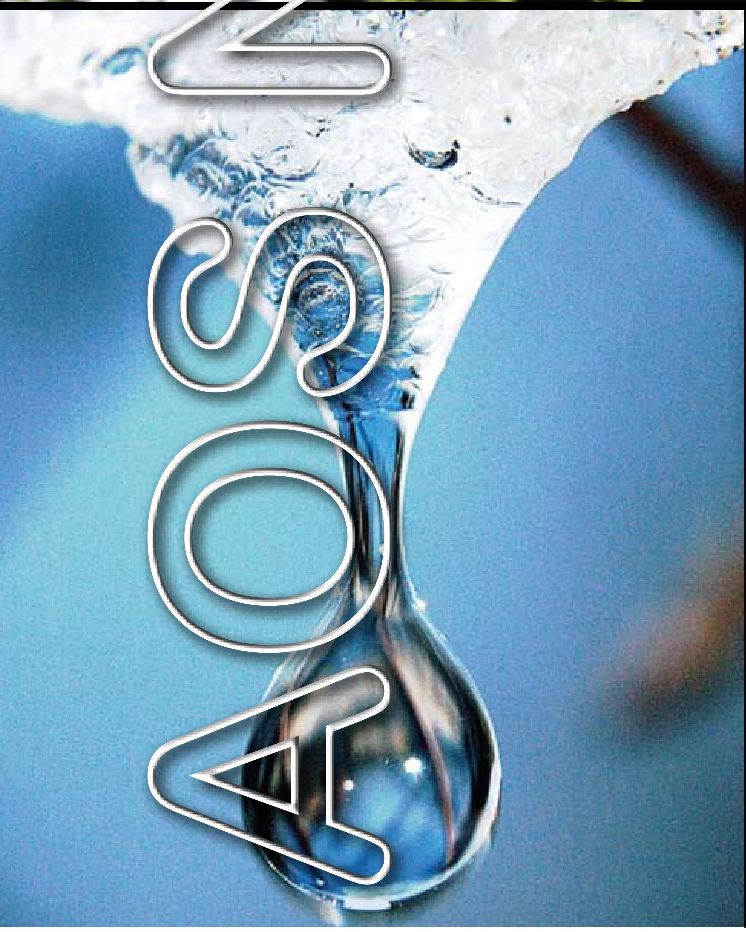
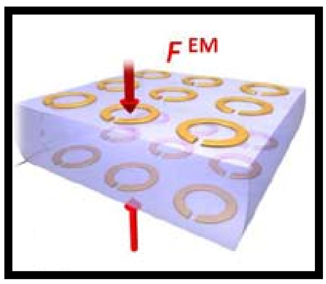
AOS News

Volume 28 Issue 3
September 2014
ISSN 1832-4436
Registered by Australia Post
Publication No: 233066 / 00028



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.
- 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.

Advertising:
Potential advertisers in AOS News are welcomed, and should contact the editor.
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 (December 2014) should be with the editor no later than 14 November 2014, advertising deadline 7 November 2014.

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Australian Optical Society website:

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Articles

Departments

Cover Pictures:

- Upper, An Australian spider orb-web, see page 11. Spider silks have been shown to have useful optical properties. Image is courtesy of Greg Staib.
- Lower, Ice drop and droplet lens, see page 30. Ice drop image is courtesy of Gregory Carter.
- Insets (left to right)
  - Orbital debris catalogued by NASA as of 2009, see page 19.
  - The shadow of an aeroplane on clouds, surrounded by a halo of coloured rings, see page 37. Image is courtesy of Alex Tudorica.
  - Schematic of magnetoelastic metamaterials, see page 27.

AUSTRALIAN OPTICAL SOCIETY

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President's Report

Since this is my final column as AOS President, it is timely to reflect on the future of optics and barriers to progress. One issue that continues to be a major problem for Australian science in general is the significant under-representation of women working as professional scientists, particularly at senior levels. This represents a substantial loss of talent with a potentially negative impact on the economy and the advancement of science. In 2009, I attended the Women in Science forum at Parliament House in Canberra. This was held to discuss strategies to address the findings presented in Sharon Bell's report, 'Women in Science' in Australia. It was found that all areas of science continue to suffer a 'leaky pipeline', where the proportion of academics working in universities who are women decreases with seniority. This is also the case in fields where women dominate undergraduate degrees. One of the dispiriting facts highlighted by Professor Bell was how little improvement there had been since the previous report in 1995. Although there is federal and state anti-discrimination legislation in place, concerns about the influence of low-level and unconscious bias persist and there is scope for raising awareness of these issues across the sector.

It is encouraging to see organisations such as the Australian Academy of Science through its Science in Australia Gender Equity Steering Committee looking to address the issue. A workshop will be held in November to discuss initiatives such as the possibility of developing a local version of the United Kingdom Athena SWAN Charter which provides awards to institutions demonstrating best-practice in progress in equal opportunity.

In addition to the loss of women from science at the professional level faced by all STEM disciplines, physics and engineering face the additional challenge that many girls and young women do not study physics or higher level mathematics in the final years of school. This leads to relatively low numbers of women pursuing undergraduate degrees in the physical sciences and engineering. There exist, however, some exciting initiatives aimed at encouraging girls to consider pursuing physics in the final years of high school. The ARC Centre of Excellence in Coherent X-ray Science established the 'Growing Tall Poppies' programme aimed at girls in year 10 and seeks to highlight the interdisciplinary impact of the physical sciences. It is wonderful to see that the program has recently attracted substantial funding through the Australian Maths and Science Partnerships Programme (AMSPP) to continue the program nationally. The International Year of Light next year is also an excellent opportunity to broaden the appeal of science through an appreciation of the wonder of light and its central place in our lives.

A further problem emerging from the relatively low numbers of women studying the physical sciences and engineering in our universities is the potential for students to feel isolated and outnumbered. Twenty years ago I was involved in the establishment of a program in the School of Physics at the University of Melbourne aimed at increasing the participation of women in research higher degrees in physics. We have seen an increase in the proportion of women studying at the higher levels, but there is still enormous value in these kinds of activities and I am excited about attending the next event to be held at Mt Buller in October. Similar programs exist in other disciplines and institutions and these all play a key role in retaining talented women. It is apparent that the under-representation of women working in the physical sciences and engineering is a complex issue requiring a range of different strategies for improvement.

As this will be my last column, I would like to acknowledge the hard work of the members of the Council, particularly our Secretary, John Holdsworth, and Treasurer, Simon Fleming. As a small organisation, we are very dependent on the contributions of volunteers and I urge members to consider standing for Council or putting up their hand to help in other ways - it is a truly rewarding experience. I would also like to thank the various people who have been involved in organising our highly successful conferences during my term as President and those who are currently working hard on upcoming events. The editor of the AOS News, Jessica Kvansakul, has also done excellent work in the regular production of the News over the last two years and Matt Collins has provided invaluable assistance as webmaster. Finally, I thank all AOS members for their continued support and enthusiasm that ensures our influence extends well beyond the activities directly organised by the Society.

Ann Roberts
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. We seem to have ended up with the theme of optical applications inspired by nature in this issue, with three of the articles coming under this topic. As you may have noticed from the cover, we have an interesting article by Steve Lee on making incredibly cheap lenses based on droplets as they are formed in nature. It is a wonderfully simple idea in essence, so I hope you like the article. There is also an item from Doug Little, who has been looking at the optical properties of spider silks, which is fascinating. The work helped Doug win the 2014 National Measurement Institute (NMI) Prize, so congratulations to him for this. Snjezana Tomljenovic-Hanic and colleagues have written about their use of silk and nanodiamonds for biological applications. The two materials complement each other well and are both biocompatible, so they have found exciting possibilities by combining them and give an overview of their recent work here. Other articles in this issue include an item on using lasers to help with the problem of space debris and a piece on nonlinear metamaterials, as well as our 'Everyday Life' section, which looks at retro-reflectors 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.

One thing many of the articles in this issue also have in common is the media attention the research has generated. We have included details of some of the articles written about these projects online. Not only is this attention good for the individuals in question, but also for keeping general interest in science and informing people about optics research that is happening in Australia and New Zealand. It can be difficult when promoting research as the media are always looking for an interesting story that the public can relate to and can often misunderstand the point of the work or give misleading impressions. It is still important that people hear about exciting work that is taking place as we do need the general public to be interested in what we do and have some incentive to support science. I think that all of the work in this issue that has generated media attention has managed to do this successfully, with the message coming across well, so hopefully acts as inspiration.

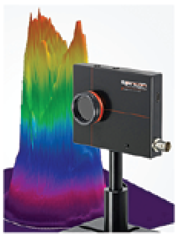
Preparations are moving forward for the International Year of Light that is taking place in 2015, with an Australian website recently launched to help coordinate events here (light2015.org.au) as well as a social media handle (@ LightYearAU). It is a great opportunity to showcase optics to the general public and the importance of light and light-based technologies to society. Hopefully many of you will be able to participate or assist in some way so that it can be a successful endeavour and help everyone to appreciate light and perhaps understand our interest in optics.

As Ann Roberts has mentioned in her President's Report, she is coming to the end of her term as AOS President. I want to thank her for all her help with persuading people to write articles for AOS News and making sure we had all relevant items covered in the news sections. I look forward to working with the new president and thank all of the council members for their hard work and support.

I hope you enjoy this issue of AOS News and look forward to receiving more interesting submissions for the next issue.

Jessica Kvansakul
Editor

Photonics
& Optoelectronic Accessories



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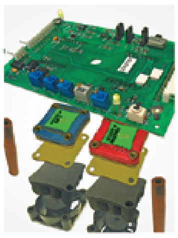

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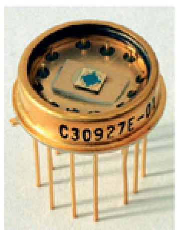

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A New Constitution for the Australian Optical Society

At the AGM last year and in the previous issue of the AOS news, the need to bring the governing documents of the AOS up to date after 30 years was flagged. In the first half of 2014 members of Council, with legal advice, have worked on drafting a new constitution. Members were emailed a copy on 11 July and invited to provide feedback and comment. The final draft of the constitution is now available on the AOS website, optics.org.au, and will be put to the AGM in November for endorsement by members. Below is a summary of the key changes to our governing documents.

Changes made to the Governing Documents of the Australian Optical Society

1. The Memorandum of Association and Articles of Association have been incorporated into one document to form a Constitution.
2. References to the Companies (Tasmania) Code have been updated to refer to relevant sections of the Corporations Act 2001 (Cth), the federal legislation which governs companies in Australia.
3. The process for election of Councillors has changed. Under the previous governing documents, members were to elect a Vice-President and Treasurer every second year, along with Councillors to fill the positions of retiring Councillors. Members will no longer elect someone to be Treasurer and this position will be filled by the Council from among the elected Councillors.
4. The process for filling casual vacancies of a President or Vice-President of the society has changed. Previously, a vacancy was to be filled by one of the Councillors until the next Annual General Meeting. Under the new Constitution, if a vacancy occurs in the office of President, the current Vice-President will fill the position as Acting President for the remainder of the presidential term. If a vacancy occurs in the office of Vice-President, the Council will appoint one of the Councillors to fill the position as Acting Vice-President for the remainder of the vice-presidential term.
5. Clauses allowing the Council to appoint advisors have been simplified and now expressly allow for the appointment of student and industry advisors.
6. Electronic meetings and electronic voting for resolutions of members are now specifically provided for in the Constitution.
7. The time ranges allowed for Annual General Meetings have been removed, and the Constitution now requires an Annual General Meeting to take place once each calendar year.
8. The quorum requirements for general meetings remain at two thirds the number of financial members of the Society or twenty five financial members, however, if quorum is not met within ten minutes from the start of an appointed meeting time, business transacted at that meeting will be notified to members following the conclusion of the meeting. Members will then have seven days to respond to that business and a resolution will be made in accordance with the opinion of the majority of members who respond.
9. The Society does not by law require an audit of financial records every year, and a review of these records is only required if the Society makes more than $250 000 in a financial year, so the requirement to have the books audited annually has been removed. The Constitution now provides for a review of the records if required by law and the Council is still required to keep proper accounting records and to distribute copies to members.
10. A Clause allowing for interpretation of the Constitution so that it is in accordance with the law has been inserted.
11. A Clause allowing for amendments to the Constitution at a meeting of members has been inserted.

Ann Roberts
President

John Holdsworth
Secretary

AUSTRALIAN OPTICAL SOCIETY

Optical Applications of Spider Silks

by Douglas Little

Spider silks are materials with extraordinary mechanical qualities. Spider silks are as strong as steel, elastic as rubber, and are harder to break than any other fibre known to man [1]. With the imminent mass-production capability of spider silk-like materials, the opportunities for the optical sciences to make use of this remarkable material are numerous.


Figure 1. Sunlit Australian spider orb-web [3]. Photo: Greg Staib.

This unusual combination of strength and elasticity originates from the protein, nanocomposite, macromolecular structure of the silk. Specifically the interplay of nano-crystalline domains, called β-sheets, which give the silks their characteristic strength; with amorphous structures called α-helices, which give silks their elasticity [2]. For some spider silks, theory suggests there may be two differentiable amorphous phases and one crystalline phase.

Like any nanocomposite, the properties of spider silk can be customised by changing the proportion of the nanocomposite elements (β-sheets and α-helices in the case of spider silk); a feature that spiders dutifully exploit. Orb-web spiders, for example (Fig. 1, [3]), spin webs using two different types of silk, a stronger, stiffer silk called major ampullate silk that forms the radial "spokes" of the web, and a more elastic silk called flagelliform that forms the capture spiral, making a web that is more effective at catching prey than one made of a single type of silk [4].

These features of silks do not come about by conscious design, but through millions of years of evolution by natural selection. Silk properties are closely linked to the web's ability to catch prey, which in turn influences the spider's survivability. The emergence of different spider species is driven, in part, by spiders evolving to spin webs that are specialised at capturing certain types of prey in particular environmental locations. Many modern spiders excel at capturing flying insects, in a range of lighting environments and their emergence can be traced to the evolution of modern silks we observe today.

