back many years. For example, Mie himself became interested in what we now call the LSP resonance in the early 1900's. Here too there is further bifurcation in the terminology currently employed by the literature. An isolated resonance in a suitable nanoparticle or nanostructure might be termed a Mie plasmon[9], and indeed, this is what most of the literature is now referring to when the term 'localised surface plasmon'

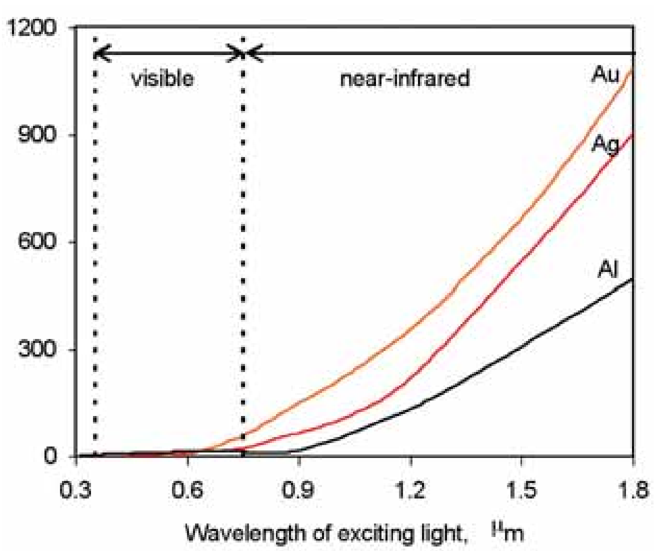


Figure 3. Theoretically predicted distances over which an SPP can propagate on a smooth surface of three 'plasmonic' metals (actual distances are invariably much smaller).

is used. However, light can also couple into periodic sub-wavelength metallic structures with the generation of plasmon resonances, this time extended simultaneously over many particles. The term Bragg plasmon has been proposed for these[9]. The resonance peaks of the two types of localised plasmon are inevitably quite different[10]. Potential or actual applications for these phenomena exist in fields as diverse as nanophotonics, chemical sensing, surface enhanced Raman scattering, and optical filters. These applications are in many instances driven by the strong enhancement in electric fields that occurs close to the surface of nanostructures undergoing plasmon resonance, Figure 4.

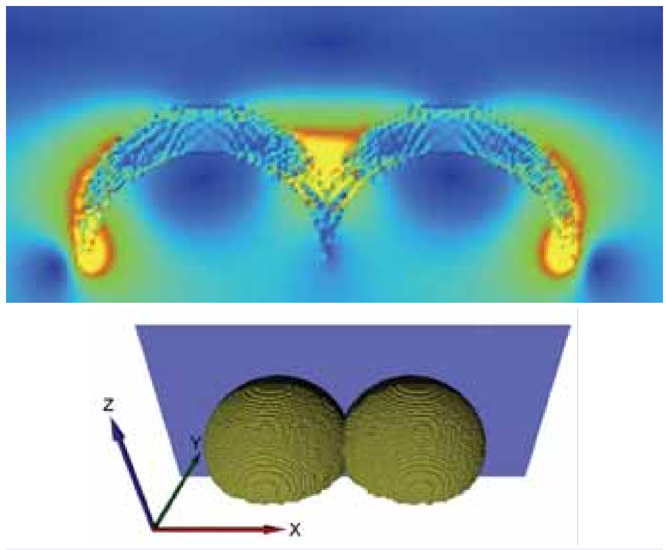


Figure 4. Electric fields generated on a conjoined pair of silver semi-shells incident light of 410 nm. In this case, the fields are greatest around the rims of the semi-shells and at the point of their intersection.

The LSP resonance in simple nanospheres, commonly made of gold or silver, has been rather thoroughly explored over the centuries. Readers wishing to find out more about its application in Raman time are referred to a recent article on the famous Lycurgus Cup in *Gold Bulletin*, a free electronic, ISI-accredited, journal[11]. The LSP resonance is slightly red-shifted as particle size or refractive index of surrounding medium increases, while increase in the size alone also increases the proportion of scattering relative to absorption. The Lycurgus Cup has a different colour in transmission to reflection because of this interplay between scattering and absorption. However, the biggest change in optical properties occurs if the nanospheres agglomerate. In this case the resonance is displaced to red or near-infrared and a colloidal suspension becomes dark blue (and unstable). The phenomenon is the basis of some extremely sensitive analytical techniques for DNA[12] or metal ions.

Although the LSP of nanospheres is interesting and technologically useful, those of more complex nanostructures such as nanoshells, nanoprisms and nanorods are even more exciting. These particles have more than one resonance, and the frequency and intensity of the various resonances can be tuned by control of the particle geometry. Couple this with the fact that the particles can be readily synthesized by wet chemical means, with controllable aspect ratios, and some of

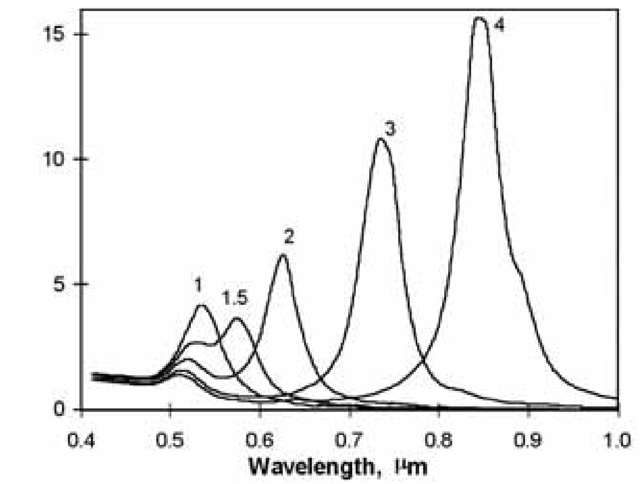


Figure 5. Effect of nanorod aspect ratio on the longitudinal plasmon resonance of gold nanorods suspended in water.

the increase in numbers of plasmon-related papers mentioned earlier is explained! Nanorods, in our opinion, are the better option for technological exploitation[13]. The red shift in longitudinal plasmon resonance of nanorods as a function of aspect ratio is clearly evident in Figure 5.

Light absorbed but not re-radiated (scattered) must manifest as heat, and there are a number of potential applications based on the idea of 'plasmonic heating'. Foremost amongst these must surely be the use of antibody-functionalized gold nanoparticles to actively target diseased cells or organisms. Once attached to the target cell, a highly localized thermal payload can be delivered by appropriate illumination with a laser[14]. Normally, it is cancerous cells that are the intended target, but in our group we have been targeting[15] *Toxoplasmosis gondii*, an infectious organism that serves as a model for protozoan parasites generally. The use of absorptive nanoparticles in spectrally selective coatings for architectural glass is another exciting, and already commercial, application[16].

