

Volume 28 Issue 4

December 2014

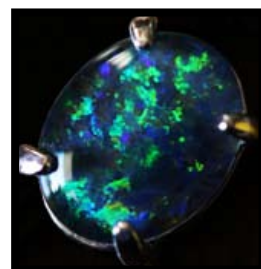
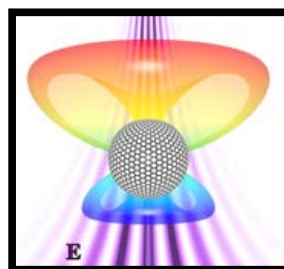
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INTERNATIONAL YEAR OF
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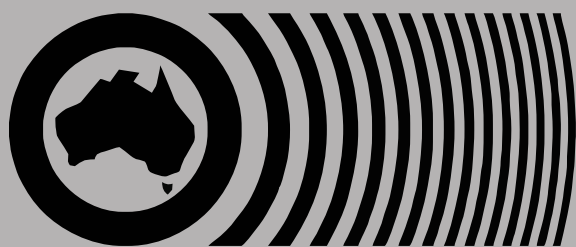
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AOS News is the official news magazine of the Australian Optical Society. Formed in 1983, the Society is a non-profit organisation for the advancement of optics in Australia. Membership is open to all persons contributing to, or interested in, optics 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.

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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.
- Review Article
Simply give a run down of the work conducted at your laboratory, or some aspect of this work.
- Conference Report
- News Item
- 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.

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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Rates: Under Review

Places may be booked for placing ads - this attracts a 10% surcharge. Black and White in main body of newsletter - free to corporate members.

COPY DEADLINE

Articles for the next issue (March 2015) should be with the editor no later than 13 February 2015, advertising deadline 6 February 2015.

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AOS News is the official news magazine of the Australian Optical Society. The views expressed in AOS News do not necessarily represent the policies of the Australian Optical Society.

Australian Optical Society website:
<http://www.optics.org.au>

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- Membership
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- Prizes/awards
- Conferences
- Jobs/Scholarships
- Affiliated societies
- ...and more

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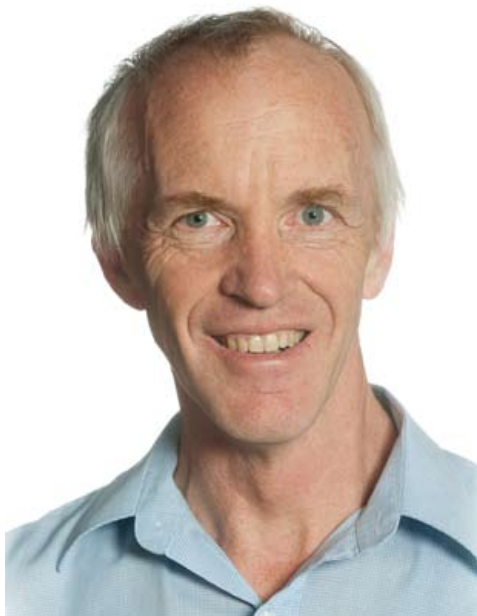
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President's Report



It is a privilege to have become the president of the Australian Optical Society and, in writing my first report in this capacity, I am aware of how well the Society has been served by previous presidents and other office-bearers. I particularly wish to thank Ann Roberts for her great leadership of AOS over the past 2 years; amongst the many achievements she oversaw include the celebration of the AOS's 30th anniversary, the revision of our constitution and the commitment of AOS to the International Year of Light 2015.

The AGM was held on Thursday 6 November 2014 during the IPOS symposium at the University of Sydney. Congratulations to Simon Fleming in becoming Vice President and to Ben Eggleton, John Harvey, Maryanne Large and Dragomir Neshev for being re-elected to Council. I thank Judith Dawes, who concluded her time as a Council member at this AGM, for her long and enthusiastic service to AOS over a considerable period of time. There is now a casual vacancy (to fill Simon Fleming's position) and the Council are grateful that he will remain in the Treasurer role for the time being. At the time of writing the Council is dealing with the filling of this vacancy. In recent months the Industry representative on Council, Alex Stanco of Lastek Pty. Ltd., has been replaced by John Grace

of Raymax Lasers. I welcome John to this role, and thank Alex for his many useful contributions to Council during his term. At the AGM the new constitution was approved.

At the AGM the prizes for 2014 were announced and warm congratulations to Professor Tanya Monro for being awarded the W.H. Beattie Steel Medal, Dr Jochen Schroeder the Early Career Researcher award winner, Rory Speirs the AOS Warsash Prize winner and Matt Collins the AOS Postgraduate Student Prize winner. Please remember that applications for the 2015 awards, including the Technical Optics Award, are due on 31 March 2015.

As most AOS members would know, next year is the International Year of Light 2015 (IYL). In Australia this is supported by AOS, the Australian Institute of Physics and the Astronomical Society of Australia. The organising committee, led by Ken Baldwin, is made up of representatives from optics, physics, astronomy, arts, and education across Australia and as reported elsewhere is seeking to remind a broad range of groups about the role of light in science, industry, the arts, culture, education, and the wider community. There has been a series of briefing events around the country, e.g. at Fed Square Melbourne I was pleased about their enthusiasm to include IYL in their "Light in Winter" program in 2015. The recent Nobel Prize announcements were well-timed to underscore the importance of light and research into light for our society, with the Physics Prize for blue light-emitting diodes (Akasaki, Amano and Nakamura) and the Chemistry Prize for microscopy techniques providing a resolution better than the diffraction limit of light (Betzig, Hell and Moerner). Indeed the recent publication that highlighted STEM, (i.e. Science, Technology, Engineering and Maths) by our Chief Scientist, Professor Ian Chubb, as being vital to our future also provides us with further opportunities to highlight the importance of light.

The next major event on the AOS calendar is the 21st Biennial Australian Institute of Physics Congress "The Art of Physics" which will be held at the Australian National University in Canberra in the week December 7-11. The Congress also incorporates the Annual meeting of the AOS as well as meetings of the many technical groups and discipline areas of the AIP. AOS will welcome representatives of our international partners, OSA, SPIE and OSI (Optical Society of India). There are many papers in optics and photonics, both contributed, invited and plenary, and I look forward to seeing many AOS members during this meeting. For those attending, I hope you enjoy making new contacts as well as catching up with colleagues you might not have seen for a while. Please also visit the technical exhibition and meet our corporate members.

In the previous week, also in Canberra, the OSA is holding its Optics and Photonics Congress on Light, Energy and the Environment (AOS is a technical co-sponsor). The student-run IONS-KOALA Industry workshop is being held 23-28 November at the University of Adelaide, and they are to be congratulated for their efforts.

May I take this opportunity to wish all AOS members the very best for the festive season and for your plans for 2015.

Stephen Collins
AOS president

Editor's Intro



Welcome to another issue of AOS News. We have a great selection of articles again this time, so thank you to everyone who sent something in. There are a few conference reports from some of the meetings that have happened recently around Australia and a nice selection of articles. There is also more information about plans for the International Year of Light 2015 and how we can get involved in this. Other articles in this issue include an item on optical elastography and a piece on graphene plasmonics, as well as our 'Everyday Life' section, which looks at the optical properties of opals in this issue. 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.

I wish to welcome to the new AOS council and in particular Stephen Collins as president. Details of all the appointments can be found in the news section on page 19 and have been mentioned by Stephen in

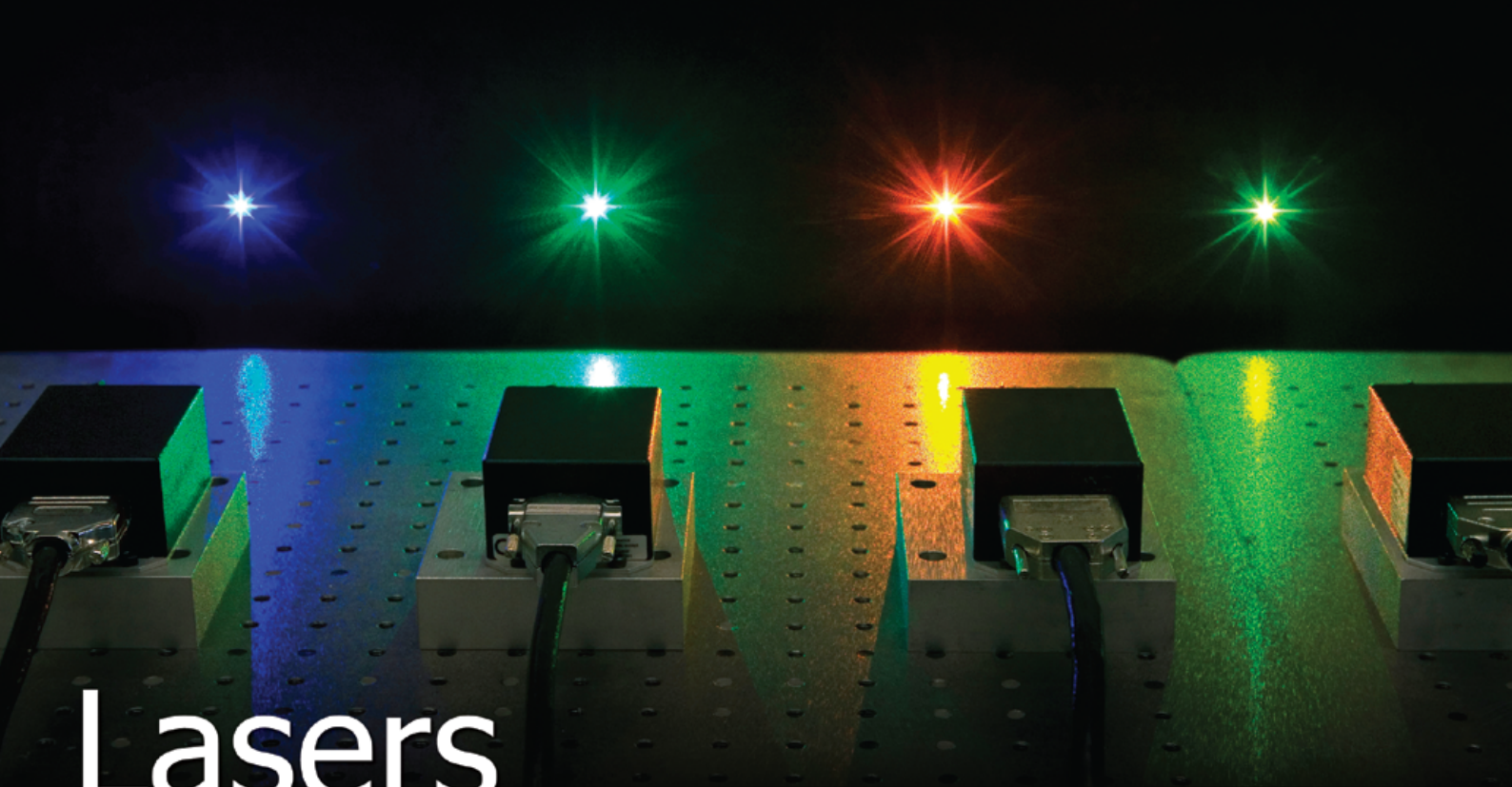
his column. There will be updates to some of the positions that will be sent to members via email or can be seen on the AOS website, optics.org.au. I'd also like to congratulate Steve Lee and Tri Phan for winning the ANSTO Eureka Prize for Innovative use of Technology. You may recall reading about Steve's work in the article on droplet lenses in the September issue of AOS News (A droplet approach to lens making, page 30). It does sounds like a very useful technique with a wide variety of applications, so well done to the team for their achievements.

It has been a year with many changes for a lot of people, particularly in the university sector, with everyone trying to work out the best way forward within the current conditions. In light of this it was very interesting to see the recent release of the strategic approach to science recommended by Chief Scientist Ian Chubb in 'Science, Technology, Engineering and Mathematics: Australia's Future'. The importance of science and technology to society and the economy was highlighted and suggestions made for a strategic plan on STEM to be put in place in Australia, as currently it is the only OECD country without such a national strategy in place. The response to these suggestions remains to be seen, but it is hoped that some of the recommendations may be followed.

