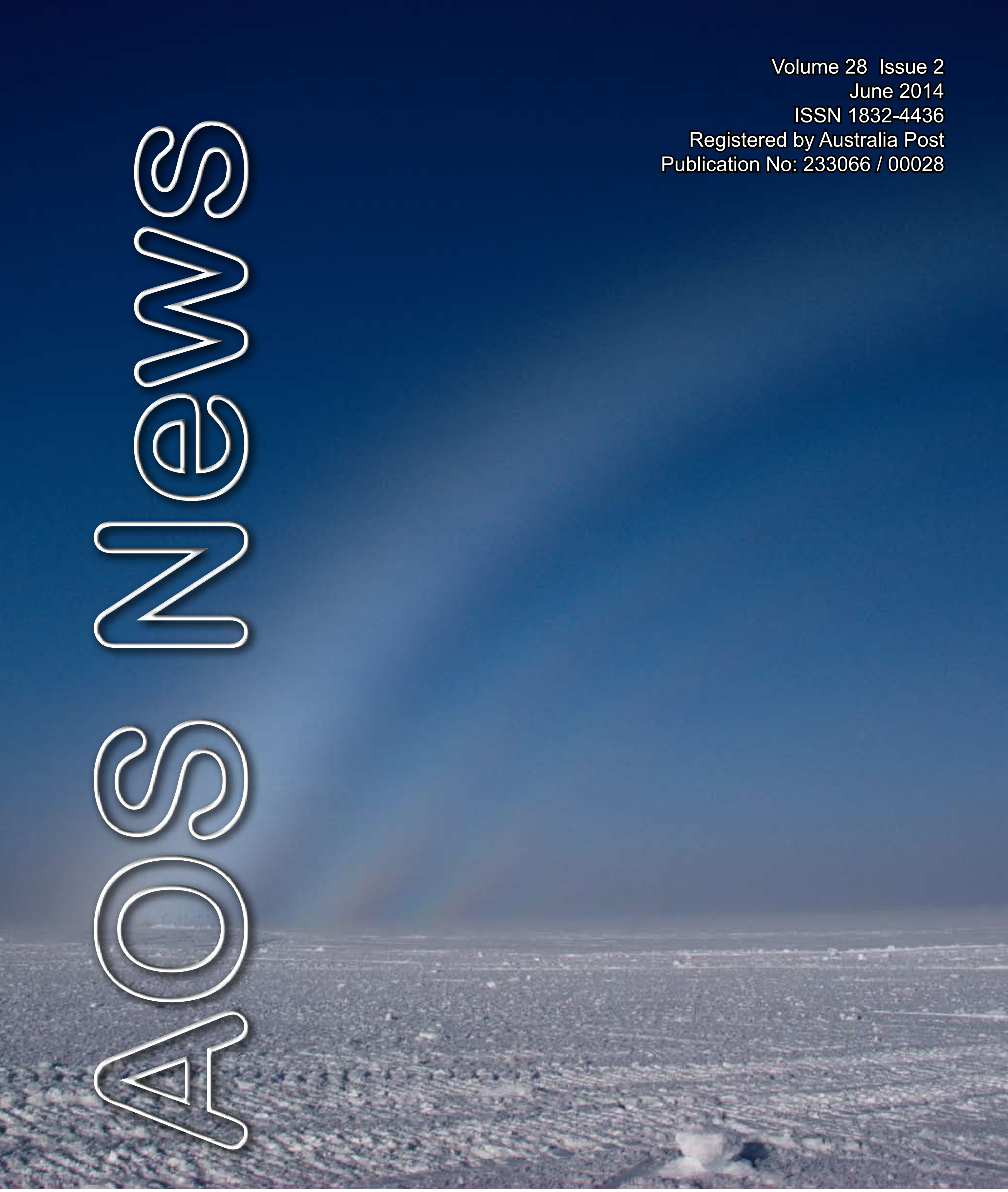

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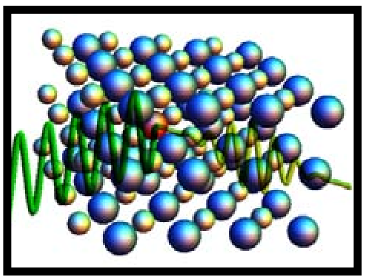
AUSTRALIAN OPTICAL SOCIETY



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AOS News is the official news magazine of the Australian Optical Society. Formed in 1983, the Society is a non-profit organisation for the advancement of optics in Australia. Membership is open to all persons contributing to, or interested in, optics in the widest sense. See the back page (or the AOS website) for details on joining the Society.

Submission guidelines

The AOS News is always looking for contributions, especially from AOS members. Here is a short summary of how to make a submission.

How can you submit?

► The easiest way is by email. We accept nearly all file formats. (Famous last words!).

► Submitted articles will be imported into an Adobe InDesign file. It is best if the diagrams and other graphics are submitted as separate files. All common graphics formats are acceptable, but the resolution must be in excess of 300d.p.i.. Be aware that all colour diagrams will be rendered in grayscale, so if you do use colours, choose colours that show up well in grayscale.

► When using Greek letters and mathematical symbols, use font sets such as Symbol or MT Extra. Please avoid using symbols that are in Roman fonts, where the Option or Alt key is used; e.g. Opt-m in Times font on the Mac for the Greek letter mu.

► If using TeX, use a style file similar to that for Phys Rev. Letters (one column for the title, author and by-line, and two for the main body). The top and bottom margins must be at least 20mm and the side margins 25mm. Submit a pdf file with the diagrams included (no page numbers), as well as copies of the diagrams in their original format in separate files.

► If using a word processor, use a single column. If you do include the graphics in the main document, they should be placed in-line rather than with anchors, but must be submitted separately as well.

What can you submit?

- Scientific Article
  A scientific paper in any area of optics.
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- Conference Report
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- Book Review
- Cartoon or drawing

Reviewing of papers

On submission of a scientific or review article you may request that the paper be refereed, and if subsequently accepted it will be identified as a refereed paper in the contents page. The refereeing process will be the same as for any of the regular peer reviewed scientific journals. Please bear in mind that refereeing takes time and the article should therefore be submitted well in advance of the publication date.

June 2014 Volume 28 Number 2

Articles

Departments

Cover Pictures:
- A fogbow at Summit Camp, Greenland Ice Sheet, see page 33.
- Insets (left to right)
  - A defect in a wide bandgap semiconductor emits single photons on demand, see page 25. Image is courtesy of Milos Toth.
  - Lindsay Botten and Ross McPhedran at an event to mark their retirements, see page 15.

Submission Of Copy:
Contributions on any topic of interest to the Australian optics community are solicited, and should be sent to the editor, or a member of the editorial board. Use of electronic mail is strongly encouraged, although submission of hard copy together with a text file on CD will be considered.

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Copy Deadline
Articles for the next issue (September 2014) should be with the editor no later than 14 August 2014, advertising deadline 7 August 2014.

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President's Report

The much anticipated Federal Budget, with significant implications for science, technology and engineering has finally been handed down. At an event on 8 May, at the Melbourne Centre for Nanofabrication, Higher Education Minister Christopher Pyne flagged ongoing support for the National Collaborative Research Infrastructure Strategy (NCRIS) with $150 million committed from July 2015. This was confirmed in the formal presentation of the budget along with continued support for the Future Fellowship scheme, providing funding for 100 Australian fellows per year over the next few years. However, these positive outcomes need to considered in light of the reduction in funding of $111 million over four years to CSIRO, $120 million to DSTO and $27.6 million to ANSTO along with a $75 million reduction in the budget of the Australian Research Council.

The abolition of Commercialisation Australia and the Investment Innovation Fund has left confusion around support for start-up companies. Although some of the functions of these and related organisations will be moved to the new Entrepreneurs' Infrastructure Programme the total funding available is significantly less than that of the various schemes it subsumes. Furthermore, the decrease in funding for the Collaborative Research Centre scheme and the end of government support for NICTA from June 2016 also removes pathways to the commercialisation of innovation and academic research collaboration with industry.

The establishment of the $20 billion Medical Research Futures Fund is an interesting initiative, although the means to fund its establishment via a co-payment for general practitioner and medical services is controversial and has the medical research community feeling conflicted over its benefit. The simultaneous cut-backs to broadly directed research in the enabling disciplines that has been traditionally funded via the Australian Research Council and CSIRO runs the risk of producing a substantial capability gap. It is well known that research in the physical sciences and engineering has underpinned significant advances in health and medicine. In the area of optics alone, the development of microscopy and other imaging techniques, the widespread use of spectroscopic methods for analysis and the invention of the laser come readily to mind. With the contraction of funding for non-medical research, there is a risk that the interdisciplinary research that is widely regarded as laying the foundation for major advances in drug delivery, tissue engineering, bionics, neuroscience and a broad range of other areas will mean that Australia will not only be unable to contribute to these anticipated major developments in health science, but ultimately, access by the broader community to these advances will be delayed.

I won't comment in detail on extensive changes to the higher education sector since this has attracted considerable attention in the popular media, but the reduction in funding for research higher degree students through the Research Training Scheme needs to be singled out. Research students play a very significant role in the Australian research effort and the value they return far exceeds the amount of funding required to support their positions.

It is clear, that the lack of a coherent science strategy for Australia is being felt and the absence of a clearly defined science portfolio in the Federal Government is a problem. Furthermore, there is a manifest need for an articulation of the nexus between academic research, innovation and commercialisation. Science and Technology Australia (STA) have provided an analysis of the budget that has been circulated to members of the AOS (and can be seen at scienceandtechnologyaustralia.org.au). Organisations like the AOS will be working with STA and other cognate societies to advocate for Australia to have a clearly articulated vision, with an appropriate funding framework, for science and a roadmap showing the way forward.

