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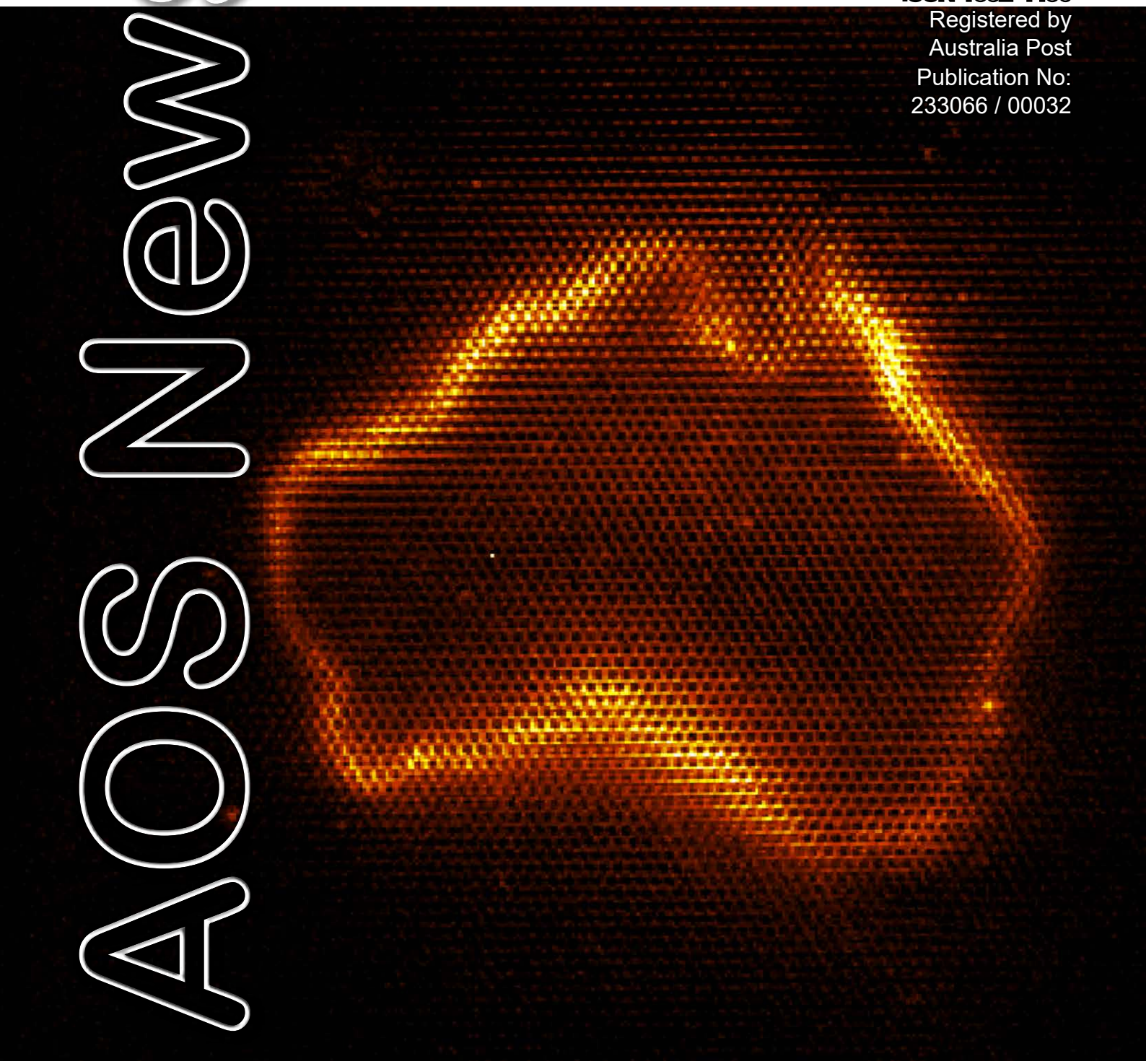

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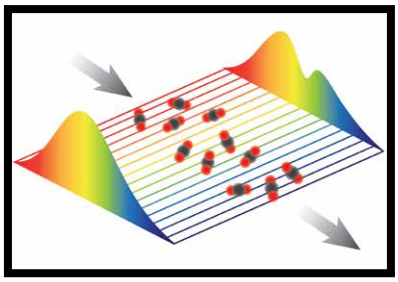

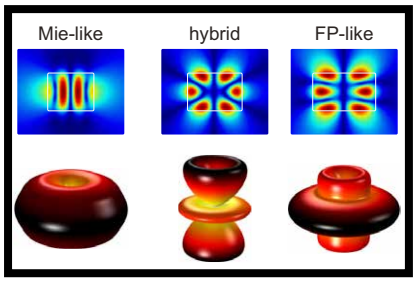

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AOS News is the official news magazine of the Australian Optical Society. Formed in 1983, the Society is a non-profit organisation for the advancement of optics in Australia. Membership is open to all persons contributing to, or interested in, optics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

Submission guidelines

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

Call for submissions!

Please consider writing something for the next issue.
We are looking for:

Scientific articles on any aspect of optics

Review articles on work in your lab

Conference reports from meetings you attend

Articles for the Optics in Everday Life section

General interest articles

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
- General Interest Article: Any item of interest to members such as reports on community engagement, science in society, etc.
- Article for Optics in Everyday Life section: An explanation of the optics behind any interesting effect, phenomenon, or device.
- News Item
- Obituary
- Book Review
- Cartoon or drawing
- Crossword or puzzle

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.

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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 AOS council. Use of electronic mail is strongly encouraged, although submission of hard copy together with a text file on CD will be considered.

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Rates: Colour pages $345, Black and White pages $175, with a surchargee for choosing a specific page for the ads (rates excl. GST). 1-2 Black and White pages in the main body of the newsletter are free to corporate members.

Copy Deadline
Articles for the next issue (Mar 2019) should be with the editor no later than 18 Feb 2019, advertising deadline 11 Feb 2019.

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

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

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- Membership
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Articles

Departments

Cover Pictures:

- The next winner of the AOS photo competition is Sergey Kruk, Australian National University. Topological Australia is a photograph of an optical topological state shaped into an Australian continent (arXiv:1811.12130 *"Nonlinear mapping of photonic topological edge states"*), see page 15.
- Insets (left to right)
  - An optical frequency comb measuring the amount of carbon dioxide in a gas mixture. This technique can be used to look for biomarkers in breath samples, with the eventual goal of allowing simple early detection of disease, see page 8.
  - All-dielectric resonant nanophotonics uses subwavelength Mie-resonant dielectric nanoparticles to create highly efficient optical metadevices. Here we see the physics of quasi-BIC resonances in an isolated subwavelength nanoparticle, see page 27.

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President's Report

This is my first report as President, and I am pleased to be writing it after a very successful AOS meeting in Perth held as part of the AIP meeting in early December. I am also honoured (and not a little apprehensive) to take over this role from Simon Fleming, who has provided tremendous service and helped the Society to make considerable progress on a number of fronts. The most notable of these concerns the issue of gender equity where the AOS formal policy has had a considerable impact, not just on the running of our local conferences, but also in influencing other optical societies around the world to introduce similar policies. I hope that we can continue to develop our policies and broaden their impact.