Orb-weavers (*Araneidae*) are a family of spider species that have evolved to capture prey in bright-light environments, where ancestor spiders had been restricted to capturing prey in shade and seclusion. Fulfilment of this evolutionary niche has proven enormously successful, with over 3000 known orb-web species that are prevalent across every continent except Antarctica.

Light has played a unique role in the evolution of orb-weavers and their silks, because the appearance of the silks plays an enormous role in the efficacy of the orb-webs for prey capture. Compared to cribellate silks (cob-webs), orb-weaver (ecribellate) silks are much smoother, transparent, more homogenous in shape, and use a transparent glue to make silks sticky in place of velcro-like hairs found in cribellate silks. These features of orb-web silks conspire to reduce the visibility of silks, as anyone who has inadvertently stumbled through an orb-web can attest, even in bright sunlight.

Biologists have suspected for some time that orb-weavers don't just customise the mechanical properties of the silks, but the optical properties as well [5]. These hypotheses have proven difficult to test however, mainly because so little is known about the optical properties of the silks.

When we commenced our work on spider silks, only very coarse measurements of refractive index, and some work on birefringence had been done. Absorption, dispersion and other basic optical characteristics were simply unknown.

To better characterise the optical properties of spider silks, we needed to first and foremost be able to accurately measure refractive index. The challenge with spider silks is their small diameters (< 10 µm, Fig. 2) and the fact they cannot be cleaved in the same way optical fibres can, which prohibits the application of "standard" refractive index measurement techniques.

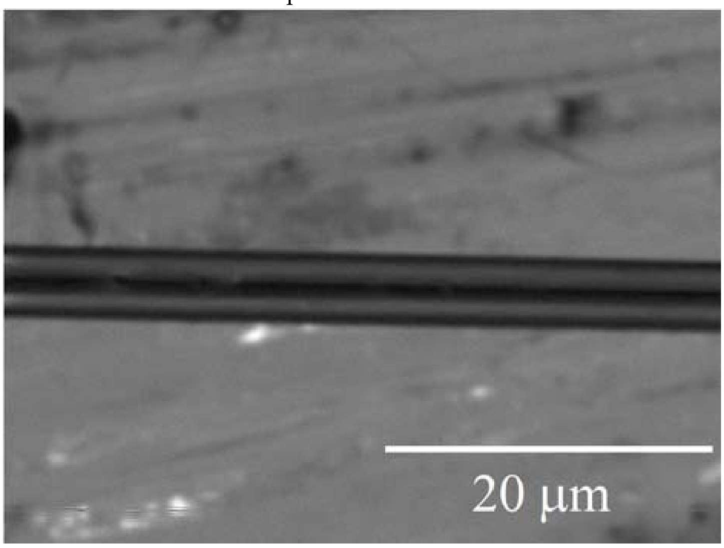

Figure 2. Major ampullate silk of a St. Andrew's Cross spider (*Argiope Keyserlingi*) taken using environmental (low-resolution) scanning electron microscopy, with a measured diameter of around 4.5 µm.

Figure 3. Major ampullate silk of a St. Andrew's Cross spider (*Argiope keyserlingi*) silk immersed in liquid. Silk is illuminated with polarisations (from right to left); parallel to the silk axis, 64 degrees to the silk axis, and perpendicular to the silk axis.

In 2011, we successfully developed a method for accurately measuring the refractive index of orb-weaver silks, which worked based on the well-known principle of refractive-index matching combined with quantified digital imaging [6]. Essentially, we would immerse the silk in a liquid and measure its visibility with a standard, bright-field microscope, using liquids that had a known refractive index, certified by a standards agency, such as NIST. With a series of such measurements, we showed that accuracy and precision better than $\pm\ 5 \times 10^{-4}$ was possible. Moreover, this technique could be applied at any wavelength with sufficient signal, enabling dispersion measurements. For birefringent silks (such as major ampullate silks), the polarisation of the illumination source could be manipulated to greatly expedite this measurement process [7] (Fig. 3).

More recently, our efforts have been focused on measuring the absorption of the spider silks. When attempting to refractive-index match a silk with a liquid, the matching is never perfect (even when using polarisation to continuously "tune" the refractive index of the silk). Some residual visibility exists because of the mismatch in the absorption of the silk and immersion liquid. Using well-known scattering formulae for cylinders (Fig. 4), it is possible to equate this residual visibility with the absorption of the silk [8].

Interest in spider silk optics now extends beyond the investigation of biological functions - researchers are now beginning to contemplate whether there are serious technological niches that could be filled by spider silks or spider-silk like materials. Last year, Huby *et al.* demonstrated light guiding in spider silks, using the silk as an interconnect between two optical devices, and measuring a loss of 10 dB/cm at a wavelength of 633 nm [9]. Spider silks used in this manner could act as interconnects that are highly resistant to mechanical stresses.

Orb-weaver silks can be incredibly fine, with diameters as small as 50 nm, which is comparable to the smallest optical fibre tapers. Tapered fibres are used principally as mode-converters, refractive index sensors and in nonlinear frequency generation. The nanocomposite structure of spider silks is suggestive of a high nonlinear polarisability, so spider-silk like materials may be better suited to nonlinear frequency conversion than conventional materials like glass. We have completed preliminary measurements of their nonlinear properties and we are further refining the experimental techniques to achieve precise and accurate measures.

Much of the technological interest in silk-like materials lies in the biocompatibility and anti-microbial properties that arise from the protein structure. Spider silks, for example have been used as scaffolds for the regeneration of skin and nerve tissue [10]. Prof. Fiorenzo Omenetto's group at Tufts University have crafted a range of optical biomedical devices using thin films derived from silkworm silk (which is similar to spider silk) [11]. Spider-silk based devices with fibre-like geometries could in future complement these existing planar devices.

While natural silks are compelling in their own right, future technological applications will likely employ silk-like materials that have been modified through the addition of synthetic nanocomposite elements to the silk structure. Lee *et al.* have demonstrated for example, that spider silk strength can be improved with the addition of metallic nanoparticles [12]. Modification of optical properties using nanoparticles in materials such as glass and polymers has been widely reported; it is therefore a logical step to investigate the use of nanoparticles to enhance spider silks.

Envisaging the optical applicability of spider silks is timely due to the mass-production capability being pursued by companies such as Spiber and Araknitek. Mass production of spider silk to date has traditionally not been possible due to the cannibalistic tendencies of spiders preventing farming on any meaningful scale. Researchers and entrepreneurs have turned to transgenic methods to

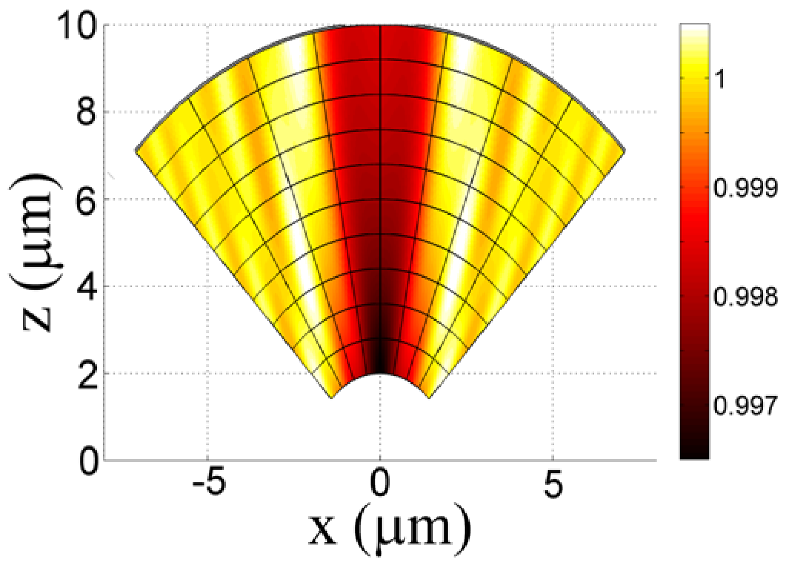

Figure 4. Calculated scattering profile of a 2 μm diameter single-cylinder silk immersed in liquid with the real-refractive-index component matched and the imaginary refractive index mismatched by 10^{-4}. Wavelength was set to 540 nm and polarisation set to be parallel to the silk axis. Values in the scale bar are relative to the incident irradiance.

facilitate the mass-production of spider-silk like materials. The earliest transgenic approach consisted of combining spider genes with those of goats, causing the goats to produce spidroin (the liquid precursor to spider silk) in place of ordinary goat's milk, before spinning the spidroin into silk via artificial means. More recent efforts have focused on transgenic silkworms and *E. coli* bacteria.

Spider-silk based optical components could be manufactured efficiently and sustainably, an important consideration given the economic and environmental issues currently facing us.

Acknowledgements

Spider silk photonics research at Macquarie University was supported by the U.S. Defense Advanced Research Projects Agency and the Army Research Office under contract number W911NF-10-1-0256 (2010-2011) and is currently supported by Australian Research Council Discovery Project DP130102674. The author would like to thank his co-authors and colleagues, Prof. Deb Kane, Prof. Mariella Herberstein, Dr. Nishen Naidoo and Mr. Greg Staib.

Media coverage

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Douglas Little was awarded the 2014 National Measurement Institute (NMI) Prize in connection with this work. He is with MQ Photonics Research Centre, Macquarie University.

News

Jim Piper celebrated in Queen's Honour List

Congratulations to Professor Jim Piper, one of the founders of the Australian Optical Society, who was recognised on the Queen's Birthday list as a member (AM) in the general division 'for significant service to tertiary education, particularly through research in applied laser physics'.

Professor Jim Piper

AOS members receive Future Fellowships

Congratulations to AOS members, Warwick Bowen and Peter Munro on being recently awarded Future Fellowships by the Australian Research Council. Dr Munro's fellowship targets the development of novel 3D optical microscopy to image deeper within tissue, ultimately aiding research fields such as neurobiology, while A/Prof Bowen's work aims to pioneer technologies to observe and control the microscopic world with unprecedented precision, and apply them to realise practical sensors with unrivalled performance.

AGM Save the Date – Thursday 6 November

The Australian Optical Society's AGM will be held during the IPOS symposium at the University of Sydney 6-7 November during the lunch break on Thursday 6 November. Details will be circulated via email once finalised.

International Year of Light

Preparation is underway for the International Year of Light, with an Australian website recently launched, light2015.org.au. There will be events throughout 2015 – feel free to contact the organising committee if you have any ideas or want to get involved. The aim is to highlight the vital role that light and light-based technologies play in improving the quality of people's lives worldwide.

To contact the Australian IYL Steering Committee, email light2015@aip.org.au.

INTERNATIONAL YEAR OF LIGHT 2015

Exploring the Nanoworld with Fluorescent Silken Nanodiamond

by Asma Khalid, Fiorenzo Omenetto and Snjezana Tomljenovic-Hanic

Our group at the University of Melbourne is actively involved in research in diamond including its use in bio-applications. Research is simultaneously underway at Tufts University to develop biocompatible silk-based bio-chips for health monitoring *in-vivo*. We have obtained excellent results incorporating nanodiamonds (NDs) into a silk matrix. The new compound was found to be highly transparent in the visible and near-infrared range matching the diamond optical centre emission. A significant increase in counts, with 2-4 times higher collection efficiency than ND single emitters without silk matrix was recorded. The toxicity test of this compound revealed a non-inflammatory response. This work, published in Biomedical Optics Express 2014, Khalid *et al*, attracted significant media attention after it was highlighted by OSA News.

Introduction

Optical centres in nanodiamond (ND) are being increasingly viewed as crucial building blocks for the development of a variety of advanced biotechnology applications due to their outstanding photostability and biocompatibility [1-3]. In particular, the negatively charged nitrogen-vacancy centre (NV^-) has been extensively explored for biosensing applications.

To date the smallest NDs used for biomarking applications are single digit nm in diameter [4], as the smaller the crystal, the more likely it is to pass through membranes freely. However, creating (sub-) nanometre size NDs hosting stable luminescent defects is a challenge, because blinking is one of the main obstacles to their widespread use [5]. Encouraging results from Australian scientists show that encapsulating an ND with a polymer improves its photostability [5]. It is believed that the change of the effective dielectric constant caused by polymer coating prevents the photoelectron from being trapped at or near the surface thus mitigating blinking. Coating with silk has the same effect, with the additional advantages of biocompatibility, non-inflammatory response, and environmentally friendly production and disposal [6].

Another issue in the use of NDs in biological applications is that functionalization of the diamond surface for specific biorecognition is complicated [2]. Additionally, surface treatment can significantly affect photoluminescence (PL) properties and questions remain as to its biocompatibility after chemical treatment [2]. On the other hand, silk functionalization is relatively straightforward. It has been shown that silk can incorporate a variety of proteins and enzymes that remain biochemically reactive. This functionalization can be as simple as mixing the dopants in with the silk solution after purification [7] or by direct chemical functionalization of chemical groups within the silk fibroin [8].