—*Ann Roberts*
AOS president

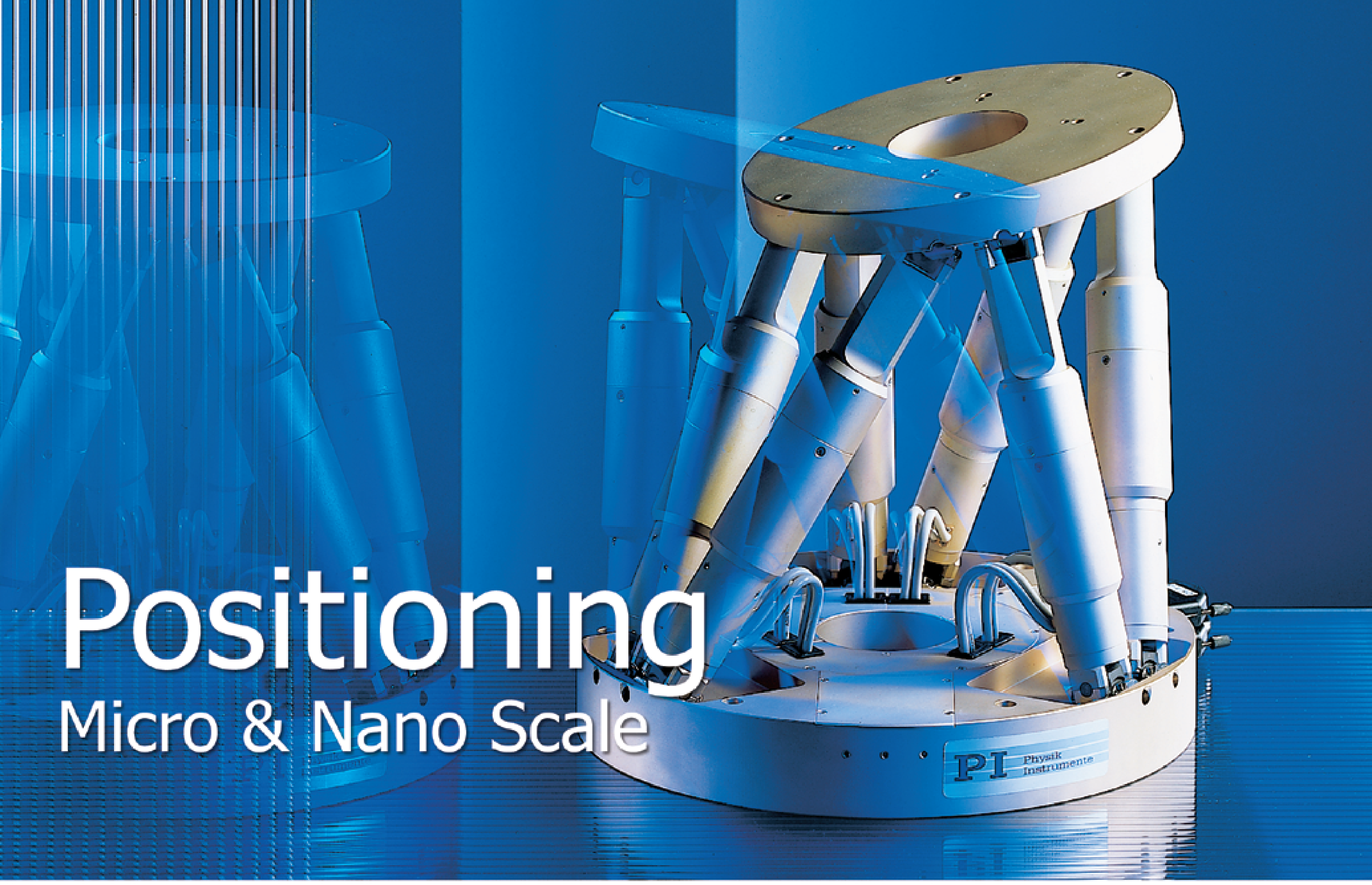
Editor's Intro

Welcome to another issue of AOS News. We have a great selection of articles this time, so thank you to everyone who sent something in. Tony Klein has taken on the role of sub-editor for our 'Optics in Everyday Life' section, so we should be able to continue to run this series. We are grateful to have an article in this section from a different author, John Lekner, and hope that you consider writing one too if you have a suitable topic. Other articles in this issue include a report on the latest Science Meets Parliament event, a commentary on the Australian optics industry and information on an experiment on the Greenland Ice Sheet. There is also another item from a 2013 AOS prize winner, Igor Aharonovich, the winner of the Geoff Opat Early Career Researcher Award, as well as a piece from the winner of the SPIE Start-up Challenge, Robert McLaughlin. It is a wonderful mix of items, and I hope you enjoy reading them all. As usual, please let me know if you have any suggestions for anything you would like to see in AOS News or have any articles or other items you would like to submit. We are happy to receive book reviews or cartoons as well as lab overviews and articles so that we have a mixture of content we can provide.

I recently read a very interesting Perspective article in PNAS by some senior scientists in the field about the problems facing biomedical research in the US as well as suggested solutions (Alberts et al., *Rescuing US biomedical research from its systemic flaws*, PNAS, 2014, **111** (16) 5773). While the information was about a different area and country, there are many similarities to issues facing scientific research in Australia, even if the underlying causes for the situations are quite different. They are worried about the sustainability of the system, reduced productivity and the impact on careers. The article points out the problem with the current situation where scientists are having to spend so much time on grant writing and administrative duties that there is not enough time for reflection and insights to occur, as well as the impact of reduced success rates for grants on truly innovative research projects. These as well as other issues highlighted are vulnerabilities that could lead to serious problems for biomedical research. The suggested methods of dealing with these issues are interesting and not all applicable to the situation here, but one of the main things the authors wanted to do is stimulate debate on the issues that will lead to eventual action. Having predictable and stable science funding and a grant system that improves scientific productivity are certainly desirable, but how likely this is to happen is another matter.

As Maryanne Large points out in her article on the Australian optics industry in this issue of AOS News, there are many more PhD students than academic positions, and with the continual reductions in research funding available this does mean that more and more people spend a lot of time training and then don't know what to do afterwards. Both articles suggest that there should be more links, training and information available at the appropriate level so that those who do not end up finding an elusive permanent academic position can still use the training directly. I liked the ideas put forward in the PNAS article of acknowledging the fact that PhD students can't all turn into successful academics and that therefore their training needs to be diversified and broadened to reflect job market reality. There are many skills acquired during a PhD that are directly useful in other settings, but students and staff alike are not well enough informed about non-research careers, and there aren't clear pathways to enter these in any case. They suggest students get experience in different career environments and mention masters programs that are already emerging that provide instruction in leadership, project management, teamwork and communications skills in addition to their scientific training as being a good way to go. Along with Maryanne's suggestions about closer links between various parts of the optics industry, government and academia, I think the ideas have a lot of merit. There are many smart and dedicated students who will not go on to lead independent groups, but nevertheless would like to utilise their training and only need assistance in finding the various ways that this can be done in a non-research or just non-university setting. Hopefully programs like those suggested will be able to help with this and that the AOS can also help with informing academic researchers and students about the industry possibilities and be a place where everyone can meet as Maryanne suggests.

—*Jessica Kvansakul*
Editor



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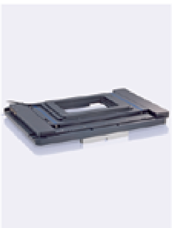

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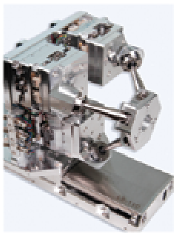

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Science Meets Parliament 2014

by Maryanne Large

The 14th Science meets Parliament (SmP) attracted 200 scientists from across the nation, and more than half the Federal Parliament, with 130 Federal Parliamentarians taking meetings and attending events. Maryanne Large was one of the AOS representatives.

All images from SmP taken by Lorna Sim / Science & Technology Australia

Bill shorten presenting

Science meets Parliament is an annual event organised by Science and Technology Australia (http://scienceandtechnologyaustralia.org.au). All Science organisations affiliated with STA are invited to send two delegates for two days of meetings and professional training. More than half of all members of parliament take part in this event - a remarkable degree of involvement in an event which is apparently unique in the world.

The first day of the meeting was mostly taken up with lectures and professional training. We heard talks by politicians, the policy makers in the public service, journalists, public intellectuals and science communicators – even an expert tweeter.

There were many insights. For example the journalists discussed the difference between worthy news and "newsworthy". How do they decide which story to run and which to drop? There's no simple formula, but many pointers: proximity helps, and, timeliness, but one of the most important factors is impact on people's lives. Medical stories are intrinsically more personal, easier to relate to than physics ones, so they are disproportionately represented. They discussed the role of the journalist in telling the story, and the need for brevity and context. Surprisingly they suggested that radio and local newspapers, and of course the Conversation and the internet, may be better vehicles than national newspapers. They are less time constrained and allow more scope for the scientist to speak directly. However, national newspapers do have one particular virtue: however much the popularity of newspapers has dropped in other social circles, politicians read them avidly.

The need for scientists to be able to explain their work clearly was made repeatedly. Public understanding of science and engagement with it is key to a vibrant science sector. A public profile can also give you the status of an "expert", with potential influence, including on policy.

Maryanne Large asking a question

However, policy influence does require some understanding of the political context. In one of the most revealing sessions, a group of policy insiders acted out the roles of science lobbyist, and pro and an anti-science politicians, illustrating the arguments and counter arguments that might be expected about science funding.

The discussion was in the political context of the May budget, and a budgetary story based around reducing the deficit. The arguments were dominantly economic: the role of science in supporting and enabling the key industries in Australia: mining, agriculture, education, the need to build an economy for the future. The political imperative was underlined: we don't have a science minister. Science is now a part of the industry portfolio.

The "fake" politicians repeated the line that, "yes, you have a good story. But a good story just gets you in the door". Pretty much everyone that gets to that stage has got a good story: about health, disability, education, the drought, mining or manufacturing… making your case stand out amongst these requires data, strategy and preparation.

While these discussions were sobering, there were some notes of optimism. Few scientists take on the role of engaging with politicians and policy makers. So if you do take this on, you may find you may be surprised by your level of influence. Politicians recommended we would have more influence if we spoke with a unified voice: finding the 90% of things we agree on is better than having many fragmented voices. Endorsements by independent third party organisations can be extremely powerful. Bill Shorten noted how the Productivity Commission's endorsement of the economic impact of National Disability Insurance Scheme gave it a credibility that it would not otherwise have had. Finally, there was a strong sense that scientists needed to engage with both sides of politics. In a sense we need to elevate science above the political debate. Farmers have been far more successful

A group meeting Tony Abbott in his office

than scientists in achieving this kind of bipartisan support.

The second day was a large number of meetings with politicians. I met two: Kelly O'Dwyer (Lib, Victoria) and Alannah MacTiernan (ALP, WA). Both were very sharp and very well informed. Kelly O'Dwyer had started a bipartisan group to support women in science, and Alannah MacTiernan asked such detailed questions about astronomy (the SKA) and genomics that I wondered if she had had any scientific training. "No," she said, almost regretfully, "I'm just a lawyer. But I read the New Scientist every week." She had some useful advice to help make the case for funding: find and highlight the instances where publically funded research had enabled technological advances[1].

The event has made me keen to follow up and maintain a bit more of a political dialogue about science. I think the word "dialogue" is important. We all have things to say, but it's also important to listen. Unless we understand how politicians are thinking, and the context in which they operate, it will be almost impossible to present a case that they will find persuasive.

For those wanting to know more, the STA's Youtube channel makes many of the talks available:
www.youtube.com/user/scienceandtechau

[1]There is an excellent TED talk about this: Mariana Mazzucato: Government -- investor, risk-taker, innovator

Maryanne Large is with the University of Sydney.

Adam Bandt from the Greens launches the "respect research" campaign

SPIE News

by Amy Nelson

Rapid Feedback in Hostile Chemical Environments

An invited paper presented by Charles Harb of the University of New South Wales at SPIE DSS in Baltimore, 5-8 May, caught the attention of our science writer for the event.

Charles Harb, University of New South Wales, described work on cavity-enhanced spectroscopy in a novel twist on traditional detection methods to provide rapid measurement and feedback in hostile chemical environments, in an invited talk in the conference on Micro- and Nanotechnology Sensors, Systems, and Applications at SPIE DSS in Baltimore, Maryland, USA. The annual event is sponsored by SPIE, the international society for optics and photonics.

The results described by Harb in "Pulsed quantum cascade laser based hypertemporal real-time headspace measurements," demonstrated a significant improvement in detection capability over traditional methods.

Real-time headspace analysers are critical for rapid measurement and feedback in hostile chemical environments. The team looked to develop a system with a wide tuning range, and hence the ability to detect a wide range of materials, that could be deployed in the field and provide rapid feedback, high sensitivity, and robust operation.

To accomplish this, the team developed a variation on the traditional cavity ring-down spectroscopy system. Rather than


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operating in the time domain, the team looked in Fourier space and adopted a frequency domain approach when analysing the cavity decay.

Exciting the cavity with amplitude modulated light and studying the relative attenuation of harmonic components allows for extraction of the decay constant. Given that power in the fundamental and second harmonic are highly correlated, studying the ratio of the two signals results in a highly stable signal.

The result is a system that can acquire more than 150,000 spectral data points across a spectral bandwidth of 1,400 nanometres in less than 4 seconds at detection levels in the parts per billion range.

Data demonstrating detection of chemicals such as acetone, acetonitrile, nitromethane, and combinations of these substances at detection distances as large as one metre was presented as was real-time rapid scan data illustrating the hypertemporal capability of the system useful in understanding the flow patterns of the substance under study.

Daily News from SPIE DSS can be seen here: spie.org/dssnews

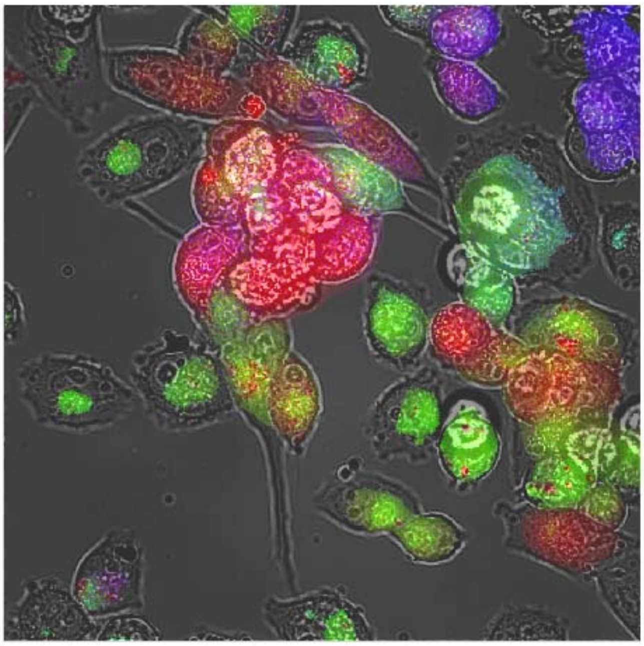
Hyperspectral Imaging for Stem Cells, Diagnostics

Work by Ewa Goldys of Macquarie University was covered in our event news from SPIE Photonics Europe (spie.org/x107471.xml) in Brussels, 13-17 April.