At the AOS meeting we had a healthy turnover of Councillors and office bearers, and I would like to record my thanks to retiring Council members (Ben Eggleton and Stephen Collins) and welcome the newly elected Council member Irina Kabakova. Simon Fleming became past President, I became President and John Holdsworth was elected as Vice President. John has a long history of contributing to the AOS and I Iook forward to working with him and with Simon as we move forward in 2019.

It was a great pleasure as my first formal duty as President to award the AOS prizes for 2018. These prizes were awarded at the AOS conference dinner held in perfect conditions in the grounds of the University of Western Australia on December 12, and I would like to repeat here my congratulations to the winners. The AOS Beattie Steel medal went to Professor Halina Rubinsztein-Dunlop, the Geoff Opat Early Career Researcher Prize was won by Dr Mohsen Rahmani, the Postgraduate Student Prize was won by Ms Rocio Camacho Morales, the John Love Award went to Professor Robert Scholten, and the Warsash Science Communication Prize in Optics was won by Ms Sarah Katherine Scholten.

In this first report it seems an appropriate time to mention the major issues that I hope to make progress with over the coming two years. These are:

(i) Developing a long term arrangement for the organisation of the ANZCOP conference, and the avoidance of potential conflicts with competing conferences in our region.

(ii) The commissioning of a survey of the Photonics enabled industry in Australia and New Zealand, together with the research capabilities, which will be valuable for promoting our discipline and its applications, both with funding agencies and with the general public.

(iii) A careful investigation into the value of AOS membership.

We had representatives from both the OSA and the SPIE at the AOS meeting and they not only awarded their prizes, but also participated in a number of informal discussions concerning longer term plans for coordination of efforts to promote Optics Research and Photonics enabled industry in our region. We also discussed ways in which the different Optical Societies can interact and assist each other.

Members will be aware of the issues regarding the collision between the ANZCOP conference in recent years and an SPIE conference with substantial Photonics content, which has run in the adjacent week in 2015 and 2017. It is not possible to send large groups of students and staff to two conferences so close together, so I was pleased to announce at the AOS dinner that we have reached an agreement with SPIE that the next ANZCOP meeting will run as a combined conference in Melbourne in December this year. The Conference will be called ANZCOP 2019 incorporating ACOLS, ACOFT and SPIE Nanophotonics.

SPIE is also supporting our efforts to organise a Survey of Photonics enabled industry in Australia and New Zealand, and we plan to commission this report in the first half of this year.

The third issue on my list is of particular interest to me as the first New Zealand President of the Society. We have seen some fluctuations in membership over the last few years influenced by a number of things. Some of these are technical, such as the changing way in which membership can be renewed, but others are more subtle. I think it is important to establish the benefits of membership in these days of increased electronic connectivity, and burgeoning opportunities for interactions outside formal Societies.

I would like to conclude this report with best wishes to all of our members for a Happy and productive New Year.

John Harvey
AOS president

Editor's Intro

Welcome to another issue of AOS News. We have a couple of articles relating to AOS prizes this time - there is the winning entry of the Warsash Science Communication Prize in Optics for 2018 by Sarah Scholten entitled 'Sniffing out disease' as well as an article by a group containing two of our 2017 prize winners. Sergey Kruk won the 2017 Geoff Opat Early Career Researcher Prize and Yuri Kivshar won the 2017 WH (Beattie) Steel Medal. There is also an item considering the relationship between optometry and optics and a look at how lighting affects paintings over time. Our 'Optics in Everyday Life' section explores the eye as a photon detector. We also have the next winner of our photo competition and details on how to enter. As usual, please let me know if you have any suggestions for anything you would like to see in AOS News or have any articles or other items you would like to submit. I would like to thank Simon Fleming for his support during his time as AOS President and look forward to working with John Harvey as the new president. I would also like to thank Tony Klein for his help with the Optics in Everyday Life section and for coming up with so many useful ideas and topics to cover.

The subject of mentors was mentioned in a couple of articles in Nature careers recently, offering some useful reflections. A recent paper in Nature Communications showed that academic success is affected by the choice of mentor at both the graduate and postdoctoral levels, but that it is the latter that is more important. As well as learning new skills and concepts, the networks and advice offered are equally valuable. The authors suggest that researchers fare best when trained by mentors who are successful and have trained a lot of other people. These mentors are not only more experienced, but are also likely to have more connections that can provide a boost to future career prospects. The greatest chance of success was also achieved when the postdoc mentor offered different aspects of work in a complementary but different area to the PhD that could be brought together by the researcher in their own work. This allows the accumulation of skills and provides a new pathway for people to form for themselves. Another article was about some recent awards for good mentors that discussed the need for mentors and some of the qualities present in the awardees. Some of them had a history of finding students from less developed areas and helping them do well. Others were always around to help lab members and offer advice on anything or offered underrepresented students particular support to help them succeed.

Although these articles had a lot of useful information they were mainly restricted to direct supervisor/student or postdoc relationships rather than looking at other types of mentor. Many universities have recently initiated programs to match mentors and mentees across disciplines as well as the informal mentoring that often occurs. These relationships can be equally valuable as someone outside the direct group or department has a different viewpoint and is less likely to have any conflict of interest when offering advice. Being able to consult and discuss issues with an extra person can be very valuable and offers benefits for the mentor as well as the mentee. It is useful to have a mentor at any career stage and peer mentoring is also valuable. I attended a session for early career researchers a few years ago where they recommended peer mentoring and offered the opportunity to start our own groups after the meeting. Groups were formed randomly and I found my time with three other young women at various career stages to be both enjoyable and beneficial. Being able to offer support and see your own progress as reported to the group once a month was great and offered the opportunity for reflection on my own direction as well as insights and ideas from others.

All types of mentoring are important, so it is good to contemplate sometimes whether we have the mentors we need and are acting as guides in the best way to our own mentees. A recent article in Science book reviews asked people to describe one quality they would like to follow when acting as mentors themselves. It was an impressive list mentioning many attributes including support for the individual, empathy, offering impartial advice, showing respect and trust, having open communication and providing the freedom to explore. Hopefully we can all bring some of these qualities to our own relationships. There is a lasting impact that any mentor can leave so it is important to try and find the right people to provide advice and support and to offer the best guidance possible to mentees.

I hope you enjoy this issue of AOS News and wish you all the best for the coming year.

Jessica Kvansakul
Editor

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Warsash Science Communication Prize in Optics 2018: Sniffing Out Disease

by Sarah Scholten

This article is the winning entry for the Warsash Science Communication Prize in Optics for 2018, a prize open to AOS student members whose Honours, Masters or PhD research work has been accepted for publication in a refereed journal in the past year. Congratulations Sarah.

Sarah Scholten being presented the Warsash Science Communication Prize in Optics at the AIP Congress 2018 dinner by AOS President John Harvey. Photo courtesy of Andrew Brown, SPIE.

Now there's another thing to worry about while brushing your teeth before that hot date – your bad breath may contain the calling card of a deadly disease.