The safety and efficacy of silk is proven [9,10] and silk fibroin has approval for medical use from the US Food and Drug Agency. Silk has been used in medicine for centuries but only recently has fabrication of optical silk fibres and thin films with high optical quality been demonstrated [9]. Silk fibroin is a naturally occurring protein polymer (or biopolymer), composed of some 5000 peptides, found in conjunction with the binding protein sericin in structural fibres spun by spiders and silk-moth pupae [9]. The silk fibroin films and fibres are transparent and clear, with optical transmission of over 95% in the visible and losses as small as 0.25 dB/cm. This is extremely important as the emission of the optical centres of interest is in the visible and near-infrared wavelength range. There are very few materials used in photonics that are

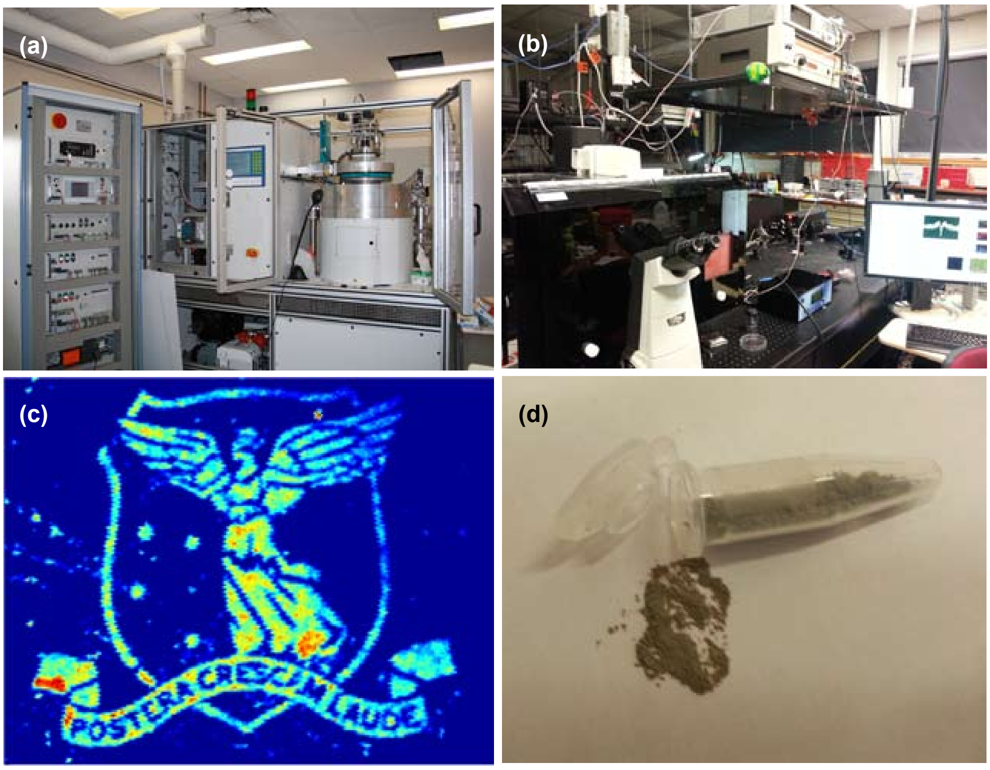

Figure 1. (a) CVD chamber for diamond growth and (b) one of five confocal microscopes at the University of Melbourne. (c) Confocal laser scanning microscopy image of patterned area fabricated using E-beam lithography and seeding with colloid NDs after CVD growth - UoM logo [3]. (d) Commercially purchased NDs - 3 nm average size.

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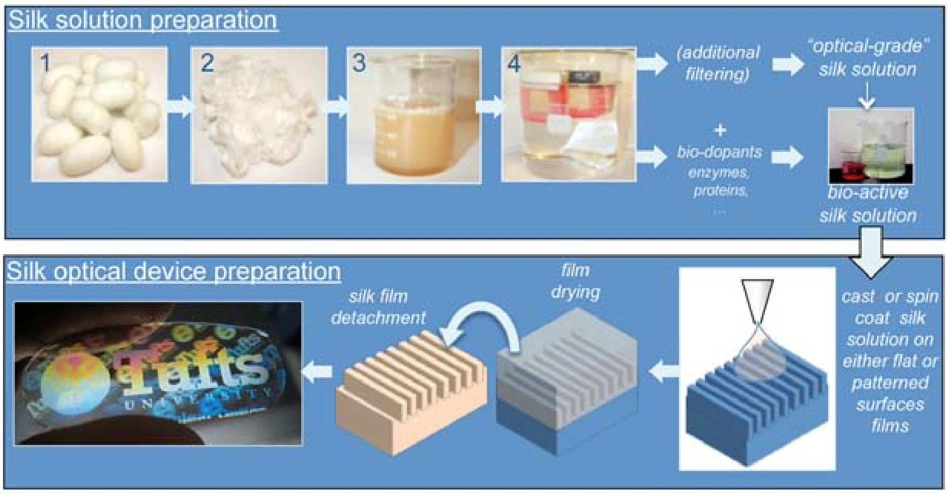

Figure 2. The processing steps of silk optics from silk cocoons to optical structure, in this case a white-light hologram, fabricated at Tufts University [9].

transparent in this wavelength range. It is also extremely important that the silk-based optical structures are processed at room temperature, as processing at higher temperatures can affect emission properties of optical centres in fluorescent NDs [1].

While nanodiamonds and silk have attracted much research attention individually, the combination of these two extraordinary biocompatible materials was pursued for the first time. We have combined these two materials as their physical properties perfectly complement each other [6].

Results

First, the spectral properties of silk films were investigated with and without NDs. Both films were found to be highly transparent with transmission across the visible spectrum. However, small losses in transmission, less than 5%, were measured for the ND doped silk film, which can be attributed to the scattering of light by NDs [6].

Second, the change in the emission properties of NDs embedded in silk relative to air was studied at the University of Melbourne. The ND solution was drop-cast on a marked silicon substrate that provided the ability to address the same NDs before and after silk coating. Silk coating was performed at the University of Sydney.

Scanning confocal fluorescence maps were taken with an excitation power of 600 µW at a wavelength λ = 532 nm and fluorescence collected in a spectral window of 650 nm to 750 nm. Figure 3(a) shows a 5 µm × 5 µm confocal map of NV fluorescence from NDs on the silicon substrate. The bright fluorescent circular regions in the image correspond to NDs that can contain single or multiple NV-defects. The presence of a single defect inside a particular ND was confirmed using a Hanbury-Brown and Twiss (HBT) single photon antibunching system [6]. The silk-coated-ND film on silicon was again analysed with the scanning confocal fluorescence microscope. Using reference markers, the same 5 µm × 5 µm region of Fig. 3(a) was located and re-scanned as shown in Fig. 3(b).

The background-subtracted average counts after silk coating were found to be around 2.2 times higher than the average counts before coating in this particular case. A total of eleven defect centres with single photon emission were analysed. Each of the single centres was found to exhibit an enhanced emission rate after being covered with silk. The enhancement factor was found to vary in a range of 1.6 - 3.8 times. The experimental enhancement data was found to be in good agreement with the theoretical modelling showing an increase in the range from 2.8 to 4.9 times for parallel and orthogonal polarizations of the dipoles respectively [6].

Lastly, the non-toxicity of the ND-doped silk films was evaluated through an *in-vivo* mouse model at Tufts University. The ND-silk films were implanted subcutaneously into female Balb/c mice, as shown in Fig. 3(c). The films were retrieved after two weeks to determine the inflammatory response. The experiment revealed the absence of any severe inflammatory response, indicating the implanted devices induced no significant adverse effects to the mice. The experiments were pursued in accordance with Institutional Animal Care and Use Committee (IACUC) approved protocols.

Conclusions

Our results of silk coated NDs showed a significant rise in brightness compared to the original brightness of the ND single emitters without silk coating. The rate of enhancement was found to be in good agreement with the theoretical model. The toxicity test of the ND-silk films *in-vivo* revealed a non-inflammatory response. In the next step, the optical superstructures, consisting of silk-natural biopolymer and fluorescent NDs will be designed, constructed and tested for future biomedical applications. We expect numerous biotechnical and medical applications to emerge as these two extraordinary biocompatible materials perfectly complement each other.

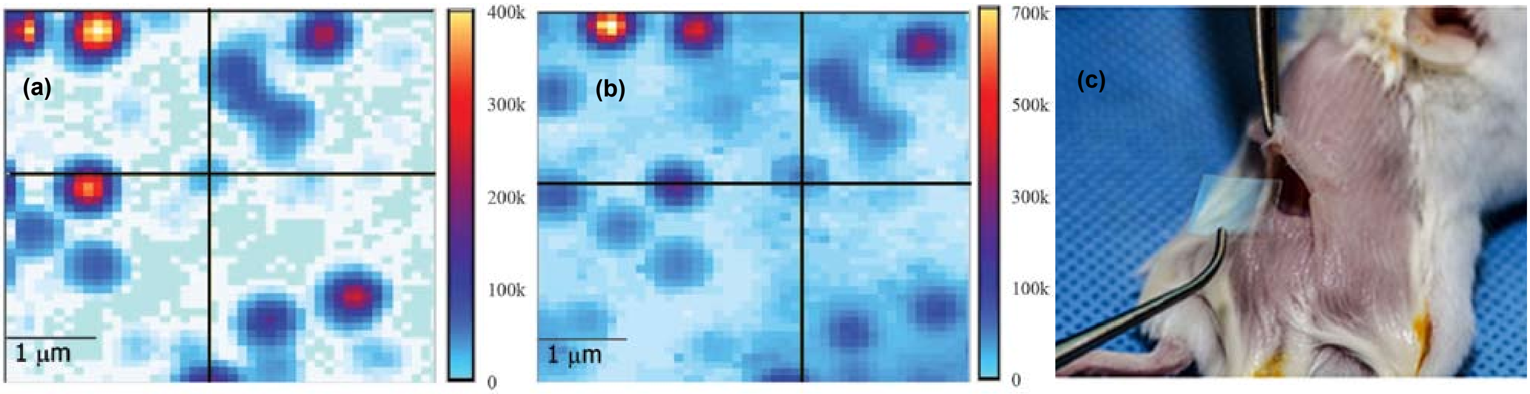

Figure 3. Scanning confocal fluorescence map of a 5 µm × 5 µm region of the sample (a) before and (b) after coating with silk. The maximum counts of the confocal fine scan increased after coating - evident from the intensity scale bar to the right of the images. The cross hair specifies an ND containing a single defect centre. (c) Animal toxicity test of ND-silk films by introducing films into the animal tissue for two weeks.

Acknowledgments

The authors acknowledge H. Tao, J.E. Moreau, D.L. Kaplan, F.G. Omenetto, B.C. Gibson and P. Domachuk for their contributions to the projects. P. Domachuk sadly passed away in January 2013. This work was partly supported by an award under the Merit Allocation Scheme on the National Facility of the National Computational Infrastructure. A. Khalid acknowledges Melbourne Research Scholarships awarded by The University of Melbourne and the Overseas Research Experience Scholarship (ORES) that enabled her to visit Tufts University for three months. S. Tomljenovic-Hanic acknowledges an ARC Australian Research Fellowship (DP1096288).

Media coverage

e! Science News (esciencenews.com/articles/2014/01/27/a.silk.coat.diamonds.makes.sleek.new.imaging.and.drug.delivery.tool)

phys.org (phys.org/news/2014-01-silk-coat-diamonds-sleek-imaging.html)

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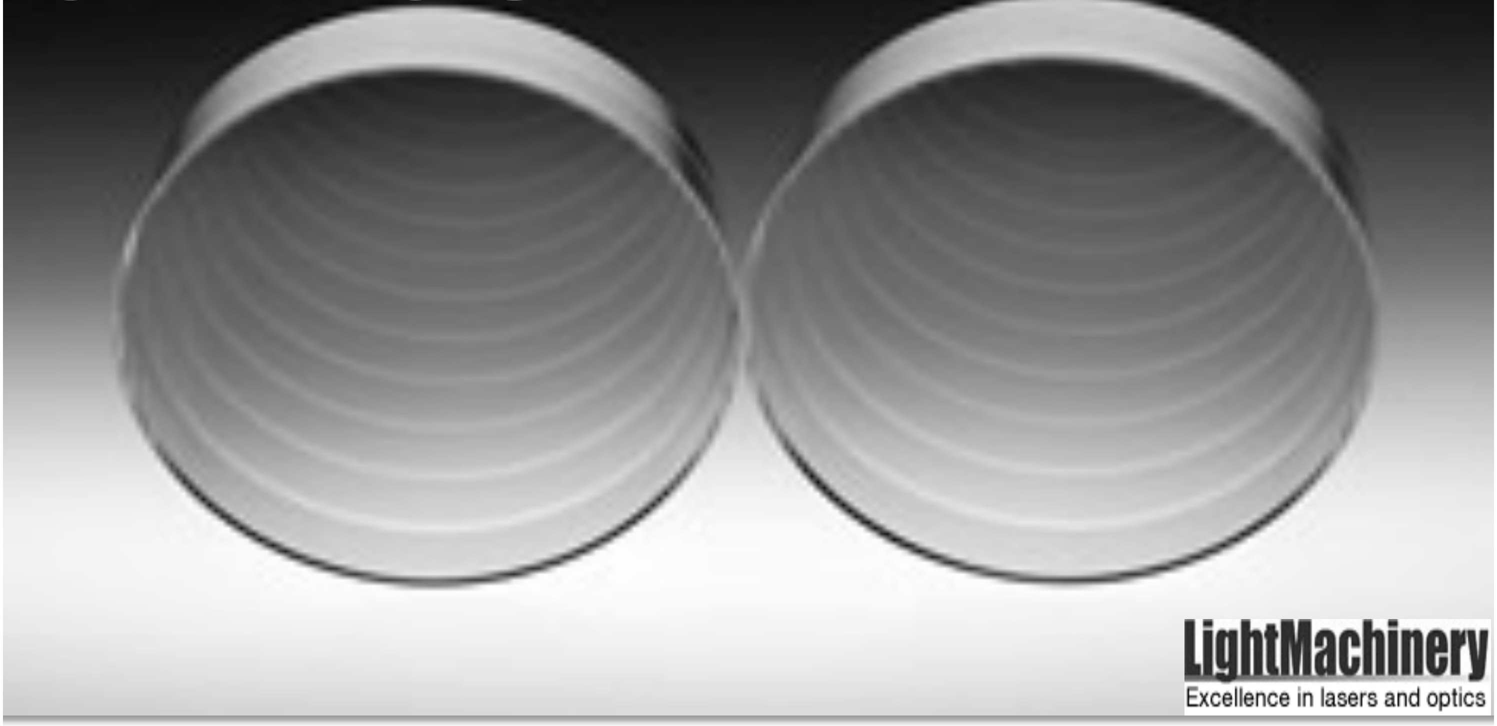
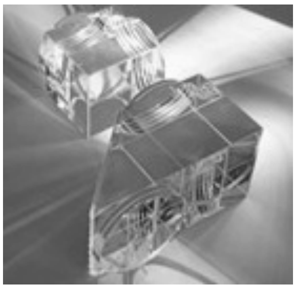
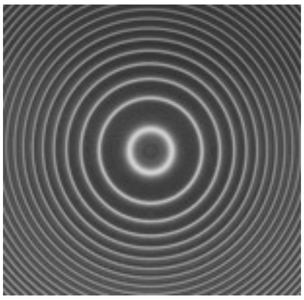
OPTICS

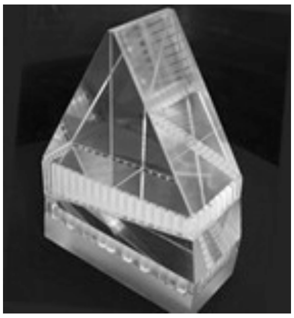




Beam splitters:
Can be cubes, plates, hexagons, pentagons, polarizing, non –polarizing, narrowband, broadband, dielectric, air-spaced, metal, cemented, optically contacted.