The topic of 'metamaterials' is inevitably closely associated with 'plasmonics' these days, although it should be noted that 'metamaterials' in an experimental sense started life in the microwave community[17, 18]. Of course, there is still plenty of action in the microwave metamaterials game but that does not concern us here. Rather, it is the idea that the metamaterials paradigm can be extended into the optical frequencies that is of interest. Indeed, this idea has generated a great deal of popular attention because exotic concepts such as 'negative refraction', 'negative reflection', 'cloaking' or 'hyper- or superlenses' are closely associated with the optical metamaterials theme[19-22]. Other possibilities[23-25], such as getting magnetic activity from non-magnetic structures (a.k.a. 'optical magnetism'), or chiral activity, or artificial plasmas may prove to be just as useful. The central idea in the optical metamaterials field is that the current loops of the microwave metamaterial antenna elements can be substituted at optical frequencies with plasmons. So, in the end we will lay claim to it here as being just another aspect of 'plasmonics', indeed the various kinds of 'lenses' mentioned above are usually grouped together as 'plasmonic lenses'. Fortunately or unfortunately 'cloaking' in the visible is somewhat of a ***gedanken experiment***, usually requiring extreme and unphysical values of dielectric constants[19] and, we believe, likely to stay that way, but limited cloaking in the microwave regime has been demonstrated. We should also mention the work by Nicorovici, Milton, McPhedran and Botten that uses plasmon resonances to achieve one form of cloaking in the quasistatic regime[20]. On the other hand, negative refraction at optical frequencies has been demonstrated a few times recently[21], for example, a value of refractive index n of -1.13±0.34 has been claimed for near-infrared radiation of 1775 nm[21]. Plasmonic lensing of various kinds has also been demonstrated[22-24]. Nevertheless, the field of metamaterials is still quite fraught with disagreement between experts, suggesting that understanding of the relevant phenomena is still evolving rapidly. This makes question time at associated scientific meetings quite lively! Aside from anything else, these systems are not only very lossy, but their particular special effects are nearly always highly dispersive, disappearing once the wavelength of light is varied off the 'sweet spot'. Also, these 'metamaterials' are extremely anisotropic, to a degree far greater than found in naturally occurring anisotropic materials like quartz or calcite.

We have barely touched on all the interesting aspects of 'plasmonics' in this short article, but hope to have whetted your appetite. Despite its century-old antecedents, this is a fast moving field and still full of surprises.

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Prof. Michael Cortie is Director of UTS's Institute for Nanoscale Technology. His research interests encompass nanoscale optics, materials, and the applications of precious metals.

Dr Adel Rahmani has conducted research in nano-optics for the past 15 years in Europe, the USA and Australia, with a particular interest in the control of electromagnetic fields on the nanoscale.

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Life After Physics

by Craig Evenden

I first remember becoming interested in science when I received a book about the solar system for my eighth or ninth birthday. However it wasn't until my early years at secondary school that I really started to appreciate science. This appreciation, combined with some really great teachers, fuelled a passion for science and in particular, physics.

During my early secondary school years I thrived in the subjects such as Chemistry, Engineering Science, Physics and Mathematics. I particularly enjoyed the experimental side of chemistry, and with assistance from my career advisor at the time decided to conduct my Year 10 work experience at BHP Steelworks in Newcastle as an Industrial Chemist. Even though I enjoyed this exposure to the world of Industrial Chemistry, shortly after I decided that physics was my preferred interest. This interest was also supported by a fellow family member who had also completed a Physics degree and embarked on a PhD in Astrophysics at Mt Stromlo Observatory, near Canberra.

As it turned out, Physics gave me the tools necessary to understand the natural world and helped me acquire special problem-solving skills that would, unbeknownst to me at the time, assist me in my career.

Whilst the majority of my fellow students embarked on higher education in the fields of Computing and Engineering, I decided to follow my passion for physics at the University of Newcastle. Like most struggling students the thought of accumulating a large HECS debt turned my focus to the Defence Force and during the second year I applied for a position with the Royal Australian Air Force. The thought of the Defence Force paying for university whilst offering full time work upon completion of my studies was very enticing; however I was unsuccessful in pursuing this venture and returned my focus to completing my physics degree at the Univ. of Newcastle in 2001.

Shortly after, I obtained part-time work as a laboratory demonstrator for first year students in the physics laboratory, which not only provided supplementary income but also a sense of satisfaction. At this time I also conducted part-time tutoring of senior secondary school chemistry and mathematics students. Teaching had always been in the back of my mind as a possible career alternative, and the laboratory demonstrating and tutoring made me think more seriously about this option.

During my final year I was offered a short-term position as research assistant in a section of the University of Newcastle Physics Department at what is now called "The Surface and Nanoscience Group". The research focused on Energetics in Single-walled, Open-ended Carbon Nanotubes under the supervision of Marian Radny. Whilst conducting this work I also thought seriously about conducting further study and perhaps to follow the path of academia.

At this time, a few of my friends who had undertaken engineering degrees were busily sending out CVs applying for various jobs. I thought I would also test the water and

decided to apply for a part-time job developing a computer program for Weir Engineering, a company specialising in pumps, valves and hydro-cyclones. My application was successful and I started developing the program. The computer program was developed to expedite the selection process of water pumps and components. The time at Weir opened my eyes to the world of sales, manufacturing, management, engineering and quality control.

With all these opportunities presenting themselves, I began thinking more seriously about my future and was left with the conundrum of what career path to follow. Thinking back, the experience at Weir was probably the pivotal moment in tipping the scales towards a career in industry. Following the completion of my undergraduate degree I remained at Weir; a decision that was weighted heavily in its favour due to financial reasons and also the career opportunities offered.

For the next few months I worked at Weir until the release of the Beta Version of the computer program. Following a successful trial of the program, I anticipated a full time position at Weir that did not eventuate. Not all was lost though, since my time there assisted me with my next opportunity. Working at Weir I gained some knowledge regarding noise and vibration testing conducted on pump systems. Basically, pump system operations were simulated on a test rig prior to delivery to the customer. The test regime included noise and vibration analysis to determine misalignment, unbalance, mechanical looseness, cavitations, resonance, gear wear, broken teeth, and bearing wear.