Under distress from certain illnesses, including oesophageal and lung cancers, a person's body will produce molecules known as `biomarkers'. These biomarkers are unique to each disease, and may be hidden within your breath long before noticeable symptoms. Early detection of these biomarkers through routine non-invasive breath screening would allow earlier intervention – and better outcomes - for many often fatal ailments.

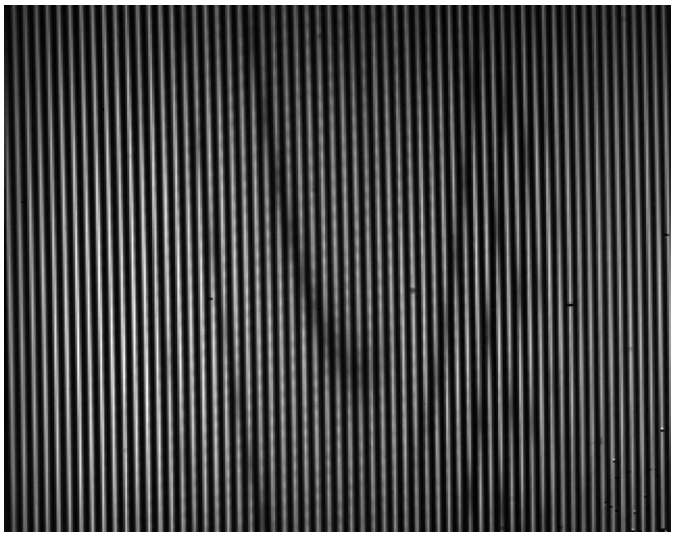
While linking biomarkers to their diseases is a rapidly expanding field of research, a simple device for rapid breath screening is still needed, and is the focus of PhD student Sarah Scholten at the University of Adelaide, Australia, and her colleagues. The team have developed a prototype utilising a laser technology called an optical frequency comb. Each laser pulse from a frequency comb contains hundreds of thousands of different laser frequencies or colours. When this light is passed through a sample of gas, a characteristic pattern of colours is absorbed unique to each type of molecule - like a fingerprint. Analysis of these fingerprints allows determination of the amount of each type of molecule in the gas sample simultaneously.

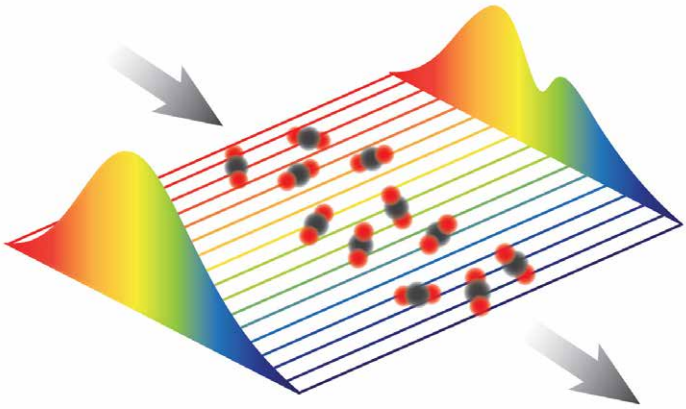
In this first demonstration the group measured a mixture of carbon dioxide – a major component of the exhaled breath - and nitrogen, and were able to measure the composition within 1% accuracy in real-time [1]. The system continuously monitored the mixture over three hours as the amount of carbon dioxide was changed. While this first demonstration was aimed towards atmospheric monitoring applications, Sarah and her team are next aiming to detect some already-identified biomarkers with this system. "That's the ultimate goal we're working towards – medical breath analysis" she says.

References

[1] SK Scholten, C Perrella, JD Anstie, RT White, W Al-Ashwal, NB Hébert, J Genest, and A Luiten, *'Number-Density Measurements of CO_2 in Real Time with an Optical Frequency Comb for High Accuracy and Precision'*, Phys. Rev. Applied **9**, 054043 (2018). DOI: 10.1103/PhysRevApplied.9.054043.

Sarah Scholten is a PhD student at IPAS, University of Adelaide.





Left) The characteristic absorption fingerprint of carbon dioxide (in shadow) as seen by the detector; Right) A simplified diagram showing the principle of the experiment. Carbon dioxide molecules flow through the sample chamber, and are interrogated by the 'rainbow' of colours produced by the comb. Their presence leaves a characteristic fingerprint on the comb light.

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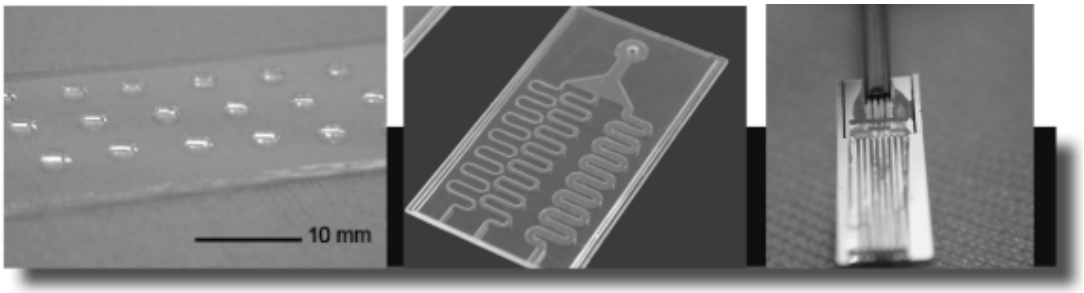

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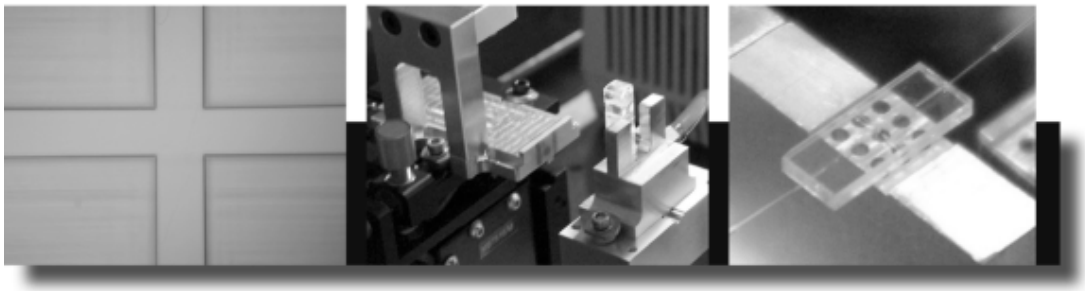
Nanostructure

Blazed grating

Micromechanics



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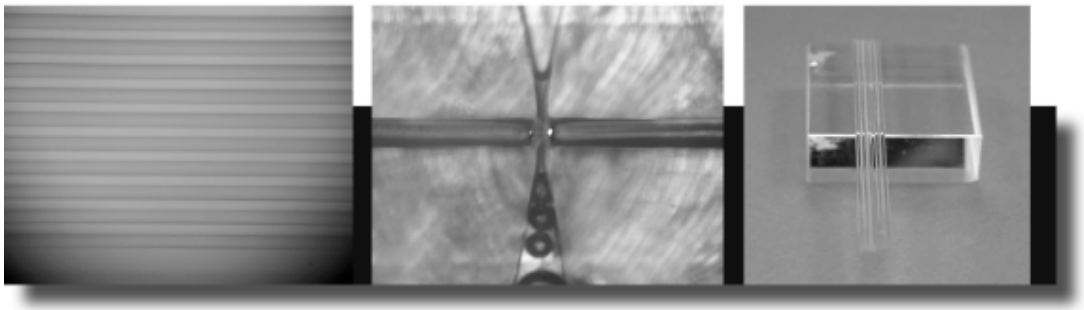