I attended the recent Melbourne briefing event for the International Year of Light that is taking place in 2015. There were a wide variety of people present, all hoping to contribute to the success of the year. There were representatives from diverse areas such as museums and art galleries, school teachers and lighting engineers, showing what a large area the theme of light encompasses. I do encourage everyone to consider helping out in some way as it will be a great opportunity to showcase optics to the general public and the importance of light and light-based technologies to society. Some of the ideas for events and activities both large and small sound very exciting, with plenty of opportunity to take part at any level, including just promoting the year itself. There are some lovely posters that have been designed by students at Offenburg University that you can download (see the front cover for an example), as well as merchandise being sold by the SPIE to celebrate the year. For more information please see the Australian International Year of Light website, light2015.org.au.

I hope you like this issue of AOS News and wish everyone an enjoyable festive season and successful 2015.

Jessica Kvansakul
Editor



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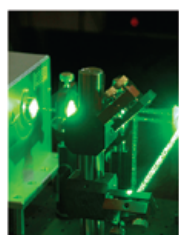
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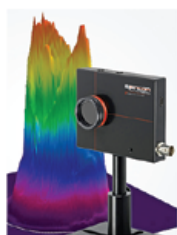
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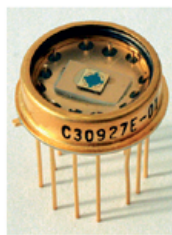
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INTERNATIONAL YEAR OF LIGHT AUSTRALIA 2015

Welcome to the Year of Light 2015 in Australia

by Ken Baldwin, Chair International Year of Light
2015 in Australia

Welcome to my first newsletter as Chair of the Australian committee for the International Year of Light 2015 Australia.

From synchrotron light to sunlight, from photosynthesis to the stars, and from Instagram to smart-lighting; it is undeniable that light in all its forms has a profound effect on our lives.

The United Nations has declared 2015 the International Year of Light and Light-based Technologies.

The aim of the Year of Light is to highlight the importance of light and optical technologies and their role in our lives, through a mix of science, art, culture and education.

And this year's Nobel Prizes have done just that.

The physics prize was awarded to the creators of the blue LED (light-emitting-diode). As the Nobel committee said, "Incandescent light bulbs lit the 20th century; the 21st century will be lit by LED lamps". The invention of the blue LED, after the red and green, was the final step that made it possible for LEDs to power a multitude of modern devices from sensory lighting to mobile phones.

And the chemistry prize was for a revolution in light microscopy that now allows researchers to watch molecules at work in living cells.

Light and light-based technologies promote sustainable development and

provide solutions to global challenges in energy, education, agriculture and health. Think of:

- laser communications connecting the world; city to city and the remotest locations
- the sensory lighting revolution that's transforming homes, businesses and the built environment; new products that save resources, money and effort
- light in art; from Turner and Matisse to holograms and laser beams on cityscapes
- synchrotron light that reveals the molecule that triggers coeliac disease
- Australian telescopes probing the secrets of the Universe; and the challenges of light pollution in cities
- solar power delivering energy on the go; enabling water transport on farms, and small powerful self-sustaining lights replacing dangerous kerosene lights in refugee communities
- smartphone science that detects the visible/near-infrared spectrum.

The International Year of Light 2015 in Australia is supported by the Australian Optical Society, the Australian Institute of Physics and the Astronomical Society of Australia.

Our organising committee is made up of representatives from optics, physics,

astronomy, arts, and education across Australia – but we're reaching beyond that into science, industry, the arts, culture, education, and the wider community.

We've started the ball rolling with a series of briefing events around the country. Sydney, Canberra, Brisbane and Melbourne shared some great plans and ideas that are coming together in a wonderful fusion of science, industry, the arts and education.

Fed Square Melbourne, VIVID Sydney, CSIRO and Questacon are already planning programs with a 'light' theme for 2015. And the Australian Science Teachers Association has adopted light for its National Science Week schools theme.

In this bulletin we:

- outline ways to get involved
- list current funding opportunities
- report on the briefings around the country
- explain the buzz around the Year and light technology
- share links for the web, YouTube and Twitter.

This is the year for thoughts and discussion around light to fill minds with bright opportunities and 'light-bulb moments'.

We want to educate people on how light technologies work and inspire people to think about innovation and light.

Being a part of the year is open to all people interested, so spread the word.



Briefing event at Fed Square, Melbourne.

Envision how you or your organisation can use and participate in the Year in local, national and global realms. The more input and energy we can generate, the better the Year of Light can become.

If you'd like to get involved check out the resources on our website <http://light2015.org.au>

You can also share your thoughts, and any plans you have for the Year with us by emailing info@light2015.org.au or tweeting @LightYearAU.

And watch out for more announcements at the website for the Year in Australia as well as in this newsletter.

Finally, we'll be looking for sponsorship, as well as promoting a range of grants that tie in with the Year to help you hold Year of Light events.

We hope the Year will leave a lasting legacy of the impact of light in our lives.

I'm looking forward to hearing about your bright ideas.

Regards,

Ken Baldwin
Chair International Year of Light 2015 Australia
Director of the Energy Change Institute at The Australian National University

The Year of Light in Australia is happening

Briefing events around the country facilitate the sharing of great ideas

At our Year of Light briefings we connected with some amazing talent. Here's a taste of things to come:

Sydneysiders will kick off the Year of Light 2015 with a bang - the famous Sydney Harbour fireworks display will start the year, and Sydney is planning to continue its light-based cultural programs through the year. Our Sydney briefing event was attended by architects, light artists, the lighting industry, and scientists alike, which should make for some interesting collaborations.

Canberra folk are coming together to produce educational material about light for kids and the public - from new exhibits at Questacon, to resources for teachers from CSIRO. The schools theme for National Science Week in 2015 will be Making waves - the science of light. Teaching resources based on the theme will be available from the website by May 2015.

Being the sunshine state, Queenslanders will be showing Australia all the cool things they are doing with solar energy, as well as smart street lighting, lasers by the river and more.

Melburnians are hosting a panel of speakers and storytellers to share the mysteries of light over time during the Light in Winter at Fed Square in 2015. Melbourne's festivals with lasers and universities with photonics will also light up the space. And there is a lot more in store for Melbourne.

These are just some of the ideas which came to light at our first briefing sessions held around the country this month. We'll share more news on events and programs as they firm up.

We encourage you to get involved with an aspect of light that interests you. Together we can spread the message of light and light-based technologies into Australian homes, workplaces, schools and streets. The future of light is bright.

What you can do

What does light mean to you? And what part of its story do you want to share?

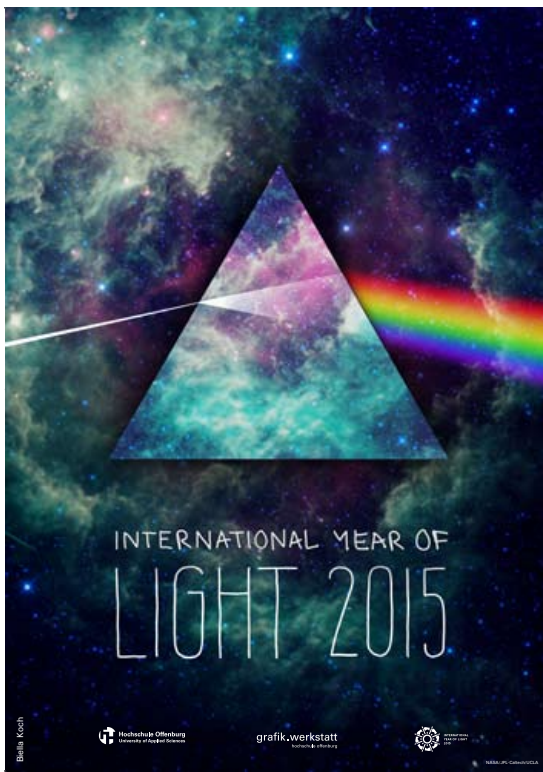
The year is an opportunity for people to promote everything 'light'. We all have our own interpretation of how light and light based technologies are important to us. But what about the possibilities of light to change the future of society? How can solar efficiency be applied to improve the lives of those who need it most? How do we use light in our everyday lives? And where can light take us?

Run an event, connect with existing events, find funding, and engage with your local community.

- Get educated - learn more about photonics and light technologies. Solving the challenges of the 21st century will depend as much on photonics as the 20th century's solutions depended on electronics.
- Be creative and capture an audience to inspire about light, and how light-based technologies can improve energy efficiency and be the basis of future technological advances.
- Get talking - invite a guest speaker to talk about photonics and their



IYL bookmark (spie.org/Documents/AboutSPIE/bookmark_EPS.pdf).



LYL posters can be downloaded courtesy of Offenburg University (www.magic-of-light.org/iyl2015). Poster designed by Biella Koch.

applications for your community; tell the story of light.

- Get your organisation involved - create an exhibit using a gallery of images displaying examples of the myriad wonderful things that light can do, and how it plays a critical role in our lives every day.
- Give a presentation to a classroom, community group, or colleagues using slides prepared and ready to go. You can top it off with eight minutes of 'terror' via the short video, "A Day without Photonics: a Modern Horror Story."
- Wear an IYL t-shirt, tie, or scarf - they're not only attractive, but could spark a conversation about why and how light plays such important roles in our lives. (spie.org/x109208.xml)
- Download the IYL bookmark and give one to all of the people in your life who read paper books - and drop off a supply at your local library or bookstore.
- Print out an IYL poster for your workplace, bed room, or classroom.

All the information you need is at www.light2015.org and you can list your event on our Australian website light2015.org.au.

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Check our website for updates and news

Some money to get started – current grant rounds

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vividssydney.com

VIVID Sydney is first and foremost a light festival, but they are also into creative and new ideas.

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If you know of any other funding or event opportunities, let us know at info@light2015.org.au

Why Light Year Matters

Explore the spectrum of light - read about the importance of light in our everyday lives on the International Year of Light website

Photonics is the science and technology of generating, controlling, and detecting particles of light, called photons. The application of photonic technologies is versatile and can be found in communication, entertainment, medical, manufacturing, automotive, energy, lighting, agriculture, photovoltaic, security, art ... and the list goes on.

This is why light matters:

- Energy - governments and scientists worldwide are working to develop affordable and clean solar energy technologies
- Economic Impact - Growth in the photonics industry more than doubled that of the worldwide GDP between 2005 and 2011
- Light in the Built Environment - technologies that improve energy efficiency cost and control, and can be adapted easily to local needs
- Connecting the World - fibre optics,

sensors, social media and video conferencing allowing us to stay connected wherever we might be.

Help us create a bigger year

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Invest in new partnerships with the UNESCO, and with the Year of Light in Australia community.

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- Demonstrate your commitment to optimising light for a better world.
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- promote all things great about the special year.

Sponsorship, funding and in-kind contributions can boost the Year of Light Australia message and outcomes. Contact info@light2015.org.au to enquire about the stream of benefits and options.

Finally,

If you have any flashes of brilliance or light-bulb moments about events or initiatives and you can see potential for them to be a part of the year, let us know by emailing us at info@light2015.org.au

The International Year of Light Australia 2015 is supported by the Australian Optical Society, the Australian Institute of Physics and the and the Astronomical Society of Australia.



**INTERNATIONAL
YEAR OF LIGHT
AUSTRALIA 2015**

Peter Schultz, Co-inventor of Fibre Optics

by Fotios Sidiroglou and Stephen Collins

Peter Schultz, along with Robert Maurer and Donald Keck developed the first fibre optics for communications at Corning in the 1960s. Peter visited Australia in December 2013, and relayed the story of this discovery along with his view of current and future directions for optical fibre communications at ANZCOP 2013 and university audiences at UNSW and Victoria University.

Dr Peter C. Schultz, co-inventor of the fibre optics now used worldwide for telecommunications visited Australia in December 2013. In his tutorial presentation at ANZCOP (Australian & New Zealand Conference on Optics and Photonics) held in Fremantle “Optical Fibers for Communication: Past, Present and Future” he described in detail the research undertaken by three Corning scientists (Dr. Robert Maurer, Dr. Peter Schultz, and Dr. Donald Keck) in the mid-1960s that ultimately led to the realisation of low-loss optical fibre.

Schultz explained how he, Maurer and Keck were aiming to develop pure glass fibre optics to efficiently transmit light over long distances. The design needed a single mode fibre with loss of only 20 dB/km, when the best bulk optical glasses around had attenuations of 1000 dB/km, which was a huge challenge. The final solution ended up using silica and a unique vaporization method rather than the traditional melting process, allowing them to come up with an efficient optical fibre in 1970.

The team faced many challenges in developing a low-loss optical fibre using silica. Silica’s high melting point caused problems when trying to draw a fibre, and it also had a very low refractive index compared to other easily available glasses at the time. Schultz described how they ended up devising the optical fibre system consisting of an inner core of silica mixed with a dopant to improve the refractive index, resulting in the first low-loss optical fibre design.