Hyperspectral imaging (HSI), widely used for decades in mineralogy, surveillance and the food industry, is now showing great promise for cell characterisation -- including stem cells -- and could be used to aid medical treatment of a wide range of conditions. In an invited talk in the Biophotonics conference, Ewa Goldys noted that the vast range of cell types presents a major identification challenge.

Classic characterisation techniques tend to be slow and cumbersome, and while fluorescence typically relies on the use of biomarkers and staining compounds, a new label-free approach by Goldys and her Macquarie University colleagues in Australia requires only the natural autofluorescence of biological tissue to work.

Read more:
optics.org/news/5/4/22



HSI can be used to distinguish cells, with a variety of possible applications, including investigating cancer cell development. Here cancer cells are coloured according to hyperspectral features. Image shows mutated cancer cells.

Who wants to be an Entrepreneur?

Simon Poole of Finisar participated in a panel for students and early-career professionals wanting to know more about entrepreneurship at SPIE Photonics West in San Francisco in February.

Photonics industry veteran Simon Poole shares career advice with students.

Photonics industry insiders gave job interviewing tips, a crash course in feasibility analysis, and their perspectives on entrepreneurship and other non-academic careers to about 100 students attending one of several industry events at Photonics West.

Simon Poole, director of new business ventures for Finisar in Australia, advised optics and photonics experts who want to start their own business to "identify the opportunity, get into the market fast, and iterate."

The serial entrepreneur who turned to the commercial side of photonics after running an academic research group for seven years emphasized the importance of speed in many areas of a new business, such as getting to market rapidly and quickly terminating employees who don't work out. But Poole also recommended taking time to hire the right people -- and to "smell the roses."

Andrea Belz, CEO of Belz Consulting, and Jim Fisher, vice president of optical components and the Vibration Control Group at Newport, also underscored the importance of finding a good work-life balance.

Job seekers must be able to "ask the right questions to the right people," Fisher said, but they should first take the time to answer the most important questions: what really drives you, and where do you want to end up.

The full event news is here:
spie.org/x105834.xml

Amy Nelson is PR Manager with SPIE

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The Endless Σummer

by Martijn de Sterke, Boris Kuhlmey and Chris Poulton

Friday 21 February was the day of the Endless Σummer, the occasion to mark the retirements of two pillars of Australian optical science, Ross McPhedran (AOS' foundation secretary and later Editor of AOS News) from the School of Physics at the University of Sydney, and Lindsay Botten from the School of Mathematical Sciences at UTS.

Ross and Lindsay have maintained a close and highly productive collaboration ever since their PhD studies at the University of Tasmania in the 1970s. Over their careers Ross and Lindsay contributed greatly to optics and electromagnetism, in areas as diverse as diffraction gratings, photonic crystals and photonic crystal fibres, and wave propagation in random media. The name "Endless Σummer" refers to Lattice Sums, conditionally convergent series over a periodic lattice of points that are important in the solution to a number of problems in theoretical electromagnetics. Approximately 60 people attended the day, including present and former students, as well as colleagues, some of whom had come from interstate and even from overseas.

The programme was diverse with speakers presenting on the many aspects of Ross and Lindsay's research careers, their contributions to the two Universities, to Australian Research infrastructure, and to the research community as a whole.

Figure 1. End of the morning session

The day started at the University of Sydney with presentations by Tim Bedding (Head of the School of Physics), Don Melrose (U Sydney), Natasha Movchan (U Liverpool, UK), Graeme Milton (U Utah), David McKenzie (U Sydney), Maryanne Large (U Sydney), Yuri Kivshar (ANU), AOS President Ann Roberts, a former student of Ross' (U Melbourne), David Mills (formerly at U Sydney), Peter Robinson (U Sydney), and Pavel Belov (St Petersburg). After lunch the afternoon session at UTS started with an interview conducted by former AOS President Chris Walsh, who quizzed Ross and Lindsay about their Tasmanian days, and how they both ended up in Sydney. The interview offered some insights on the evolution of academia over the last few decades, and some more philosophical reflections on its future. Afternoon speakers were Tim Langtry (UTS), Gordon McLelland (formerly UTS), Mark Wainwright (ANU), Ben Eggleton (U Sydney), Stefan Enoch (Institut Fresnel, Marseille), and Tom White (ANU). Boris Kuhlmey presented on behalf of Daniel Maystre, Ross' long-term French collaborator from Marseille. The day finished with a dinner with more speeches and an opportunity for Ross and Lindsay to reply.

Among the highlights of the day was "Abramowitz, Prince of Denmark," Peter Robinson's variation on Hamlet's famous soliloquy, the first four lines of which read (with apologies to William Shakespeare):

Figure 2. Ross McPhedran

"To sum, or not to sum - that is the question;
Whether 'tis nobler in the mind to suffer
The recursive nature of divergent functions,
Or to use identities against a sea of terms, …"

Graeme Milton, Ross's former student talked about his early research work with Ross, and how Ross and Lindsay's work on the electromagnetic theory of gratings had influenced his own seminal work in the field of composite materials. Natasha Movchan spoke about her long-standing collaboration with Ross and about her work on elastic waves, research that had its origins in the grating theory developed by Ross and Lindsay.

Maryanne Large's presentation, "When Ross met Aphrodite" referred to Ross and Lindsay's work on the "Sea Mouse," Aphrodite Aculeate, a 10 cm long sea creature with iridescent hairs which have a photonic crystals-type structure inside them. For years Ross travelled internationally with a sample of a sea

Figure 3. Lindsay Botten

mouse and pulled it out as the occasion demanded. Both Yuri Kivshar and Pavel Belov presented Ross with cartoons - Pavel's can be seen in the background of Fig 1.

Ross remains research active and he remains a Chief Investigator in CUDOS, the ARC Centre for Ultrahigh-Bandwidth Devices for Optical Systems. Lindsay retired from UTS and is no longer a CUDOS Chief Investigator, but is now the Director of NCI (National Computational Infrastructure), the National Supercomputer Facility in Canberra. The Endless Σummer was organised by Martijn de Sterke, Boris Kuhlmey, and Chris Poulton and was generously sponsored by the University of Sydney, UTS and by CUDOS.

Figure 4. Ross and Lindsay being interviewed by Chris Walsh

Martijn de Sterke and Boris Kuhlmey are with the School of Physics and CUDOS, University of Sydney. Chris Poulton is with the School of Mathematical Sciences and CUDOS, UTS.

Figure 5. From left to right: Natasha Movchan, James Yardley, Chris Poulton, Ross, Pavel Belov.

Figure 6. From Left to right: Geoff Smith, Gordon McLelland, Lindsay, Graeme Cohen, Tim Langtry.

Figure 7. Snjezana Tomljenovic-Hanic and Yuri Kivshar.

Figure 8. AOS President Ann Roberts (left) and AOS past-president Judith Dawes (right).

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Growing the Australian Optics Industry - *How can the AOS help?*

by Maryanne Large

Although Australia has a vibrant research community in optics, it is generally poorly connected to the wide diversity of companies working in and with optics in Australia. These companies are often using leading edge techniques and help to support sectors as diverse as communications, manufacturing, entertainment, forensics, mining, medical devices and agriculture. This article asks why the academic optics community is so poorly connected to industry, and seeks ways to improve and build these connections.

At the end of 2013, as part of the AOS Industry subcommittee, I helped to compile a list of companies in Australia working in optics. I'd become aware of some statistics that made me curious to know how extensive the industry really was.

For example, a recent US study [1] showed the enormous impact the laser has had on the global economy. In the transport sector, laser sales of $1.3 billion enabled cutting and welding technologies for a $500 billion industry in automotive and aeroplane manufacturing. The flow-on impact to the economy was estimated at $1 Trillion dollars. In health care, they found that laser sales of $400 million leveraged an economic impact of $2.5 Trillion, by enabling diagnostics, surgery, blood testing and sequencing. In communications, laser sales of $3.2 billion underpinned the routing and transport of information, which enabled the Internet, e-commerce, computing and supported the entertainment industry (music and movies). In total, laser sales of $5 billion underpinned economic activity of $3.5 Trillion – an astonishing leverage of almost 1000 to 1.

Other studies in the US and Europe estimated that global sales of the photonics industry were more than $400bn p.a., growing at ~10% p.a. *Photonic-enabled* technologies were even more significant. These technologies include information technology, flat panel displays, optical communications, defence, solar energy, medical devices, lighting, measurement and vision and manufacturing. Overall, photonic-enabled technologies accounted for 10% of global GDP [2,3].

These figures sounded truly impressive, and since Australia has historically been very strong in optical technologies, I felt there should be a similar impact here. But there was a disconnect - graduates coming out of universities with optics PhDs did not seem to be overwhelmed for a choice of jobs in optics related companies.

I also knew some less inspiring statistics. Only 2.4 per cent of innovation-active businesses in Australia collaborate with universities [4] and we have one of the lowest rates of researchers in the private sector within the OECD (only the Slovak Republic, Poland, New Zealand and Portugal are lower) [5].

I began the industry audit with a genuine sense of curiosity: were there a whole lot of companies out there I didn't know about? Were there big players in research beyond the names I knew: the telco companies, Finisar, Silanna, Suntech, Canon and Bluglass?

I quickly realised that an audit is a complicated beast. There are optics suppliers, companies that use optics or are enabled by it but are mainly about something else, optics companies that are not research active, companies who are active in research but mainly overseas, companies that work in longer or shorter wavelengths than is usually meant by "optics", government and semi-government organisations, and of course companies that develop products based on optics research. Which ones to count, and where to stop?

I stopped at 187 companies or organisations. The list is complicated and incomplete, but it's already enough to reveal that there were indeed quite a lot of companies I didn't know about before, and a diverse range that encompasses some of our major industries, as well as some interesting boutique ones. Here is a taste:

- Rofin, who make optics for forensics
- Colour Vision Systems, who make equipment for sorting agricultural products
- Camsensor, who do computer vision analysis of food and wood
- Maptek, who manufacture laser imaging technology
- Corescan, who do hyperspectral imaging on core samples
- Ellex, who make ophthalmic laser products
- EOS, who make electrooptics for the space industry
- Farley Laser Lab, who do laser and plasma processing

A Maptek laser scanner in use in the field. Maptek conducts extensive R&D, writes software and manufactures high end hardware technology which is used at mining operations worldwide. I-Site laser imaging technology - hardware and software - is developed and built in Adelaide. Maptek are the only company manufacturing laser scanning hardware in Australia. I-Site laser scanners feature high end optical, survey grade systems that produce the accurate results that mining demands.

A new Farley LaserLabs laser cutting machine, based on a fibre laser. This machine was developed by Farley engineers in Australia and China. Farley Laser Labs targets a global market and have a real focus on efficiency - so access to the latest technologies and processes are very important in the product development stage.

- Moglabs, a spin-off from the University of Melbourne, who make tuneable lasers and electronics
- Laservision, who create large scale multimedia displays using lasers (including at the Sochi Olympics)

There really was a world of optics industry out there that I knew very little about. Now that I do, I think it's critical that we increase connections between such companies and researchers.

There are compelling reasons to do so. For students and early career researchers, the driver is jobs. While researching this article I found a 2010 study prepared by the Royal Society. They were surveying the UK science and technology community, but I suspect the results for Australia would be very similar. They found that only **3.5%** of PhD graduates in science would find permanent academic careers, and that only **0.45%** would become professors.

These are shocking figures. A lot of optics PhD students aspire to an academic future, but either they don't really think about the chances of success, or perhaps just believe they will be one of the lucky ones. The statistics tell another story. If you don't believe them, try this thought experiment: think of the number of PhD students in your department and of the number of permanent positions that have become available in the last 5 years. Of course, there are other universities. But the story is much the same there too. Even students who do tremendously well will have to be very, very lucky to get a permanent academic job. At the very least, it's worth having a variety of options.

For academics, research funding often drives interest in industry. Funding is increasingly competitive - a particular problem in Australia, which to all intents and purposes has a single funding source. This makes science vulnerable to political interference. Countries such as the UK, Canada and New Zealand have already linked science funding to economic impact, and my guess is that it's extremely likely to happen here too.

A greater diversity of funding and jobs are excellent motivations for increasing engagement with industry. But for me the real reason is that, in our society, companies are the mechanism by which research leaves the university and has impact in the community. Why would you invent a cure for cancer and not use it? What would be the point? Why would you develop a radically better camera or laser, a more energy efficient telecom system or a more sensitive gas sensor and have the only impact be citations or conference invitations? Carrying these tasks to completion *requires* engagement with industry. Publications are too often considered the only endpoint of research.