I was no stranger to the physics of sound since during my final year I presented a seminar on the phenomena of sonoluminescence. At the time, and actually still to this day, this phenomenon intrigued me greatly.

Like x-rays and radioactivity, sonoluminescence was discovered while its discoverers were looking for something else. In 1929, H. Frenzel and H. Schultes witnessed the appearance of luminescence when an oxygen gas was dissolved in water and a sufficiently strong ultrasonic signal irradiated the liquid. To confirm their observations, they exposed a photographic plate with traces of the light induced by acoustic waves. The luminescence emanates

from collapsing gas bubbles during a process called acoustic cavitation and indicates the momentary creation (in the space of 10^{-10} seconds per sound field cycle) of very high temperatures (about 5,000 degrees Kelvin) such as are found on the surface of the sun. Cavitation refers to the formation, growth and implosive collapse of bubbles in a liquid.

I had first witnessed (or actually heard) cavitation during water pump testing at Weir Engineering. The cavitation sound could be said to be analogous to rocks running through a pipe. When water enters a pump, its velocity increases causing a reduction in pressure within the pumping unit. If this pressure falls too low, some of the water will vaporise, forming bubbles entrained in the liquid. These bubbles collapse violently as they move to areas of higher pressure creating the noise and vibration from the pump.

After an empty bubble implodes under the pressure of the surrounding liquid, its deflated skin may fill with vapor or gas and become a soft bubble, similar to bubbles in beer. At this time that the normally dispersed energy of a sonic vibration becomes intensely focused inside the bubble compressing its gaseous contents to the point of luminescence. The collapsing bubble also produces a sound wave, which can be measured with a fibre-optic hydrophone.

A widely supported model of sonoluminescence is called the "hot spot theory", which suggests that the energy fueling the initial expansion and formation of a cavitation bubble is squeezed into a high temperature plasma core upon the bubble's implosion, that occurs at over four times the speed of sound. The primary reason for this interpretation is that the emission of light occurs at the point when the bubble has reached its minimal detectable size. The hot spot theory also concludes that the high pressure arising during the bubble's swift implosion (several thousand atmospheres) incites explosive shockwave synthesis in solid matter. Because of the speed of tremendous oscillations in heat and pressure caused by cavitation bubble collapse, ultrasound may offer a highly efficient means by which to synthesize, at the nanoscale, matter such as metals, alloys, carbides, oxides and colloids.

Weir could not offer me a full time position so I decided to apply to various companies, particularly those specialising in acoustics and vibration. Eventually I was offered a position as Acoustics and Vibration Engineer with VIPAC Engineers & Scientists Ltd, an Australian owned multi-disciplinary engineering consultancy. VIPAC incorporate advanced technology with acoustic and vibration engineering principles and employ that in a wide range of applications including wind, acoustics and vibration, fluid mechanics and thermo-dynamics and across a broad spectrum of industries; from Aerospace and Defence to consumer appliances.

I spent the next 6 years at VIPAC and during that time conducted a variety of noise and vibration assessments ranging from underground mining to aircraft testing.

In 2007 I joined GHD, an international professional services company who employs over 6 500 people in a network of more than 100 offices throughout Australia, New Zealand, Asia, the Middle East, the Americas and Europe. At GHD I am currently employed as Acoustics and Vibration Engineer working across a broad range of global market sectors such as Infrastructure, Mining & Industry, Defence, Property & Buildings and the Environment.

As Acoustic and Vibration Engineer at GHD, the tasks performed are similar to the basic framework used for conducting experiments in a laboratory. A typical job comprises conducting measurements out in the field then generating a computer model to validate the measurements. Finally there is interpretation of the results, conclusions, and recommendations. Although this basic framework is evident in most of my jobs, every job is unique and it is this variety of work that presents new and challenging problems and keeps motivation levels high.

Another attractive feature offered by GHD is the opportunity to undertake GHD Business School; something that was set up to deliver technical, administrative and leadership skills training. It assists in defining career development pathways and identifies training required for staff to develop the skills needed to enhance career paths.

Often I am asked about whether my physics degree prepared me for a career in industry. The answer is yes and no, not so much in terms of direct application but for the way in which physicists are good analytical thinkers and problem solvers. I can safely say that the theoretical and technical components of the degree assisted greatly; however, there is still quite a large gap between the time when university ends and industrial working life begins. Similar to engineering, it may be beneficial to undertake a period of industrial work experience to bridge this gap.

I have found that presenting ideas and information to a technical (and sometimes non-technical) audience is important. As such, it would be advantageous to conduct seminars and present papers to facilitate this skill.

A degree in physics provides students with much more than just a "challenging" university experience, it leaves them with marketable skills that will be valuable throughout their careers. Based on my experience in industry it is apparent that this is also the view shared by a number of human resources personnel and management staff.

As opposed to what most people would think, physics major graduates possess the skills necessary to work in any area of science or technology and are certainly not just restricted to research or academia.

Often I am asked about whether my physics degree prepared me for a career in industry. The answer is yes and no...

The recent and ancient history of a start up company

by Ian Bassett

Preamble

Our Immediate Past President, Dr. Cathy Foley, recently offered the following rule of thumb: it takes about 15 years from bright idea to working device[1]. We at Smart Digital Optics (SDO) can confirm it. When we tell people we haven't seen for a while that we are working on an optical fibre electric current sensor they are apt to nod sympathetically and recall that we were already working on an optical fibre current sensor the last time we spoke with them, in say 1988.

But the shape and the essential details of the problem have kept changing, and we have learned richly at every stage. How did we stay alive? We were variously employed by the University of Sydney (and the University of NSW), supported by the Australian Research Council, by TransGrid (formerly the Electricity Commission of NSW) and by Asea Brown Boveri (ABB, an amalgam of Swedish and Swiss companies), and by the former Australian Photonics Cooperative Research Centre. We have had much free advice, moral support and networking opportunities from Australian Technology Park Innovation (ATPi). We have received support from the Federal Government's Commercial Ready program, closed since the last election. It is possible that the latter kind of very useful support for early stage commercialisation may be restored in some form. Leaving aside the latter possibility we are from now on wholly dependent on commercial activities of SDO, that is, on sales or investment or both.

From the perspective of SDO and the information in the last paragraph the Federal Government has on the whole been playing an appropriate and useful role in providing infrastructure for scientific research of the sort which has a chance of being turned to commercial advantage – for its investors and for the nation.