Since then fibre optics have developed and become an integral part of our world. The advance by the research team resulted in the transformation of Corning from a kitchenware company to an important player in the high technology field. In

recognition of their achievement, Drs. Maurer, Schultz, and Keck were inducted into the National Inventors Hall of Fame in 1993 and were awarded the National Medal of Technology from President Clinton for this accomplishment (the highest technology award of the US government) in 2000. Through his involvement in the optical fibre industry since that time Schultz provided his perspective on the evolution of fibre types and manufacturing to the current state-of-the-art and their impact on global telecommunications present and in the future.

During his visit to Australia Peter Schultz delivered this talk to university audiences in Sydney (UNSW) and in

Melbourne (Victoria University). In attendance at Victoria University was Senator Conroy, currently Shadow Minister for Defence. Senator Conroy was recognised by The Optical Society (OSA) as the 2011 Advocate of Optics, which he accepted at the opening ceremony of the IQEC/CLEO Pacific Rim 2011 Conference in Sydney on 29 August, 2011, for his role in starting the optical-fibre-based NBN (National Broadband Network) in his then role as Minister for Broadband, Communications and the Digital Economy. In a short response Senator Conroy reiterated the previous government’s belief that optical fibre was the best comprehensive way of addressing future broadband requirements for Australia.

Fotios Sidiroglou and Stephen Collins are with Victoria University.



Left to Right: Prof Stephen Collins, Prof Peter Dawkins (Vice Chancellor, Victoria University), Dr Peter Schultz, Senator Stephen Conroy, Prof Chris Perera (Dean, College of Engineering and Science, Victoria University), Dr Fotios Sidiroglou.



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Photons Going for a Quantum Walk on a Nonlinear Chip

Developing quantum computing relies on realising controllable entangled states of light or matter. We have shown that photon pairs generated on a nonlinear chip with coupled waveguides can feature strong reconfigurable entanglement.

by Alexander S. Solntsev, Dragomir N. Neshev, and Andrey A. Sukhorukov

Quantum entanglement underpins the realisation of quantum simulators and computers, which can be used for unbreakable cryptography and powerful computational algorithms. Entangled photons are an ideal medium for creating and manipulating quantum states due to the low noise and ease of transmission. A qubit encoded into a photon can be easily sent between different photonic elements along an optical fibre, in analogy with the transmission of classical bits along electrical wires. Furthermore logic operations can be performed on entangled photons by exploiting the nonlinearity inherent in quantum measurement [1]. The practical implementation of complex applications requires the minimisation of coupling losses, as well as stable quantum interference. Low losses and interferometric stability allow strong entanglement between output photons. One of the biggest milestones in achieving these requirements is the integration of photon sources together with optical circuits on the same photonic chip.

To achieve this milestone our team at the Australian National University proposed a nonlinear photonic chip based on coupled waveguides as a flexible integrated platform [2]. Following this theoretical idea, in collaboration with researchers from the ARC Centre of Excellence

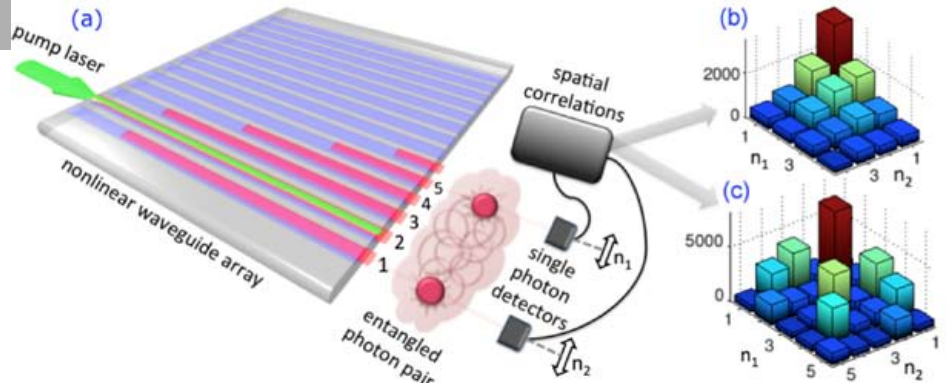


Figure 1. (a) Scheme of the experimental setup. A laser beam generates photon pairs, which simultaneously undergo quantum walks in a waveguide array. At the output a photon pair exhibits strong spatial entanglement between the different waveguides, leading to non-classical photon correlations. Changing the pump beam position can tune these correlations (b,c), as measured by translatable single-photon detectors. The correlations (b,c) show the probabilities of one photon from a pair leaving the waveguide array from waveguide n_1 , while the other photon leaves from waveguide n_2 . The pump wavelength is 775.7 nm.

CUDOS nodes at RMIT University and the University of Sydney, as well as with researchers from Friedrich Schiller University Jena and the University of Paderborn in Germany, we demonstrated experimentally the generation of photon pairs with reconfigurable non-classical correlations on a chip [3]. In the experiment, photon pairs with reconfigurable spatial entanglement at telecommunication wavelengths were created through spontaneous parametric down-conversion in an array of coupled nonlinear waveguides in lithium niobate crystal [see Fig. 1(a)], pumped by a laser beam with power of less than 0.5 mW.

Since photon pairs were generated inside the waveguide array, the usual lossy interface between the quantum source and the quantum circuit was avoided and the instabilities related to bulk quantum optics were eliminated. These photon pairs were generated at the pumped waveguide and then spread to other waveguides in the regime of quantum walks. In this regime photons walk every possible path along the waveguide array and exit in a superposition of many possible path-entangled states.

In contrast to previously investigated quantum walks in linear structures [4] where the degree of entanglement

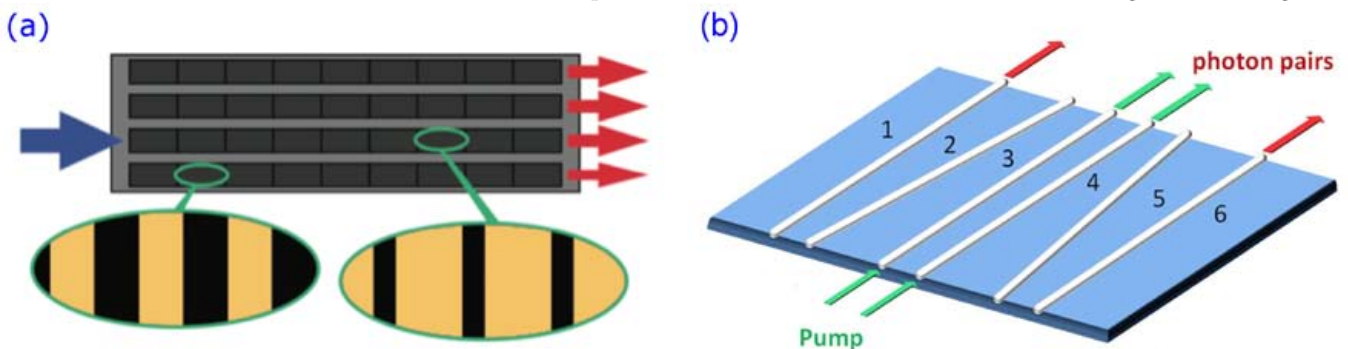


Figure 2. (a) Illustrative diagram showing the electrically-poled waveguide array. Different sections of the waveguide array have different electrically-poled domain structures. Here black and yellow colours correspond to the opposite directions of ferroelectric dipole moments. The pump laser is shown in blue and the field of the generated photon pairs is in red. Switching between different Bell states can be done by shifting the pump between different waveguides. (b) Scheme of adiabatically coupled waveguiding structure: pump beams (green colour) are coupled to the central waveguides 3 and 4, the Bell states (red colour) are formed in the edge waveguides 1 and 6 that are separate from the pumped waveguides.

remains the same as the entanglement at the input, a steady increase of the spatial photon entanglement inside the nonlinear chip was identified [3]. The experimentally detected correlations of photons exceeded a classical bound by four standard deviations, confirming a non-classical quantum state at the output of the chip. Importantly, we were able to control the generated photon states by tuning the pump wavelength or pump-beam position [see Fig. 1(b,c)].

Furthermore, the output entangled states can be carefully engineered by poling of ferroelectric dipole moments in the waveguide array [see Fig. 2(a)]. The resulting ferroelectric domain structure alters the generation of photon pairs. Then real-time tuning of the quantum output can be achieved by altering the intensity and phase of the classical lasers driving photon-pair generation in each waveguide of the array. Driving multiple waveguides simultaneously produces a linear combination of the outputs weighted by the complex amplitude of the driving laser in each waveguide. With particular ferroelectric domain poling

pattern, this approach opens a path to all-optically reconfigurable generation of all maximally entangled photon-pair states, so-called Bell states [5]. Compared to reconfigurable Bell-state generators based on thermo-optics and electro-optics [6], our all-optical control through quantum walks on a nonlinear chip offers enhanced flexibility and speed.

Finally, additional functionality can be added by introducing adiabatic waveguide coupling through inclined waveguides in the structure [see Fig. 2(b)]. In this way it is possible to generate spatially entangled photon pairs, while simultaneously providing spatial pump filtering and keeping photon-pair states pure. The estimated performance of the pump filtering in such waveguide arrays with adiabatic coupling can be of the order of 70 dB [7]. For particular coupling between the central waveguides, any photon-pair Bell state can be generated based on spatial entanglement between the outer waveguides 1 and 6.

These findings reveal new possibilities of designing integrated quantum photonic circuits. Scaling this system to more photons

may also allow the generation of large-scale multi-photon spatial entanglement useful for a range of emerging quantum information applications.

References

- [1] PK Kok et al., Rev. Mod. Phys. **79**, 135 (2007).
- [2] AS Solntsev et al., Phys. Rev. Lett. **108**, 023601 (2012).
- [3] AS Solntsev et al., Phys. Rev. X **4**, 031007 (2014).
- [4] A Peruzzo et al., Science **329**, 1500 (2010).
- [5] JG Titchener, AS Solntsev, and AA Sukhorukov, arXiv:1411.0448 (2014).
- [6] H Jin et al., Phys. Rev. Lett. **113**, 103601 (2014).
- [7] CW Wu et al., Opt. Lett. **39**, 953 (2014).

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OECC/ACOFT, a Premier Conference in Melbourne, 2014

by Benjamin Eggleton, and William Shieh

The 19th OptoElectronics and Communication Conference (OECC) and 39th Australian Conference on Optical Fibre Technology (ACOFT) was held from July 6-July 10, 2014 at the Melbourne Convention and Exhibition Centre, in Melbourne, Australia.

OECC is the premier conference in the Asia Pacific region for showcasing the latest world leading research in the fields of photonics and optical communications.

OECC/ACOFT 2014 attracted over 500 delegates with 80% of attendees from overseas. The Conference ran for five days in July 2014, and included 4 specialised workshops, 6 technical scopes, 97 invited presentations, 233 oral presentations, 379 total paper submissions and 23 post deadline paper submissions.

Headlining the event were six keynote speakers at the Plenary Sessions. Dr Andrew R. Chraplyvy from Alcatel-Lucent Bell Labs, USA revealed how fibre nonlinearities have shaped optical communications; Professor Shanhui Fan from Stanford University disclosed the new physics of nanophotonics for information and energy applications; Mr John Lord, Chairman of Huawei Technologies (Australia), presented his perspective on the new era of connectivity and shared wisdom in today's information age that require equivalent advances in the security of our information and infrastructures; Professor Alan E. Willner from University of Southern California, gave an insight on optical communications using multiplexing of multiple orbital-angular-

momentum beams; Dr. Masaya Notomi from NTT Nanophotonics Center presented femtojoule per bit optical communication in a chip by integrated nanophotonics.

Four workshops on highly controversial yet timely and relevant topics kick started the conference on Day 1, ensuring lively debates between the workshop speakers and also opportunities for delegates to interact with the workshop speakers. Topics included, "Optical Communication Energy Efficiency – A Looming Crisis?", "Quantum Photonics – The Holy Grail for Computing and Secure Communications?", "Optical Communications: The Limits for Highest Spectral Efficiency Transmission", "Photonics Industry Workshop – The ABC to Entrepreneurship and Company Start-up Success".