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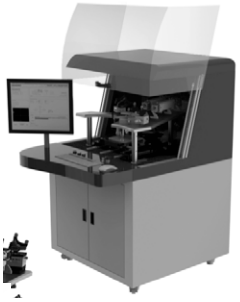

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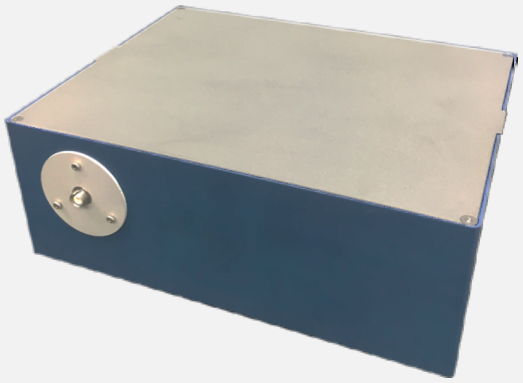

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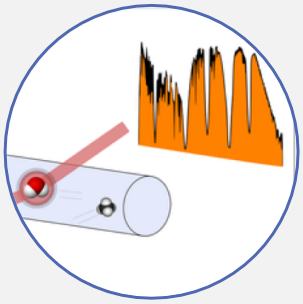

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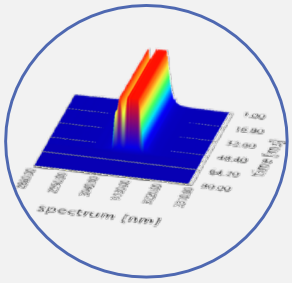

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Are We Witnessing the Disconnect Between Optometry and Optics?

by Uchechukwu L Osuagwu

Despite the importance of optics to optometry and and the history of the discipline, optometry seems to be losing its connection with optics. Here this issue is discussed along with examples of how to bring the two areas closer.

Optometry, Optics and the Optical Society

The optometry profession as defined by the World Council of Optometry (WCO) is a healthcare profession that is autonomous, educated, and regulated (licensed/registered), and optometrists are the primary healthcare practitioners of the eye and visual system who provide comprehensive eye and vision care, which includes refraction and dispensing, detection/diagnosis and management of disease in the eye, and the rehabilitation of conditions of the visual system. Though it developed out of physics and optics, optometry appears to be moving away from optics towards a healthcare profession. A shift that has stretched students between numerous courses as diverse as microbiology, practice legislation, mathematics, and pharmacology [1]. Students no longer see the relevance of optics in optometry education and therefore reluctantly engage with optics. Such an attitude may have been unintentionally encouraged by the continuous exclusion of optometry students/professionals in optics related activities such as the 2017 Optical Society student leadership conference (SLC), which had only one optometry student in attendance.

Optics is the science of vision and light and unarguably, the history of the optometry profession shows that the profession emerged from optics, thus the saying that, "where there is light, there is vision". Philosophers of Antiquity speculated not only about the nature of light, but also about the process of vision in the body, for example, the Empedocles' extromission theory [2]. Optics remains at the core of optometry and in some European countries, optometry and optics are considered as one profession, though this is also an inaccurate representation. Re-affirming the importance of optics to the profession and to ensure a high standard is maintained, the European Council of Optometry and Optics (ECOO) in establishing the European Diploma in Optometry program decided to combine the strong physics/optics focus of some German Universities' programs with the clinical focus of the UK model. Even in the UK where the optometrist profile is one of the less physics-oriented in Europe [1], the importance of optics is still affirmed by the regulating bodies and optometrists themselves. The question is then how to best reconnect optics with the optometry profession.

The Optical Society

The Optical Society (OSA) which was founded 100 years ago, has evolved into a global enterprise serving a worldwide constituency. Over the course of the association's history, 34 of its members have been awarded a Nobel Prize in Physics, Chemistry or Physiology/Medicine. Recognising the contributions of optometry in optics the association very recently awarded the 2018 Edwin H. Land Medal to an Optometry Professor Ann E. Elsner of Indiana University and Aeon Imaging, USA for her contributions to the fields of ophthalmic instrumentation and vision science with innovative imaging technologies, state-of-the-art psychophysical research and entrepreneurial ventures [3].

The association organises several meetings including the Frontiers in Optics + Laser Science (FiO + LS) conference and exhibition which I attended in 2017 and sponsors over 350 chapters in 61 countries. With over 1,200 attendees at the 2017 meeting, I found my poster to be the only optometry-related presentation, at least on the day of my presentation. A recent survey showed that optometry students consider refraction and optics their core strengths and that a background appreciation of optics was important for students to better understand the visual difficulties experienced by patients and helps the practitioner to provide optimum correction. In the survey, optics was found to be useful in many ways. For example, a knowledge in optics was helpful when demonstrating professional knowledge to patients. The practitioner is able to answer questions related to anti-reflection coatings, polarisation and the students were also able to make sense of claims that are related to commercial instruments.

The Australian Optical Society

Formed in 1983, the Australian Optical Society (AOS) is tasked with the advancement of optics in Australia. Membership is open to anyone contributing to or interested in optics in the widest sense and the association has a joint membership deal with The Optical Society. For students, there is no joining fee for membership with AOS for the first year, however, there is an annual fee of $20 after that, while still a student. While OSA is more geared towards vision science at least through its specific groups, the AOS has a much smaller membership. The association organises joint events with OSA such as the IONS KOALA Conference on Optics, Atoms, and Laser Applications which is an annual student conference held in Australia and New Zealand and sponsored by The Optical Society (OSA). The 11th instalment of this conference was recently co-hosted by the OSA student chapters at Macquarie University and the University of Sydney. It was at a similar event in Brisbane that the immediate past executives of the QUT student chapter established contact with post graduate students of QUT Physics department who are now active members

QUT OSA student chapter members with OSA representatives and the AOS News editor at a Centennial Reception at a conference in Brisbane in 2016.

of the student chapter after several failed attempts to reach them over the years. During the events, we also established relationships with some of the OSA executives shown above including the Chief Executive Officer, Elizabeth A. Rogan and the Past President, Dr Eric Mazur.