As a nation we are proud of our world-class research, and justifiably so. But we don't have much cause for pride in our ability to translate this research excellence into high tech industries.

There are no simple answers to why and how this came to be. Personally I believe a big part of the problem is cultural: there is a sense that industry is about money rather than knowledge. It's like being a merchant or a carpenter rather than a priest or a poet. It's a view that might have been compelling in ancient Greece, but today it's a myth and a damaging one.

I recently read a quotation by the former director of CERN, Robert Aymar. He said: "History teaches us that big jumps in human innovation come about mainly as a basic result of pure curiosity. Faraday's experiments in electricity for example, were driven by curiosity, but eventually brought us the electric light. *No amount of R&D on the candle could ever have done that.*" [7].

I'm sure most academic scientists would find this statement uncontentious. But even ignoring the fact that he preferred to mention the electric light bulb rather than the World Wide Web (a quite important invention that which was actually developed at CERN), there is little in his statement that bears much critical scrutiny. The quote about the light bulb is a misattribution. Originally it was used in connection with Edison, who of course *was* mostly motivated by a desire to make a light bulb. Faraday was fascinated by candles (he used them to study basic science and even wrote a book about them [8]), and he certainly wasn't averse to solving practical problems. Indeed, it takes a wilful kind of blindness to ignore Faraday's excitement at inventing the electric motor, or his role in investigating explosions in coal mines, pollution in the Thames, corrosion of metal ships or the design of lighthouses. These were not add-ons to a life in "pure" research: they were a part of his research life, just as his research was a part of his life solving practical problems. Each informed the other.

In the nineteenth century there was no distinction between "pure" and "applied" (impure?) research. Everyone did both,

MogLabs is a University of Melbourne spin-off that develops tuneable lasers.

The Polilight, produced by Rofin Australia is a forensic light source used in 88 Countries. There are some 14,000 units in use. Dr Hardian Fraval, Managing Director of Rofin Australia comments: "It is a good example of taking Research from the ANU and successfully translating it into a commercial product. Improving the interaction of Academic research with companies like Rofin is vital for all our futures. Commercializing technology is a challenge. We are starting to work with some graphene /LED applications which look exciting."

and ideas from one seamlessly moved into the other. Siemens and Maxwell worked on developing the telegraph, Tesla on everything from power generation for cities to radio and remote controls, Watt worked on steam engines. The whole of thermodynamics, one of the most philosophical and abstract areas of physics, developed out of a desire to increase the efficiency of steam engines. Sadi Carnot (he of the Carnot cycle) was an officer in the French Army and was reputedly very annoyed to discover that not only were English engines more efficient than French, but there were profound fundamental reasons limiting the efficiency of any engine.

Even quantum mechanics had its genesis in an industry project. Planck was employed by German energy companies to develop a more efficient light bulb, and it was in the process of carefully making these measurements that he discovered that the Raleigh-Jeans law did not hold. R&D on candles might not have led to the light bulb, but R&D light bulbs produced quantum mechanics.

Although this is a true story, and an interesting one, I have never seen it in a physics textbook, while the Edison/Faraday candle quotation keeps on earnestly doing the rounds. The intention may be noble (to protect research in basic science) but it deliberately obscures a much richer and more powerful story about the interrelationship of science and technology. Recalling that much richer story is timely.

If we are to progress in improving our high tech industry, we need to move beyond stereotypes. Not all problems in industry are trivial or boring. Not all problems in academic research are profound. Some industry researchers are motivated by curiosity; some academic researchers are motivated by ambition. Many of our most powerful insights, as well as most important technologies, have come from connecting science to real world problems: a collision of the abstract and the practical. There is a change in perspective that this intellectual dissonance implies that can be very revealing.

I believe we have suffered as a community by imposing artificial distinctions between basic and applied research, science and engineering, and between research and industry. The tiny number of academic positions and the punishing publication metrics for success have conspired to produce universities where very few researchers have any commercial experience. Most have very little idea of the process for commercialising their work: identifying and quantifying a market, the role of investors, what grant support is available, how long it takes, how much it costs. The flow on effect is that students too, fail to learn these skills.

Societies like the AOS can help bridge this gap. In an ideal world the AOS would be an intellectual meeting place for everyone working in optics: academic, government and industry. We could help make connections between them stronger, and help develop policies, share ideas and resources. We must also start celebrating the successes of our optics industries- some of whom are world leading.

The AOS is keen to play this role. We are actively to trying to foster the optics industry in Australia, and to help develop new industries based on optics research. To help start this process, we are developing an "Industry" section in the AOS journal and on the website. We are beginning to contact optics companies we have identified in our audit to ask them how they may want to be involved. We are also keen to explore new ways of encouraging and celebrating innovation, perhaps by finding industry mentors and connecting them with young researchers, or providing an industry prize or seed funding.

This is just the start of a conversation about how to improve- please let us know your ideas, either by sharing them on the AOS Linkedin site, or by emailing me at: maryanne.large@sydney.edu.au

There is enormous potential to do more. 2015 is the International Year of Light. Strengthening the optics industry in Australia would be a great way to celebrate.

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Maryanne Large is Associate Professor of Innovation and Commercialisation with the University of Sydney and is on the AOS council, heading the Industry Sub-Committee.

CALL FOR ABSTRACTS AND REGISTRATION NOW OPEN

The 21st biennial Australian Institute of Physics Congress, *The Art of Physics*, will be held at the ANU in Canberra in the week of December 7-11 in 2014. The Congress also incorporates the annual meeting of the Australian Optical Society as well as meetings of the many technical groups and discipline areas associated with the AIP. The AIP Congress will be preceded by the *OSA Renewable Energy and Environment Congress*, which will also be held at the ANU on December 2-5.

The Call for Abstracts is now open. See http://aip2014.org.au/abstracts Submissions close Friday 27 June 2014.

Take advantage of our generous early bird rates by registering before Friday 29 August 2014. See http://aip2014.org.au/registration

We are keeping registration costs 10% lower than the previous Congress, with even more attractive rates for students. Your full registration will include the welcome reception, full day catering and access to a number of other exciting activities and events. Further details can be found on the Congress website.

The Congress will be held over five days with plans for seven concurrent sessions, daily plenaries, poster sessions and a packed and lively social calendar. The *Art of Physics* theme was chosen to explore the links between, and the beauty of physics and art. We have assembled a stellar cast of plenary speakers, including two Nobel Prize winners:

- Prof Steven Chu, co-recipient of the Nobel prize for Physics (1997)
- Prof Paul Corkum, Director of the Attosecond Science Program at NRC and University of Ottawa.
- Prof Steven Cowley, CEO, United Kingdom Atomic Energy Authority
- Dr Lisa Harvey-Smith, project scientist for the Australian SKA Pathfinder (ASKAP)
- Prof Lawrence M. Krauss, Arizona State University & ANU
- Prof Steven Sherwood, Climate Change Research Centre, UNSW
- Prof Anke Rita Kaysser-Pyzalla, Scientific Director HZB and chair of IGAFA
- Professor Lisa Randall, Theoretical particle physics and cosmology at Harvard University
- Prof Serge Haroche, co-recipient of the Nobel prize for Physics (2012)

Please make sure you submit your abstract for the Congress before **27 June** so that your paper can be considered for inclusion in the Congress program.

Microscope-in-a-Needle Wins SPIE Start-Up Challenge for UWA

by Robert McLaughlin

A/Prof. Robert McLaughlin delivering the winning business pitch.

Commercialisation of new optics technologies is a complicated and difficult journey. To help train a new generation of entrepreneur-researchers, the SPIE has created the SPIE Start-up Challenge, a 'three-minute business pitch' competition held annually in San Francisco.

The Start-up Challenge is part of Photonics West, the world's leading biomedical optics, optical MEMs, photonics, and industrial laser conference and exhibition, which attracts over 20,000 attendees. Research groups and start-up companies were invited to submit a short business plan, describing their innovation, and 25 teams from around the world were chosen to compete.

The microscope-in-a-needle – a miniaturised OCT probe capable of imaging cancer and identifying blood vessels.

Our research group, the Optical + Biomedical Engineering Group (OBEL) at the University of Western Australia, was fortunate to be amongst those chosen, and I was invited to present our work on a special type of miniaturised optical coherence tomography (OCT) probe. The probe is so small that we have managed to encase it within a medical needle – a 'microscope-in-a-needle'. The project, led by myself and the head of group, Winthrop Professor David Sampson, opens new biomedical applications for OCT. Working with surgeons, radiologists and pathologists, we have been exploring how such a probe can be used to perform safer brain biopsies and provide intra-operative guidance to breast cancer surgeons.

During Photonics West, the SPIE offered a half-day workshop to competitors to help them fine-tune their business pitch, and networking opportunities with entrepreneurs, investors and intellectual property specialists. The take-home message was simple: networking is critical to a successful start-up, so start meeting people.

In the competition finals, eight groups were invited to present a 3-minute business pitch to a full auditorium, and answer commercial and technical questions from the judges. With tough competition from MIT, University of Toronto and a range of new tech companies from around the world, our group from the University of Western Australia were awarded first prize for our microscope-in-a-needle innovation. This included a cheque for $10,000 from the SPIE, and $5,000 in equipment from Edmund Optics.

The feedback from the judges to all competitors was clear. If you want to engage with investors, then learn to talk business. Many of the unsuccessful teams had spent their three-minute pitch explaining details of their technology. However, the judges first wanted to know who the market was, and how much they were willing to pay. In business, if you can't answer these questions, then the technology is irrelevant. As a researcher who is more familiar with the science, this lesson was the real prize that I took home from the competition: entrepreneur-researchers need to know their business case as proficiently as they know their research.

Part of the winning team from the Optical + Biomedical Engineering Lab, UWA receiving their prize. (L-R) Kelsey Kennedy, W/Prof. David Sampson, A/Prof. Robert McLaughlin, A/Prof. Brendan Kennedy, Peijun Gong.

Links:

2014 SPIE Startup Challenge Results
http://spie.org/x106250.xml

Microscope-in-a-needle helps breast cancer surgeons identify tumor edges
http://spie.org/x107440.xml

Optical + Biomedical Engineering Lab
http://obel.ee.uwa.edu.au

Robert McLaughlin is with the University of Western Australia.

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This comprehensive Congress examines frontiers in the development of optical technologies for energy production, transmission and use. It also examines the use of optical and photonic approaches to monitor both energy usage and the effect of energy production on the environment. It is designed to bring together researchers, engineers and managers to foster timely information exchange between the disciplines involved in these fields.

PLENARY SPEAKER:

Steven Chu, *Stanford University, USA*

KEYNOTE SPEAKERS:

James G. Anderson, *Harvard University, USA* (E2)
Martin Green, *Australian Centre for Advanced Photovoltaics, University of New South Wales, Australia* (PV)
Toshihiko Iwasaki, *Konica Minolta, Japan* (SOLED)
Roland Winston, *University of California Merced, USA* (SOLAR)

OPTICS AND PHOTONICS FOR ENERGY AND THE ENVIRONMENT (E2)

E2 focuses on monitoring and controlling the generation of energy and its impact on the environment. The conference will showcase optical techniques and instrumentation used in monitoring, sensing and transmitting information relating to energy and the environment. It will bring together people from industry, university and government to address environmental impacts of energy production and policies to guide its management. Special emphasis will be on sensor devices for energy, environment and pollution monitoring, energy usage and transmission (including smart grid technology) and energy efficiency in industry.

OPTICAL NANOSTRUCTURES AND ADVANCED MATERIALS FOR PHOTOVOLTAICS (PV)

PV brings together experts in nanophotonics, materials science and photovoltaics to discuss the latest developments in nanophotonic enhancement and nanostructured materials for the next generation of solar cells. Nanostructured materials and photonic enhancement schemes offer unprecedented opportunities to control both the optical and electrical properties of next-generation solar cells. This meeting covers all aspects of optical nanostructures for photovoltaic applications, from surface textures and diffraction gratings through to emerging topics such as plasmonic enhancement, nanowires, quantum dots, novel materials and spectral flux management in multi-junction solar cells.

OPTICS FOR SOLAR ENERGY (SOLAR)

SOLAR focuses on optics for solar energy applications including design, modeling, integration of novel materials, manufacture, field-testing and deployment, and economics. All forms of solar energy generation, transmission and storage – from thermal to photovoltaic to novel methods – will be covered. The program will highlight presentations spanning technology, public policy and finance.

SOLID STATE AND ORGANIC LIGHTING (SOLED)

SOLED focuses on new materials (both organic and inorganic) and new devices for lighting, their manufacture and lighting policy. The conference will showcase the latest inorganic and organic materials developed for solid-state lighting, novel lighting structures, theory and modelling, and manufacturing and lighting issues. It aims to bring together people from along the research, development and manufacturing pipeline with presentations from industry and academia.