Ancient history

The basic idea of our optical fibre current sensor is about as old as anything in optical fibre technology, and the physics goes even further back, to Michael Faraday, who observed the effect of a magnetic field on light in 1845. Like so many of Faraday's fundamental discoveries, the work was apparently completed in a few days. Our current sensor looks as if it *should* be simple – the fibre is looped around the current, the current produces a magnetic field, the magnetic field causes the polarisation of the light to change as it passes around the fibre loop. This change in polarisation is used to measure the current. But there is more to it, which has taken us and others many years to find out. Our research started with an honours project in Physics which turned into a PhD for Dr. Ian Clarke.

We make use of the common sort of optical fibre, the sort used for telecommunication, plus some special fibre, which we had to learn how to make when we had the facilities to do so – these facilities are now on their slow way to the University of Adelaide. The most common sort of optical fibre is about one tenth of a millimetre in diameter. The light guided by the fibre is confined to a small region in the middle, of diameter about one tenth the diameter of the fibre, or one hundredth of a millimetre. The light in this tiny central guiding region has polarisation properties similar to those of light in empty space or in a uniform medium (like the glasses which Faraday studied.) Fibres of this sort are today's great carriers of phone conversations and other forms of what is technically called information.

Anyway, optical fibre is very slender and flexible, and it is an attractive thought to simply loop it around the busbar carrying a current, put light in at one end with defined polarisation properties, and observe the changed polarisation of the light coming out the other end. Especially as the signal can be conveyed by more fibre to the comfort and safety of a control room, where all the electronic and digital signal processing takes place. The busbar is perhaps at 100,000 volts or more above ground potential, and the fact that optical fibre is an electrical insulator is one of its advantages here. The conventional method for measuring current, in high voltage applications, is called a current transformer or CT. It is bulky, and entails a high voltage drop over a comparatively short length of insulator. Our optical fibre current sensor is much smaller, at least potentially cheaper, more environmentally friendly, with a larger dynamic range, and no danger of insulator breakdown.

At the beginning of our project, telecommunication by optical fibre was well under way, but the fibre served only to connect repeater stations at intervals of some 50 km, where the optical signal was converted into an electrical signal, recognised, rejuvenated, reconverted into an optical signal and launched into the next section of optical fibre cable. Laboratory research at the University of Southampton and elsewhere showed the possibility of making in-fibre optical amplifiers, so that the repeater station could be replaced by in-fibre amplification, cheaper than a repeater station and with much less to go wrong. Australia's Overseas Telecommunication Commission (OTC), at that time separate from the larger domestic telecommunications organisation, set up an in-

Fig 1. A fixed DC sensor in context with a unit which generates the high current being measured.

Fig 2. A high voltage current sensor, including the "link" which carries the fibres from high voltage to ground

house research laboratory, to pursue this possibility and adopted a policy of making close links with University research and (in an enlightened move) of spending as much outside as in-house on research. We became involved through a Chemistry honours student project supervised by Mark Sceats. It was this initiative of OTC, associated with OTC'S Don Nicol and the then Managing Director, George Maltby, which led to the foundation of Sydney University's Optical Fibre Technology Centre (OFTC). The chemistry honours project and the current sensor project helped. Funding by the NSW Electricity Research Board was supplemented by an ARC grant, including the late Prof Pak Chu of the UNSW. Pak and his department already had a distinguished record of achievement in optical fibre research and was the other principal competitor for a proposal by OTC to set up and provide initial funding for an optical fibre fabrication facility for special fibre, such as amplifier fibre, on a University campus.
Our proposal may have had the advantage of being more boastful than Pak's (as observed by one of the giants of 20th century Australian industry, W.S. Robinson, garlands are not distributed for pessimism[2].) Our real knowledge of optical fibre fabrication at that time depended on one person, who was not present, Simon Poole from the University of Southampton, recent PhD and co-inventor of the optical fibre amplifier. We won the bid, Simon Poole joined us, and we remained on good and cooperative terms with Pak Chu's group.

It must be said that a hitch occurred at the point at which the University of Sydney had to sign to take on the task and receive the money – rumour has it at least that the signer said that he did not want a bloody factory on the University campus, but then signed anyway. The initial funding amounted to around 3 million dollars, and about half of that came from the Federal Government's Department of Industry Science and Technology (minister John Button). The boast which won the funds (authors Tony Stokes, Mark Sceats, and me) spoke of seeding new industries in Australia, and much else. Those new industries actually happened, and the enterprise never looked back, at least until the world wide downturn in the IT/telecommunication industry in the year 2000 which saw some of our spinoff companies cut back, with some negative financial consequences. From 1990 to about 2000 the umbrella institution was the Australian Photonics CRC of which the OFTC was a co founder and remained a part.

Most of the OFTC projects have been related to telecommunications applications. The current sensor project has been an exception. It has benefited from the ability of the OFTC fibre fabrication group to make special fibre. The main type of special fibre required for the current sensor is called spun birefringent fibre. It has a spiral internal structure, and is hard to make. The loop of special fibre which goes around the current in the current sensor has the required Faraday response; if ordinary telecommunication fibre is formed into a loop, the Faraday response is negligible, so the special fibre is a necessity. The basic patent on which our current sensor depends is in the name of Ian Clarke and was an outcome of his physics PhD project, and is owned by the University of Sydney. The main novel element is the *combination* of spun birefringent fibre with a classical interferometry configuration, the Sagnac interferometer. This provides the fibre loop which encircles the current, and the magnitude of the current is recorded as a phase difference between clockwise and counter clockwise going light. This is just the original Faraday phenomenon in a different context.

The slow gestation of the current sensor continued. As deregulation encroached on the NSW electrical power industry, support was taken up first by Pacific Power and then by TransGrid, and we wish to pay tribute to that unfailing support, which has been both in cash and kind, the in-kind being mainly related to field trials. A companion project on optical fibre based voltage sensing was introduced some seven years ago, and some of the ABB and TransGrid support has gone into that.