Why the disconnect between Optometry and Optics

My participation as a student chapter representative at the SLC and as a presenter at the Frontiers in Optics conference in September of 2017 was a fascinating and expository experience. I had the opportunity to meet and discuss science with some world-leading scientists in optics, astronomy, photonics and physics. As a postgraduate student, it was an unforgettable experience which I think most optometry students would love to have. Two hundred and fifty students (69% of whom were men) from 49 different countries attended the SLC and 79% of the attendees were from outside of the USA. Given the very large number of applications/fields that are enabled by optics and photonics, I felt alone as the only optometry student at the SLC. I spoke a different professional language from the rest of the students who on seeing my poster asked how an Optometry school came to host a student chapter for The Optical Society. This reflects simply what very big disciplines optics and photonics are and how very many activities they enable, from fibre communications to medical imaging to petawatt-laser-driven studies of conditions in the cores of stars. Of the many optometry schools in the USA, I was most surprised that not one was represented at the SLC possibly because of the non-existence of student chapters in these institutions or the gradual disconnect between optometry and optics. Also, the fact that my presentation was "the only optometry-related presentation at least on the day of my presentation" could reflect the lack of interest among the optometry community in presenting at a show like FiO or in organising sessions for it. This may be unfortunate, and may also say more about the optometry community and the change in focus.

Sitting in one of the plenary lectures and listening to a world-leading researcher in automobile design discuss the evolution of driverless cars and the progress made over the years to ensure their safety on roads, the speaker pointed out the importance of peripheral optics in the design of these cars. In the absence of the young dynamic optometry scientists in such innovative research discussions, I pondered on Atchison's [4] observation in his article 'who needs Optics', which was written more than a decade ago. He stated that, "if we discard the skills afforded to us through the knowledge of optics, we run the risk that the scope of the profession will be restricted; others will fill the vacuum we leave behind and we may be thwarted in expanding in the directions we wish to move by legislative or other obstacles". The dissociation between the optometry profession and optics which was predicted [4] may be happening sooner than we thought. How have we progressed this far leaving optics behind? Neither I nor the SLC conference organisers whom I had a chat with on this issue had an explanation. Obviously, the non-participation of optometry students in the OSA chapter activities could explain their absence in

OSA 2017 student leadership conference.

the SLC. To the best of my knowledge, only one Optometry school (Queensland University of Technology, Brisbane, Australia) hosts an OSA student chapter, a fact that was corroborated by one of the organisers during our discussion. The staff was in disbelief at this particularly when I traced back the link between the histories of both fields (Optometry and Optics) and how bringing in such a clinical group in the student chapter activities could give the association a face-lift and open up greater opportunities for advocacy.

Over the course of the conference, the thoughts of optometry involvement in OSA Student chapter activities resonated in my mind. Looking back to Australia where I had left to attend this conference, the sight of the disconnect between the Optometry School/ students and AOS was not farfetched. Until we established connections with the organisation through our published articles in their newsletters, we had not heard of this association nor had anyone ever mentioned it to us. It would be interesting to see optometry students get involved in AOS and the association needs to do more in promoting their activities among the optometry student community. At a group advocacy visit to the US congress designed by the association to give student leaders a first-hand experience with elevated level advocacy, I was allocated to a group of five with two female representatives of the association (one very experienced in advocacy, having worked for many house members in the past, and the other less experienced but with great passion for women's rights) and a Harvard University Professor who was also working with Yale University at the time, and who did most of the talking. We visited four members of the US congress and at each of the meetings a brief introduction of background, specialty and how our areas of specialty related to optics was necessary. It felt odd at times when it got to my turn, but what was stunning was the reaction of the congress-men and women when I spoke about the role of optics in the design of optometry/ ophthalmology instruments such as optical coherence tomography (OCT) which has become a diagnostic tool for most retinal diseases and the effective use of lasers for treatment of several blinding diseases.

Recommendation for a reconnect

The Optometry profession could increase the profile of the different professional opportunities available to its graduates by encouraging participation in such grass root programs. Besides taking advantage of the wonderful opportunity/ sponsorship provided by the parent body (The Optical Society) in funding the running of the student chapters and the activities, involvement of optometry students will engage young optometrists' minds and reduce the current gap between optometry and optics. As a student member of various optometry/ ophthalmology organisations and the past president of the QUT Optical Society Student Chapter, there are numerous benefits provided by OSA to its student members which are not offered by many other optometry associations: The provision of annual running funds for each student chapter and grants to enable student chapters to hold events, annual sponsorship of one student chapter member to attend the SLC/FiO conference (flight + accommodation), discounts on publication fees for any of the association journals, opportunities to join different scientific groups, fellowship membership, the possibility of becoming an OSA ambassador or joining the travelling lecturer program on graduation. These are motivations to prompt a rethink within optometry schools to establishing a student chapter at their institutions. The process is simple and requires five active members to secure funding.

De-emphasising the teaching of optics in the current optometry curricula is something the optometry regulating bodies should revisit. This would re-engage the optometry students in optics related activities and work towards closing the gap between both professions and re-enforce the belief that optics is a relevant topic in optometry practice. My concern is that the skills that have long been the backbone of the Optometry profession may be devaluing as the profession seeks to focus on eye disease diagnosis and ocular therapeutics. Finding more engaging ways of teaching optics courses is important in reconnecting both professions. Putnam [5] showed that by supplementing the traditional pdf problem solutions with video solution teaching methods at Arizona College of Optometry, there was an extremely positive feedback from the students. The author suggested that introducing optometric applications as well as incorporating dynamic and interactive teaching methods very early in a professional optometric curriculum would help to fill the gap in the optometric optics education settings. I have devoted the coming years to doing so. I am dedicating some of my time to introducing the younger optometrist and optometry students across the globe to optics and I would love to see greater participation of optometry students in both OSA and AOS activities. Currently, QUT Optical Society is the only student chapter established and run by optometry students who are mostly higher degree research students.

In conclusion, optometry students and schools need to be involved in the activities of the Optical Society or their local optical groups since this is a win-win situation for everyone. The new technological world is more likely going to divide than unite us and the schools, students, stakeholders and optometry boards must resist that by coming back to the backbone of the profession. Together we will be stronger in advocacy. Long live optometry and long live optics and optical societies.

References

[1] V Nourrit, *Should optics be taught to optometry students?* Proc. SPIE 9666, 11th Education and Training in Optics and Photonics Conference, 966616 (5 June 2009).

[2] JR Gregg, *The Story of Optometry*, New York: Ronald Press, (1965).

[3] https://www.osa.org/en-us/about_osa/newsroom/news_releases/2018/the_optical_society_and_society_for_imaging_scienc/.

[4] DA Atchison, *Editorial: Who needs optics?* Clinical and Experimental Optometry (2003), 86, **1**, 1–2.

[5] NM Putnam, *Optics education in an optometric setting*, ETOP 2017 Proceedings, X Liu and X Zhang eds, 104521E, (Optical Society of America, 2017).

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AOS Photo Competition

Help us demonstrate the beauty of optics and photonics.

Please submit photographs that capture some aspects of optics and photonics, and are aesthetically pleasing. They can, for instance, be of your research, of optical phenomena, of optical devices.