2013 AOS Geoff Opat Early Career Researcher Award - Dr Igor Aharonovich

The ECR award is made annually to an AOS member who has demonstrated outstanding early achievement in the field of optics. The award is named after Professor Geoffrey Opat who was an extraordinarily versatile scientist and was widely respected in the Australian and international optics communities. He was Professor of Experimental Physics at the University of Melbourne and made contributions to particle physics, neutron optics and atom optics. Professor Opat was a dedicated member of the Australian optics community and was President of the AOS in 1988 and 1989. He was an outstanding teacher and mentor to students and young academics and is remembered fondly by those who knew him. More details about the award at optics.org.au.

Dr Igor Aharonovich received BSc and MSc degrees from the Technion in Israel and completed his PhD from the University of Melbourne. After a postdoctoral position at Harvard, he joined the School of Physics and Advanced Materials at University of Technology, Sydney where he is a Senior Lecturer and DECRA Fellow. His research interests are focused on nanophotonics, including investigating novel quantum systems and biosensors.

AOS President, Ann Roberts presents Igor with the award.

Defects in Wide Band-Gap Semiconductors – Unparalleled Sources for Quantum Photonics

by Igor Aharonovich

Single photons are vital constituents of quantum information processing applications, integrated nanophotonics networks and quantum communications. Over the last several decades, a significant amount of research has been dedicated to studies of single photon emitters – their generation, characterisation and implementation. The original sources were based on filtering faint laser pulses, photons based on spontaneous parametric down conversion and trapped ions. However, the motivation to have access to solid state sources, triggered, "on demand" emitters, and most importantly scalability - led to the rigorous exploration of single molecules, quantum dots and very recently - defects in wide bandgap semiconductors.

Although optical properties of defects in semiconductors have been studied for almost a century, little spectroscopy has been done on single defects in these materials. In 1997, Gruber et al. [1] discovered that isolated nitrogen vacancy (NV) centres in diamond can be observed using standard confocal microscopy, and several years later the first antibunching curve - the unambiguous proof that a source of photons is non-classical (i.e. quantum) has been reported from this same defect [2]. The antibunching measurement is rather simple: it is based on the traditional Hubury, Brown & Twiss (HBT) interferometer that was originally employed to measure the angular size of stars [3]. In the field of quantum optics, the stream of photons arrives onto a beam splitter and is directed to two separated avalanche photodiode detectors that are sensitive to single photons. The detectors are connected to a correlation card that bins the arrival of the photons. If, at a given time, there is no coincidence of photons it means that the emission is from a non-classical source. As the statistics are accumulated, the antibunching curve is formed with a traditional dip at zero delay time.

The isolation of single NV centres in diamond immediately sparked the attention of several groups worldwide that started to look for other quantum emitters. The goal was to identify a narrowband emitter, with short lifetime and linearly polarised photons - ideally at the near infrared spectral range. These are the optimum parameters for a single source to be used in applications like quantum cryptography, quantum communications and nanophotonics where the information is encoded in the polarisation state of the emitter. Identifying emitters in the infrared is important to enable free space communication and to match the traditional 1.5 μm frequencies used for

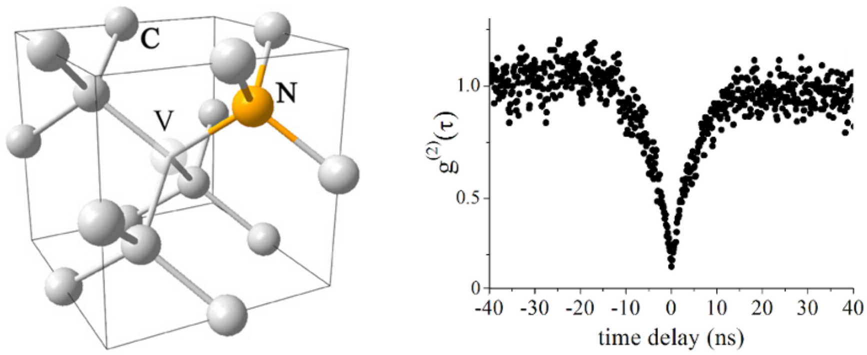

Figure 1. Left: The figure shows a crystallographic structure of the well-known nitrogen vacancy (NV) centre in diamond. Right: antibunching measurement that illustrates single photon emission. The coincidence at zero delay time are approaching zero, an indication that a single photon emitter is probed.

telecommunications.

Within several years of the original discovery of the NV centre, new emitters based on silicon, nitrogen aggregates, transition metals and other impurities have been isolated in diamond [4]. The unique advantage of diamond in this regard is that all these emitters are optically stable at room temperature and maintain their non-classical behaviour. While some of these defects have been studied previously as ensembles (e.g. SiV defect), single photon spectroscopy and rigorous materials engineering have been extremely valuable to identify new defects that were previously unknown. The SiV defect is an excellent example of an ideal emitter for quantum cryptography. Its zero phonon line is centred at 740 nm and its full width at half maximum is narrow (~5 nm at room temperature). Its excited state lifetime is only ~1 ns and it can exhibit count rates as high as millions of single photons per second [5].

The research into single emitters in diamond has certainly come a long way. However, on a fundamental level other wide bandgap materials that host defects should exhibit similar properties. Indeed, in recent years single defects in ZnO, SiC and other semiconductors have been observed [6-8]. This research, however, is still in its infancy: we do not know how to fabricate these single photon sources reproducibly, neither do we know their full elemental composition or symmetry. A collaborative effort is certainly required to isolate and then deterministically fabricate quantum emitters in these materials. Moreover, exploring the underlying photophysical properties of these emitters will give us the tools to learn more about the host material itself. For instance, understanding strain effects in thin membranes, controlling the emitter's stability in individual nanoparticles and understanding the surface effects on the fluorescence. This knowledge will eventually usher a germane platform for nanophotonics and quantum information processing, translating single photon sources from the optical bench top to a commercial technology. Integration of emitters with optical fibres, photonic resonators and the realisation of electrically triggered defects are the first steps towards the commercialisation paths. With a myriad of opportunities to develop, the ultimate application of single quanta of light in the physical or the biological sciences is yet to be seen.

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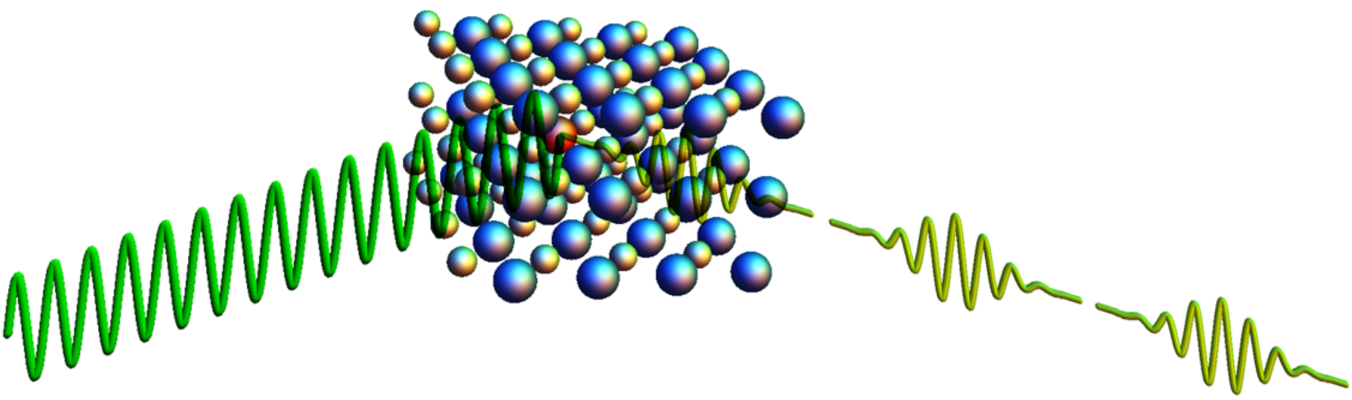
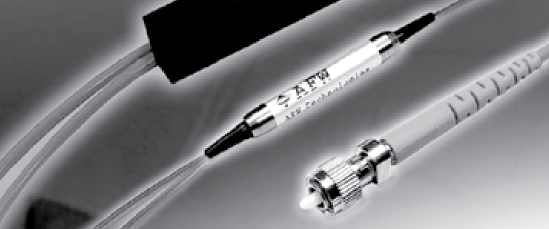


Figure 2. Schematic illustration of a defect in a wide bandgap semiconductor that emits single photons on demand upon green laser irradiation. Image is courtesy of Milos Toth.



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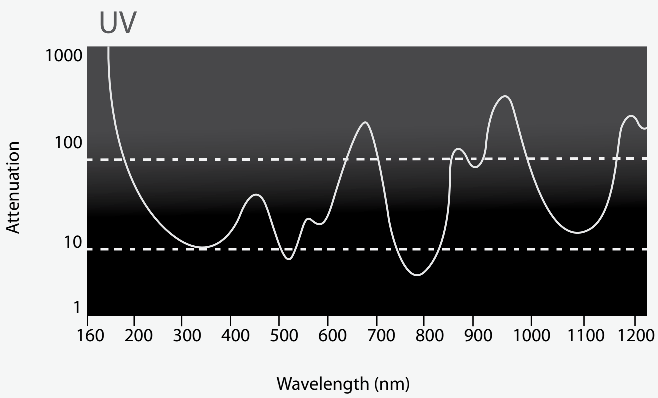

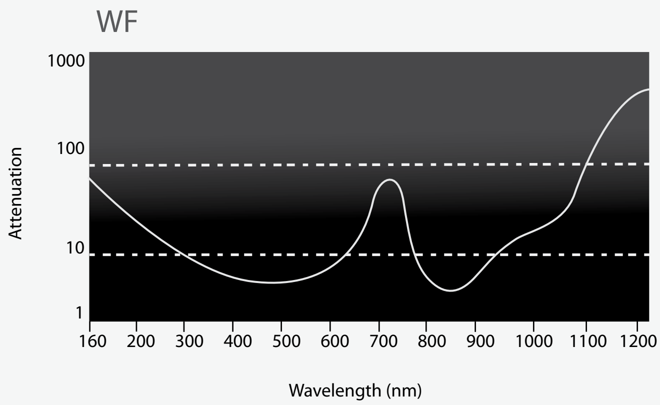

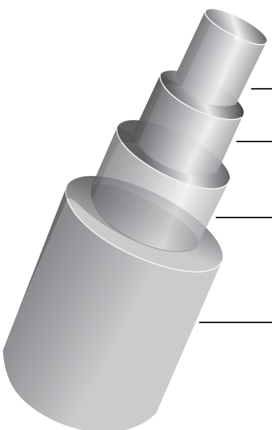

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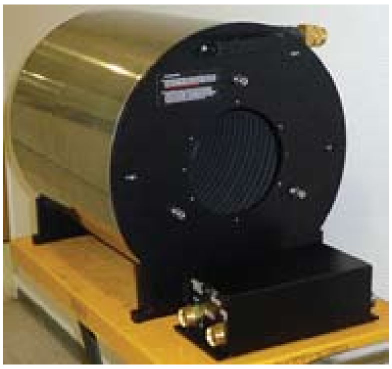

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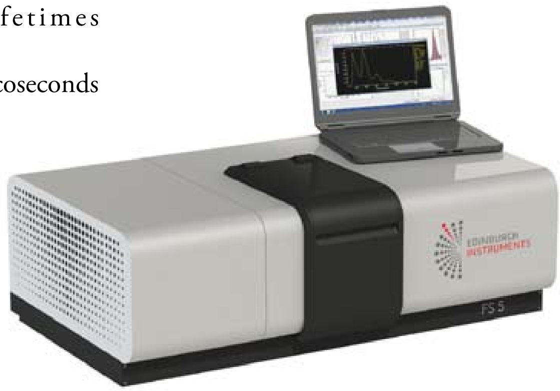

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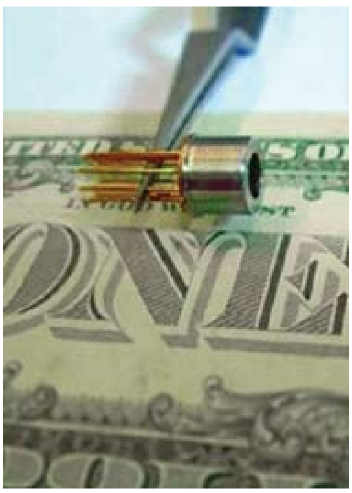