What were also featured in the conference were a host of carefully selected invited and tutorial speakers who are research and industry leaders in the fields of photonics and optical



Ben Eggleton at the opening of the conference.

communications. They were presenting the latest breakthroughs in technology and applications, and providing insights into the research and industry roadmap ahead. Amongst our 66 invited speakers, Professor Ken-ichi Kitayama from Osaka University, Japan, presented the plethora of technology options for next-generation passive optical networks. Professor Ivan Djordjevic from the University of Arizona, USA, described his latest work on adaptive nonbinary low-



Plenary sessions by Alan Willner (left) and Shanhui Fan (right).





Socialising at the reception (left), chair's reception (above) and gala dinner (below).

density parity check coded modulation for optical transport networks. Dr. John Travers from Max Planck Institute for the Science of Light, Germany, presented the latest advances in nonlinear optics in gas-filled hollow-core photonic crystal fibres. Professor Barry Luther-Davies from the Australian National University described work on chalcogenide materials for nonlinear photonics in the near and middle infrared.

Aside from invited talks, five tutorials were lined up to provide delegates with an instructional overview of the progress in research. For instance, Dr. Seb Savory from University College of London provided an overview of the leading and most effective DSP techniques to be used not only in point to point links but also from the optical networking context, in his talk entitled, "Digital Signal Processing: Enabling a Revolution in Optical Networking". Professor Masataka



Nakazawa from Tohoku University, Japan, presented the latest trends in ultrafast and high spectral efficiency optical transmission with a specific focus on multi-core fibres for space division

multiplexed transmission in his tutorial entitled, "Ultrahigh spectral efficiency systems-Pushing the limits of multi-level modulation, multi-core fiber, and multi-mode control".

WOMBAT

**Workshop on Optomechanics and
Brillouin Scattering: Fundamentals,
Applications and Technologies**



WOMBAT - Workshop on Optomechanics and Brillouin Scattering

20 - 22 July 2015, Sydney

Invited Speakers

Kerry Vahala, Gaurav Bahl, Peter Rakich,
Jean-Charles Beugnot, Raphael van Laer

Organising Committee

Ben Eggleton, Christopher Poullton, Michael Steel,
Andrey Sukhorukov, Warwick Bowen, Irina Kabakova,
Alvaro Casas Bedoya, David Marpaung, Christian Wolff, Moritz Merklein



<http://www.cudos.org.au/wombat.shtml>

News

News from the AGM

The AOS 2014 AGM was held on 6 November. The new constitution was passed without further amendment. It will replace the original Memorandum of Association and Articles of Association and be available at optics.org.au shortly. Stephen Collins is now President of the society, while Simon Fleming is now Vice-President. Outgoing President, Ann Roberts, remains on the Council for the next two years as Past-President.

The following were elected to two year Council positions:

- Ben Eggleton
- John Harvey
- Maryanne Large
- Dragomir Neshev

All those who stood for election are thanked for their interest and commitment to the organisation and the outstanding service to the society of outgoing Past-President, Judith Dawes, was acknowledged. Secretary John Holdsworth advised that he will be standing down toward the end of this year and he was thanked for his enormous contribution in this role over the last decade. The election of Simon Fleming to Vice-President and the imminent departure of John Holdsworth from the Council means that there are two casual vacancies which the Council is currently working to fill. Another recent change to Council membership occurred when Alex Stanco recently stepped down as industry representative and was replaced by John Grace (Raymax). Alex's contribution to the Council is gratefully acknowledged.



Simong Fleming is the new AOS Vice-President

AOS member Steve Lee and Tri Phan winners of the ANSTO Eureka Prize for Innovative Use of Technology

Congratulations to Tri Phan from the Garvan Institute and Steve Lee from the Australian National University for winning the ANSTO Eureka Prize for innovative use of technology for their work 'DIY droplet lens'. As explained in Steve's article in the last issue of AOS News, Tri and Steve have developed a simple and cheap way of making high-performance lenses by curing a droplet of plastic as it hangs upside down. The lenses cost less than a cent to make and the team have designed a simple device consisting of a lens holder and LED light source for \$2 that can easily be fitted to a smartphone. This results in a portable, digital microscope with magnification up to 160x.

"By making microscopy inexpensive and accessible to the public the droplet lens will inspire a new generation of amateur scientists and adventurers to explore and discover the hidden microscopic world," Australian Museum Director and CEO Kim McKay said, "It could also help facilitate 'citizen scientists' in their study of an endless array of fields and trigger new industries. Who knows what this could lead to next"

For more details on the technology see the article by Steve on droplet lenses in the last issue of AOS News.

For information about all prize winners and finalists, see australianmuseum.net.au/eureka.



Steve Lee and Tri Phan at the Eureka prizes

Doctoral consortium @ PHOTOPTICS 2015

3rd International Conference on Photonics, Optics and Laser Technology, 12-14 March, 2015, Berlin, Germany

The Doctoral Consortium on Photonics, Optics and Laser Technology is intended to bring together Ph.D. students within the Photonics, Optics and Laser Technology field to discuss their research in an international forum. More precisely, the Doctoral Consortium will provide students with an opportunity to:

- Present their research work in a relaxed and supportive environment;
- Receive feedback and suggestions from peers and experienced faculty members;
- Gain an overview of the breadth and depth of Photonics, Optics and Laser Technology;
- Obtain insight into directions for Photonics, Optics and Laser Technology research taken by other doctoral candidates;
- Discuss concerns about research, supervision, the job market, and other issues;
- Network with peers and future colleagues

Important deadlines:

Doctoral Consortium Submission: January 5, 2015

Author Notification: January 23, 2015

Camera Ready and Registration: February 2, 2015

<http://www.photoptics.org/DoctoralConsortium.aspx>



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5th IPOS Symposium on Imaging Spectroscopy

by Alexander Argyros

The 5th IPOS Symposium on Imaging Spectroscopy was held on the 6th and 7th of November 2014 at the New Law School of the University of Sydney. The event was a great success with 140 registrations.

The Symposium brought together optics and photonics researchers from Australia and around the world, with emphasis on the chosen topic of Imaging Spectroscopy. An aim of the Symposium was to explore the wide range of techniques and applications, and also possibilities, of this emerging area which has implications for medicine, agriculture, defence, astronomy and many other fields.

The Symposium was opened by the DVC-R of the University of Sydney Prof. Jill Trehwella, and by IPOS Director Prof. Ben Eggleton who gave the opening address and a review of recent IPOS activities. They were in turn followed by Prof. Charles Bachmann, Rochester Institute of Technology, USA, speaking about hyperspectral remote sensing of coastal areas, and Prof. Brian Wilson, University of Toronto, Canada, speaking about spectral imaging of tissue in-vivo. The afternoon session had three further talks on diverse topics from Prof. Salah Sukkarieh on field robotics and spectroscopy, A/Prof. Baohua Jia, Swinburne University of Technology,

on on-chip imaging, and Prof. Joss Bland-Hawthorn on 3D spectroscopy in astronomy and space science. A review of IPOS research followed in the evening in the form of short talks and a poster session.

The second day began with Prof. Andy Yun, Harvard Medical School, on in-vivo Brillouin microscopy, followed by Prof. David Sampson and A/Prof. Vincent Wallace also on medical imaging themes. A wide range of topics were covered in the remaining two sessions - Dr. Girish Lakhwani spoke about single-molecule spectroscopy, Dr. Roy Hughes, DSTO, about the miniaturization of hyperspectral instruments, Dr. Robert Content, AAO, about integral field spectroscopy for astronomy, Dr. Antonio Robles-Kelley, NICTA, about scene analysis, and finally



The Chair of the organising committee Dr Sergio Leon-Saval, getting ready to start the Symposium.

Dr. Elizabeth Carter who spoke about the applications of vibrational spectroscopy to imaging biological samples.

The Symposium was sponsored by the CUDOS ARC Centre of Excellence, the Astrophotonics group of the University of Sydney, Warsash Scientific, Lastek, the Australian National Fabrication Facility (ANFF), and PAS Portable Analytic Solutions, with the Australian Optical Society (AOS) as a technical co-sponsor.

The Symposium organising committee was chaired by Dr. Sergio Leon-Saval and co-chaired by Dr. Irina Kabakova. The committee consisted of Prof. Ben Eggleton, Prof. Joss Bland-Hawthorn, A/Prof. Alexander Argyros, Prof. Peter Tuthill, Dr. Joel Carpenter, Dr. David Marpaung, and Dr. Julia Bryant. Thanks goes to Vera Brinkel and Silke Weiss for their excellent assistance with the organisation of the Symposium, and to the CUDOS Centre of Excellence for making their time available.

A/Prof. Alexander Argyros is with the Institute of Photonics and Optical Science, School of Physics, the University of Sydney.



Prof. Charles Bachmann during his presentation.

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samples

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SensL Announce New 'C-series' of Silicon Photomultipliers (SiPM)

SensL's new C-Series SiPM sensors feature industry-leading low dark count rates of <100 kHz/mm² with exceptional breakdown voltage uniformity. The spectral range is between 300 to 800 nm with a peak photon detection efficiency (PDE) at 420 nm greater than 40%. The C-Series sensors are available in 1 mm, 3 mm and 6 mm sizes and can be packaged in a variety of formats. The 4-side tileable surface mount (SMT) package is compatible with lead-free,

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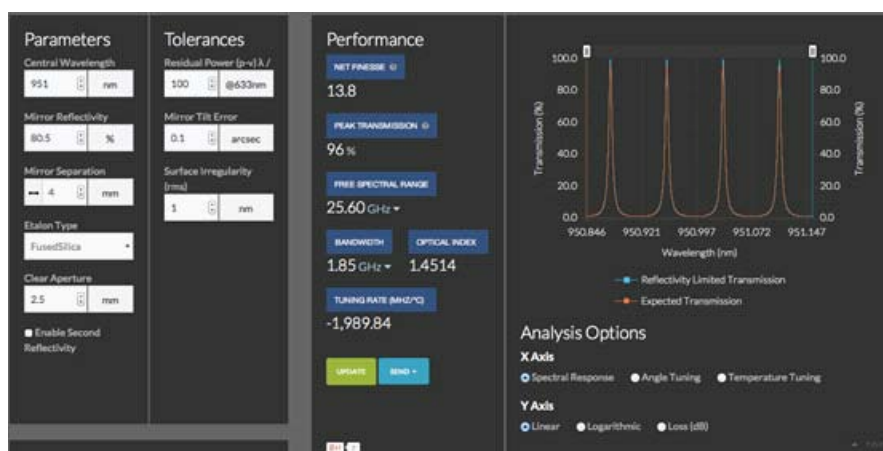
The new C-Series SiPM sensors have extended sensitivity down to 300 nm for improved UV sensitivity and 250 ps coincidence resolving time (FWHM) for LYSO scintillators. They have Ultra-fast rise times of 300 ps with 600 ps pulse width for improved multi-photon resolution capability, temperature stability of 20

mV/°C which negates the need for active voltage control and an operating voltage of less than 30 V.



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Optical Design Centre from LightMachinery



new set of optical tools located in the cloud based Optical Design Centre. Available for free from lightmachinery.com the tools include advanced modeling software for the design of etalons, virtually imaged phase arrays (VIPAS), and fizeau wedges.

The online design software is already popular. From a decibel to percentage calculator, to a complex optimizing multi-layer thin film coating designer, the software is used daily by students and engineers all over the world. The software was released as part of an overall rebuild of LightMachinery's online presence which features multiple platform support to accommodate a growing segment of users on Android and iOS devices.