The work from 1992 was joined by John Haywood full time and his contribution has grown from an initial emphasis on electronics to include the optical design and optical experimentation, and he now leads the entire project as the Chief Executive Officer of SDO. I must also mention Andrew Michie who has also for many years made a variety of creative contributions to the work in a most selfless manner and without demur taking an interest in every facet of the work and acquiring competence in every aspect of it. Besides being a Director and employee of SDO, Andrew is now effectively leading the kindred project to develop an optical fibre voltage sensor. Mamdouh Matar has played a central and ongoing role in the current sensor design and fabrication. Mark Sceats has been good for many an insightful contribution. Andrew Graf has contributed to mechanical design and Goran Edvell to the interface

Fig 3. A portable sensor for DC

with conventional switchyard equipment. Several fourth year honours Electrical Engineering students have contributed and at the same time have gained valuable experience, like all of us with a longer association with the project. The design at the end of our current sensor contract with ABB was not essentially different from that of Ian Clarke, published in 1993. What was added was product development, the details of the electronics, the choice of optical components, the testing against environmental stresses (temperature and vibration), the choice of operating optical wavelength, the actual method of fabricating the special spun fibre, to whose specification was added the requirement to be polarising. The fibre fabrication team included Danny Wong, Ron Bailey, Justin Digweed, and Tom Ryan. ABB's interest in the project grew from the early 90's to the point where the project was effectively managed by Margareta Bjarme seconded from ABB in Ludvika, Sweden. Margareta managed the project from 1995 to the end of the contract in December 1999, and was the champion and indispensable agent of our education in the real commercial requirements, ably assisted by Tony Lee of ABB Transmission and Distribution, Moorebank. Margareta has a gift for asking the right questions. Towards the end of the ABB contract, field trials were conducted by ABB and TransGrid at the Sydney West switchyard with satisfactory results.

Politics

Any country which hopes to act effectively needs to understand the world. Such understanding can be got by taking part in it, actively and widely. It is necessary in particular to take an active part in what is peculiar to the present day, industry derived from complex knowledge. The Japanese knew from the shock intrusion of the West in 1851 that they must learn to participate or go under. Other countries accept the same principle. Our Australian polity would be stronger, capable of doing more for Australia and for the world, if we did better in science based industry, where at present we do less than our share. Sport in Australia sets a good example. And we are moving. When I was a child in Melbourne, I knew of only 3 kinds of cheese, none of them much good, and few serious persons considered it possible to do many things outstandingly well in Australia, apart from playing sport and fighting military battles. The repertoire is larger now, but one occasionally still comes across the early negative attitudes. Some years ago, I was told by a senior investment adviser to a major Australian insurance company that there is no point in *making anything* in Australia. We do not need to allow such old prejudice or contemporary folly to persuade us to bury our talents. Alan Walsh's atomic absorption spectrophotometry was a triumph, and among its earliest beneficiaries were Australian hospitals and mining companies. Although the business soon passed out of Australian hands, the purchaser, the California based Varian, remains in Melbourne as a major manufacturer and exporter of spectroscopic instruments, with about the same number of Australian employees as the original company (Techtron) at its peak. I once had an opportunity to ask Alan Walsh about the reason for the original manufacturer being taken over. He said that it was because of the difficulty of finding in Australia the resources needed to market and service the instruments, which soon came to be predominantly sold overseas. Perhaps management and capital today will be more ready to believe that an Australian technology based manufacturer can grow to meet the demands of a global market.

The concept of natural advantage is a useful one in economics. Australia is usually seen as having such an advantage in mining and farming, but not in manufacture. But off shore location of parts of a manufacturing process is as accessible from Australia as from most places, and at present day Australian wage levels and exchange rates such off shore relocation may be less needed. And besides, there are elements in the Australian culture which are beneficial to the conduct of business, and capable of improving competitiveness in any field. I have in mind two forms of scepticism. Scepticism about the supremacy of the value of material gain, and scepticism about hype, sometimes called having a good bullshit meter. Both kinds of scepticism of course need to be used in moderation, but one can select from one's cultural traditions, and expect the chosen ones to grow with exercise. I wish to add that both forms of healthy scepticism seem to be alive and well in Sweden.

George Maltby, on a visit to OFTC, gave us his reasons for doing research in a company, which as I remember it included the following:
- being an intelligent buyer;
- being able to negotiate with new suppliers, and not being dependent on old relationships;
- a source of bright recruits; and
- generating an IP portfolio to barter.

All these reasons translate into reasons for a country to do research. To the concept of natural advantage should be added the concept of natural disadvantage, the disadvantage of natural ignorance. This I think is what Maltby was referring to in the context of a company, and it applies equally to a country.

Recent history

ABB had been going to commercialise our current sensor, but towards the end of the nineties it became clear that they had turned to another optical fibre current sensor, one which they had themselves developed. This change of direction by ABB gave us the opportunity to commercialise our own current sensor. Our company Smart Digital Optics Pty. Ltd. was formed in 2004 by John Haywood, Andrew Michie, Ian Bassett and Mamdouh Matar. When we obtained the licences to commercialise the key patents held by the University, we were joined by Neville Sawyer A.M. as Executive Chair and Peter Janssen as a Director. At the time of writing the other directors are Haywood, Michie and Bassett. Sawyer and Janssen bring much needed and appreciated business experience to SDO, as well as investment. We have also been joined by John Ingram and Sameh Nagib as full time employees. Ian Clarke and Hamish Hawthorn of ATPi are welcome observers at SDO Board meetings. A representative of the Melbourne based venture capital firm Starfish also has the right to attend as observer, in recognition of a modest early investment.

Two useful discoveries have been made by SDO in the current sensor project after its severance from ABB. One renders negligible the effect of certain forced vibrations, the other, which dates from the year 2000, makes the effect of small errors in the loop of special fibre encircling the current quadratically small. This is done by interrogating the sensor multiple times - in quick succession, using a pulsed source – and taking certain averages in real time, using fast digital arithmetic. We call the method **N**etwork **I**ndependent **M**ultiple **I**nterrogation, or NIMI[3,4]. At first we saw NIMI as a method of improving the accuracy of Sagnac and other two beam interferometry. Later, we saw it in a more general and perhaps more interesting light: NIMI can be regarded as a method of interrogating a passive object through a medium whose local transmission properties fluctuate strongly and randomly (but sufficiently slowly); it is not confined to interferometric applications. It can be seen as depending on a form of common mode cancellation, one in which the cancellation is effected by real time digital arithmetic. In principle, at least, this computed common mode cancellation can be used to correct transmitted phases, not just intensities.

SDO now has the right to commercialise that part of the required IP which is owned by the University of Sydney, and can expect to own this in due course as well as the IP which it has recently developed.

Sales, the essential and ultimate test of commercial viability, have started and interest from the world wide industry is growing. There are three areas of application of SDO's current sensor. High current DC, as used for example in the electrolytic separation of metal aluminium from ore; very high voltage DC for power transmission – voltages above 800,000 have been increasingly employed in India and China; and the largest commercial market, high voltage AC for power transmission. Most sales to date have been in electrolytic smelting, where we have both portable (or calibrator) units and fixed units, and have sold 4 units and leased another 4 calibrator units for short periods. We have a project in progress, in AC power transmission, with a major system integrator whose headquarters are in Spain, to set up a full scale three phase power measuring unit in the field and in this connection have sold four AC units. We have a similar project with the Queensland electric power transmission company Powerlink.