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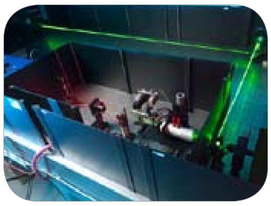

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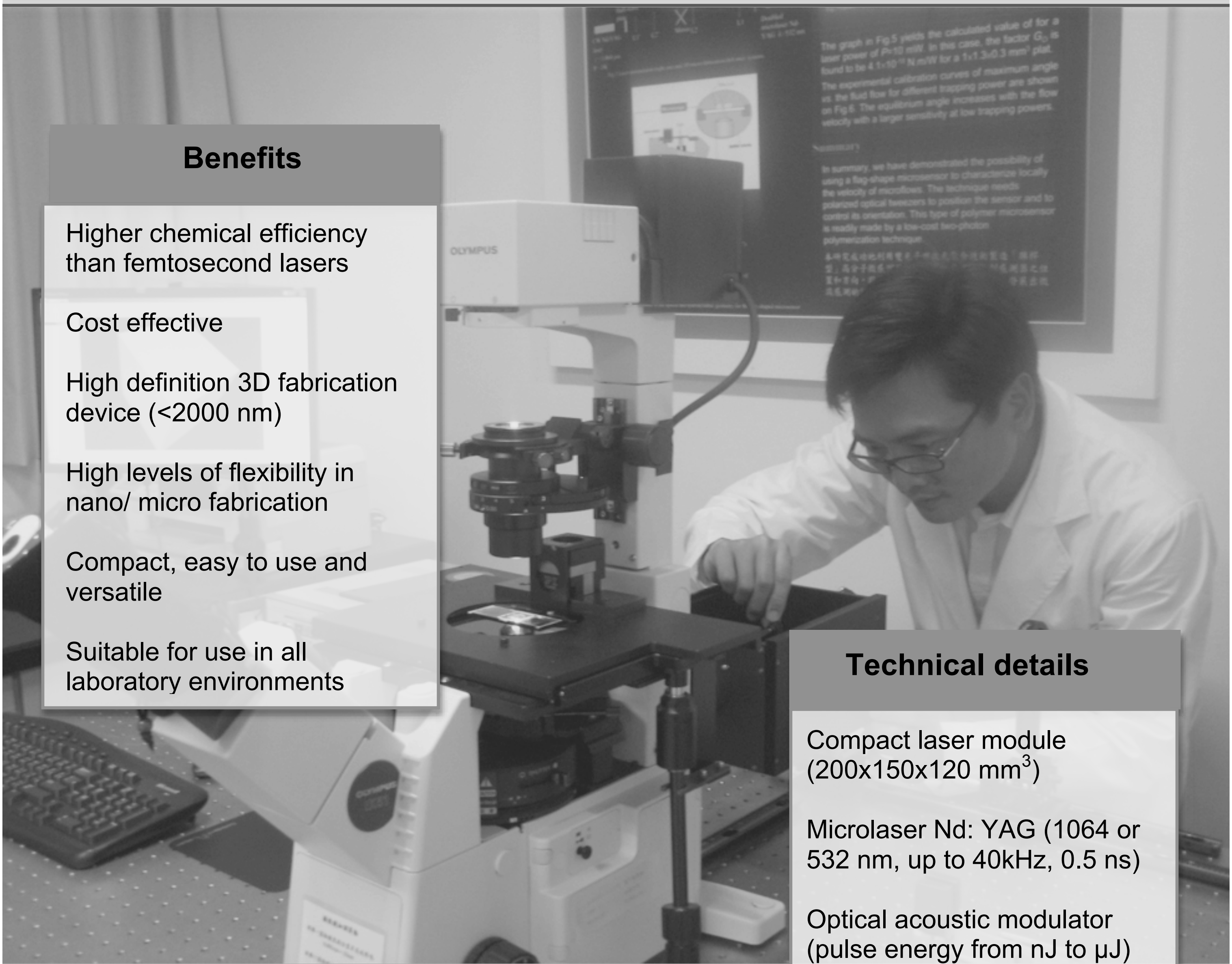

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Optics at Summit

by Murray Hamilton

This article describes the testing of a new optical instrument for meteorology. It is an in-situ sensor for clouds, which distinguishes liquid from solid particles by measuring the change in polarisation of the backscattered light.

A weather balloon with polarsonde about to be released by a Danish high school student. The polarsonde is held by the technician at right, and is taped to a radiosonde which will relay the data.

Clouds are an important part of the climate system and represent one of the main uncertainties in climate and weather models. For example the models are not capturing Southern Ocean cloudiness and cloud type correctly, and our understanding of cloud evolution also has large gaps.

Optical probes are very important tools in both the monitoring of cloud and the study of cloud microphysics; that is the partitioning of cloud particles into the solid and liquid, the size distributions, the crystal habits and the processes by which the cloud particles evolve [1].

The particular question that we are addressing is whether super-cooled liquid droplets are present in a cloud. This is a question of great importance to aviation as super-cooled liquid droplets freeze on solid surfaces and cause planes to ice up. Also the radiative transport properties of a cloud depend on the ice-fraction if it is mixed phase cloud. Lidar observations indicate that super-cooled liquid appears to be more prevalent in the southern hemisphere [2], and this is thought to be related to the lower aerosol loading of the southern atmosphere, compared to the northern.

Super-cooled liquid water forms spherical droplets, whereas ice crystals have a variety of forms, generally with a hexagonal symmetry. This means that the two phases change the polarisation of scattered radiation differently. As a rule of thumb, spherical droplets cause no depolarisation in the backscatter direction, whereas nonspherical ice particles cause depolarisation. This principle is used in satellite based lidar such as the CALIOP lidar on the CALIPSO satellite [3].

However for operational meteorology and high resolution studies of cloud microphysics satellite lidar data is too sparse; overpasses happen only once every two weeks or so. Ground-based measurement thus has its place, but here again there are limitations. Lidar measurements are limited to the proximal edge of optically thick clouds, and radar is expensive. The solution we are developing is an in-situ sensor – a balloon-borne polarimetric backscatter sonde, or "polarsonde" for short.

The polarsonde emits linearly polarised light from an LED and detects light which is nearly in the backscatter direction. There are two detectors, one for light polarised parallel to that of the emitter, and one for the perpendicular polarisation. The device is attached to a radiosonde which provides telemetry as well as temperature, humidity and pressure measurements. It is low-cost so that the device can be expendable.

The midnight sun illuminates the 50 m tower and the Mobile Science Facility which houses the ICECAPS lidars, radiometers and radar.

Any atmospheric measurement technique requires extensive validation, since each has its unique set of limitations, so it is important to compare the polarsonde with as many other methods as possible. A site which is nearly unique, and very well suited to validating a balloon-borne cloud probe, is Summit Camp, at the summit (oddly enough) of the Greenland Ice Sheet.

Summit Camp began as an ice core drilling site – the GISP II borehole, located here, reaches 3200 m to the bedrock below, which is approximately at sea level. Later it became an atmospheric chemistry site, with the establishment of the Greenland Environmental Observatory (GEOSummit) by the National Science Foundation and the Danish Commission for Scientific Research in Greenland. It hosts routine atmospheric observations by NOAA, and several other scientific programs. Two in particular are relevant to the polarsonde; ICECAPS [4] which is a program run by a consortium of US Universities, and the Greenland Isotopes Project [http://climate.colorado.edu/research/greenland/] led by David Noone of CIRES at the University of Colorado.

The ICECAPS facility includes lidars, radar and radiometers that are useful for the polarsonde validation, as well as regular weather balloon flights that host the polarsondes. Summit has a 50 m tower that is instrumented at various levels, and polarsondes are mounted at 10 m height, with an adjacent weather station and a fog monitor belonging to the Greenland Isotopes Project. The fog monitor is an

A fogbow at Summit. This shot is underexposed to highlight the supernumerary bows. The droplets causing the bow were supercooled liquid water.

optical particle sizing instrument [http://www.dropletmeasurement.com/]. Fogs containing supercooled liquid droplets are common at Summit. The photo of the fogbow is evidence of this – the ambient temperature was about –10°C. This fogbow also shows very prominent supernumerary bows which are evidence that the droplets are quite monodisperse. The Greenland Isotopes Project is also providing the data transfer from Summit for the tower mounted polarsondes.

In July 2012 and July 2013 I made trips to Summit to install and replace the tower mounted polarsondes, and to establish procedures for balloon launches of polarsondes. Summit is run by the NSF, which sometimes allows other projects to operate there as paying customers. Collaboration with NSF funded projects does help smooth the path! Access is available to scientists only in the summer, and is provided by the New York Air National Guard, who operate ski equipped Hercules aircraft and provide logistical support for a number of stations on the ice sheet. (This is the same US Air Force unit that provides logistics for South Pole Station.) I travelled to Kangerlussuaq on the west cost of Greenland, from Denmark, in order to catch the flight up to Summit. This routing was vastly more comfortable than flying by Hercules to "Kanger" from upstate New York!

Summit has a summer staff of about ten, and a total summer population of between twenty and fifty. This number was boosted close to the maximum, on both of my trips, by school parties – the NSF runs an outreach program for US, Danish and Greenlandic high school students who participate in various science activities on the coast and a couple of sites on the ice sheet. Summit has a mess building, some laboratories, a workshop, and sleeping quarters for the staff, but visiting scientists sleep in "tent city". Actually the tents get quite toasty inside in 24 hour sunlight, up to +10°C, though if the "night" has been overcast it can be quite chilly by 6 am.

Summit is a good place for viewing various atmospheric optical phenomena; there were of course fogbows, though I missed seeing the various ice-crystal halos and their related phenomena such as parhelia and arcs which tend to occur in colder weather, both earlier and later in the year. Nevertheless the suite of instruments on and around the tower includes webcams with panoramic views, so that at appropriate times of the year and day, these can be seen via the internet [climate.colorado.edu/~dcn/Summit/webcam.html].

The operation of the polarsondes is made challenging by the large temperature extremes; in winter the temperature can be as low as –60°C, and in summer just over 0°C. The temperature inversions also can be quite extreme; the 10 m point on the tower is sometimes 15°C warmer than at 2 m above the surface. Thus we are needing to find ways to compensate for temperature induced drifts. Dealing with the intense ambient light in summer also proved a challenge. Nevertheless, the current iteration of the instrument is producing results that we can meaningfully compare with the other instruments at Summit. Ironically this instrument that detects icing conditions seems itself sometimes to be affected adversely by icing (the balloon-borne version), and this remains a hurdle to be overcome.

In addition to the testing of polarsondes at Summit, they are also being evaluated by Droplet Measurement Technologies, Environment Canada and the Belgian Royal Meteorological Institute. Here in Australia we plan to deploy the polarsondes on cloud physics campaigns on and over the Southern Ocean. Balloon launches will occur from sites such as Macquarie Island, and from ships such as CSIRO's new vessel the RV Investigator. Such campaigns offer the most convenient concentration of other instruments that will enable the continued validation.

Waiting in the departure lounge at Summit.

This research was funded by the Sir Ross and Sir Keith Smith Fund, and the University of Adelaide. The assistance of the Summit Camp staff, DSTO and the Australian Bureau of Meteorology is gratefully acknowledged.