Etalons:
Solid etalons, air spaced etalons, piezo tunable etalons, Gire Tournois etalons. Fabry Perot etalons from 1mm square to 100mm in diameter.



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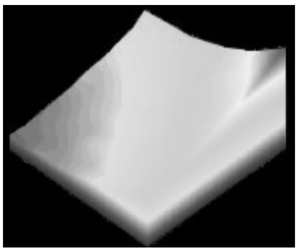

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Cleaning up Earth's Orbital Trash using Lasers

by Lyle Roberts

Orbital space debris is presenting itself as one of the greatest threats to the continued utilisation of the near-Earth space environment, and Australia has the right expertise to do something about it. The solution? Lasers.

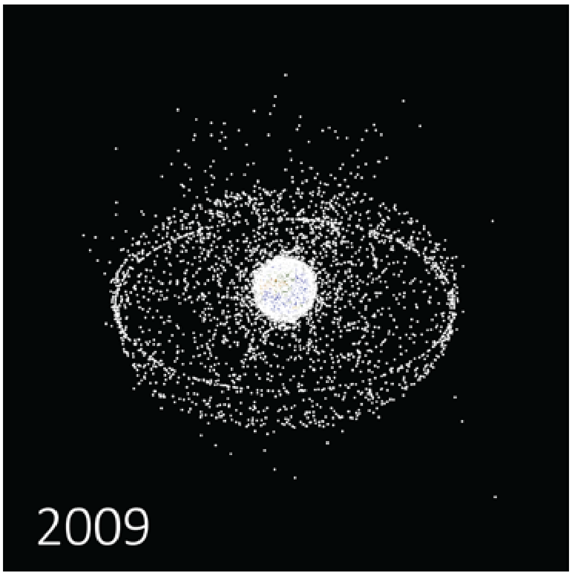

Figure 1. Orbital debris catalogued by NASA as of 2009 [1]. The white orb in the middle is the Earth shrouded by debris in low Earth orbit. The distinct outer halo is the geosynchronous orbit (GEO).

In the last 50 years society has become increasingly dependent on the utilisation of the near-Earth space environment. The global positioning system and Earth observing weather satellites are just a couple of examples of space assets we use on a daily basis. Their role in our lives has become so common that we often take them for granted; and if we are not careful, we could lose it all. In the same way that garbage is damaging planet Earth, the amount of trash we leave in orbit following satellite launches is beginning to reach dangerous levels.

Space debris

Space debris is a significant and pernicious threat to near-Earth space activities, motivating the development of various technologies to clean it up. The list of potential solutions is varied and highly ambitious, ranging from direct mechanical interaction such as electro-dynamic tethers, to using high-power ground-based lasers to physically push debris out of orbit.

In October 1957 Sputnik became the first human-made object ever to be launched into space, and according to NASA [1], the total number of satellites that remain in orbit since then totals just under 4,000 - over half of which are no longer operational. But that's not all that remains in orbit; in addition to satellites there are currently over 13,000 other objects orbiting the Earth that have been catalogued by the Space Surveillance Network operated by the United States Air Force (USAF). This 'trash' consists of discarded rocket stages and fragmentation debris; basically anything in orbit that serves no useful purpose. But that's just debris we can *see* - it is estimated that there are over 500,000 uncatalogued fragmentation debris objects in orbit, most of which are no larger than 10 cm in size.

The Kessler syndrome

The 2013 movie Gravity capitalized on a theory called the Kessler syndrome [2,3] - a scenario where the density of orbital debris reaches a critical point where just one more collision would trigger a runaway chain reaction of collisions rendering low-Earth orbit (LEO) unusable. An event of this kind could be catastrophic, potentially destroying key assets in LEO (including the international space station and many earth-observing weather satellites), and making it very difficult to safely launch anything beyond LEO.

Figure 2 shows the total number of orbital objects being tracked by the USAF as of 2013 [1]. This visual representation of the natural population growth of catalogued objects in near-earth orbit highlights the three primary mechanisms that influence the debris population: i) the consistency with which new satellites are launched into orbit; ii) the occurrence of major debris-debris, debris-satellite, and satellite-satellite collisions; and iii) the natural orbital decay of objects due to atmospheric drag.

It is unlikely that the number of satellite launches each year will decrease, which means the population of objects in orbit will (at the very least) continue to climb linearly. Realistically we can expect the debris population to grow rapidly due to mutual debris collisions, which - if nothing is done to stop it - will soon become the dominant source of new space debris.

In early 2007 a Chinese anti-satellite (ASAT) demonstration generated 2317 trackable debris fragments, along with over 150,000 untrackable objects smaller than a cricket ball. Four years later in February 2009 the accidental collision between the Iridium-33 and Russian Cosmos-2251 communications satellites generated over 2,000 new trackable debris fragments, and an unknown amount of untrackable debris [1]. If this isn't immediately alarming then consider it this way: these two collisions generated as much debris in two years than the previous 30 combined, and despite the fact that the total number of collisions resulting in the termination of an active satellite is only four (as of early 2014) [4], each time a collision occurs, the likelihood of subsequent collisions rises.

The population of orbital debris is, however, somewhat balanced by natural orbital decay due to atmospheric drag, which gradually degrades the velocity and therefore altitude of orbiting objects.

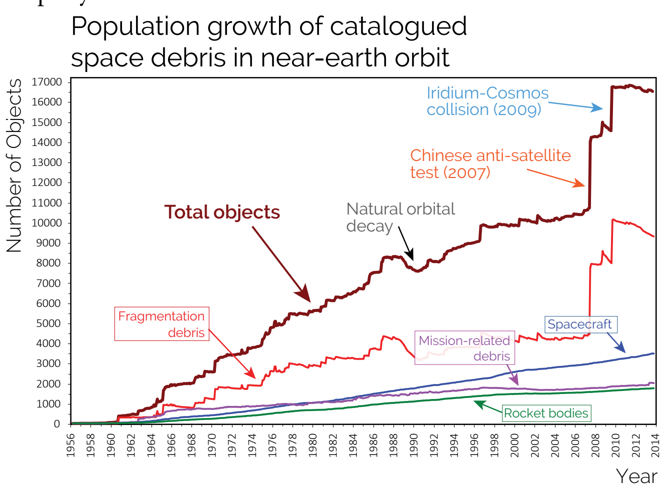

Figure 2. Total number of objects in Earth orbit by object type officially catalogued by the United States Space Surveillance Network. There was more debris generated between 2007 and 2009 than the previous 30 years combined.

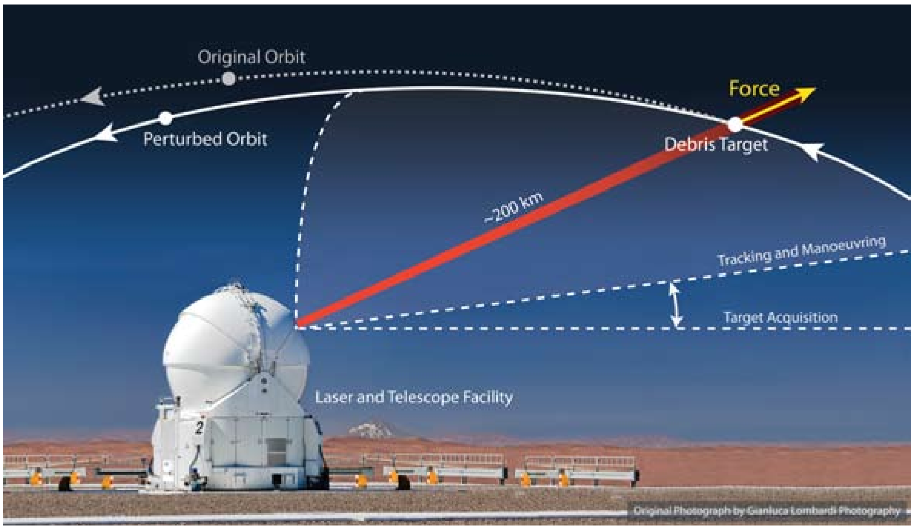

Figure 3. Space debris tracking and manoeuvring concept, adapted from [4,5]. Original photo by Gianluca Lombardi Photography.

While it can be expected that the overall population of orbital debris will decrease over time as a result of drag, it is important to recognise that it will do so *very* slowly - certainly not any faster than the overall rate of debris generation. Furthermore, because drag is proportional to the density of the atmosphere (which decreases with altitude), the effect it has on debris in high-Earth orbits is borderline negligible. Debris in high-Earth orbits will remain there for thousands of years.

Space environment management

In order to preserve the near-earth space environment it is necessary to add a fourth mechanism to the list above: iv) active space environment management; an intervening mechanism that aims to remove debris from orbit and reduce the overall likelihood of future collisions.

The greatest risk we face at this stage is more catastrophic Iridium-Cosmos type collisions. The United States Space Surveillance Network (SSN) continuously catalogues the trajectory of most large debris objects in orbit, forecasting days in advance to calculate the likelihood of potential collisions. This information allows satellite operators to assess the risk and, if necessary, manoeuvre their assets to avoid collision. This is, however, only a useful strategy if at least one of the colliding objects has the ability to change its orbit. The majority of large debris objects in orbit do not have this capability, and we are powerless to do anything about it.

The good news is that development of the technology needed to address the space debris threat is already underway, separated into two categories: direct mechanical interaction / rendezvous (e.g., electro-dynamic tethers and grapples), and remote laser interaction, including both precision range measurements of debris targets and manoeuvring via ablation and/or photon pressure. Current cost estimates for removing large objects by rendezvous sit at hundreds of millions of dollars per target. There is also a relatively high risk associated with deploying intervening 'debris-clearing' satellites into orbit. For these reasons, many direct mechanical interaction solutions are not yet mature enough to be implemented. A cheaper, lower risk solution is to use high-power ground based lasers to push debris around in orbit using high-energy ablation and/or photon pressure [4,5]. The advantage of this approach is that if a collision is likely to occur between a debris fragment and an operational satellite, then it will be much cheaper to push the debris out of the way of the satellite, instead of the other way around. This concept is shown in Figure 3, and also applies for preventing debris-debris collisions.

Ground-based laser systems

A number of ground-based laser ranging systems are currently in operation around the world [5], none of which have the capability to significantly alter the orbit of pieces of debris. These systems typically use pulsed lasers to illuminate the target so they can track it, and can track debris as small as a cricket ball. Their ability to track smaller objects is limited by the poor signal-to-noise ratio of the reflected light returning from the debris target, which itself depends on the total amount of light hitting it. The smaller the target, the less light it reflects. The obvious solution to this problem is to direct more light onto the target, but this isn't very straightforward since lasers are limited in power for various reasons. But essentially by increasing the total power on target, and moving to continuous wave (CW) operation instead of pulsed lasers, we may be able to improve the overall ranging accuracy of existing systems, and provide the capability to remotely manoeuvre space debris via ablation (where the intensity of the laser is so great that it evaporates material from an object's surface), and/or photon pressure, which is effectively momentum transfer from photons to a physical object. Both of these capabilities have not yet been demonstrated for various reasons, one of which being our ability to direct sufficient light onto the target.

Optical Phased Array

The total amount of power delivered by existing systems can be increased using an optical phased array (OPA) to coherently combine multiple lasers. In essence, an OPA uses the interference between multiple, coherent lasers to form a coherent and contiguous optical wavefront in the far field. A consequence of this coherence is that the peak far field intensity of the central interference lobe scales with the square of the number of apertures (N^2), compared to linear (N) scaling for incoherent combination as shown in Figure 4. OPAs can also dynamically manipulate the distribution of optical power in the far field, permitting beam steering and forming, which allows them to pre-compensate for atmospheric turbulence.

Both coherent beam combination

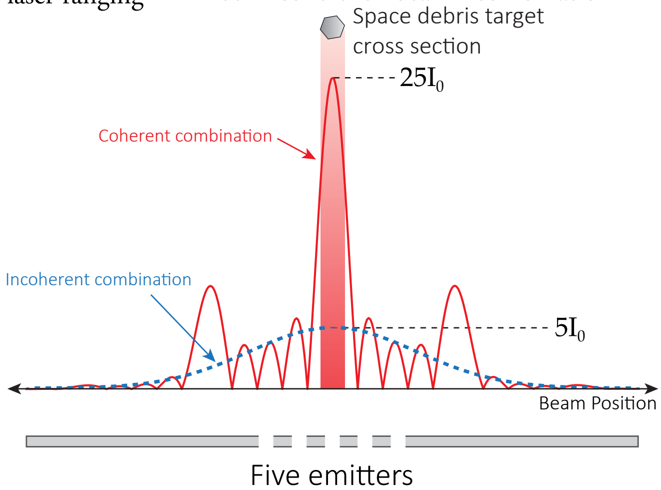

Figure 4. The intensity of the central interference fringe produced by coherent combination scales with the square of the number of emitters.