Known for their expertise in optics, LightMachinery have launched a new web site containing freely available design tools. Holding US patented technology in fluid jet polishing, a wide variety of optical components can be polished to surface qualities exceeding $\Lambda/100$ with very

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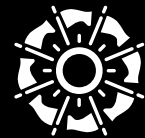
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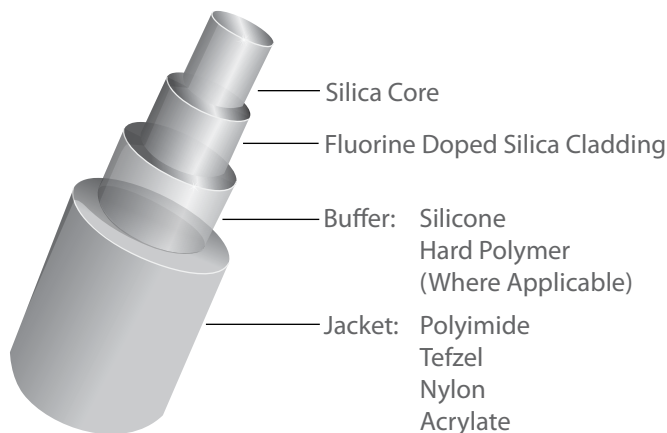
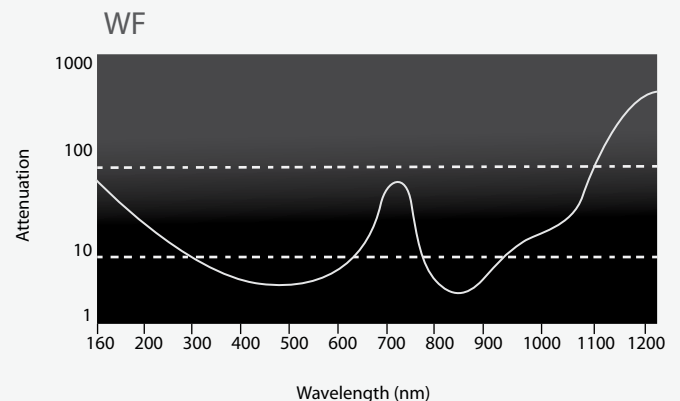
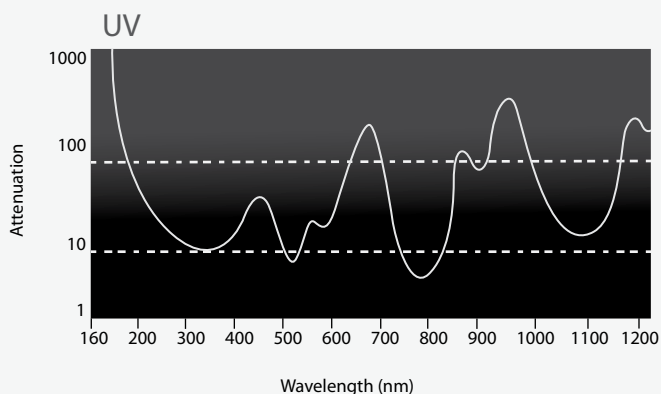
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Optical Elastography: Visualizing the Microscale Mechanical Properties of Tissue

by Kelsey M. Kennedy, Brendan F. Kennedy, Lixin Chin, Philip Wijesinghe, Andrea Curatolo, Shaghayegh Es'haghian, Peter R.T. Munro, Robert A. McLaughlin, and David D. Sampson

Tissue mechanics plays a crucial role in the progression of diseases such as cancer. Researchers at the Optical + Biomedical Engineering Laboratory at The University of Western Australia are using optical techniques to reveal the mechanical properties of tissue on a microscopic scale.

The onset and progression of disease is often accompanied by changes in the mechanical properties of tissue. When physicians manually palpate tissue, they are feeling for changes in mechanical properties to aid their detection or diagnosis of a condition. Palpation provides a qualitative, subjective assessment of a tissue's mechanical properties, but in the past 25 years, mechanical imaging techniques have emerged that aim to quantify and map these properties, allowing clinicians to "see" how tissue "feels."

The most prominent of these techniques, elastography, involves applying a load to tissue and using medical imaging to measure the resulting tissue displacement, from which mechanical properties may be calculated and mapped onto an image. Elastography was originally developed using ultrasound and MRI [1], with spatial resolutions in the range 0.1-10 mm; that is, on the scale of regions of tissue and organs. But disease-related mechanical changes progress on the cellular to microstructural scales. For example, a breast tumour that has grown to a centimetre in size may feel stiff to the human touch; but on a microscale, individual tumour cells are known to be softer than normal cells to allow them to more easily migrate through tissue, and these cells are intermingled with fibrous and fatty tissues of the breast, resulting in a complex environment with heterogeneous mechanical properties.

To probe tissue mechanics on these smaller scales, researchers have begun to explore elastography based on optical imaging [2, 3]. Techniques based on modalities including optical coherence

tomography (OCT), holography, and Brillouin microscopy have emerged, allowing visualization of the microscale mechanical properties of tissue in clinical areas including ophthalmology, cardiology, dermatology, and cancer imaging. Importantly, these optical techniques are non-destructive and often suitable for *in situ* and *in vivo* measurements, distinct from laboratory-based, cellular-scale mechanical techniques such as atomic force microscopy. This young research area has experienced rapid growth in number of publications in the past five years, and an optical elastography sub-conference has been established at SPIE Photonics

West to accommodate the growing research community, entering its second year in 2015 with a record number of submissions.

Our group in the Optical + Biomedical Engineering Laboratory at The University of Western Australia is developing novel mechanical imaging techniques based on OCT, including optical coherence micro-elastography for measuring tissue strain with micro-strain sensitivity, and optical palpation for visualizing tactile information. Most recently, we have begun to apply these techniques to reveal mechanical heterogeneity in breast cancer tissues, with potential to provide improved guidance of breast cancer surgery.

Probing microscale tissue mechanics using optical coherence tomography

Optical coherence micro-elastography (OCME) [3, 4] employs OCT to measure the displacement of tissue under

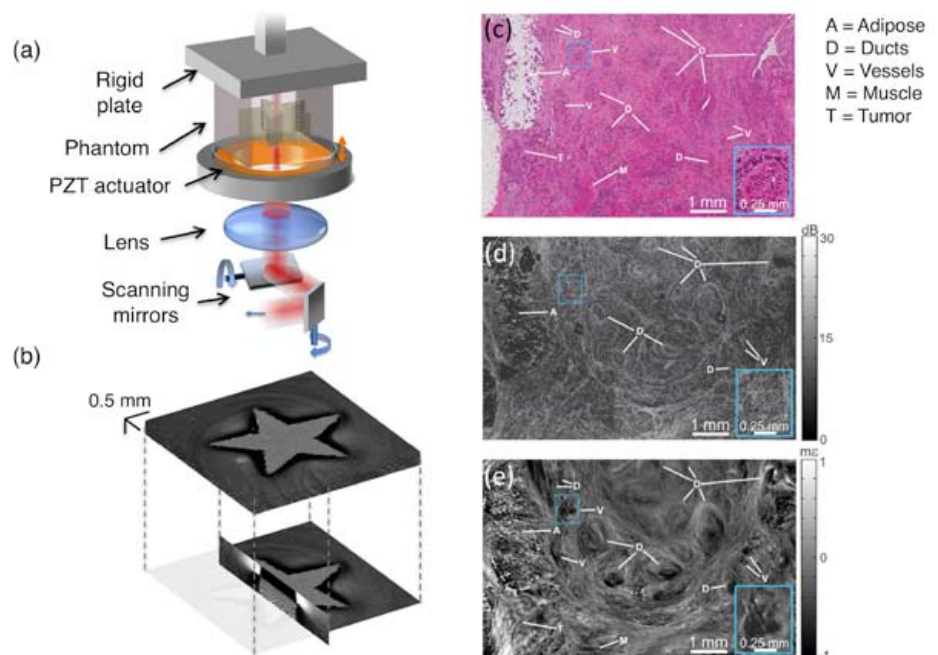


Figure 1. (a) Schematic of the OCME system. (b) 3D micro-elastogram of a phantom containing a stiff, star-shaped inclusion embedded in soft silicone. (c)-(e) Histology, *en face* OCT image and *en face* micro-elastogram, respectively, of freshly excised human breast cancer tissue. The OCT and micro-elastogram show good correspondence to features in histology, and OCME provides enhanced contrast of some features, including a region of invasive tumour (T). A=adipose, D=ducts, V=vessels, M=muscle, T=tumour. From [3].

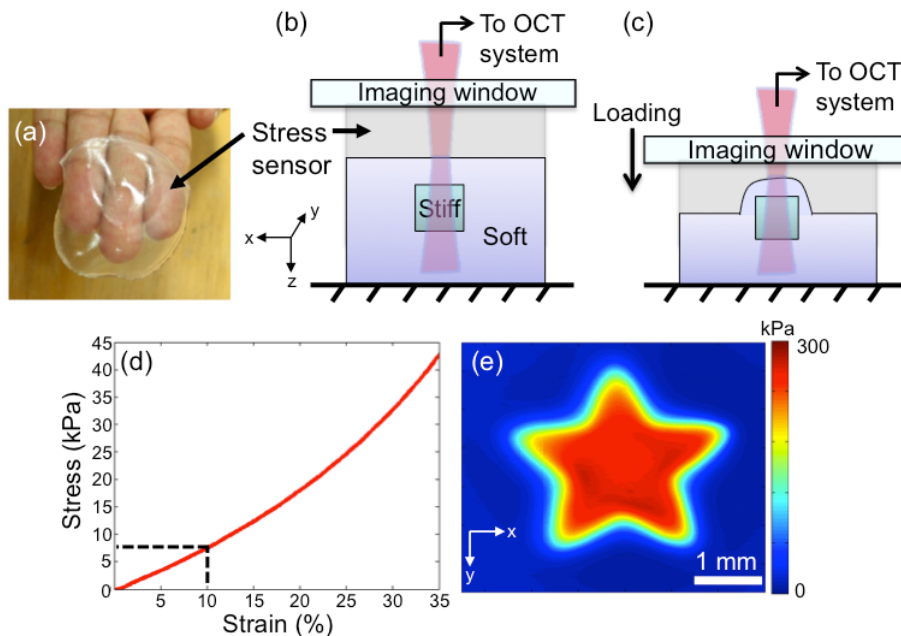


Figure 2. (a) Photograph of compliant stress sensor. (b)-(c) Schematics of optical palpation setup before and after loading, respectively. (d) The stress-strain curve of the sensor material, used to estimate stress from measured strain. (e) Optical palpation image of a stiff star-shaped inclusion embedded in soft silicone. Adapted from [7].

a compressive load. OCT, based on low-coherence interferometry, provides 3D images of tissue reflectance with ~ 10 μm isotropic spatial resolution. OCT can operate at high speeds (>100 Hz frame rates) and can be delivered deep into the body via fibre-optic probes. Another advantage of OCT is its exquisite sensitivity to tissue motion; a change in the phase of the OCT signal is proportional to axial tissue displacement, allowing sub-resolution, nanometre-scale displacements to be detected. In elastography, this elevated sensitivity to displacement should allow detection of more subtle changes in mechanical properties compared to ultrasound or MRI-based elastography techniques.

A schematic of our OCME set-up is shown in Fig. 1(a). A compressive load is applied on the same side as imaging using a window fixed to a ring-shaped, piezoelectric (PZT) actuator. The resulting displacements are measured from the change in phase of the OCT signal at each pixel, and the axial strain is calculated as the spatial derivative of displacement. The strain is used to form an image (micro-elastogram) and is proportional to the inverse of the elasticity of the sample under the assumption of uniform stress. Fig. 1(b) shows a micro-elastogram of a silicone phantom comprising a stiff, star-shaped inclusion embedded in a soft matrix. The softer matrix undergoes a high level of strain under the compressive load, whereas the star is more rigid and undergoes less strain.

Toward improved guidance of breast cancer surgery

We are exploring the potential of OCME to provide improved guidance during breast cancer surgery. Currently, surgeons lack a precise guidance method to delineate the boundaries of a tumour. As a result, one in four women that undergo breast-conserving surgery for treatment of breast cancer must return for a second surgery due to insufficient removal of tissue in the first instance. The mechanical contrast provided by OCME, combined with the structural information afforded by OCT, could help highlight tumour boundaries during surgery and reduce the number of unnecessary and traumatizing surgeries. Fig. 1(c)-(e) shows an OCT image and micro-elastogram, compared to corresponding histology, of surgically excised tissue from a breast cancer patient. Features of breast microstructure, including ducts and blood vessels, are visualized in the OCT image and the micro-elastogram. In addition, a region of invasive tumour cells (stained purple) that are infiltrating connective tissue (stained pink) gives a heterogeneous strain pattern in the micro-elastogram; whereas in the OCT image, this region of malignancy is indistinguishable from the uninvolved breast tissue.

We are continuing to image breast cancer tissue samples to establish the sensitivity and specificity of OCME for detecting tumour boundaries. In parallel, we are engineering improvements to the OCME system toward intraoperative use,

including methods to increase imaging speed [6]. Moving beyond breast cancer, we recently demonstrated the ability of OCME to differentiate intact and necrotic muscle tissue in mouse models of muscular dystrophy [5].