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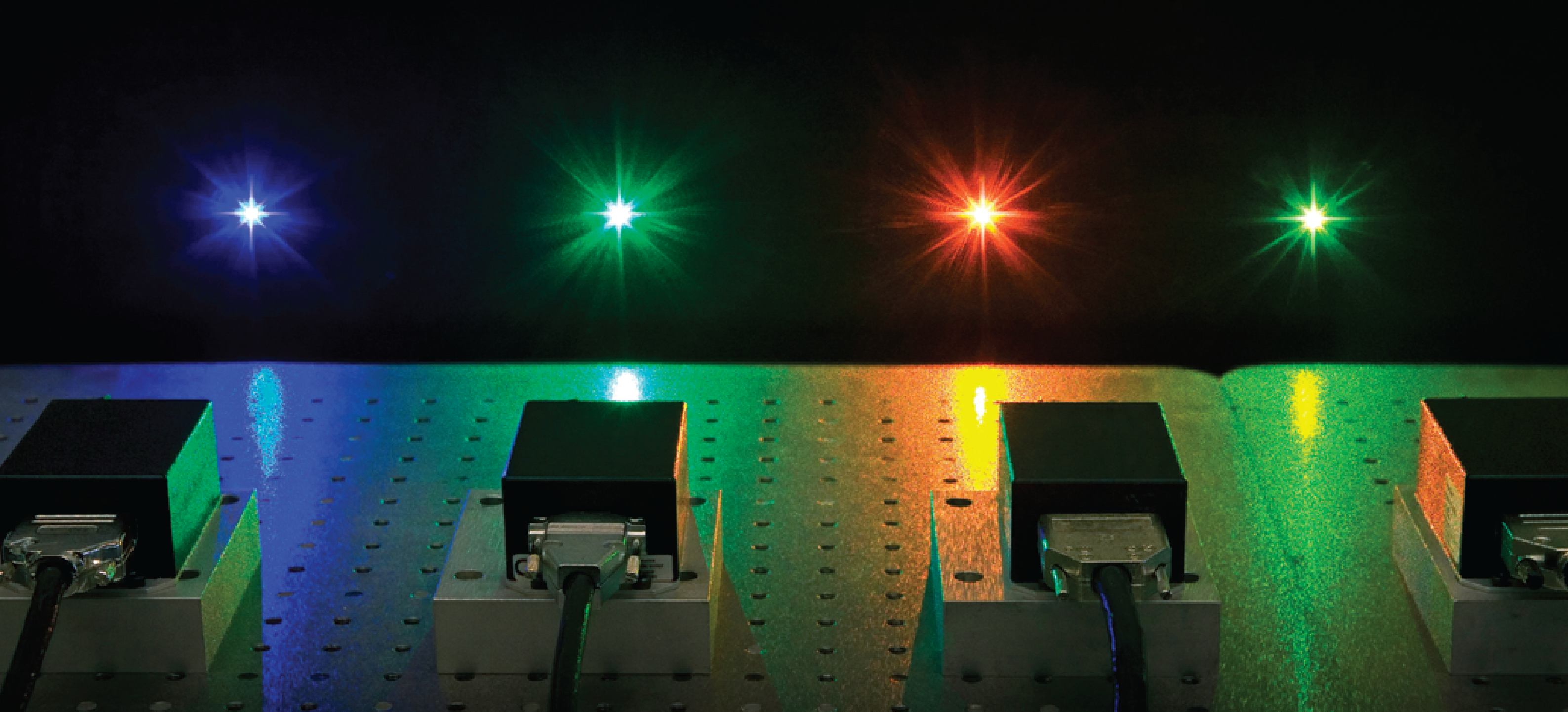
Murray Hamilton is with The University of Adelaide

The main street of Kangerlussuaq. The buildings speak of the town's and airport's early history as a World War II and Cold War airbase. The red building is the hostel for scientists destined for the ice sheet.



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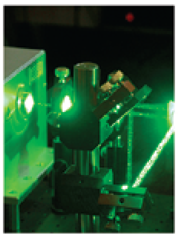

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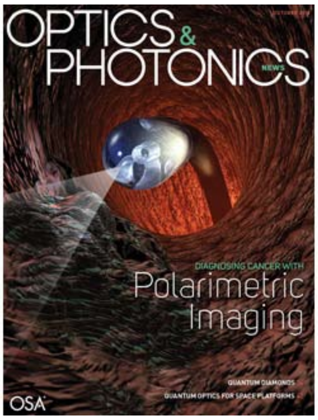

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"Magnetic Light": Optical Magnetism and Antennas for Light Based on High-Index Dielectric Nanoparticles

by Andrey E. Miroshnichenko and Yuri S. Kivshar

The last few years have witnessed the birth of a new branch of nanophotonics aimed at manipulating strong optically-induced electric and magnetic resonances in high-refractive-index dielectric nanostructures. Here we introduce this new, rapidly developing field of nanophotonics that can be exploited to boost the performance of many photonic devices at the nanoscale.

Control of light at the nanoscale is demanded for the future of successful on-chip integration. At the subwavelength scale, conventional optical elements such as lenses become non-functional, and they require a conceptually new approach for the design of nanoscale photonic devices. Recent decades have witnessed a growing research interest in the study of *plasmonic nanoparticles* made of gold or silver. The resonant light-matter interaction that is at the origin of the spectacular colour changes of such structures has multiple applications ranging from bio-imaging and thermotherapy to solar cells and information storage. However, only a small fraction of realistic applications of plasmonics has materialised into real products, mainly due to high losses of metals at visible frequencies and their incompatibility with CMOS fabrication processes.

Most surprising, it was already predicted a few years ago that dielectric nanoparticles with a strong magnetic response can be used as building blocks to explore new types of interactions at the nanoscale. Recently, three international research teams, including our Nonlinear Physics Centre in Canberra, demonstrated experimentally that nanoparticles made of low-loss high-refractive-index dielectric materials offer a promising solution for a new generation of nanophotonic devices, removing many severe limitations of plasmonic structures but exhibiting a strong resonant response at the nanoscale [1-5]. The key to such novel functionalities of high-index dielectric nanophotonic elements is the ability of subwavelength dielectric nanoparticles to support simultaneously both electric and magnetic resonances, which can be controlled independently [5].

It is well known that the magnetic response of many natural materials at optical frequencies is very weak. Thus, only the electric component of light is directly controlled in many optical devices. However, it has already been established that *artificial magnetism* can be achieved at high frequencies in nanostructured materials. One of the canonical examples is a split-ring resonator (SRR), an inductive metallic ring with a gap (a building block of many metamaterials) that can support an oscillating current giving rise to an optically-induced magnetic moment (see Fig. 1). Unfortunately, intrinsic losses of metals set the fundamental limit for the use of SRRs at optical frequencies. This is where silicon nanoparticles with the size of a few hundred nanometres make an attractive alternative. High-refractive-index dielectric nanoparticles were predicted to exhibit strong magnetic resonances in the visible [6]. A magnetic resonance originates from the excitation of a particular electromagnetic mode inside the nanoparticle with a circular displacement current of the electric field. This mode is excited when the wavelength of light becomes comparable to the particle's diameter. It has an antiparallel polarization of the electric field at opposite sides of the particle while the magnetic field is oscillating up and down in the middle. Recently, this fundamental phenomenon of strong magnetic resonances was experimentally observed throughout the whole visible spectral range from blue to infra-red for silicon nanoparticles with sizes ranging from 100 to 270 nm [1,2].

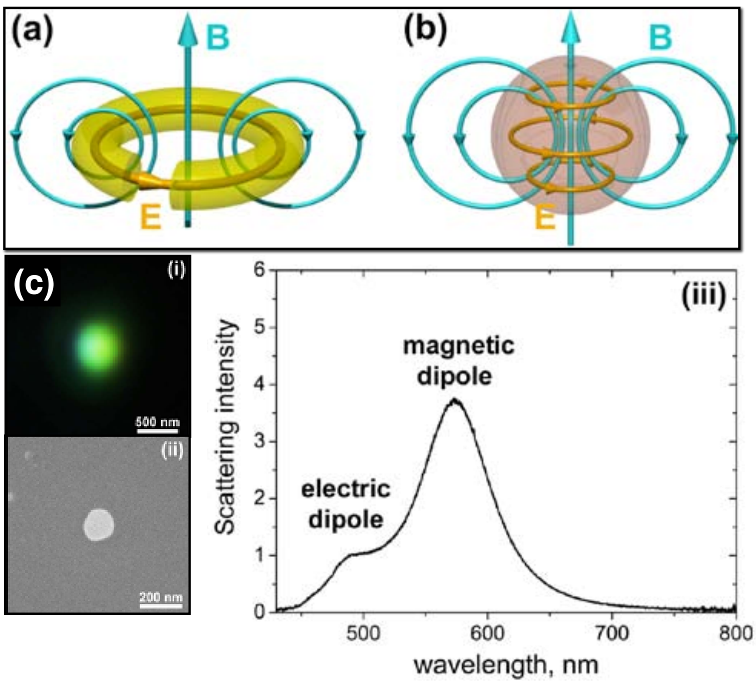

Figure 1. Optically-induced magnetic resonances. (a,b) Magnetic field distributions for a split-ring resonator and high-refractive index dielectric nanoparticle at the magnetic resonance. (c) Close-view dark-field microscope (left) and SEM (right) images of a silicon nanoparticle with dark-field scattering spectra exhibiting a magnetic dipole resonance [1,2].

Another example is the coupling of silicon nanoparticles and SRRs allowing for control of the magnetic interaction between optically-induced dipole moments. If the spacing between a nanoparticle and SRR becomes smaller than a critical value, the induced magnetisation can be inverted. This leads to a staggered pattern of magnetic moments, with a unique possibility for light-induced artificial *antiferromagnetism* at optical frequencies [7]. This approach can be generalised to construct a variety of novel hybrid structures supporting and controlling *optically-induced spin waves*.

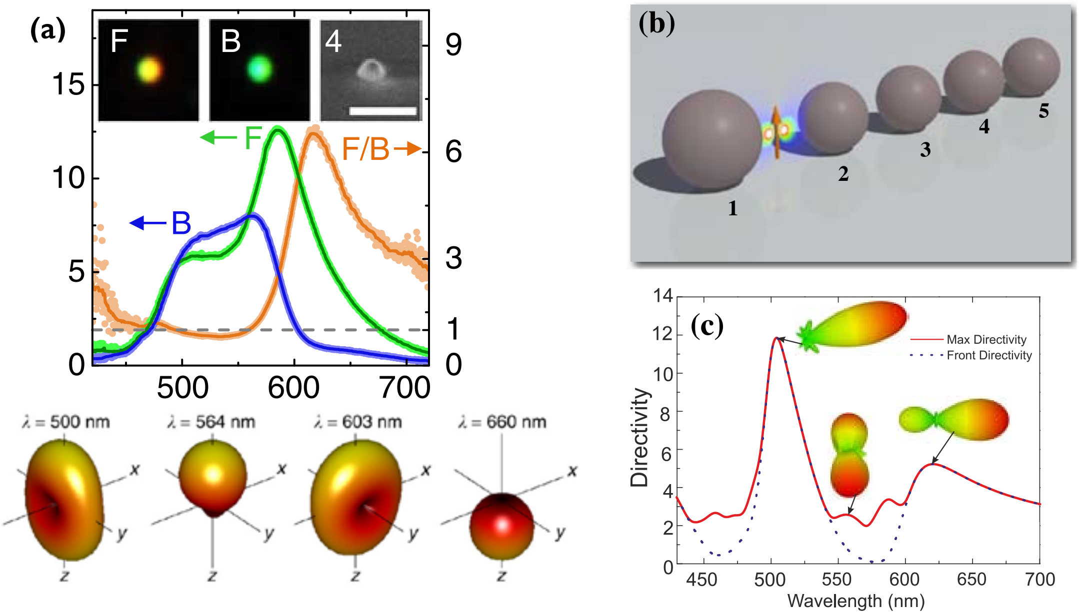

Figure 2. Unidirectional scattering of light. (a) CCD images of the forward and backward scattering by Si nanoparticles [4]. (b) Structure of a Yagi-Uda nanoantenna composed of high-index all-dielectric nanoparticles. (c) Variation of the emission patterns for a Yagi-Uda dielectric nanoantenna [9].

Recently, a new field of optical nanoantennas emerged offering most promising solutions for on-chip integration. Most optical nanoantennas consist of plasmonic nanoparticles due to their ability to capture and concentrate visible light at subwavelength dimensions. But the main drawback in the visible frequency range is their intrinsic losses, which affect strongly the overall performance of plasmonic structures limiting their scalability and practical use.

The basic principle of nanoantenna operation can be explained in the simplest system of interacting dipoles. According to the Rayleigh approximation, any single subwavelength element radiates light as an electric dipole, i.e. uniformly in the transverse direction relative to the dipole orientation. Thus, to control any radiation pattern, one needs to have at least two elements and take advantage of their interference. An ideal optical nanoantenna would emit light predominantly in one predefined direction. The simplest structure exhibiting a unidirectional radiation pattern consists of two dipoles separated by a quarter of a wavelength with additional $\pi/2$ phase shift between them. It turns out that waves generated by such a dipole pair interfere constructively in one direction and destructively in the opposite direction. However, the interference condition implies that system's size should remain of the order of a wavelength.

Dielectric nanoparticles with high refractive index offer new possibilities for achieving wave interference. *Interaction of magnetic and electric dipoles* leads to entirely new scattering properties. Indeed, the coexistence of both electric and magnetic resonances results in unidirectional and azimuthally symmetric scattering (see Fig. 2). *This property makes subwavelength dielectric nanoparticles the smallest and most efficient nanoantennas*. In particular, the forward and backward radiation patterns of spherical Si nanoparticles with the radius ranging from 50nm to 100nm were measured experimentally showing a strong resonance behaviour [3]. Such a resonant response can be further enhanced, for example, in layered nanoparticles with metal cores and dielectric shells [8]. A superposition of electric and magnetic resonances of a single core-shell nanoparticle results in the resonant suppression of the backward scattering and unidirectional emission by a single subwavelength element [8]. The directivity can be further enhanced by forming a chain of such nanoparticles (see Fig 2). Together with low losses of dielectric materials, this property suggests a novel principle of optical nanoantennas made of dielectric nanoparticles [9]. Such all-dielectric nanoantennas exhibit much higher radiation efficiency than their plasmonic counterparts allowing more compact designs.