Our Spanish collaboration seems particularly important, and the year 2009 may be decisive for our future. On our side is versatility based on an excellent technical team, plus growing business experience and good guidance from the Chair and other independent directors.

Coda

Bassett and Haywood were awarded the inaugural Alan Walsh Medal for Service to Industry of the Australian Institute of Physics, in 2002. Time will tell to what extent this award was merited.

Margareta Bjarme, in about the year 2000, asked us to confirm that we could obtain the required information from the sensor through the optical fibre network which we had then only sketched. In answering her question, we took a large step forward in understanding the potential of the NIMI method.

The economic downturn is not necessarily a disadvantage to SDO. In hard times, people and companies tend to turn to cheaper products, especially if those products are also better than the competition. We believe that SDO's current sensors are both better and cheaper, especially at high voltage. While the most suitable product does not necessarily win in the market place, but remains in obscurity, we are trying within the limits of our resources to become better known

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Ian Bassett received his PhD in Chemistry from the Univ. of Melbourne in 1959 and has been a lecturer and senior lecturer at the School of Physics, Univ. of Sydney, 1964-2008. He is a Fellow of the Optical Society of America and Co recipient with John Haywood of Alan AIP Walsh Medal. Ian is Co founder of Smart Digital Optics.

Quanta

Special Relativity Treatment of Stimulated Emission

by G.J. Troup, D. Paganin and A. Smith

Many monographs on Special Relativity treat the absorption and the spontaneous emission of a photon by an atom, but omit the treatment of stimulated emission! We discuss certain subtleties that emerge in the analysis, which may be unfamiliar to students. For reasons that will become obvious we first revisit spontaneous emission[1].

An atom of rest mass M_o in the laboratory frame emits a photon of energy Q, and therefore of momentum Q/c, where c is the speed of light. After emission the atom has energy $M'c^2$ and momentum $M'v$, where v is the velocity of recoil. So we have for conservation of energy and momentum, respectively

$$M_0c^2 = M'c^2 + Q \tag{1a}$$

$$0 = Q/c - M'v \tag{1b}$$

which can be solved for the unknowns. We do not yet discuss the solution. In the case of stimulated emission, we have an incoming photon of energy Q, and 2 outgoing photons. We can either postulate that each of the outgoing 2 photons have energy Q also, and check the solution of the new equation to see if it exists, or invoke the indistinguishability of the photons as required by quantum mechanics to have the 3 energies equal. Either way, eqns. (1a) and (1b) now become

$$M_0c^2 + Q = M'c^2 + 2Q \tag{2a}$$

$$Q/c = 2Q/c - M'v \tag{2b}$$

It is obvious that eqns. (1a) and (2a) are equivalent, as are eqn. (1b) and (2b). Therefore the solution of the equations for stimulated emission is that for spontaneous emission, with the 3 photons having identical energies and being indistinguishable. Thus the indistinguishability of the photons is required by special relativity, and the atomic recoil is also taken care of. We should also recall that the *atomic* properties determine the necessary photon energy, and that the width of the energy levels is infinitesimal in this treatment. The solution for Q in terms of the energy difference

$$Q_0 = (M_0 - M_0')c^2$$

where M_0'

is the rest mass of the recoiling atom, is

$$Q = Q_0\{1 - Q_0 / M_0c^2\}$$

This shows clearly the effect of the atomic recoil.

Reference

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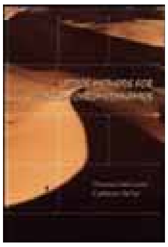
Reviews



Lattice Methods for Quantum Chromodynamics
by Thomas DeGrand and Carleton DeTar,
World Scientific Publishing, 2006
345 + xv pages, US$58.00 (hardcover)
ISBN: 981-256-727-5

This book describes lattice based methods that have been developed for modelling strong interactions of quarks and gluons over long distances where the strong interactions are strongest and perturbation methods fail.

The book is well written for a specialist audience. If you do not already have a solid background in Lagrangian dynamics, guage theories, tensor analysis, Feynmann path integrals and Feynmann diagrams, Lie groups and Lie Algebras, and renormalization group methods then this book is not for you.

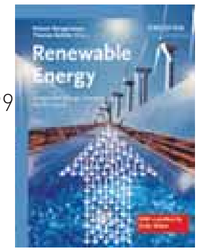
The book is for graduate students and researchers with expertise in the field of quantum chromodynamics who wish to learn about the lattice based methods.

John Holdsworth
University of Newcastle

Zero to Infinity. The Foundations of Physics
Peter Rowlands
World Scientific, 2008
xxi + 713pp., $US98 (hardbound)
ISBN-13: 978-981-270-914-1

World Scientific have published this book by Peter Rowlands as volume 41 of their series on Knots and Everything

Renewable Energy. Sustainable Energy Concepts for the Future
Roland Wengenmayr, Thomas Bührke (Eds.)
Wiley-VCH, Weinheim, 2008 118pp., UK£18.99
(hardbound) ISBN: 978-3-527-40804-7



This book features nineteen articles describing the sources of renewable energy and examining the changes that have taken place, and those changes still required, in order for the various approaches to become, or at least approach, economic alternatives for energy production. The solar thermal installations in Spain, the wind farms of Denmark, the northern European coastline and sea front are well discussed and set a tone for the book.

I was interested to learn the German 2005 annual energy demand of 14,238 PJ was met with a renewable contribution of 4.6%. These facts both highlight the extraordinary amount of energy a modern advanced economy uses and the difficulty in total replacement of conventional coal-fired power generation with renewable sources.

The book is relatively Euro-centric with a German flavour in examples and figures quoted so it does not quite translate as an appropriate Australian reference text but does have a comprehensive overview of the technology behind renewable energy sources. Equally as well it states eloquently the need for the political will to embrace change in sourcing the energy needs of an economy.

While there were a couple of typographical errors, the Wiley –VCH quality in production is evident and the graphics are good. Overall, it is a useful book for high school and university libraries to have as a resource for students examining the energy debate.
John Holdsworth
University of Newcastle

Theoretical Physics Group formed

Following a request by five members the AIP Council meeting in February approved the formation of a theoretical Physics group. The purpose of a group is to provide a forum for members who have a common interest in the advancement and dissemination of knowledge of some branch of physics – in this case theoretical physics.