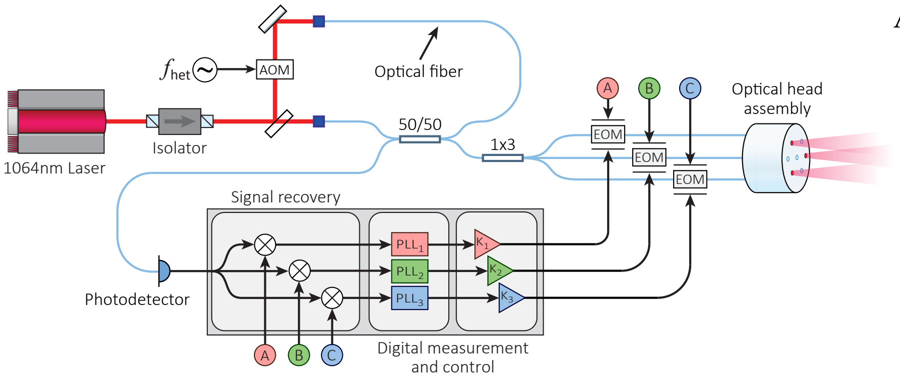

Figure 5. Simplified architecture of an internally sensed optical phased array. A high-power version of this would have separate lasers or amplifiers in each arm of the array.

and beam steering/forming require the stabilisation and precise control of the output phase of each transmission aperture. A simplified architecture of the internally sensed OPA developed at the Australian National University is shown in Figure 5 [6]. The ability to measure and control each emitter independently is enabled using digitally enhanced heterodyne interferometry [7], which simultaneously isolates the phase information of each emitter using spread-spectrum modulation techniques, similar to those used in the global positioning system and some mobile phone systems. This technique of independently measuring the phase of each emitter shifts the complexity from the optical system into digital signal processing. It is also readily scalable and is well suited to the computational power of field-programmable gate arrays.

A key feature of the OPA we are developing is internal sensing, where all the control signals needed to stabilise the relative output phase are derived from the small fraction of light that is reflected back into the fibre at the OPA's glass-air interface. The basic principle of internal sensing is that the relative phase of the light at the array's output can be inferred by measuring the back-reflected light. When each emitter is illuminated by the same source, then the relative phase at the output depends primarily on the differential phase shifts experienced through uncommon optical path lengths in the system. Internal sensing infers the differential phase shift of the double-pass signal reflected off the emitter's surface. Feeding back the measured phase information to stabilise the relative optical path lengths of each emitter then controls the relative phase at the output of the array. If all emitters share a common reference surface that is either polished flat, or calibrated accurately, then the phase of the combined wavefront in the far field can be controlled [6,8].

Performance

The measures of performance for OPAs are RMS output phase stability across all emitters (in this case three), and intensity scaling. The RMS output phase stability tells us how good the control system is at stabilising the relative output phase between all of the emitters. Any changes in phase at the output will alter the distribution of optical power in the far field, so if the controller is doing its job then we should not expect to see many changes at the detector. The measured result was found to be $\lambda/120$, where λ is the wavelength of the laser being used (in this case 1064 nm). What this result tells us is that when the system is locked, the relative output phase does not vary by more than about one-hundredth of a wavelength. To provide some gauge as to whether or not this is good, current benchmarks sit at around $\lambda/20$.

Intensity scaling was measured using a camera to record a cross-section of the interference fringes for one, two, and three emitter configurations. The results are shown in Figure 6 showing both normalised simulated and measured results. The normalised intensity for the one, two, and three emitter configurations was measured to be 1.00, 3.87, and 9.03 respectively. This is a great result because it tell us that we are fully benefiting from using coherent techniques for beam combination.

Future Development

With the validation of the internally sensed OPA architecture, we are now working towards scaling the total output power to more than 45 Watts as a stepping stone toward powers high enough to remotely manoeuvre debris (on the order of kilo-Watts). To do this we are investigating using multiple high power lasers, or fibre amplifiers. It is expected that the most viable option will be to use fibre amplifiers arranged in a master-oscillator power-amplifier configuration, and test results for this will be published soon. The next stage of development beyond that will be integration with the laser ranging facility operated by EOS Space Systems at Mount Stromlo in Canberra.

This research is supported by an ARC Linkage Grant between the Australian National University and EOS Space Systems Pty. Ltd.

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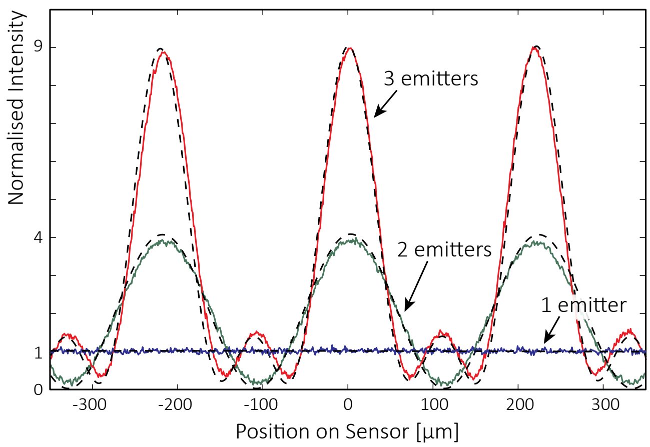
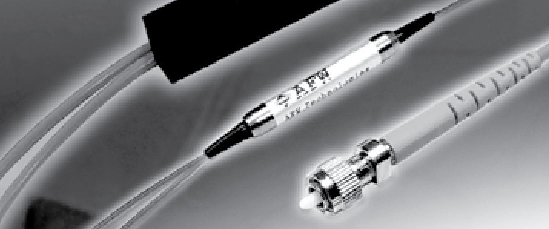


Figure 6. Simulated (dashed) and measured (solid) intensity scaling using an optical phased array.



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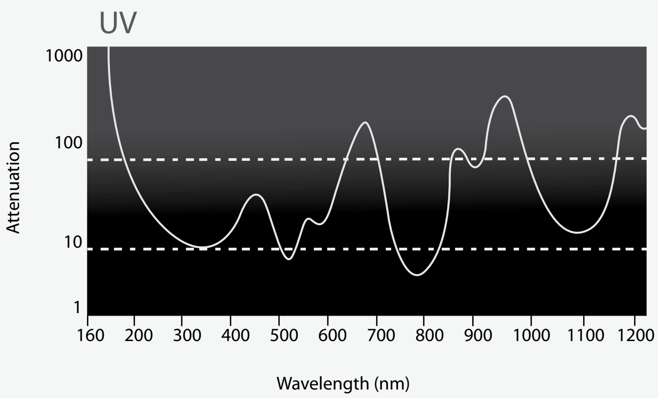

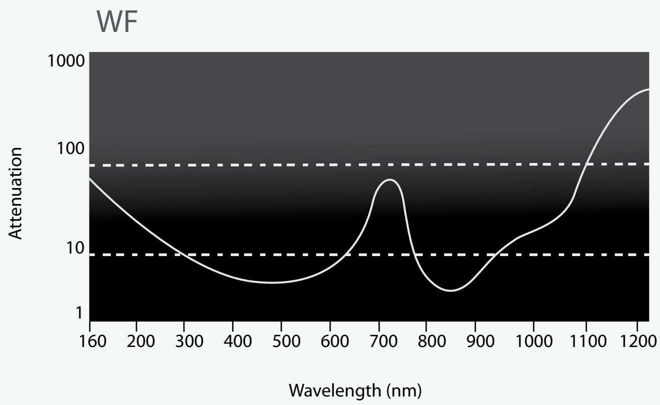

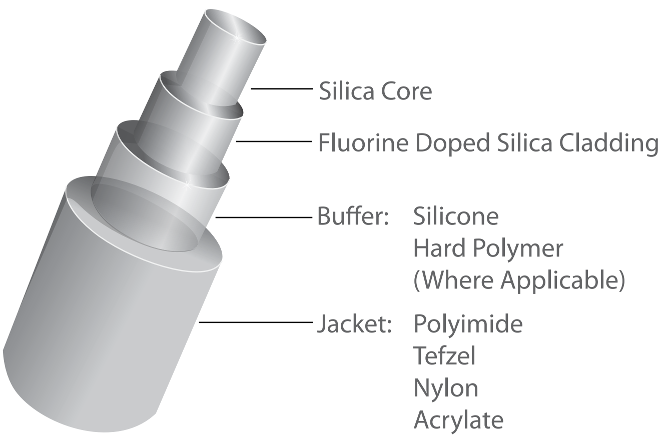

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The 2015 International Year of Light

Summary:

The International Year of Light is a global initiative to encourage engagement with both the scientific and cultural elements of light and light-based technologies.

Light-based technologies are a major economic driver with the potential to revolutionize the 21st century as electronics did in the 20th century. The IYL will highlight to the citizens of the world the importance of light and optical technologies in their lives, for their futures, and for the development of society.

Activities are planned so that people of all ages and all backgrounds from all countries will enjoy and appreciate the central role of light in science and culture, and as a cross-cutting scientific discipline that can advance sustainable development.

The International Year of Light (IYL) has more than 100 partners from over 85 countries, accompanied by the UNESCO **International Basic Sciences Programme (IBSP)**. The IYL will consist of coordinated activities on national, regional and international levels.

Australian Program:

Australia's International Year of Light program will draw from ideas including, for example:

- Public:
    - Leveraging key light events in including VIVID, Enlighten, Sydney Festival, White Night etc.
    - Engaging large sporting/entertainment events to use light-based technologies to raise awareness
- Government:
    - Members of the optics community will compile Australian information and statistics on the benefit of optics to the Australian economy.
    - The optical sciences community will use IYL to promote optics as a national research priority.
    - IYL aims for a significant presence at Science meets Parliament in March 2015
- Education:
    - IYL will generate teacher resources to help promote optics education
    - IYL will leverage museums to tailor existing programs to incorporate optics themes
    - IYL will run a photo competition with a "light" theme amongst schools to enable students to see the importance of light in their daily lives.

Australian Committee:

The Australian International Year of Light program will be coordinated by:

- ACT: Ken Baldwin (Chair, ANU), Celine D'Orgeville (ANU), Stuart Kohlhagen (Questacon), Delese Brewster (ASTA)
- NSW: Deb Kane (Macquarie), Ben Eggleton (U. Sydney), Fred Watson (AAO)
- Northern Territory: Jim Mitroy (Charles Darwin University)
- Queensland: Alessandro Fedricci, Halina Rubinsztein-Dunlop (University of Queensland)
- South Australia: Andre Luiten (University of Adelaide), Ken Grant (DSTO)
- Tasmania: Marc Duldig (University of Tasmania)
- Victoria: Ann Roberts (U. Melbourne), Warrick Couch (SUT), Andrew Peele (Australian Synchrotron)
- Western Australia: David Sampson (University of Western Australia)
- New Zealand linkage: Cather Simpson (University of Auckland), John Harvey (University of Auckland)

INTERNATIONAL YEAR OF LIGHT

UNESCO

The University of Adelaide OSA Student Chapter is proud to present,

IONS-KOALA 2014

Sunday 23rd to Friday 28th November

What is the KOALA conference?

KOALA is Australia's only student conference in the fields of optics, quantum optics, atom optics, photonics and laser technology. We aim to help encourage the next generation of Australian early career researchers and scientists by providing them with the skills to confidently and successfully enter the broader scientific community. We aim to achieve this by providing a nurturing environment for attendees to experience presenting their research outside of their university, networking and developing collaborations with other student researchers from around Australia.

What should I expect?

KOALA is aimed at research students from around Australia and internationally and runs over 6 days. To make the conference as accessible as possible meals and accommodation are included as part of the registration fee.

The McLaren Vale wine region outside of Adelaide

Throughout the week there will be a comprehensive academic program including both professional development and social activities. The conference program features two international invited speakers, student talks, a poster session and an industry workshop where attendees can meet and greet with representatives from Australian companies and research institutions. Social activities include a Scientific Photography Gallery exhibition organised by the OSA Student Chapter, and the Conference Banquet social day in McLaren Vale — one of the wine regions close to Adelaide City.

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IONS-KOALA 2013 Conference Attendees in the University of Sydney

How do I register?

IONS-KOALA 2014 is open to any University research student, including PhD, Masters, Honours and Undergraduate. The conference program is aimed towards researchers in optics, quantum optics, atom optics, photonics and laser technology. Research outside of these areas is still accepted as long as it is consistent with the spirit of the conference.

Registration is open until 30 September at ions-koala2014.osahost.org/registration

Registration is $170 AUD which will include accommodation, food, and conference activities. Travel grants are available and AOS Members receive a $20 AUD discount.

Final year undergraduate and honours students are invited to apply for the **New Horizons in Science Award**, which will cover **both conference registration and travel costs.**

Visit the official IONS- KOALA 2014 website at ions-koala2014.osahost.org for more details and to register. If you have any questions, feel free to contact us at info@koala2014.com.

We hope to see you in Adelaide during this workshop!

A New Twist on Nonlinear Metamaterials

by Mingkai Liu, David A. Powell, Ilya V. Shadrivov, Mikhail Lapine, and Yuri S. Kivshar

Additional degrees of freedom are extremely valuable for the novel design and advanced applications of metamaterials. Recently, a new generation of nonlinear metamaterials called magnetoelastic metamaterials was introduced, employing various types of electromagnetic-elastic coupling. This brings a number of unusual nonlinear effects into play, including bistability, self-oscillation, chaos and spontaneous symmetry breaking.

The field of metamaterials experienced a rapid development over the past 15 years. Many exotic properties unavailable with naturally occurring materials have been predicted and verified experimentally. These studies revolutionised our traditional methodologies to manipulate electromagnetic waves, and they have inspired many unconventional ideas in optics and photonics, promising various meta-devices [1].

Many of these unusual effects begin with the building blocks of metamaterials - the so called *meta-atoms,* which are artificial sub-wavelength resonators with deliberately designed geometry. One prominent example is the split ring resonator that can support an artificial magnetic response. When two or more meta-atoms are packed together and work as a functional group (so called *meta-molecules*), their interaction can provide additional degrees of freedom to tune the near field and far field responses of the system.

An important practical direction in the development of metamaterials is achieving dynamic control over their exotic properties. This can be done in two different ways. One option is to include nonlinear or tunable elements into meta-atoms, allowing the local electromagnetic environment to be changed by external signals. The other way is to design meta-molecules with a structural degree of freedom so that their mutual interaction can change their geometry and configuration.

Although in general the solutions based on structural tuning have slower modulation speed compared to the ones based on nonlinear or active media, they show advantages in other aspects such as modulation range and the ability to manipulate meta-molecules individually. For example, mechanical tuning is now widely used in THz metamaterials [2]. However, structural deformation based on static electric or magnetic forces is not so straightforward for systems of sub-micrometre or even smaller size.

A CUDOS research team from the Nonlinear Physics Centre at the Australian National University and the University of Sydney are actively working towards the improvement of self-tunable metamaterials. Recently, they introduced the concept of magnetoelastic metamaterials, where the lattice is deformed by the resonantly enhanced electromagnetic force [3]. Such designs are scalable down to tens or hundreds of nanometres; more importantly, interaction between electromagnetic resonance and structural dynamics can provide rich novel effects beyond simple modulation, as has been evidenced by cavity opto-mechanics [4].