Thus, the unique optical properties and low losses make high-index dielectric nanoparticles perfect candidates for the design of high-performance nanoantennas, low-loss metamaterials, and other novel all-dielectric nanophotonic devices.

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Optics in Everyday Life: Why Some Things are Darker When Wet

by John Lekner

From early childhood we learn to distinguish wet from dry, not just by touch, but also by sight. Many objects, notably those with rough and absorbing surfaces, are darker when wet: they reflect less light.

My professional interest in this phenomenon was triggered by a short shower, which produced darkening of the asphalt surface on my walk home sometime in early 1987.

I came up with an explanation, elaborated with Mike Dorf from Harvard, then visiting Wellington; we submitted our paper to Applied Optics. A very detailed and helpful review came back from Craig F Bohren, who happened to be an Editor, as well as the author (which we had quoted) of a competing explanation of the phenomenon. (Not often does one get a 7-page critique from an Editor!) Bohren pointed out that our explanation was rather similar to a much earlier one by A K Ångström about the albedo, i.e. the fraction of light reflected by various surfaces. (Tony Klein tells me that Anders Knudssen Ångström was the grandson of Anders Jonas Ångström the famous spectroscopist).

Ångström noted in *The albedo of various surfaces of ground* [Geografiska Annaler **7** (1925) 323] that the 'reflection power of the surface of the earth' needs to be known in order to understand 'the heat economy of the earth's atmosphere and the circulation of energy within it'.

He suggested that a rough absorbing surface reflects less light when wet because of the diffuse reflection from the rough surface. If the rough absorbing surface is under a thin layer of water, the diffuse reflection leads to internal reflection from the water-air interface, and thus more absorption.

This idea is illustrated in Figure 1: a fraction 1-R_l, where R_l is the reflectivity at the liquid surface, is transmitted into the liquid layer; a fraction *a* of this is absorbed at the solid surface and (1-R_l)(1-*a*) reflected. At the liquid surface, there is probability *R* of reflection back to the absorbing solid, and so on. (A planar liquid surface is drawn, but the idea works for an arbitrarily curved or distorted surface.)

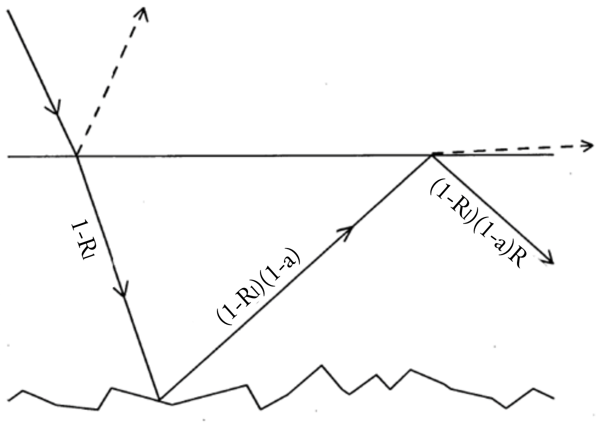


Figure 1. Liquid layer on a rough surface. The fraction of light intensity along paths in the liquid layer is indicated. The dashed lines indicate light which contributes to the albedo.

The probability of absorption by the rough surface (the fraction of light not emerging) is

$$P = (1-R_l)[a + a(1-a)R + a(1-a)^2R^2 + \cdots]$$
$$= \frac{(1-R_l)a}{1-(1-a)R}$$

Ångström evaluated the angle-averaged internal reflectivity *R* by assuming that all of the light with internal angle of incidence greater than the critical angle $\theta_C=\arcsin(1/n)$ for the liquid is reflected (as it is) and that none incident at smaller angle is reflected (a good approximation, but not exact). His result, assuming a surface which has intensity reflected at angle θ proportional to cosθ (i.e. a so-called Lambertian surface) is

$R = \cos^2\theta_C = 1 - 1/n^2$

These equations together are equivalent to Ångström's result, except that he also omitted the (1- R_l) factor. The effect of reflection below the critical angle can be calculated exactly [J Lekner and M C Dorf, *Why some things are darker when wet*, Applied Optics **27** (1988) 1278], but the resulting *R* is only about 10% bigger for water.

The albedo *A*=1-*P* for a wetted surface is plotted against the corresponding dry value (no liquid film) in Figure 2 below: we see that the wet albedo is smaller than the dry albedo except in the limit of very small absorption.

Bohren's earlier explanation of the wet-dark effect was in terms of multiple scattering by particulate matter [described in *Multiple scattering at the beach*, Weatherwise, August 1983; and elaborated by S A Twomey, C F Bohren and J L Mergenthaler in *Reflectance and albedo differences between wet and dry surfaces*, Applied Optics **25** (1986) 431].

The basic idea is that water decreases the relative refractive index and thereby increases the degree of forward scattering. In wet sand, for example, each sand grain scatters more in the forward direction

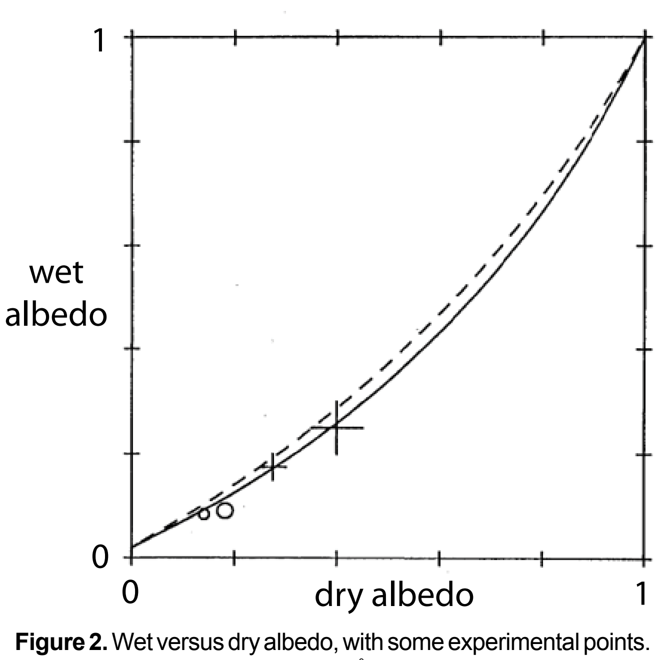


Figure 2. Wet versus dry albedo, with some experimental points. The dashed curve is based on Ångström's approximations. [Based on Figure 3 of the Lekner-Dorf paper.]

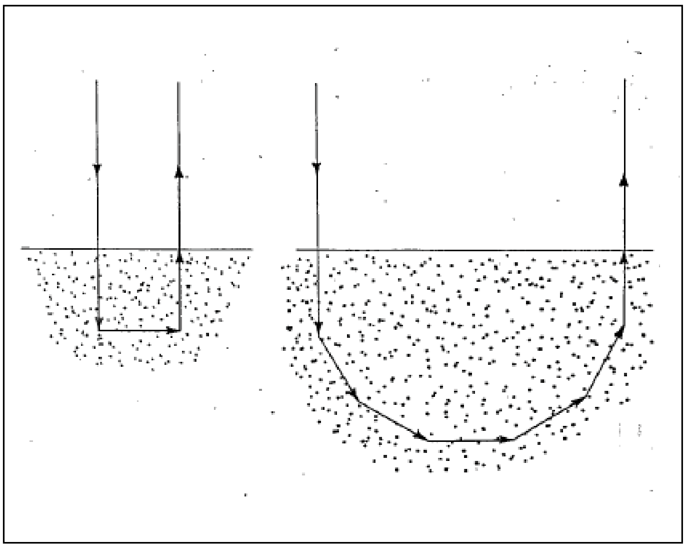


Figure 3. A light ray requires just two scatterings of 90 degrees to re-emerge, but six scatterings of 30 degrees (the shortest possible path is assumed in both cases).

than in dry sand. This is schematically illustrated in Figure 3 (based on Figure 3 of Bohren's paper), and in Figure 4 – a photograph which supports it. If the probability of absorption at each scattering is a, as in the previous treatment, the light emerging will be respectively $(1-a)^2$ and $(1-a)^6$ times the incident intensity, for the idealised paths on the left and right of Figure 3.

One interesting and verifiable consequence of the multiple scattering explanation is that the better the match of the liquid refractive index with that of the scatterer, the more forward bias there is in the scattering, and the darker the wetted substance. The Bohren papers show sand (n≈1.5) wetted with water (n≈1.3) and with benzene (n≈1.4). The latter is much darker, because of the closer index match. The effect of index matching is also in the Ångström theory through the probability of absorption a, which is greater when the solid is wetted, because it reflects less. In fact the multiple scattering approach gives a graph of wet versus dry albedo [Twomey, Bohren and Mergenthaler, Figure 5] almost the same as Figure 2 above, based on Ångström's idea and its developments.

The two theories, based on such different approaches, are complementary. Ångström's idea is best for surfaces such as asphalt or concrete, the Bohren idea of multiple scattering together with enhanced forward scattering applies best to finely divided granular materials such as sand. Clothing fabric is an intermediate case; wet the sleeve of a light blue shirt, and try to decide which of the effects discussed above is predominant in producing the resultant dark patch.

With thanks to Tony Klein for editorial improvements and for Figure 4.

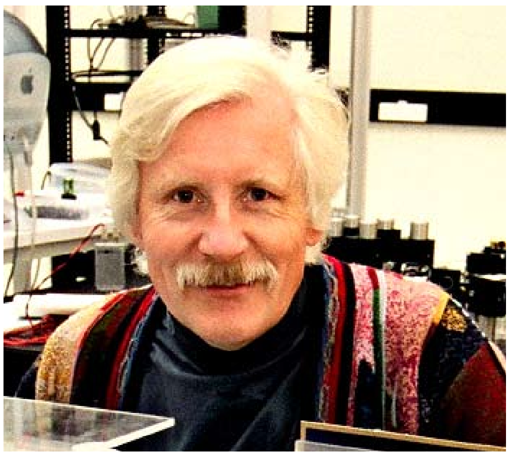
John Lekner is Professor of Theoretical Physics at Victoria University of Wellington, and author of *Theory of reflection of electromagnetic and particle waves* (Springer).

Figure 4. Wet and dry areas of sand.

News

AOS Member elected Academy Fellow

The AOS congratulates member and former society President, Professor Hans Bachor, of the Australian National University on his election to the Australian Academy of Science. Hans, who is also Chair of the AAS National Committee for Physics, was elected for his pioneering work in quantum optics, which has opened new paths for quantum computing and quantum optical communication technologies.



Professor Hans Bachor

AIP Congress (incorporating the Annual AOS Meeting)
7 – 11 December 2014

The 21st biennial Australian Institute of Physics Congress, *The Art of Physics*, will be held at the ANU in Canberra in the week of December 7-11 in 2014. The Congress also incorporates the annual meeting of the Australian Optical Society as well as meetings of the many technical groups and discipline areas associated with the AIP. Plenary speakers include Stephen Chu, Paul Corkum and Serge Haroche. Abstracts are due 27 June. For more information visit: aip2014.org.au. The AIP Congress will be preceded by the *OSA Renewable Energy and Environment Congress*, which will also be held at the ANU on December 2-5.

Revision of AOS Constitution

The AOS is currently governed by a Memorandum of Association and Articles of Association that date from the establishment of the society over 30 years ago. As a consequence, our constitution is out-of-date and needs to be brought into line with current Corporate Law and to take into account changes in practice such as the use of electronic media to hold meetings.

With legal advice, the AOS Council is working on a revised constitution to be put to the Annual General Meeting later this year. A draft will be placed on the AOS web site in June along with a summary of key changes and feedback from members sought before 1 August 2014. This will permit time for the Council to address issues raised by members in the final version to be made available before the AGM.

Members will be emailed when the draft is ready for comment.

International Year of Light

Royal Philips, an international leader in lighting technology is the first patron-sponsor of the International Year of Light. Philips will work closely with the IYL2015 consortium, which includes the AOS, on actions throughout 2015 to highlight the vital role that light and light-based technologies play in improving the quality of people's lives worldwide.

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