Existing groups are Nuclear and Particle Physics, Women in Physics, Physics Education, Quantum Information, Concepts and Coherence (QUICC), and Solar Terrestrial and Space Physics (STSP).

If you wish to become a member of the Theoretical Physics Group, please contact:

Professor Vladimir Bazhanov
Theoretical Physics, Research School Physical Sciences & Engineering, The Australian National University at:

vladimir.bazhanov@anu.edu.au

See also *http://www.aip.org.au/content/groups*

Product News

Lastek

New Aerotech AGR Series Worm-Drive Rotary Stages

• Innovative precision worm-gear assembly provides outstanding accuracy and repeatability over a long lifetime
• Enhanced speed and load capacity
• Large aperture addresses a wide range of applications
• Continuous 360º rotary positioning
• Direct encoder options
• Operation over a wide temperature range

AGR series motorized rotary stages offer significant improvements in speed, load capacity, and long-term positioning performance versus previous generations of worm-gear-drive stages. The AGR stages address a wide range of applications for general purpose positioning in laboratory and industrial uses.

Innovative Gear Design
A unique preloading scheme avoids changing wear characteristics, allowing orders of magnitude increase in stage life without any degradation in stage performance, and allows stage operation over a wide temperature range.

The addition of a larger clear aperture is a key enhancement over previous generations of worm-gear-driven stages. The large aperture permits applications requiring a through-hole or accommodations to mount an optic, including articulation of beam polarizing lenses, for cabling and/or air lines, or for vision/camera/inspection applications.

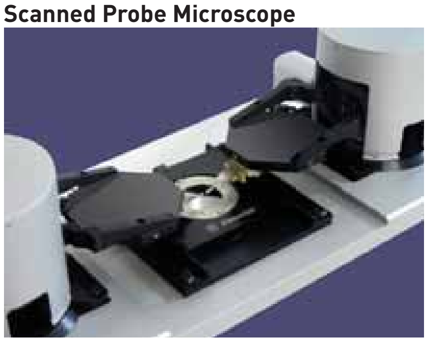
Other Features
The AGR stage base is fabricated from a special aluminum alloy which offers significant weight savings in multi-axis arrangements and other weight critical applications, while providing high structural stiffness and long-term stability. Each stage incorporates dual large-diameter pre-loaded angular contact bearings optimally separated to provide excellent error motion specifications, as well as the best possible load handling capability.

All stage tabletops feature aluminum hardcoat plating and stainless steel Heli-Coil® inserts to prevent thread wear.

Flexible Options
Options include flexible motor selections as well as a direct encoder mounted concentric to the axis of rotation for outstanding repeatability and to virtually eliminate hysteresis and backlash. Vacuum-compatible (for use in pressures as low as 10^{-6} torr) and other customized versions are also available.

Motor and Drives
Standard AGR stage configurations feature Aerotech's brushless servomotors. However, all AGR stages can be outfitted with stepper or DC brush motors. A full range of matching Aerotech drives and award-winning controls are available for a complete, single-source solution.

Nanonics Imaging Introduces The HydraTM , A Revolutionary Bio Scanned Probe Microscope



BioAFMs on the market today are seriously limited by geometric and optical obstruction and interference. Thus, BioAFMs cannot be integrated into upright microscopes or advanced concepts in optical microscopy such as 4pi configurations or many non-linear optical protocols. In addition, studying samples such as single molecules on opaque substrates or simultaneously investigating optically and with AFM, highly scattering samples such as biological tissue have been impossible. Furthermore, all BioAFMs today suffer from optical interference from the feedback mechanism used.

The Nanonics Hydra resolves all of these and many other limitations in BioAFM, thus opening new horizons for the application of AFM in biology. The ground up design of The Hydra provides no geometric or optical obstruction or interference either from above or below the SPM system.

The Hydra incorporates, for the first time, the critically acclaimed tuning fork feedback mechanism which provides UltraSensitive Liquid Cell operation for new sensitivities in AC force spectroscopy.

The Hydra with its ground breaking Tuning Fork Liquid Cell also permits Nanonics to now offer its singular innovation of MultiProbe Atomic Force Microscopy to the BioAFM researcher allowing for new directions in BioAFM imaging and manipulation.

The Hydra comes with a NanoToolKit of glass based probes including transparent AFM probes and nanopipette probes for conductance and futuristic structurally correlated patch clamp applications. This complements Nanonics' unique probes for thermal conductivity as well as electrical and scanning electrochemical microscopy.

The Hydra with its fully optically integrated, non-interfering design is ideal for all modes of optical microscopy including standard fluorescence techniques, confocal, TIRF, FRET and DIC. Nanonics is also renowned in NSOM and AFM Raman combinations with tip enhanced Raman scattering. The Hydra is unique in its ability to provide such advanced chemical imaging without limitation to the microscope or the microRaman platform used.

For more information please contact
Lastek Pty Ld
Adelaide U. Thebarton Campus
10 Reid St, Thebarton, South Australia
Toll Free: Australia 1800 882 215 ; NZ 0800 441 005
T: +61 8 8443 8668 ; F: +61 8 8443 8427
email: *sales@lastek.com.au*
web: *www.lastek.com.au*

Warsash

New Energy Saving High-Power Piezo Amplifier from PI

Warsash Scientific is pleased to present the new E-617 high-power amplifier from Physik Instrumente (PI). A patented technology reduces the power loss and minimizes heating of the piezo actuators. This is done by combining a PWM (pulse-width-modulation)-switching amplifier with energy recovery technique.

The advantages of this technology can be seen in high-dynamic (required by fast scanners, valve and shutter operation), 24/7 operation, especially with the huge capacitive load of a large actuator or a serial combination of several piezos. The output voltage of -30 to +135 V is suited for operation of multilayer piezo ceramic actuators. The output power of 100 W is much higher compared to common linear amplifiers.

The E-617 is available in three versions: as OEM electronics, for top-hat-rail mounting and for the modular E-500 controller system. Here, the amplifier can be combined with several servo controller and digital interface modules according to the requirements of the application and the piezo positioning system.

New OEM multi-axis control electronics system for piezo tip/tilt mirrors

Now available from Warsash Scientific is the new compact E-616 OEM Driver/Controller Electronics for Multi-Axis Piezo Tip/Tilt Mirrors from Physik Instrumente (PI).