The first prototype of magnetoelastic metamaterials comprises an array of meta-atoms embedded into an elastic substrate [Fig. 1(a)]. When the structure is illuminated with a frequency close to the resonance, the material is compressed by electromagnetic forces between meta-atoms, which in turn changes their mutual interaction, shifting the resonance and affecting the electromagnetic forces. Thus, the array compression is determined by the stable equilibrium of the system, when the electromagnetic and elastic forces are eventually balanced. Such nonlinear feedback gives rise to strong self-tuning and bistability [3], with the frequency shift successfully confirmed in a microwave experiment [Fig. 1(b)]. Similar effects have also been demonstrated in a metamaterial composed of flexible helices [5].

Where the power available for possible application is limited, the initial design, based on collinear force balance, is not optimal. For such cases, we introduced a new solution by exploiting the torsional deformation of a chiral meta-molecule composed of two twisted split-ring resonators [6], [see Fig. 1(c)]. Here, we use electromagnetic torque to change the mutual twist angle between the two split-rings, and the restoring feedback

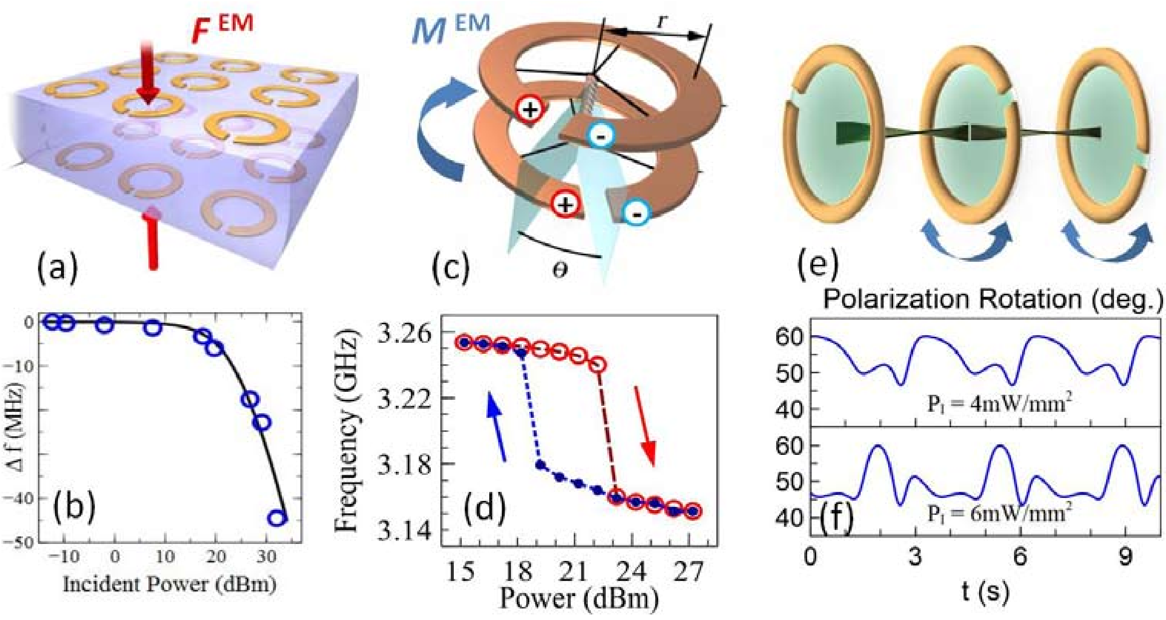

Figure 1. (a) Schematic of magnetoelastic metamaterials and (b) the observed self-tuning effect [3]. (c) A torsional meta-molecule with two split-rings and (d) the observed bistability [6]. (e) A torsional meta-molecule with three split-rings and (f) the dynamic optical activity due to self-oscillation [7].

is provided by the twist of a thin rubber wire. Since the effective lever arm of electromagnetic torque is much larger than the restoring torque, the torsional deformation can be huge even under a moderate pump power level (< 1mW/mm^2). With this design, we experimentally demonstrated a giant bistable response [Fig. 1(d)], and the range of bistability can be well controlled by changing the pump frequency. Such kinds of torsional magnetoelastic chiral meta-molecules provide an ideal platform to study slow nonlinear effects.

While the above examples mainly provide a stationary nonlinear response, our further research revealed that the dynamic response of magnetoelastic chiral meta-molecules is also nontrivial. To demonstrate this, we have extended the two-ring meta-molecule with a third ring, so there are two links for elastic feedback [Fig. 1(e)]. Due to the additional degree of freedom, the system can gain net work from the incident wave to compensate the mechanical damping during oscillation. When the gain and loss are balanced, the system can turn into dynamically stable self-oscillations [7]. Unlike the situation with typical opto-mechanical systems, self-oscillations in our meta-molecule can also be immune against damping. Such a specific situation occurs when all the equilibria of the system are unstable. As a consequence of internal oscillations of the chiral meta-molecules, a scattered wave experiences a dynamic evolution of the rotation of its polarisation. Such dynamic nonlinear optical activity is a unique property hardly found in natural chiral molecules.

Having analysed the basic mechanism of the nonlinear response in single magnetoelastic chiral meta-molecules, we could proceed towards more complex scenarios, when these meta-molecules are assembled in arrays and interact with each other, as happens in bulk metamaterials. In this situation, in addition to bistability and self-oscillations, we can also observe and control artificial phase transition effects, even though no natural phase-changing materials are involved [8].

Most importantly, we have observed a spontaneous symmetry breaking effect in a metamaterial composed of enantiomeric torsional meta-molecules [Fig. 2(a)], i.e. chiral meta-molecules with opposite handedness [Fig. 2(b)]. In such a scenario, the initial configuration of the system satisfies chiral symmetry such that left-

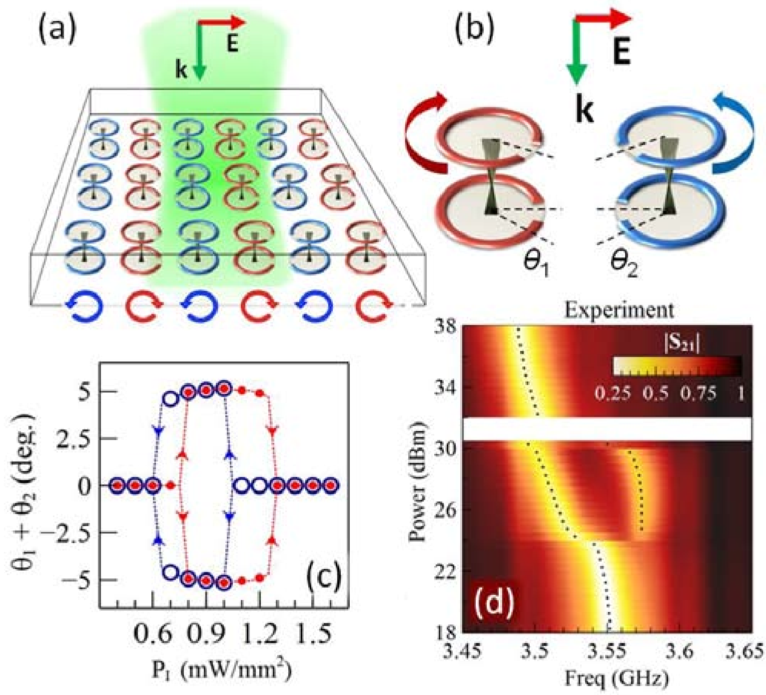

Figure 2. (a) Schematic of a metamaterial composed of enantiomeric torsional meta-molecules. (b) A pair of enantiomeric meta-molecules and (c) the chiral symmetry breaking effect. (d) Mode splitting due to chiral symmetry breaking observed in experiment [8].

handed and right-handed meta-molecules have the same magnitude of electromagnetic response, and the net chirality of the whole system vanishes. However, due to the intermolecular interaction, the system stability changes, and such symmetry can be broken when the incident power exceeds a certain threshold value [Fig. 2(c)]. The chiral symmetry breaking directly leads to nonlinear optical activity, energy localisation and mode splitting. The predicted effects were successfully demonstrated in a microwave experiment where two enantiomeric torsional meta-molecules are electromagnetically coupled. As can be seen in Fig. 2(d), a single resonance under chiral symmetry configuration splits into two new resonances in the power regime where the symmetry is broken. Such achiral-chiral transitions can be considered as an analogue of the phase change from antiferromagnetic state to ferromagnetic state found in iron selenide.

To conclude, our work has shown that by coupling electromagnetic resonances and structural deformation, a rich variety of novel effects can be found in magnetoelastic metamaterials. We are confident that such phenomena should be available in a wide frequency range from microwaves up to optics. At high frequencies, the most favourable structures are dictated by the possibilities of nanotechnology, bringing nano-cantilevers or nano-beams that can support strong opto-mechanical behaviour. It has been predicted that optical metamaterials based on deformation of nano-beams can yield a bistable response under power density as low as 0.2mW/μm^2 [9]. With rapid advances in nano-fabrication and the great design flexibility of magnetoelastic metamaterials, realisation of fantastic novel effects at infrared and optical frequencies can be envisioned, greatly enriching the functionality of future meta-devices.

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A Droplet Approach to Lens Making

by W. M. Lee and T. Kamal

A transparent liquid droplet acts like a thin lens. The natural interplay between gravity and surface tension shapes a hanging liquid droplet into a thin lens with a parabolic profile. Here we describe a simple but powerful approach of making high quality silicone lenses from hanging droplets. These lenses can resolve structures down to 4 µm and cost less than a cent each.

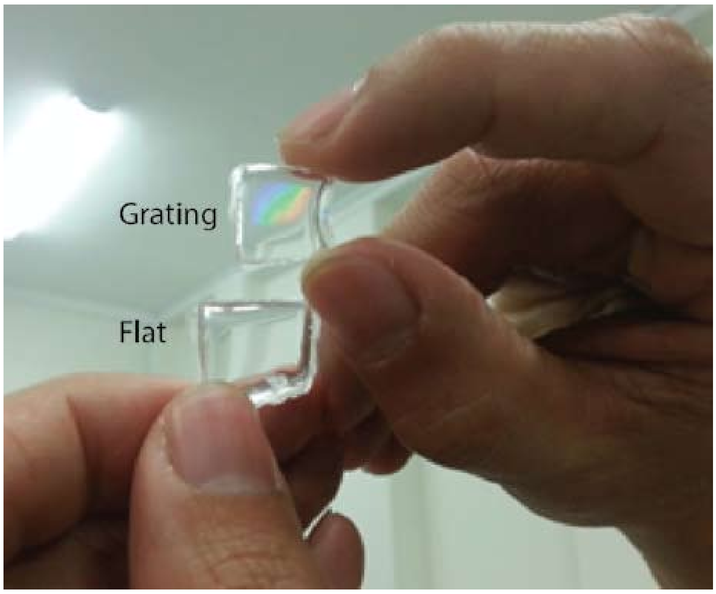

Figure 1. Visual comparison of light dispersion through PDMS blocks: flat and imprinted diffractive grating.

Droplets are made up of molecules held together by intermolecular cohesive forces. The molecular forces that work along the liquid and air interface of a droplet [1] create a smooth surface. The surface is sensitive to surface tensions, temperature gradient and light. Small liquid droplets generally assume a discrete 3D shape (e.g. pendant, sphere, and hemisphere). Commercial technologies such as inkjet printers, 3D printers, nebulizers and cell sorters rely on reliable and speedy production of droplets for printing, aerosol delivery and encapsulation of biological cells. At finer scales (micrometre), light forces [2] can also shape micro-droplets.

The basic working principles of droplet-based printing rely on how droplets separate and coalescence. In inkjet printers, individual droplets (tens of micrometres) of ink are injected into porous substrates (paper) to create large (millimetres) 2D patterns. In some 3D printing processes, polymer micro-droplets ejected from high temperature nozzles are used to build a 3D physical model. One advantage with the droplet approach in printing and manufacturing is that it leaves little material loss that contrasts with subtractive manufacturing such as cutting, milling and polishing.

Optics plays an important role in our technology-driven society such as lighting, vision, communication, health and entertainment. The underpinning technologies of optics are lenses. Since a clear droplet bends light, one can simply assume that lenses can be made out of droplets. In reality, translating this simple concept to a mass fabrication technique is a technical challenge. Droplets are often at a transition state that is notoriously difficult to control and need precise fluidic control systems [3]. While in recent years some optics manufacturers [4] have started to adopt the concept of printable optics using polymer droplets, the fabrication instruments are too expensive for home-use. The challenge we ask ourselves; can we create a lens making process out of droplets such that everyone can make it at home?

Nature makes lenses with droplets on a daily basis [1]. Single dew (macro-droplet) forms through the process of condensation, where miniscule drops of water nucleate and coalesce to form a millimetre-sized water droplet on a solid surface. This happens on window panes (partially wetted surface) and on glass panes of greenhouses, where they form a natural diffuser halving the sunlight transmission. A half-empty wine glass often displays a thin film of liquid with “tear drops” - beads of liquid forming due to the surface tension gradient (Marangoni effect). Chowdhury *et al* [5] constructed a water droplet lens microscope, using a simple plastic container, where they encapsulated the water droplet lens with wetted paper to manipulate the droplet curvature and also prevent water evaporation. This DIY approach sounds reasonably simple and powerful (i.e. every drop of water is a lens), but it is not a practical instrument because it is neither durable nor tangible. One key reason for poor physical control is not the quality of water droplets but simply that the droplet is inherently mechanically unstable. A better example of a liquid lens can be found in tunable lenses. A thin membrane (hundreds of micrometres thick) of polydimethylsiloxane (PDMS) holds a small volume of high refractive index fluid (µl) and actuation by fluid pressures changes the curvature of the PDMS membrane to

Figure 2. Ice drop (Left, reproduced with permission from Gregory Carter (www.CaptiveLight.us)) and droplet lens suspended on fingertip (Right, Stuart Hay).