A new form of tactile imaging: optical palpation

Elastography relies on tracking tissue deformation to extract mechanical properties. But what if we could measure the tactile sensation experienced by a clinician's fingertips during palpation? When we press on an object, mechanoreceptors within our skin sense pressure and transmit this tactile information to the brain. In robotics applications, tactile sensing technologies have been developed toward building an "electronic skin," which would allow robots to more comprehensively interact with their environments. These technologies typically employ some flexible medium, such as soft polymers, to conform to objects and incorporate discrete tactile sensing nodes, or "taxels," for instance based on piezo-resistors, to measure the stress distribution. Tactile imaging has also been proposed for diagnostic imaging of breast lesions; however, the spacing of the discrete sensing nodes has limited the resolution

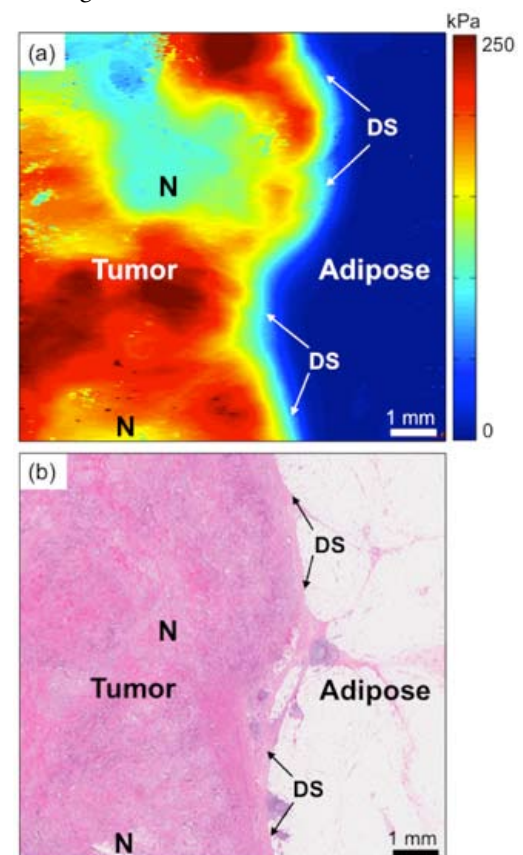


Figure 3. (a) Optical palpation image of human breast cancer tissue and (b) corresponding histology prepared in the imaging plane. DS, desmoplastic stroma; N, necrosis. From [7].

of these techniques to ~ 1 mm.

We have developed the first OCT-based tactile imaging technique, termed optical palpation [7]. We use a stress sensor consisting of compliant, silicone rubber [Fig. 2(a)] that is placed on the tissue surface. Rather than relying on electronic sensing nodes, we use OCT to measure the local strain (percent change in thickness) of the sensor under a compressive load [Fig. 2(b)-(c)]. We have characterized the stress-strain response of the sensor material and can relate the measured strain to the corresponding stress, as seen in Fig. 2(b). The resulting optical palpation image is a projection of the stress on the sample, similar to the stress felt by the fingertips during palpation. Fig. 2(e) shows an optical palpation image of a star phantom [similar to that in Fig. 1(b)]. The stiff star maps to a higher stress, and the softer matrix results in a lower stress.

Optical palpation also has potential for delineating regions of tumour in human breast tissues. Fig. 3 shows an optical palpation image and corresponding histology of a tumour boundary in human breast cancer tissue. The regions of high and low stress in the optical palpation image correspond to regions of invasive tumour on the left and normal fatty tissue on the right, as confirmed by the histology.

An advantage of optical palpation compared to OCME for mechanical imaging is that it is sensitive to mechanical contrast from features situated beyond the OCT imaging range (i.e., >2 mm in depth) [7]. Also, although optical palpation provides only a 2D projection of stress (as opposed to the 3D elastograms afforded by OCME), the 3D OCT image is retained, opening the possibility to perform optical palpation and OCME simultaneously. Knowledge of both the applied stress and the tissue strain would allow quantification of the elasticity and would better enable inter-sample comparison and longitudinal studies.

Looking forward

Beyond the techniques developed by our group, several approaches to optical elastography have been proposed, with various methods of loading tissue and detecting its response. Wave-based techniques use mechanical or ultrasonic stimuli to launch surface waves or shear waves in tissue, employ phase-sensitive OCT or holography to track their

propagation, and relate wave velocity to elasticity. Promising initial results have been demonstrated in measuring the elasticity of the cornea and skin [2]. Another exciting technique, based on Brillouin microscopy, requires no external stimulus at all and, rather, relies on inelastic light scattering due to intrinsic thermodynamic fluctuations to indicate a tissue's mechanical properties. Each of these approaches has advantages and disadvantages, and the particular tissue type and the mechanical information required largely dictates which technique is most appropriate in a given application. To date, the thrust of optical elastography research has been on the development and refinement of techniques. In the coming years, as these techniques mature, we expect the focus to shift to more rigorous application to problems in medicine and biology.

Our group is continuing to develop OCME and optical palpation toward clinical translation, especially for applications in breast cancer surgical guidance and assessment of burn scars. In addition to performing baseline clinical studies, we are developing handheld elastography imaging probes for *in vivo* skin imaging, as well as endoscopic and needle-based probes [8] to extend the potential of these techniques in a range of clinical applications.

Acknowledgements:

We acknowledge Prof. Christobel Saunders, Dr. Maxine Ronald, and Dr. Alan Tien (Royal Perth Hospital), for performing surgeries and facilitating access to tissue; and Dr. Bruce Latham (PathWest) for interpretation of histology. We acknowledge funding from the Raine Medical Research Foundation, Cancer Council Western Australia, the Australian Research Council, the National Health and Medical Research Council (Australia), the National Breast Cancer Foundation (Australia), and the National Institutes of Health (USA).

References:

- [1] K.J. Parker, M.M. Doyley, and D.J. Rubens, "Imaging the elastic properties of tissue: the 20 year perspective," *Phys. Med. Biol.* **56**, R1 (2011).
- [2] B.F. Kennedy, K.M. Kennedy, and D.D. Sampson "A review of optical coherence elastography: fundamentals,

techniques and prospects," *IEEE J. Sel. Top. Quantum Electron.* **20**, 7101217 (2014).

- [3] B.F. Kennedy, L. Chin, K.M. Kennedy, P. Wijesinghe, A. Curatolo, S. Es'haghian, P.R.T. Munro, R.A. McLaughlin, and D.D. Sampson, "Optical elastography: a new window into disease," *Optics & Photonics News*, in press.
- [4] B.F. Kennedy, R.A. McLaughlin, K.M. Kennedy, L. Chin, A. Curatolo, A. Tien, B. Latham, C.M. Saunders, and D.D. Sampson, "Optical coherence micro-elastography: mechanical-contrast imaging of tissue microstructure," *Biomed. Opt. Express* **5**, 2113 (2014).
- [5] L. Chin, B.F. Kennedy, K.M. Kennedy, P. Wijesinghe, G.J. Pinniger, J.R. Terrill, R.A. McLaughlin, and D.D. Sampson, "Three-dimensional optical coherence micro-elastography of skeletal muscle tissue," *Biomed. Opt. Express* **5**, 3090 (2014).
- [6] B.F. Kennedy, F.G. Malheiro, L. Chin, and D.D. Sampson, "Three-dimensional optical coherence elastography by phase-sensitive comparison of C-scans," *J. Biomed. Opt.* **19**, 076006 (2014).
- [7] K.M. Kennedy, S. Es'haghian, L. Chin, R.A. McLaughlin, D.D. Sampson, and B.F. Kennedy, "Optical palpation: optical coherence tomography-based tactile imaging using a compliant sensor," *Opt. Lett.* **39**, 3014 (2014).
- [8] K.M. Kennedy, R.A. McLaughlin, B.F. Kennedy, A. Tien, B. Latham, C.M. Saunders, and D.D. Sampson, "Needle optical coherence elastography for the measurement of microscale mechanical contrast deep within human breast tissues," *J. Biomed. Opt.* **18**, 121510 (2013).

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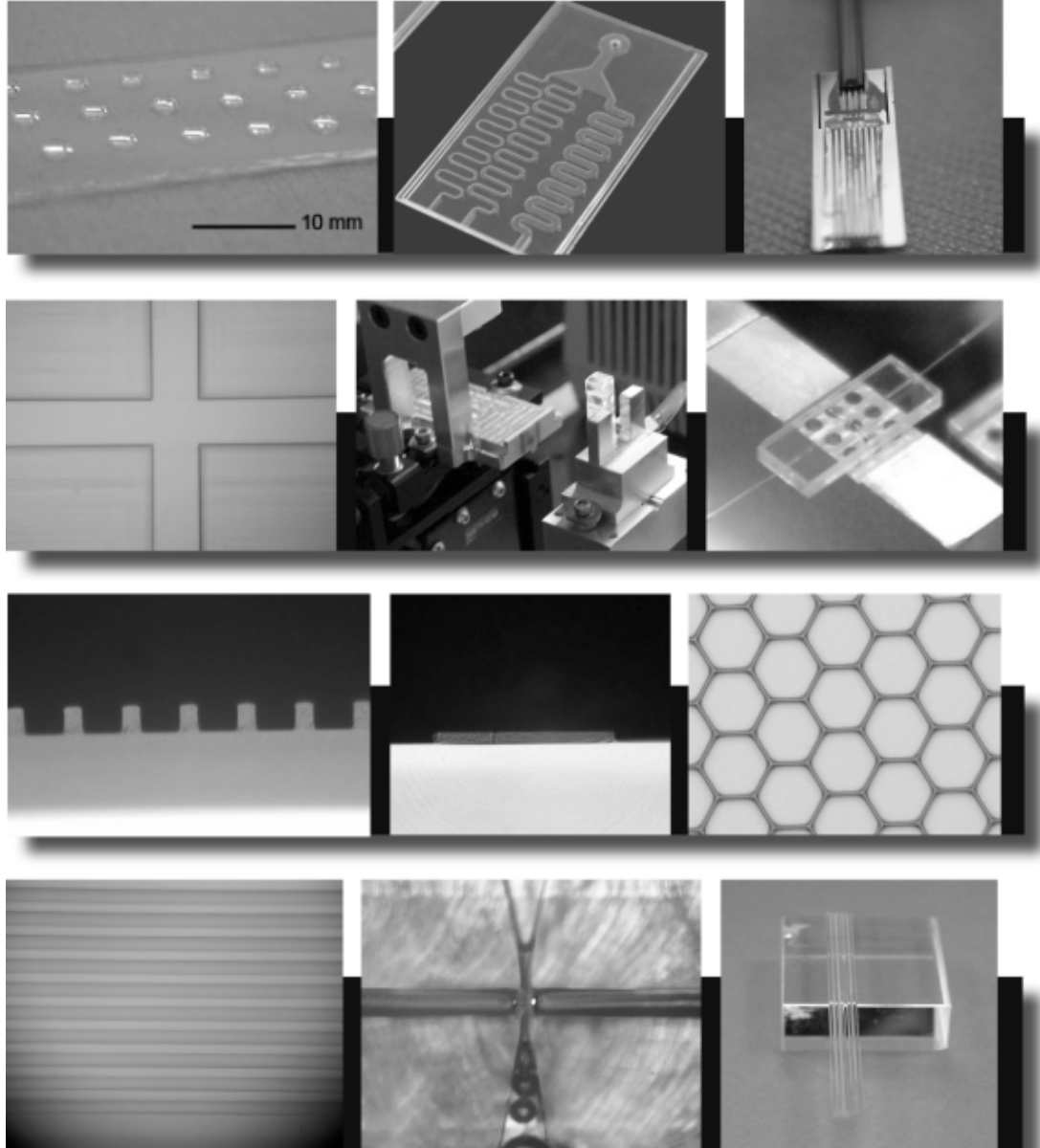
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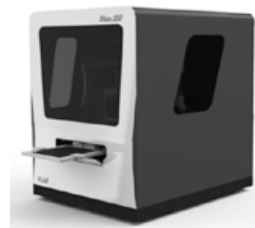
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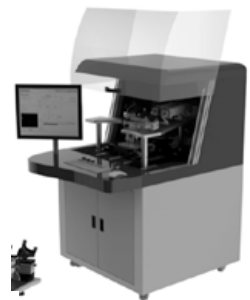


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Graphene Plasmonics: Exploring Surface Nonlinearities

by Daria A. Smirnova, Ilya V. Shadrivov and Yuri S. Kivshar

Graphene has intriguing electromagnetic properties at infrared and terahertz frequencies: it is low loss in a certain frequency range, tunable by electric and magnetic fields, and it is strongly nonlinear. Here we review several linear and nonlinear effects that we have predicted for graphene structures.