The E-616 multi-axis control electronics system was developed especially for piezoelectric tip/tilt mirrors and combines all functions of a multi-channel controller and amplifier. The deflection angle can be commanded directly, independent of the mechanical design of the tip/tilt platform. This relieves the user of the problem of external transformation in software or hardware.

PI's range of fast tip/tilt platform solutions are ideal for beam steering and stabilization in many diverse applications.

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

SciTech

Ultra-low noise CCDs for direct X-ray detection

Andor's iKon-M X-ray CCD cameras are designed to offer high-performance solutions to your direct detection X-ray needs, and come in two variants: DO and DY. The DO variant interfaces easily with vacuum chambers, whereas the DY variant is a 'stand-alone' camera with beryllium input window.

The systems offer very low read noise floor, high QE across the X-ray, XUV and EUV range, and boast negligible dark current with thermoelectric cooling to as low as -90oC. The 1024 x 1024 array with 13 μm square pixels provides both high resolution and high dynamic range. iKon-M combines kHz readout for lowest noise floor and multi-MHz readout for faster frame rates, all through a convenient USB 2.0 interface.

Andor NewtonEM EMCCD Cameras

SciTech is pleased to announce the release of the Andor NewtonEM EMCCD detector system which has been optimized for high performance spectroscopic applications. The Newton detector systems employ low noise electronics, cooling to -100°C, up to 95% peak Quantum Efficiency (QE), multi-MHz readout, USB 2.0 connectivity and versatile readout modes.
The NewtonEM employs Andor's pioneering electron multiplying CCD technology in an exclusive sensor format optimized for ultra-low light, level spectroscopy applications. The combination of the Newton's low noise electronics, high QE, fast readout, and the on-chip amplication (electron multiplication) makes this detector unbeatable for the most demanding ultra-low light level spectroscopy applications, including single photon light level spectra.

Dual output amplifiers also allow the detector system to operate in both the electron-multiplication mode and the conventional low noise readout modes, making the detector even more versatile for a wider variety of applications.

Contact: SciTech Pty Ltd
T: (03) 9480 4999
T: (02) 9705 8059
E: *sales@scitech.com.au*
W: *www.scitech.com.au*

Coherent

Coherent Inc. Libra - Integrated Ti:S Amplifier

Libra is an integrated (one-box) Ti:S amplifier from Coherent Inc featuring exceptional stability and ease-of-use. The design integrates Coherent Inc's Verdi, Vitesse and Evolution lasers with a compact, regenerative, chirped pulse amplifier. Full computer control of all sub-systems, plus a range of on-board diagnostics and detectors incorporated into a robust design, provide thousands of hours of trouble-free operation. Libra is also compatible with the OPerA Solo and TOPAS OPA's, offering exceptional noise characteristics and complete seed-to-OPA computer control.

Released at Photonics West 2009, the new Libra-HE delivers significantly higher pulse energy and shorter pulsewidth than earlier Libra models. Specifically, the Libra HE products pulse energies of over 3.5mJ at 1kHz and a choice of either <50fs or <100fs pulsewidth models. The system is offered with a standard pulse repetition rate of either 1kHz or 5kHz, at 800nm.

Characterised by its integrated, maintenance-free design, Libra allows you to focus on your manufacturing or lab work, rather than on the laser itself. Libra is equipped with a unique "seed laser-to-OPA" computer interface, enabling users to control each of the internal modules of the laser through a single laptop computer.

In addition, Libra features extensive on-board diagnostic capabilities.
• One-box, compact, computer controlled amplifier contains integrated Vitesse seed laser, Evolution pump laser, regenerative amplifier, stretcher and compressor
• E-2 Engine, high performing, highly reliable, regenerative amplifier module providing he highest energy and efficiency with improved beam quality (M2 < 1.3)
• Thermally stabilised amplifier platform
• Pulse energy to >3.5mJ at 800nm
• <50fs and <100fs pulse width available
• Stability to <0.5% rms

For further information please contact Paul Wardill or Gerri Springfield on sales@coherent.com.au
Coherent Scientific Pty. Ltd.
116 Sir Donald Bradman Drive
Hilton SA 5033

Princeton Instruments ProEM: The No-compromise Electron-Multiplying CCD Camera

Princeton Instruments has released ProEM, the highest performance EMCCD camera to be offered on the scientific imaging market to date. ProEM cameras are designed to address challenging low-light applications associated with single-molecule fluroescence, astronomy, and ion imaging, as well as many other high-frame-rate, light-starved applications. ProEM uses 512x512 and 1024x1024 back-illiminated EMCCD's and supports both electron multiplication (EM) and traditional readout ports. The EM port is used when high frame rates are required under low-light conditions, while the traditional readout port is ideal for slow-scan applications.

The cameras include several highly innovative features to ensure the highest possible bias stability and lowest noise, while the new OptiCAL feature provides EM gain calibration on demand. ProEM also provides a hardware-generated timestamp on each frame to take the guesswork out of time-resolved photometry, and a Gigabit Ethernet interface allowing the camera to be operated remotely.

Features:
• All-metal seals
• Permanent vacuum guarantee
• Air, liquid or air/liquid cooling
• Low noise
• Back illuminated EMCCD
• Single window vacuum design
• Traditional CCD or Non-EM mode

Stanford Research Systems Digital Delay Generator DG645 (4 or 8 ch)

The DG645 digital delay generator from Stanford Research Systems is a versatile digital delay/pulse generator that provides precisely defined pulses at repetition rates up to 10MHz. The instrument offers several improvements over older designs - lower jitter, higher accuracy, faster trigger rates, and more outputs. The DG645 also has Ethernet, GPIB and RS232 interfaces for computer or network control of the instrument.

Features:
• 4 pulse outputs
• 8 delay outputs (opt)
• <25ps rms jitter
• Trigger rates to 10MHz
• Precision rate generator
• Fast transition times
• Ovenised crystal or rubidium timebase (opt)
• Ethernet, GPIB and RS232 interfaces

For further information please contact Paul Wardill on sales@coherent.com.au
Coherent Scientific Pty. Ltd.
116 Sir Donald Bradman Drive
Hilton SA 5033

Conferences 2009

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

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

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

June 28 - July 3
The Many Faces of Centaurus A
Sydney, NSW
http://www.atnf.csiro.au/research/cena/

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

June 29 - July 24
Les Houches Summer School of Physics in Singapore: Ultracold Gases and Quantum Information
NTU, Singapore
http://www.ntu.edu.sg/ias/Pages/default.aspx
http://w3houches.ujf-grenoble.fr

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

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

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

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

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

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

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

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

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

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

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