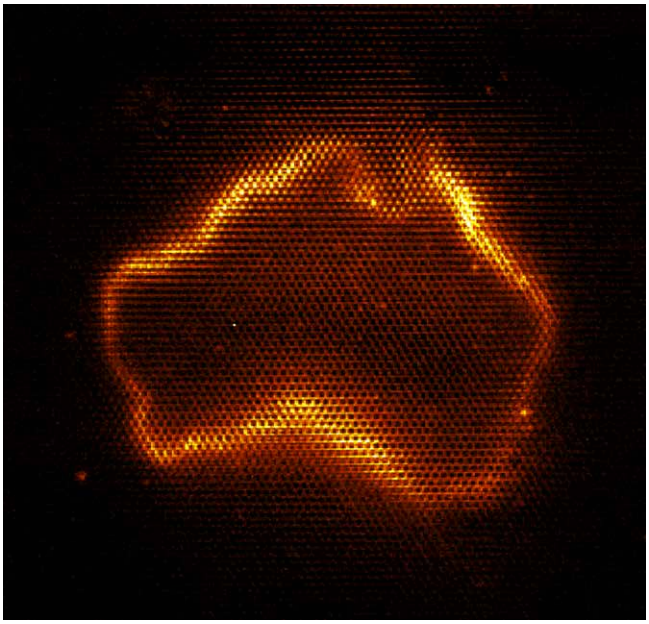
We want your assistance in generating photographs that we can use to promote Australian and New Zealand optics and photonics in print and online. We will publish the best photograph on the front cover of AOS News, and whoever submits this will get a year's membership free.

To enter, you need to send to ausoptsoc@gmail.com:

1) The photograph (see required specifications below)
2) Your name and organisation
3) A brief (one or two sentence) description of the photo
4) A covering email, that states "I ____full_name____ took this photograph and own the copyright. I hereby provide a royalty-free, perpetual, non-exclusive license to the Australian Optical Society to reproduce this photograph in print, online or other format."

The photos will be judged by a panel including three AOS Councillors, the Editor of the AOS News and the AOS Webmaster.

The competition will continue on a quarterly basis with judging for each issue of AOS News. AOS reserves the right to carry forward good entries from one quarter to the next, and in any particular quarter to award multiple winners or to award no winner. The competition will initially run until end of 2019. AOS may extend this date or terminate earlier, advising by email, through AOS News, or other reasonable communication.



Our past winners are pictured here. Above: Topological Australia, by Sergey Kruk, Australian National University, shows a photograph of an optical topological state shaped into an Australian continent. Ice bow by Stephane Coen, University of Auckland, shows a 22-degree halo around the sun, caused by high altitude ice crystals.

Conferences

2-6 August 2020, CLEO-PR 2020

The 14th Pacific Rim Conference on Lasers and Electro-Optics (CLEO Pacific Rim, CLEO-PR 2020) will be held at the International Convention Centre, Sydney, Australia from 2 to 6 August 2020. The Conference will cover all major areas in lasers and optoelectronics along with tutorial sessions, invited sessions and workshops in areas of current interest. The organising committee invites you to join us in Sydney in 2020. We look forward to seeing you there. www.cleopr2020.org

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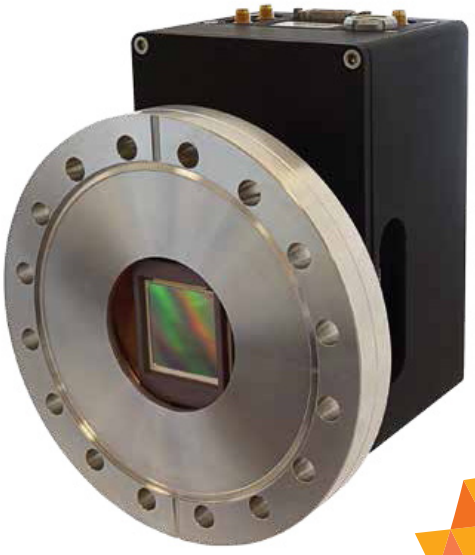

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How the Right Lighting Could Save the Mona Lisa

by Dorukalp Durmus

This article was originally published on
THE CONVERSATION

Next time you're in a museum or art gallery, observe each painting a little more closely. You may notice cracks on the surface of the canvas, especially if the painting is very old.

The damage you see is caused by radiant energy striking the painting's surface – and light (visible radiation) causes irreversible damage to artwork.

However, all is not lost. Our new research [1] shows that optimised smart lighting systems can reduce damage to paintings while preserving their colour appearance.

The dilemma

Damage to artwork by infrared, ultraviolet and visible radiation is well documented [2]. When a photon (an elementary light particle) is absorbed by a pigment in paint, the pigment molecule elevates to a higher energy state. In this excited state, the molecule's chemical composition changes. This is called a photochemical action.

Viewed from the human perspective, the photochemical action manifests itself as cracks, discolouration, or surface hardening.

Not surprisingly, daylight, which includes infrared and ultraviolet radiation, is highly damaging to paintings. In museums, it is common practice to use incandescent, and more recently, light emitting diodes (LEDs), to reduce damage.

Van Gogh's Sunflowers, 1888. The chrome yellow paint used darkens with long term exposure to light. Yellow colours are particularly vulnerable to being damaged by light.

However, a group of researchers showed that light can cause colour degradation regardless of the lighting technology. Bright yellow colours in Van Gogh's famous Sunflowers are turning dark brown due to absorption of blue and green light from LEDs [3]. Research on the conservation of artwork makes it look like this is a losing battle.

Of course, you will be right in thinking that the best conservation method would be the complete absence of light. But we need light for visibility and to appreciate the beauty of a painting.

This leaves us with a dilemma of two conflicting parameters: visibility and damage.

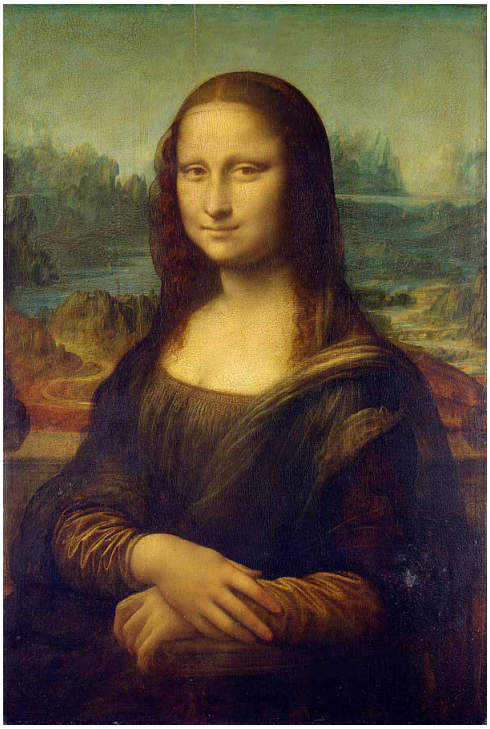
Light optimisation

Lighting technology in itself may not be enough to tackle this dilemma. However, the way we use technology can make a difference.

Our approach to address this problem is based on three key facts:

1. light triggers photochemical actions only when it is absorbed by a pigment
2. the reflectance factor of a pigment (its effectiveness in reflecting light) determines the amount of light absorption
3. light output (composition of the light spectrum, and the intensity of the light) of lighting devices, such as LEDs, can be fine-tuned.

It is possible to measure the reflectance factor of a painting and optimise lighting to reduce absorption. Previous research shows that optimising light to lessen absorption can reduce energy consumption significantly [4], and with no loss in visual experience [5]. Objects look equally natural and attractive under optimised light sources compared to regular white light sources.