Graphene is a two-dimensional array of carbon atoms arranged in a honeycomb lattice, which has remarkable electronic and optical properties [1]. Recently, its unique optical properties have generated significant interest in the research community [2] revealing its great potential for applications in photonics and optoelectronics. An optical response of graphene is characterized by a surface conductivity which is determined by the chemical potential. For photon energies below a certain level defined by the chemical potential, graphene exhibits metal-like conductivity. In this regime, similar to metals, graphene can support transverse magnetic (TM) electromagnetic surface plasmon polaritons, and they represent a coupled state of the electromagnetic field and electrons. For the range of frequencies above the chemical potential, graphene has dielectric characteristics and it supports transverse electric (TE) surface waves.

The study of plasmonic effects in graphene structures has attracted special interest from the nanoplasmonics research community due to novel functionalities delivered by such systems, including a strong confinement of electromagnetic waves by a graphene layer and the tunability of graphene properties through doping or electrostatic gating. Now graphene plasmonics [3, 4, 5] is a rapidly growing new field of physics which utilizes concepts of conventional metal plasmonics combined with the unique electronic and optical properties of graphene. Being guided by a graphene monolayer, TM-polarized plasmons with subwavelength localization have an extremely short wavelength, and that is why their excitation is rather challenging. Nevertheless, recent experiments provided the evidence of the existence of such plasmons by means of scattering

near-field microscopy and nanoimaging [6, 7].

Impelled by many theoretical proposals and experimental results, graphene plasmonics paves a way towards the development of optical metadevices. The fact that a single graphene layer can support both TM and TE polarized plasmons, and that wave dispersion properties can be changed by applying an external gate voltage to the graphene sheet is behind new types of tunable metamaterial structures based on graphene. Such structures could be used for nanoscale optical information processing and storage. As was shown in Ref. [8], coupling of the surface plasmons at individual graphene sheets results in the emergence of hyperbolic isofrequency contours that can lead to a large density of electromagnetic states in these structures.

In addition to exotic linear properties, graphene also possesses strong nonlinear properties, which are now the subject of extensive theoretical and experimental studies [9, 10, 11, 12, 13, 14]. Strong nonlinear properties suggest that graphene structures can exhibit a range of practically important effects, including nonlinear self-action of surface plasmons in graphene and the generation of subwavelength spatial solitons [15, 16, 17, 18].

In our work, we study both linear and nonlinear effects in graphene structures. We study nonlinear propagation of light in two coupled layers of graphene (see Fig. 1 (a)), and demonstrate that this simple double-layer structure can operate as an efficient optical coupler for both continuous plasmon polaritons and for subwavelength spatial solitons [17]. We have shown that multi-layer graphene structures (see Fig. 1 (b)) can be employed to increase plasmon wavelength [18, 19, 20], thus increasing

plasmon propagation length. Multilayer graphene structures also support special types of surface plasmon (see Fig. 1 (c)), which are known as Tamm states [20].

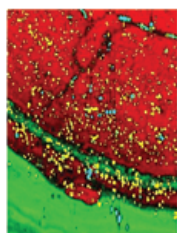
In Ref. [18] we study the nonlinear properties of a multi-layer stack of graphene sheets and predict that such a structure may support dissipative plasmon-solitons generated by external laser radiation (see schematics in Fig. 1 (d)). Specifically, we consider the generation of surface plasmons in the presence of a plane wave incident from a high-refractive-index dielectric material at an angle larger than the angle of total internal reflection. Surface plasmons are supported by a graphene multilayer being coupled to the incident plane wave via an evanescent field. We demonstrate that in such a geometry the plane wave can act as an external driving source for plasmon excitations, or as a pump that compensates the propagation losses. The plane wave can resonantly excite surface plasmons and, in the nonlinear case, dissipative plasmon-solitons. We extend the results for soliton formation in a lossless monolayer presented in Ref. [15] to the non-conservative case when the self-localized waves are dissipative solitons, in which not only nonlinearity has to compensate diffraction, but also gain has to compensate loss. For such solitons no analytical expression can be found, and the soliton profiles have to be calculated numerically. We derive nonlinear equations describing spatial dynamics of the nonlinear plasmons driven by a plane wave in the Otto configuration. We have obtained the Lugiato-Lefever type nonlinear equation and predicted the existence of single- and multi-peak dissipative solitons in such graphene structures. Additionally, we have studied the properties of TE-polarized solitons [21] and their dynamics in graphene placed on an interface between linear and nonlinear dielectrics, and observed several interesting effects, see Fig. 1 (e,f,g).

Remarkably, graphene is not only employed for planar geometries, but there are also attempts to wrap complex three dimensional objects in graphene. Previous theoretical studies suggest that



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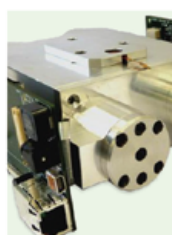
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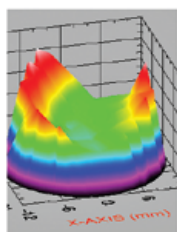
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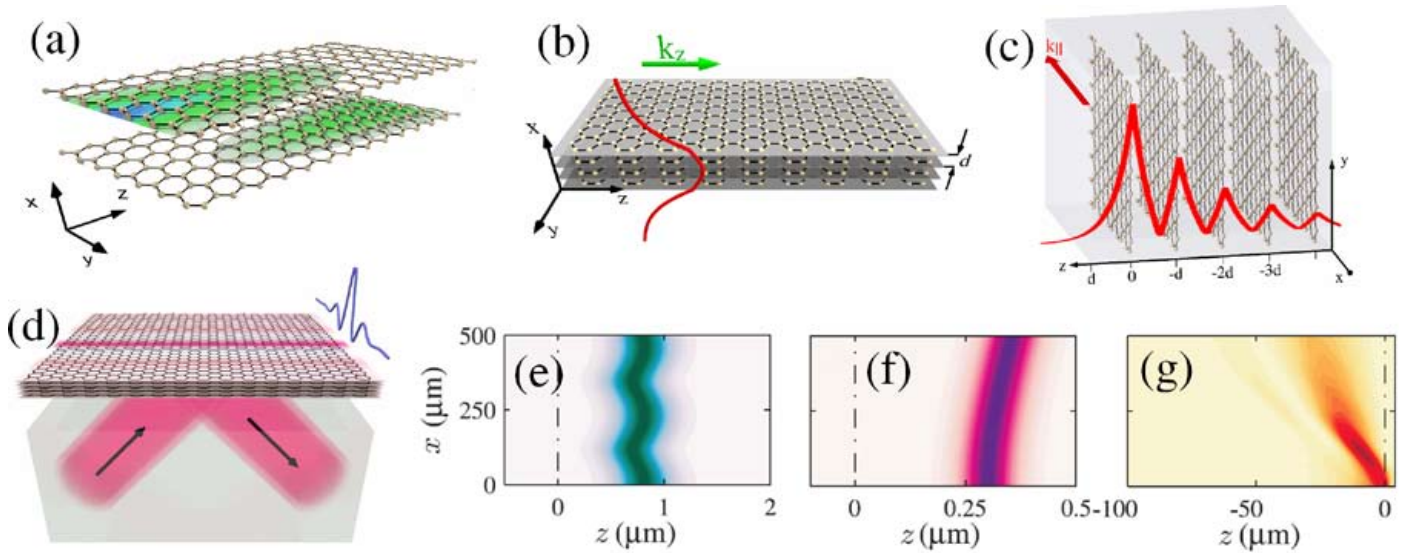


Figure 1. Several linear and nonlinear waveguiding problems solved: (a) Nonlinear graphene coupler [17]; (b) Multilayer graphene waveguide [19]; (c) Tamm states on the surface of multilayer graphene stack [20]; (d) Schematics of dissipative plasmon soliton excitation on multi-layer graphene structure [18]; (e,f,g) various soliton trajectories near the interface between linear and nonlinear dielectrics covered by graphene [21].

by wrapping spherical nanoparticles in graphene it becomes possible to achieve a tunable cloaking effect. In Ref. [22] we study the nonlinear response of a graphene-wrapped dielectric spherical nanoparticle, see Fig. 2. We consider a nanoparticle with an outer graphene layer and analyze the second-harmonic generation induced by the nonlinear conductivity of graphene. We demonstrate that a strong nonlinear response is caused by an induced surface current in the graphene nanoparticle illuminated by an external electromagnetic wave. We develop the theoretical model which allows us to obtain analytical expressions for the field multipoles characterizing the second-harmonic radiation.

Importantly, by using graphene as a cover layer of the nanoparticle, we obtain a resonant surface nonlinear response. Owing to tunability of graphene, such a geometry can provide tunability of the

nanoparticle's response by using both electric and magnetic fields, as well as by doping graphene at the fabrication stage. We suggest that the radiation pattern of the second harmonic can be manipulated by placing the particle in an inhomogeneous external field of the wave at the fundamental frequency, which is schematically shown in Fig. 2. We show that when the particle is placed in the field of the plane wave, the resonantly enhanced radiation of the second harmonic is symmetric, however in an inhomogeneous field the pattern can be modified, and we study in detail the underlying mechanisms. In particular, we show that the asymmetric radiation pattern is caused by the interference of dipole and quadrupole modes and the asymmetry of the external field changes the efficiency of the excitation of these modes. We analyse the dependence of intensity and directivity of nonlinear scattering on the frequency and structure of the electromagnetic field, revealing the asymmetric radiation patterns due to constructive multipole interference for the resonantly enhanced second-harmonic generation. For the typical parameters, we have predicted that the second harmonic is predominantly radiated in the half-space with stronger external electric field, as shown in Fig. 2.

In conclusion, graphene is a unique optical material which exhibits a large range of nontrivial linear and nonlinear effects. While most of the current studies are theoretical, we expect that they will pave the way for experimental demonstrations that in turn will lead to practical applications in optics and optoelectronics.

References

- [1] AK Geim, *Science* **324**, 1530 (2009).
- [2] RR Nair *et al*, *Science* **320**, 1308 (2008).
- [3] FHL Koppens, DE Chang, and FJG de Abajo, *Nano Lett.* **11**, 3370 (2011).
- [4] AN Grigorenko, M Polini, and KS Novoselov, *Nature Photon.* **6**, 749 (2012).
- [5] X Luo *et al*, *Mater. Sci. Eng., R* **74**, 351 (2013).
- [6] J. Chen *et al*, *Nature* **487**, 77 (2012).
- [7] Z. Fei *et al*, *Nature* **487**, 82 (2012).
- [8] IV Iorsh *et al*, *Phys. Rev. B* **87**, 075416 (2013).
- [9] SA Mikhailov, *Europhys. Lett.* **79**, 27002 (2007).
- [10] SA Mikhailov and K Ziegler, *J. Phys.: Condens. Mat.* **20**, 384204 (2008).
- [11] E Hendry *et al*, *Phys. Rev. Lett.* **105** (2010).
- [12] MM Glazov and SD Ganichev, *Phys. Rep.* **535**, 101 (2014).
- [13] JL Cheng, N Vermeulen, and JE Sipe, *New J. Phys.* **16**, 053014 (2014).
- [14] JL Cheng, N Vermeulen, and JE Sipe, *Opt. Express* **22**, 15868 (2014).
- [15] ML Nesterov *et al*, *Laser Photonics Rev.* **7**, L7 (2013).
- [16] AV Gorbach, *Phys. Rev. A* **87**, 013830 (2013).
- [17] DA Smirnova *et al*, *Phys. Rev. B* **88**, 045443 (2013).
- [18] DA Smirnova *et al*, *Laser Phot. Rev.* **8**, 291 (2014).
- [19] DA Smirnova *et al*, *JETP Lett.* **99**, 456 (2014).
- [20] D Smirnova *et al*, *Phys. Rev. B* **89**, 245414 (2014).
- [21] YV Bludov *et al*, *Phys. Rev. B* **89**, 035406-6 (2014).
- [22] DA Smirnova *et al*, *Phys. Rev. B* **90**, 035412 (2014).