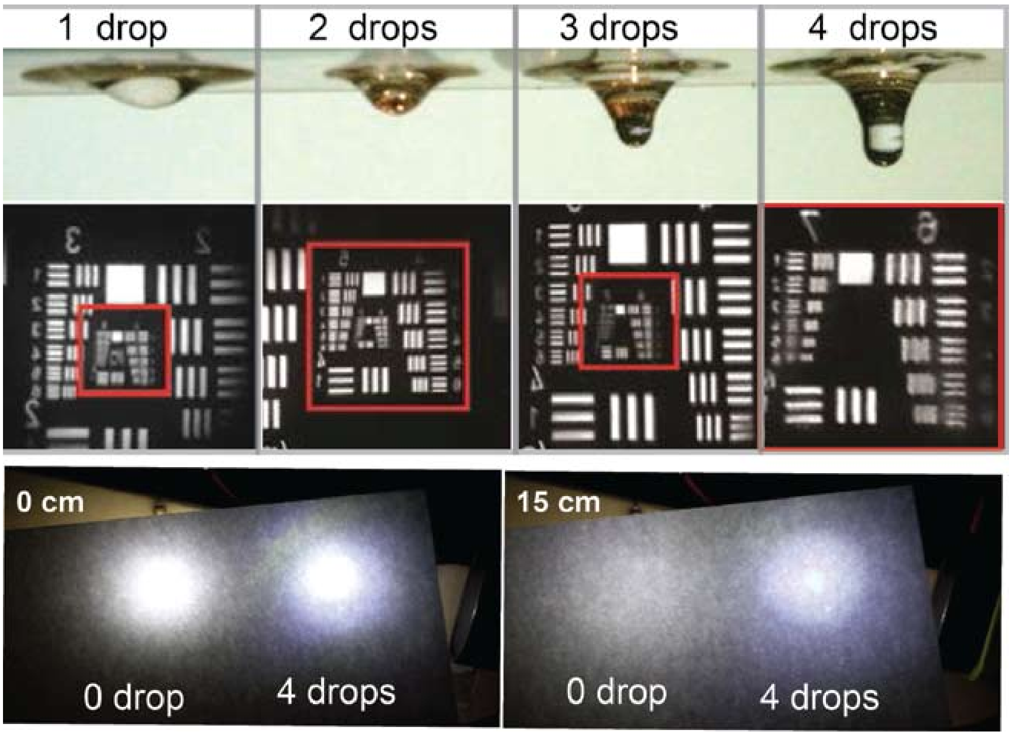

Figure 3. Imaging (USAF 1951) using a miniature camera chip and lighting performance (LED) of droplet lenses.

change the focal length of the lens. But tunable lenses have multiple moving parts which are costly.

Pre-cured PDMS is a transparent viscoelastic liquid that solidifies at low temperatures (< 200ºC). It has a higher resistance to external shearing and so deforms at a much slower rate. PDMS-based optics were demonstrated by Whitesides and co-workers [6], Gambin *et al* [7] and more recently Grilli *et al* [8]. In figure 1, we show an image that displays two sets of optically transparent PDMS substrate illuminated with room light; with (top) and without (bottom) fabricated diffractive grating.

Since PDMS has fluidic properties, Lee and his team at the Research School of Engineering invented a simple hanging PDMS droplet approach to make lenses [9]. While the shape of a hanging droplet bears a strong resemblance to a parabolic profile of a positive refractive lens, there is a need to control the curvature and thereby alter the focal length and change the resolving power of a lens. Hence we ask ourselves in the absence of external mechanical forces like in tunable lenses, "Can we use droplets to make lenses that have varying curvature?". Lee *et al* [9] answers this with an additive fabrication process. He demonstrates that as smaller layers of drops are added onto a previously cured droplet surface, the final cured droplet will possess an increased curvature and resolving power. This intuitive approach resembles that of ice drops as shown in figure 2 (left) and the droplet lens (right). In figure 3, we showcase the formation of silicone lenses made with different amounts of drops (top) and their imaging performance (middle) using a miniature imaging sensor as well as their ability to collimate light from a strongly diverging light emitting diode (LED) for over 15 cm.

Since the lenses can be made at such a low cost and are compatible with miniature devices (camera, LEDs), it appeals to a broad audience from mainstream photographers to remote field diagnostics. The success and popularity [10, 11] of this project demonstrates how simple optics from nature can still be very powerful.

The authors would like to acknowledge T. D. Abhayapala for proof-reading the article.

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Physics World physicsworld.com/cws/article/news/2014/apr/30/new-lens-could-turn-your-phone-into-a-microscope

Time time.com/86342/researchers-turn-a-smartphone-into-a-microscope

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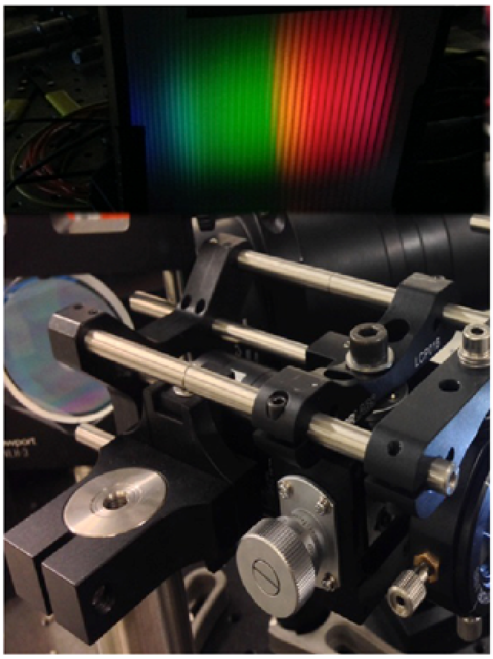

The symposium will focus on the technology, applications and future directions in the area of Imaging Spectroscopy. It aims to bring together researchers from around the world and Australia in the field of imaging spectroscopy and hyperspectral imaging, and to consider a wide range of applications from defense, agriculture, mining, astronomy and medicine. The emphasis will be on the use of photonics technology for imaging and spectroscopy, the technologies involved, in-the-field applications and innovations, and the end user perspective.

The Symposium will include the Australian Optical Society AGM.

Dates: Thursday 6th & Friday 7th November 2014
Time: 9:00 am
Venue: Lecture Theatre 101, New Law Building, The University of Sydney

COST: FREE!

Registration is essential - please visit sydney.edu.au/ipos and follow the links to register.

INVITED SPEAKERS

Prof. Ben Eggleton
The University of Sydney

Prof. Brian Wilson
University of Toronto, Canada

Prof. Salah Sukkarieh
The University of Sydney

Dr Roy Hughes
Defence Science and Technology Organisation (DSTO)

Prof. Seok-Hyun Andy Yun
Harvard Medical School

Prof. Joss Bland-Hawthorn
The University of Sydney

Dr Robert Content
Australian Astronomical Observatory

Dr Antonio Robles-Kelly
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Prof. Charles Bachmann
Rochester Institute of Technology, USA

Prof. David Sampson
University of Western Australia

Prof. Vincent Wallace
University of Western Australia

Dr Elizabeth Carter
The University of Sydney

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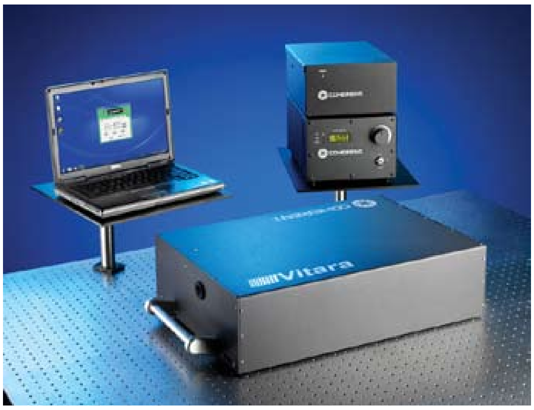
Product News

Vitara: Ultra wide TiS performance envelope on a fully automated platform



Coherent's Vitara family of automated Ti:Sapphire lasers provides the widest bandwidth available from a fully automated tuneable Ti:Sapphire oscillator platform. Vitara models have bandwidth adjustable to more than 220nm, wavelength tuning over 755-860nm, and compressed pulse durations of <8fs.

Vitara lasers are designed for maximum ease of use and are fully automated. The lasers are built to Coherent's exacting industrial laser manufacturing processes – including rigorous HASS (Highly Accelerated Stress Screening) for high reliability. The lasers include features such as:

- Computer controlled bandwidth (<180nm to >220nm)
- Computer controlled tuning (755-860nm)
- >930 mW output power
- Carrier Pulse Envelope stabilization
- <8fs pulsewidth capability
- Integrated spectrometer
- Low noise (<0.1% rms)
- PowerTrack active optimization
- Integrated Verdi-G pump laser
- Compact footprint

Some options are mutually exclusive, so please discuss your experimental requirements with our ultrafast laser specialist, Dr Dale Otten, dale.otten@coherent.com.au.

NEW - Coherent Astrella – the new standard in amplified ultrafast

The exciting ultrafast announcement from Photonics West 2014 – the Coherent Astrella. Astrella is designed and manufactured to be at the forefront of an industrial revolution in ultrafast science, and is the culmination of several development projects. Coherent's expertise as the proven leader in developing and consistently improving high power amplifier systems is leveraged together with advanced, stress-testing techniques developed for the production of our commercial lasers used in demanding industrial applications. This is backed up by affordable warranty packages providing up to five years of coverage. All this enables higher productivity and contributes to an overall lower cost of data.

- Energy >6 mJ, 1 kHz
- Pulse Width <35 fs
- Stability <0.5% rms
- Beam quality M2 <1.25

The Astrella is the new standard of both excellence and economy for amplified ultrafast, featuring:

- Integrated Vitara seed laser, new pump laser, new STAR regenerative amplifier and new proprietary sealed, compact stretcher/compressor for ultimate stability and reliability
- HASS*-tested at sub-component and system level for superior product quality and reliability
- All major sub-systems thermally-stabilized for reliable long-term performance
- Innovative, water-only cooled Ti:Sapphire rod assembly for improved beam quality and thermal management

*HASS: Highly Accelerated Stress Screening

The integrated, one-box design employs the new STAR regenerative amplifier module for increased energy, beam quality and stability. This is seeded by Coherent's hands-free Vitara oscillator, and is powered by a new pump laser offering enhanced power overhead, stability and beam quality. The final, key sub-system is the proprietary, sealed stretcher / compressor designed for superb dispersion compensation and durability.

NEW - Coherent Fidelity - 70fs, 2W fibre oscillator with adjustable chirp compression

Coherent's revolutionary ultrafast fibre oscillator platform offers a unique combination of high average power and extremely short pulses in a simple to operate, maintenance-free and compact package.

- >2W @70Mhz (nominal) average power
- <70fs pulse duration
- Built-in user-adjustable dispersion compensation

Delivering over 2W of sub 70 fs pulses at 1055 nm, the Fidelity fibre oscillator opens up a broad range of scientific and commercial opportunities in applications as diverse as optogenetics, terahertz generation and fundamental material research. Of course, for ultrafast pulses to be most effective in these types of applications, they must maintain their pulse width (maximum peak power) on target. By incorporating a user-adjustable dispersion compensation into the laser head, Fidelity delivers the shortest possible pulses to the sample.

For further information please contact Coherent Scientific at sales@coherent.com.au.

New 560 nm Picosecond Pulsed Diode Laser

PicoQuant GmbH has announced the release of the long-awaited 560nm picosecond pulsed diode laser head! The 560 nm laser is ideal for exciting fluorescent proteins like mCherry, RFP, or DsRed, and fluorescent dyes such as CY3 or Atto565. Its laser head supports picosecond pulsed as well as continuous-wave operation. All laser heads come with collimator optics that can optionally be fitted with optical fibres. The 560 nm pulsed laser matches the time resolution of mainstream detectors but at a lower price than that of commonly used solid state lasers. The new 560 nm laser head is compatible with PicoQuant's family of diode laser drivers "PDL Series". With the release of this new model the PicoQuant diode laser family "LDH Series" now covers the entire wavelength range from 375nm to 1990 nm.

Technical Data: LDH-D-TA-560

- Centre Wavelength 561 nm ± 3 nm
- Repetition rate from single shot to 80 MHz
- Pulse width < 80 ps (FWHM) at average power 0.2 mW at 40 MHz repetition rate
- Average output power in continuous-wave mode: 5 mW

Entirely new applications in bioanalytics, biochemistry, genetics, semiconductor characterisation, and quality control are expected to be made possible by the use of this new wavelength laser.

Altechna's Ultrafast Watt Pilot

The Altechna Ultrafast Watt Pilot attenuator incorporates high performance broadband polarisers, which reflects s-polarised incident light while transmitting p-polarised light.

A rotating zero-order quartz waveplate is placed in the incident polarised beam and the intensity ratio of the s-pol and p-pol beams can be continuously varied by rotating the waveplate. This allows control over the intensity of your input laser beam over a wide dynamic range without affecting other beam parameters.

Features
- Ideal for femtosecond laser pulse control
- Divides incident beam into two beams of adjustable intensity
- High optical damage threshold
- Low dispersion for femtosecond laser pulses
- Custom options available

Specifications
Design wavelength: 800 or 1030 nm
Clear aperture: Up to 50 mm
Wavelength range: +/- 50 nm

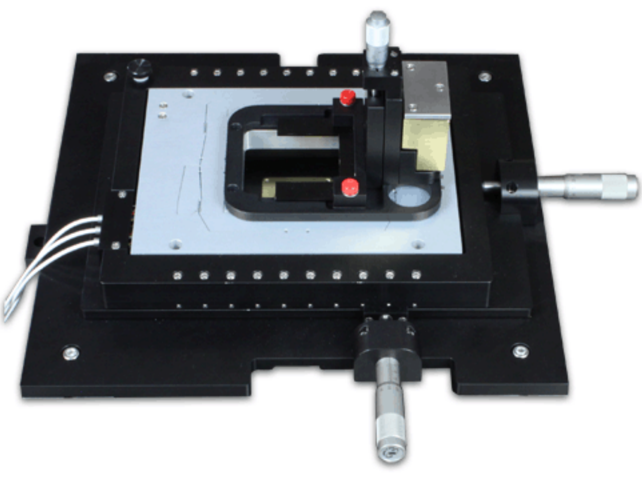
Also available are Standard Watt Pilot Attenuator for everyday applications and enhanced Watt Pilot Attenuator for demanding, high energy applications.