Lighting causes damage to paintings over time. The Mona Lisa is displayed behind protective covering with specially controlled lighting to try to minimise degradation.

In this new study, we optimised LEDs for five paintings to reduce light absorption. Using a genetic algorithm (an artificial intelligence technique) [6], we reduced light absorption between 19% and 47%. Besides the benefits for the painting, this method almost halved the energy consumed by lighting.

In addition to increased sustainability and art conservation, the colour quality of the paintings was another parameter in our optimisation process. Colour appearance and brightness of paintings were held constant not to lower the appreciation of the artwork.

This is possible due to a quirk in our visual system. Photoreceptor cone cells, the cells in our retinas which enable human colour vision, are not equally sensitive to the whole visible spectrum.

Different combinations of wavelength

and intensity can result in identical signals in our brain. This understanding [7] gives us the flexibility of using different light sources to facilitate identical colour appearances.

This smart lighting system requires scanning of the artwork to obtain colour information. Then, a precise projection system [8] emits optimised lighting to the painting.

This method offers a solution to extend the lifetime of works of art, such as the world-famous Mona Lisa, without leaving them in the dark.

References

[1] D Durmus, D Abdalla, A Duis & W Davis, *Spectral Optimization to Minimize Light Absorbed by Artwork,* LEUKOS, (2018), DOI: 10.1080/15502724.2018.1533852

[2] W Allen et al, *Control of damage to museum objects by optical radiation*, CIE 157:2004. www.cie.co.at/publications/control-damage-museum-objects-optical-radiation

[3] L Monico et al, *Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Spectromicroscopic Methods 4*, Anal. Chem., 85, 2, 860–867, (2013), DOI: 10.1021/ac3021592

[4] D Durmus and W Davis, *Optimising light source spectrum for object reflectance*, Optics Express, **23**, 11, A456-A464 (2015), https://doi.org/10.1364/OE.23.00A456

[5] D Durmus and W Davis, *Object color naturalness and attractiveness with spectrally optimized illumination,* Optics Express, **25**, 11, 12839-12850 (2017), https://doi.org/10.1364/OE.25.012839

[6] K Deb, A Pratap, S Agarwal, T Meyarivan, *A fast and elitist multiobjective genetic algorithm: NSGA-II*, IEEE Trans Evol Comp, **6**, 2, 182-197, (2002), DOI: 10.1109/4235.996017

[7] WAH Rushton, *Review Lecture. Pigments and signals in colour vision*, J Physiol. **220**, 3, 1P–31P, (1972), PMC1331666

[8] D Vázquez, A Alvarez, H Canabal, A Garcia, S Mayorga, C Muro, T Galan, *Point to point multispectral light projection applied to cultural heritage*, Proc Vol 10379, Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XIV, 103790K (2017), https://doi.org/10.1117/12.2281482

Dorukalp Durmus is with the School of Architecture, Design and Planning, University of Sydney.

The original article can be found at: https://theconversation.com/how-the-right-lighting-could-save-the-mona-lisa-95938

Australasian Research in the News

Helping make brain surgery safer

A biopsy needle that can help surgeons identify and avoid blood vessels in the brain during surgery has undergone initial tests in humans. A team of researchers and clinicians led by the University of Adelaide has demonstrated the potential of the 'imaging needle' for reducing the risk of dangerous brain bleeds in patients undergoing brain biopsy.

Published in the journal Science Advances, the researchers describe how the tiny imaging needle can detect blood vessels with a very high degree of accuracy (91.2% sensitivity and 97.7% specificity). The researchers describe how they produced the imaging device with a tiny fibre-optic camera encased within a brain biopsy needle.

Led by researchers from the ARC Centre of Excellence for Nanoscale BioPhotonics and the University of Adelaide's Institute for Photonics and Advanced Sensing, the project is a collaboration with Sir Charles Gairdner Hospital and originated out of work undertaken at the University of Western Australia.

"Brain biopsies are a common procedure carried out to diagnose brain tumour and other diseases," says Professor Robert McLaughlin, Chair of Biophotonics in the University of Adelaide's Medical School. "It is a minimally invasive operation, but still carries the risk of damage to blood vessels that is potentially fatal. The imaging needle lets surgeons 'see' at-risk blood vessels as they insert the needle, allowing them to avoid causing bleeds. The fibre-optic camera, the size of a human hair, shines infrared light onto the brain tissue. And the computer system behind the needle identifies the blood vessel and alerts the surgeon."

The imaging needle has undergone an initial validation with 11 patients at Sir Charles Gairdner Hospital in Western Australia. "These patients were undergoing other types of neurosurgery, and consented to allow us to safely test how well the imaging needle was able to detect blood vessels during surgery," says Professor McLaughlin. "This is the first reported use of such a probe in the human brain during live surgery, and is the first step in the long process required to bring new tools like this into clinical practice."

Professor Christopher Lind, Consultant Neurosurgeon at Sir Charles Gairdner Hospital and the University of Western Australia, led the clinical trial. "Bleeds are a risk in many types of neurosurgery and there is a great opportunity for new technologies like this to help us reduce those risks," Professor Christopher Lind says.

A video about the research can be seen on YouTube at: https://youtu.be/3NztRONTKgw

Source material: https://www.adelaide.edu.au/news/news104162.html

Original article: H Ramakonar, BC Quirk, RW Kirk, J Li, A Jacques, CRP Lind, and RA McLaughlin, *Intraoperative detection of blood vessels with an imaging needle during neurosurgery in humans*, Science Advances 19 Dec 2018, 4(12), eaav4992.
DOI: 10.1126/sciadv.aav4992

Quantum on the edge: Light shines on new pathway for quantum technology

Dr Andrea Blanco-Redondo in her photonics laboratory at the Sydney Nanoscience Hub, University of Sydney. Image credit: Jayne Ion/ University of Sydney.

Scientists in Australia have for the first time demonstrated the protection of correlated states between paired photons using the intriguing physical concept of topology. This experimental breakthrough opens a pathway to build a new type of quantum bit, the building blocks for quantum computers.

The research, developed in close collaboration with Israeli colleagues, is published in the journal, Science, a recognition of the foundational importance of this work. "We can now propose a pathway to build robust entangled states for logic gates using protected pairs of photons," said lead author, Dr Andrea Blanco-Redondo at the University of Sydney Nano Institute.

Logic gates are the switches needed to operate algorithms written for quantum computers. Classical computational switches are in simple binary forms of zero or one. Quantum switches exist in a state of 'superposition' that combine zero and one. Protecting quantum information long enough so that quantum machines can perform useful calculations is one of the biggest challenges in modern physics. Useful quantum computers will require millions or billions of qubits to process information. So far, the best experimental devices have about 20 qubits.

To unleash the potential of quantum technology, scientists need to find a way to protect the entangled superposition of quantum bits - or qubits - at the nanoscale. Attempts to achieve this using superconductors and trapped ions have shown promise, but they are highly susceptible to electromagnetic interference, making them devilishly difficult to scale up into useful machines. The use of photons rather than electrons has been one proposed alternative upon which to build logic gates that can calculate quantum algorithms. Photons, unlike electrons, are well isolated from the thermal and electromagnetic environment. However, scaling quantum devices based on photonic qubits has been limited due to scattering loss and other errors; until now.