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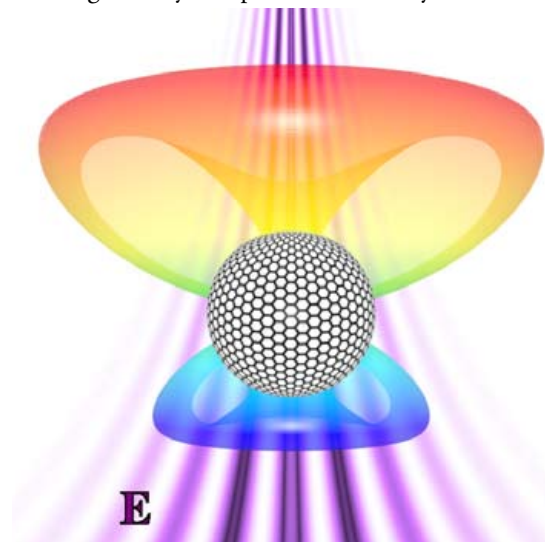


Figure 2. (a) Schematic view of a graphene-wrapped nanoparticle placed into an axially symmetric slightly inhomogeneous external field. The SH radiation is predominantly directed into the upper half-space [22].

Optics in Everyday Life: The 'Fire' of Opals

by Tony Klein

The mineral opal, chemically a form of a form of hydrated silica, is found on practically all continents, but mostly as an "opalescent", milky-white, soft rock. However, in some parts of Australia, small pieces of beautifully colored gemstones are to be found embedded in a matrix of ordinary opal.

What makes these quintessentially Australian gemstones sparkle with flecks of pure spectral colour? (Fig.1) Oddly enough, the answer to this question was a mystery to mineralogists for a long time until noted CSIRO electron microscopist John Sanders [2] discovered the surprising answer as recently as the 1970s [1].

Quite clearly, because of the spectral colours exhibited, the phenomenon of diffraction from periodic features was suspected to be the cause but nobody could guess at the nature of such periodic structures until they were revealed by electron microscopy.

It was surmised that the optical properties of precious opal, as distinct from the milky-white appearance of common opal that shows no 'fire', depends on the existence of orderly, regular arrays of optical discontinuities, spaced at repeat distances of the order of 150 to 350 nanometers, i.e. distances that correspond to half the wavelength of visible light.

Chemically, opals are made of pure, transparent, hydrated silica, i.e. hydrated Silicon Dioxide. But what the electron microscope revealed was that the silica is in the form of tiny spheres, of the appropriate range of sizes, stacked in close-packed

regular arrays, as may be seen in Fig.2, just like atoms or molecules in crystalline substances.

How these little spherical objects are formed is answered by noting that the solubility of silica in water increases markedly with temperature so that, upon cooling, silica is usually deposited as quartz crystals that are said to grow in what is called a hydrothermal process.

Alternatively, in the presence of centres of nucleation, the silica can precipitate from saturated solutions in the form of amorphous clusters. These continue to grow as concentric spheres, which then fall through the solution and end up in interstitial cavities. In most cases, a poly-disperse range of sizes result, which when dried out result in a milky-white solid of ordinary, or so-called 'potch' opal.

However, in rare cases, where the little spheres have a greater distance through which to fall, a gravitational separation can take place, where the larger spheres fall more quickly than the smaller ones

and arrange themselves in layers upon layers of uniformly sized regions of hexagonal close-packed groups, like oranges in a crate. Hence the quasi-crystalline arrangement of precious opal, usually in small pieces consisting of separate small regions, analogous to crystal grains. The opal 'grains' can vary in size, from a few millimeters, known as pin-fire opals, up to quite large ones in what



Figure 1. Precious opal. Photo: Jessica Kvensakul.

is known as boulder opals.

Because the individual silica spheres are completely transparent, pieces of opal show practically no colour when viewed in transmission. However, when viewed in reflection, strong diffraction colours are seen. These diffraction phenomena are not like those from a two-dimensional grating, such as is seen from the surface of a CD or DVD, and erroneously shown in illustrations in some popular articles. On the contrary, 3-dimensional diffraction is involved, just like in the diffraction of x-rays by crystalline solids, discovered by Laurence Bragg.

The only difference is one of scale: whereas x-rays (and thermal neutrons) have wavelengths comparable with the unit cells of ordinary crystals, Bragg diffraction of visible light by opals is governed by the spacing between the layers of the silica spheres, which corresponds to their sizes.

To prove the case and to further investigate the different types of opals (containing different types of so-called stacking faults), back around 1970, John Sanders built an apparatus consisting of a spherical glass flask with frosted walls, with a transparent entrance hole through which a collimated beam of white light was admitted. When a sample of gem-quality opal was suspended in the centre of the flask, the resulting visible diffraction



Figure 2. Electron Micrograph of precious opal. Courtesy of John Sanders.

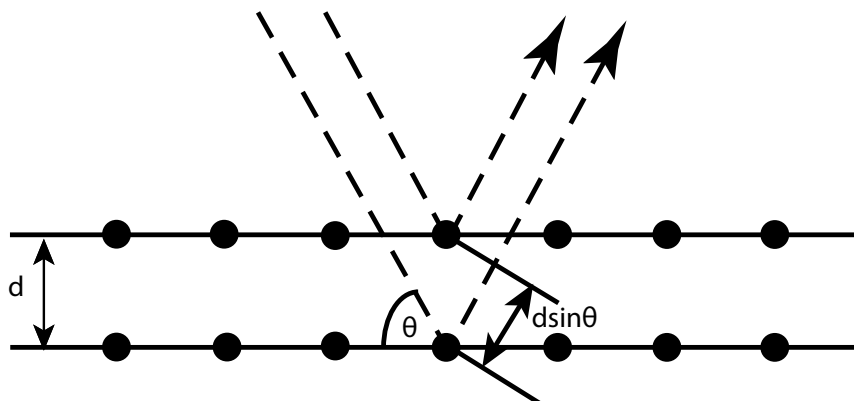


Figure 3. The geometry of Bragg Diffraction.

pattern, consisting of coloured spots and streaks, was exactly in accord with Bragg's well-known formula:

$$n\lambda = 2d \sin \theta$$

Changing the angle of incidence θ , or the viewing angle is, of course what gives rise to the play of colours or the 'fire' of the opals.

Another immediate, visible consequence of this is the background colour of the precious opal when viewed in direct reflection i.e. when $\theta = 90^\circ$ which determines the longest wavelength that can be diffracted - the so-called Bragg cutoff, which is simply $\lambda = 2d$. This, in turn, determines the rarity, hence market value, of a piece of opal. The so-called 'black opals, which show a deep red reflection, because they contain the largest silica spheres, being the most valuable, all other things being equal.

One rather interesting fact is the very high efficiency of the Bragg diffraction process: Quite a thin layer of material

is sufficient to produce complete reflection by virtue of the constructive interference of the light reflected from a relatively small number of layers. Thus, relatively thin layers of opal, sliced from a single piece can be mounted between layers of glass and exhibit the full, beautiful coloured appearance of the much more expensive solid opals. It is these so-called doublets and triplets that are the basis of the items of jewelry that are widely available at much cheaper prices but are just as interesting from the point of view of optics!

Once the structure of opals was elucidated, it was only natural that the making of synthetic opals was attempted in various laboratories by producing little spheres of colloidal or polymeric materials and letting them settle into close-packed arrays. Opal-like materials, with similar optical properties were actually successfully produced but their mechanical and chemical properties precluded widespread practical uses.

More recently, however, it was recognized that periodic structures of dielectric objects of appropriate sizes, of which opals are the prime example, can be generalized, giving rise to the whole new field of photonic crystals.

First proposed as late as 1987 by Eli Yablonovitch [3] and Sajeev John, a multi-faceted field of research has arisen, concerning methods of fabrication as well as new applications, in a variety of fields – well beyond the purely decorative.

Photonic crystals are still a hot research topic in laboratories all over the world, including Australia. But, as usual, nature got there first: Opals are only the simplest, 3-dimensional examples; the colours of butterfly wings and bird feathers are also the products of more complex types of photonic crystals.

References

- [1] PJ Darragh, AJ Gaskin and JV Sanders: Scientific American, April, 1976.
- [2] My friend John Sanders (1924 -1987) died at a tragically early age. His co-authors were both mineralogists.
- [3] See E. Yablonovitch: "Photonic Crystals: Semiconductors of Light" Scientific American, December 2001.

Emeritus Professor Tony Klein is a Foundation Member and Past President of the AOS. Tony is with the School of Physics, University of Melbourne.

Events

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

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. aip2014.org.au

19-20 January 2015 International Year of Light Opening Ceremony, France

The opening ceremony for the International Year of Light will be held in Paris, France on 19-20 January 2015. light2015.org

20-22 February 2015 International Conference on Optics and Photonics, India

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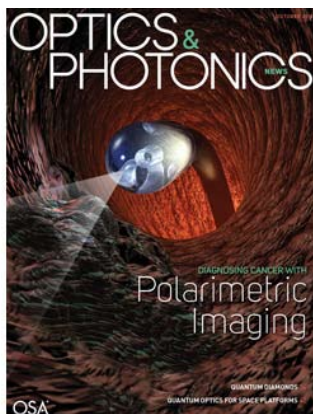


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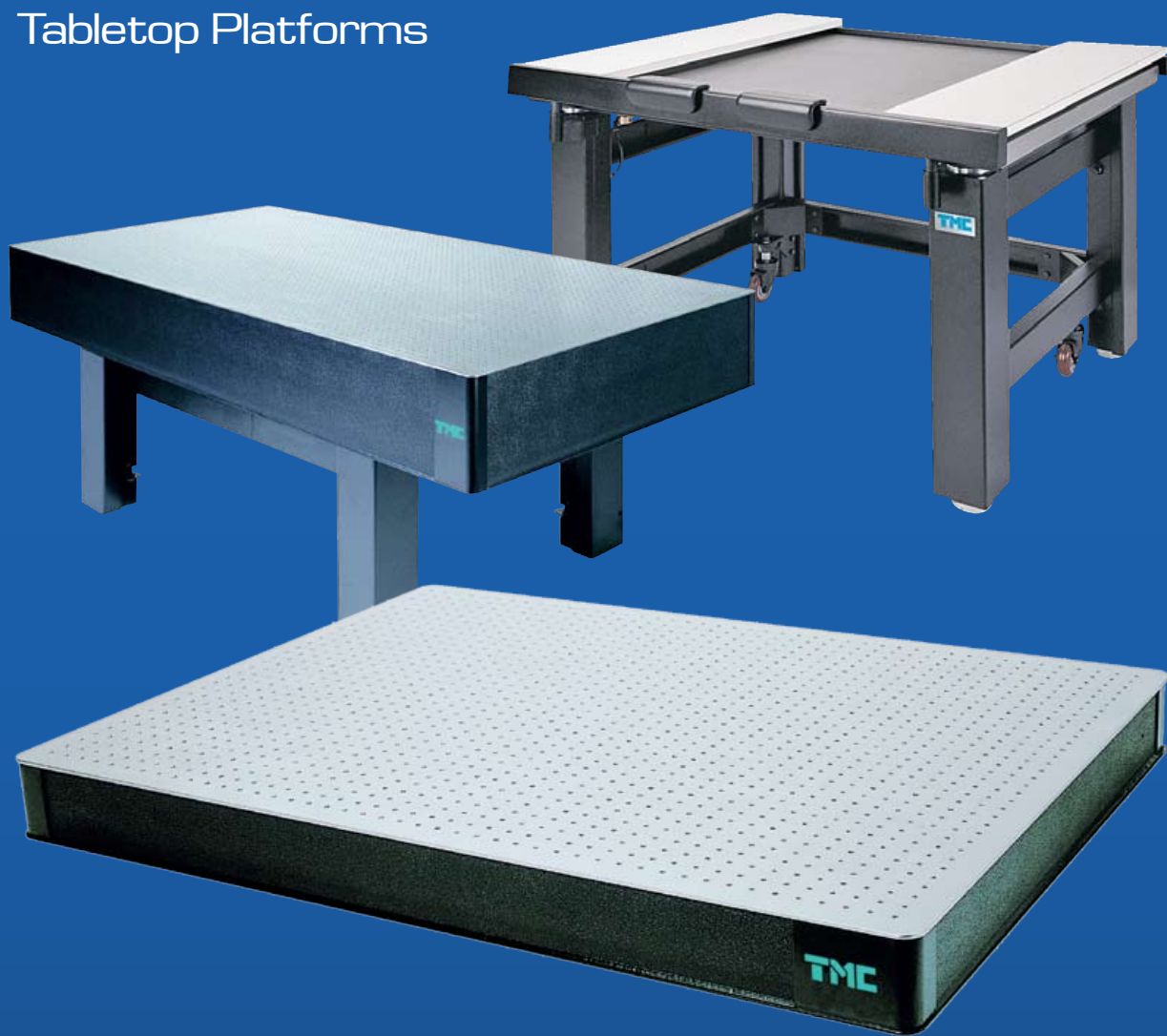




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