Mad City Labs' MicroMirror TIRF Microscopy

The technique of MicroMirror Total Internal Reflection Fluorescence (TIRF) microscopy is the only proven method to study the ordered assembly and function of multi-component biomolecular machines. The Mad City Labs' MicroMirror TIRF microscope is a high precision instrument that uses a high stability nanopositioning system.

The MicroMirror TIRF system uses through-the-objective excitation with two broadband micro-mirrors positioned at the back aperture of the objective lens eliminating the need for dichroic mirrors. This leads to superior signal-to-noise ratios and simplifies the introduction of multiple spectral lines. Each micromirror is mounted to a six axis precision mount allowing the user to make fine adjustments to the optical pathway. The imaging and motion control platform is designed to maximize optical pathway accessibility and flexibility, while also simplifying the optical alignment. An advantage of this system is the open access to the entry and exit optical pathways. The motion control platform comprises an XY micropositioning platform with an integrated XYZ closed loop nanopositioning system. The XYZ closed loop nanopositioning uses proprietary PicoQ® sensors for sub-nanometer precision and high stability.

The MicroMirror TIRF system technology enables the advanced study of complex biomolecular interactions. It is a proven design and that offers a simple yet flexible instrument platform for single molecule research.



For more information please contact Lastek at sales@lastek.com.au

2014 OSA Optics & Photonics Congress

The OSA Light, Energy and the Environment Optics Congress

2–5 December 2014 | Canberra, Australia
Energy Change Institute, Australian National University

www.osa.org/EnergyOPC

IMPORTANT DATES:

Abstract and Summary Submission Deadline:
3 September 2014
12:00 EDT (16:00 GMT)

Advance Registration Deadline:
4 November 2014

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ENERGY CHANGE INSTITUTE

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.

DANGER
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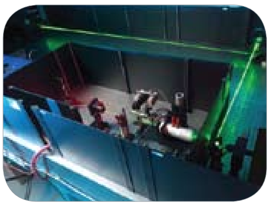

Optics in Everyday Life: Retro-Reflectors

by Tony Klein

We saw in John Lekner's article in the previous issue (Why some things are darker when wet) that very similar phenomena can have rather different explanations. This is also the case with retro-reflection, or back-scattered light.

Figure 2. Shadow of aeroplane on complex terrain. Photo: Maria Albanyai.

Apart from the eyes of cats and other animals, about which more anon, the best-known and most precise retro-reflectors are, of course, corner-cubes, in their various manifestations. These vary from the multiply embossed plastic prisms in amber or red reflectors on cars and bicycles (also metaphorically called "cats' eyes") to the high precision glass prisms used by surveyors, and the banks of such objects left behind on the moon by astronauts. With the aid of earth-based pulsed lasers, the latter established the Earth-Moon distance - as well as its rate of increase - to unprecedented accuracy over several decades of measurement.

There are, however, several other retro-reflecting situations that may not be so well known. The commonest of these is based on the properties of transparent spheres such as raindrops or dewdrops on grass or other vegetation. You may have noticed this on an early morning walk when, with the sun behind you, the shadow of your head on the dewy grass is surrounded by a bright halo! Furthermore, it is your head only - and not that of your walking companion - that shows the halo (known in German as the '*Heiligenschein*' - as in holy pictures)!

Figure 1. Shadow on dewy grass. Photo: Jessica Kvansakul.

This is actually a simple case of retro-reflection, easily explained by noting that spherical drops of water focus the sunlight coming from behind you, approximately onto their points of contact with the leaves of grass whence, when scattered in all directions, they return as a parallel beam in the opposite direction, thereby producing a bright circular patch around the shadow of the observer's head. This is illustrated in Figure 1.

The effect is enhanced with glass beads strewn on a background of white paint, as used all over the place on road signs and road markings. Beads of glass, available by the kilogram, produce even better focusing onto the points of contact and hence an even better retro-reflective property than water.

Even better still are special higher-refractive index glass beads, also available by the kilogram, which are used on airport runways, giving even better retro-reflection of aircraft landing lights, which they focus in even smaller bright spots on the white paint background on which they are partially embedded. The shadow of your head with sunlight behind you is surrounded by even brighter haloes on such surfaces - as may be seen when walking, with the light behind one, on roads marked with such retro-reflectors. (Retro-reflecting tapes on 'high-vis' vests and life jackets are based on the same principle.)

A very similar situation occurs in the case of eyes, of course, i.e. real "cats'-eyes", because the light that is focused fairly precisely on the retina by the cornea and the lens, and is not absorbed, is reflected in the retro-direction. A special brightly coloured layer of material on the retina - the *tapetum* - enhances the effect for nocturnal animals. For humans, this gives rise to the well-known "red-eye" effect in flash photography.

Yet another retro-reflecting situation, of a completely different nature, may be seen by passengers observing the shadow of an aeroplane travelling over complex terrain such as a forest or a field of crops. You have probably seen it: The shadow of the aeroplane is often surrounded by a bright halo. This, you may be surprised to learn, is due to a completely different and, in fact, a much simpler phenomenon, of a completely geometric nature.

What goes on is as follows: Rays (or photons, if you prefer) of sunlight, coming from behind the aeroplane, enter the complex surface and are multiply scattered until almost completely absorbed, thus generating the shadow. However, there is one simple way back, and that is to retrace their steps - i.e. retro-reflect - almost exactly the way they entered! Hence the bright halo surrounding the shadow, as is illustrated in Figure 2.

If you have never seen it, look out for it by sitting on the right-hand side of the plane flying North in the morning or on the left-hand side coming back in the afternoon - especially when at low altitude.

Something entirely different may be observed when flying at higher altitude, above clouds, when the shadow of the aeroplane is seen to be surrounded by a

Figure 3. Shadow of an aeroplane on a cloud. Photo: Alex Tudorica.

halo of coloured rings, as seen in Figure 3.

First observed by mountaineers climbing to peaks above the clouds, observing their shadow on clouds below them, and noting the coloured rings around their own head (and not of their companion's!). They called this type of halo the "Brocken Spectre" or the 'glory' - quite a magical experience. I have seen it myself once or twice, but even more spectacularly in New Zealand, in Rotorua, looking at my shadow on the billowing cloud of steam coming from a geyser.

It turns out that the optical phenomenon responsible for this is very much more complicated and is caused by evanescent waves guided by the spherical surface of droplets. Rays of light around a spherical droplet propagate in a special "whispering-gallery" mode of diffraction and emerge in the retro-reflected direction. It is referred to as Mie Scattering. That's as far as I can go in explaining it without heavy machinery [1] but the optics of aerosols - and analogous effects in nuclear physics - are well studied and described in the specialist literature. So, just look out for it when next flying low (or hiking!) above clouds and marvel at the beauty of it!

References

[1] HM Nussenzveig, *Optics Letters*, **27**, 16, 1379-1381 (2002)

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

6-7 November IPOS Symposium

The 5th IPOS symposium on imaging spectroscopy will be held at the University of Sydney on Thursday 6 and Friday 7 November. The symposium will focus on the technology, applications and future directions in the area of Imaging Spectroscopy and will include the Australian Optical Society AGM. Sydney.edu.au/ipos

23-28 November KOALA 2014

This year's IONS-KOALA Conference on Optics, Atoms and Laser Applications will be held at the University of Adelaide. It is aimed at students from any field of optics (Honours, Masters and PhD level) and provides a relaxing environment to present and discuss research as well as networking opportunities. Registration closes on 30 September.
ions-koala2014.osahost.org

2-5 December 2014 OSA Optics and Photonics Congress

The OSA Light, Energy and the Environment Congress will be held at the Energy Change Institute, ANU from December 2-5. 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. Advanced registration closes on 4 November. osa.org/EnergyOPC

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


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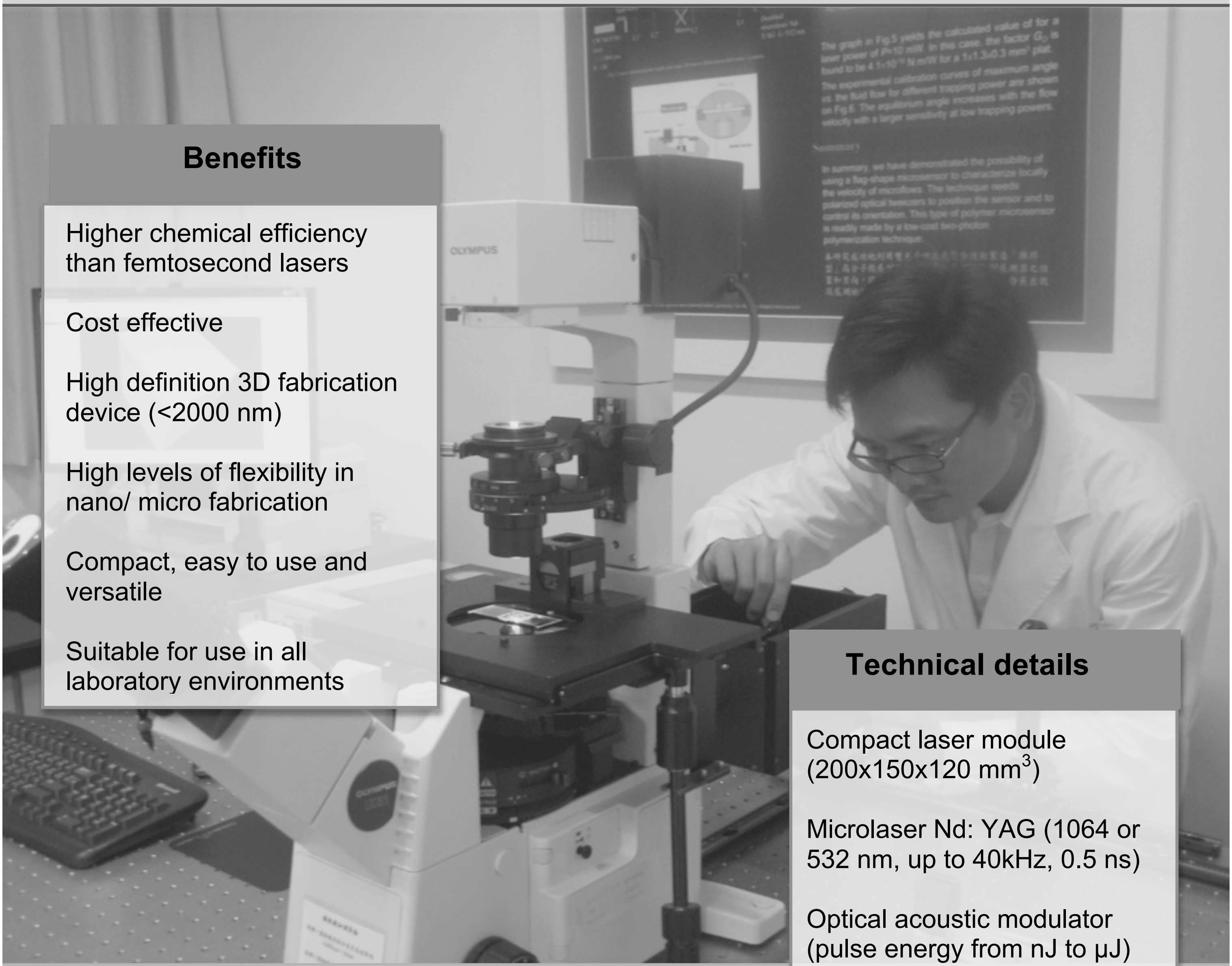

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For your all light measurement requirements, Please contact 'Photon Scientific', Melbourne. We not only distribute a wide range of optical products but we also provide services and solutions to meet your research and industrial applications.

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Fibre Optic & Photonic products

Optical Fibre Path Delay Line

AFW can manufacture compact size, robust fibre delay lines to suit your space and budget. You no longer require large fibre spools with connectorised fibre pigtails. We can make customised fibre lengths to suit your application. Suitable for optical network testing and analysis, fibre laser and time delay applications.

- Insertion loss 03 ~ 0.5dB per km
- Customised fibre length: 50m, 100m, 200m, 1km ~ 5km
- Operating wavelength range: 1260 ~ 1650nm standard
- Fibre type: G.652.D SMF

Polarization Maintaining Patch Cords/Jumper Leads

PM jumper leads are built with PM panda fibre and connect using FC, SC or E2000 connectors. PM jumpers are also available unaligned and with a 360 degree tunable ferrule for laboratory use.

- High extinction ratio over 25dB
- Wavelength range: 980nm, 1064nm, 1310nm and 1550nm
- Low insertion loss <0.4dB and return loss over 55dB
- Narrow key or wide key connectors for FC type

Polarization Beam Splitter/Combiner

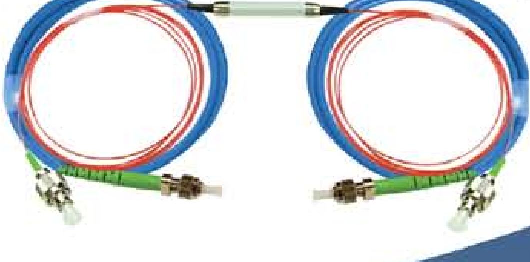
The device can combine two orthogonal polarization to one output fibre or split incoming light into two orthogonal states.

- Singlemode fibre or PM panda fibre
- High extinction ratio ER>25dB, low loss
- 980, 1030, 1064, 1310 or 1550nm wavelengths
- Supplied with FC or FC/APC connectors, narrow or wide key

Fibre Optical Isolators

Complete line of fibre coupled isolators for wavelengths ranging from 980nm to 1625nm. Available in two versions: polarization insensitive and polarization maintaining.

- Wavelength range: 980, 1030, 1064, 1310, 1480 or 1550nm
- Fibre type: PM panda, SMF28 or Hi1060
- PM isolator with or without polarizer
- High isolation and high extinction ratio
- Slow axis of fibre aligned to the connector key
- FC or FC/APC connectors, narrow key or wide key
- 300mW, 1W, 3W or 10W CW power handling



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