"What we have done is develop a novel lattice structure of silicon nanowires, creating a particular symmetry that provides unusual robustness to the photons' correlation. The symmetry both helps create and guide these correlated states, known as 'edge modes'," said Dr Blanco-Redondo, the Messel Research Fellow in the School of Physics. "This robustness stems from the underlying topology, a global property of the lattice that remains unchanged against disorder."

The correlation this produces is needed to build entangled states for quantum gates. Channels, or waveguides, made using silicon nanowires just 500 nanometres wide, were lined up in pairs with a deliberate defect in symmetry through the middle, creating two lattice structures with different topologies and an intervening 'edge'. This topology allows for the creation of special modes in which the photons can pair up, called 'edge modes'. These modes allow information carried by the paired photons to be transported in a robust fashion that otherwise would have been scattered and lost across a uniform lattice.

Dr Blanco-Redondo designed and performed the experiment in the Sydney Nanoscience Hub with Dr Bryn Bell, previously at the University of Sydney and now at the University of Oxford. The photons were created by high-intensity, ultra-short laser pulses, the same underlying technology for which Donna Strickland and Gerard Mourou were awarded the 2018 Nobel Prize in Physics.

This research is the latest in the flourishing of discoveries in the past decade on topological states of matter. These topological features offer protection for classical and quantum information in fields as diverse as electromagnetism, condensed matter, acoustics and cold atoms. Microsoft Quantum Laboratories, including the one in Sydney, are pursuing the development of electron-based qubits where quantum information is topologically protected via the knotting of quasiparticles known as Majorana fermions. This is a bit like braiding half electron states induced through the interaction of superconductors and semiconducting metals.

Topologically protected states have previously been demonstrated for single photons. However, Dr Blanco-Redondo said: "Quantum information systems will rely on multiphoton states, highlighting the importance of this discovery for further development." She said the next step will be to improve protection of the photon entanglement to create robust, scalable quantum logic gates.

Professor Stephen Bartlett, a theoretical quantum physicist at Sydney Nano who is unconnected to the study, said: "Dr Blanco-Redondo's result is exciting at a fundamental level because it shows the existence of protected modes attached to the boundary of a topologically ordered material. What it means for quantum computing is unclear as it is still early days. But the hope is that the protection offered by these edge modes could be used to protect photons from the types of noise that are problematic for quantum applications."

Source material: https://sydney.edu.au/news-opinion/news/2018/11/02/quantum-on-the-edge--light-shines-on-new-pathway-for-quantum-tec.html

Original article: A Blanco-Redondo, B Bell, D Oren, BJ Eggleton, M Segev, *Topological protection of biphoton states*. Science, 2018; 362 (6414): 568. DOI: 10.1126/science.aau4296

Product News

V-738 PIMag high precision XY stage

Physik Instrumente, a global leader in the design and manufacture of high precision motion control systems has launched V-738 PIMag magnetic drive high precision XY stage.

The PIMag magnetic direct drive does not use mechanical components in the drivetrain, with its 3-phase magnetic drive transmitting the drive force directly to the motion platform without friction. Key application areas include: laser cutting, metrology, scanning and microscopy. The V-738 has the following key features:

- Travel range: 102 x 102mm
- Resolution: 1nm
- Incremental linear encoders
- Minimum incremental motion: 20nm
- Velocity: 0.5 m/s
- Bidirectional repeatability: ±25nm
- Load capacity: 100N
- 150 x 150mm aperture

Four channel single photon counting module

Introducing the all new high performance four channel single photon counting modules (SPCM) from Excelitas Technologies. Excelitas Technologies is a global leader focused on delivering innovative, customised optoelectronics solutions.

Excelitas Technologies have extended its portfolio of low-light-level detection modules with a multi-channel version of the well-known SPCM single photon counting module that is based on a unique silicon avalanche photodiode (SLiK) that has a circular active area of 180µm with a peak photon detection efficiency exceeding 60% at 650nm. Each photodiode is both thermoelectrically cooled and temperature controlled, ensuring stabilised performance despite changes in the ambient temperature.

The SPCM-AQ4C card uses an improved circuit with a peak count rate >4 M c/s for short bursts of time on all 4 channels and a count rate of 1.5 M c/s for continuous operation. There is a "dead time" of 50 nanoseconds (ns) between pulses. The module requires +2 Volts, +5 Volt, and +30 Volt power supplies. The output of each channel – a TTL pulse that is 4.5 Volts high (into a 50 Ω load) and 25 ns wide – is available at the card edge behind the circuit board. Each TTL pulse corresponds to a detected photon.

New VIS and IR high power fibre amplifiers

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The MIR Series Mid-Infrared Laser delivers >1 mJ energy and <10 ns laser pulses with factory-selectable infrared wavelengths from 1.5 microns to 4 microns. The Mid-IR laser was developed in partnership with Bridger Photonics and offers software-selectable output pulse energies in a compact and robust package. The system is diode pumped, which eliminates the need for scheduled maintenance and water cooling. These features facilitate a hassle-free integration into laboratory experiments, or use as an OEM unit.

Specifications:

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The new Kymera 328i imaging spectrograph from Andor Technology is a highly modular spectrograph featuring patented Adaptive Focus, quadruple on-axis grating turret and TruRes™ technology delivering superb spectral resolution performance.

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The Australian Optical Society

AOS Prizes and Awards 2019

Australian Optical Society members are reminded that the deadline for applications for all AOS awards is 30 April. Please consider applying or nominating students or colleagues. All applications and nominations are to be forwarded to the AOS Secretary. Membership of the AOS is an eligibility requirement for all awards.

AOS W.H. (Beattie) Steel Medal

The AOS WH Beattie Steel Medal is awarded for an outstanding contribution or contributions to the field of optics in Australia or New Zealand by a member of the Australian Optical Society. This Medal is the most prestigious award of the Australian Optical Society and is normally presented only to a nominee at an advanced stage of their professional career with a strong and sustained record of authority, enterprise and innovation in the field of optics in Australia or New Zealand.

AOS Geoff Opat Early Career Researcher Prize

This Prize recognises an outstanding early career researcher for their contribution to the field of optics. The prize is $1500, awarded annually, and includes an invitation to give an extended presentation at the annual AOS conference. The winner of this prize will also write an article for AOS News.

AOS Postgraduate Student Prize

The Australian Optical Society wishes to encourage participation in national and international conferences by high-quality postgraduate students, and thus the Society has instituted the Australian Optical Society Prograduate Student Prize, which is a grant for conference travel valued up to $1500. Up to one award will be made in each year. Preference will be given in the selection procedures to applicants who intend to use the prize to attend and present their research results at a major conference outside Australia and New Zealand.

AOS John Love Award

This award recognises those who have made a significant achievement in technical optics, not necessarily in a manner manifested by an extensive academic record or a traditional academic reputation. The work for which the award is made must have been carried out principally in Australia or New Zealand. Applications are encouraged from, but not restricted to, young optical workers. The winner will receive a prize consisting of $300 cash, one year's free membership of AOS, and an invitation to attend the AOS conference and make an oral presentation of their work.

AOS Warsash Science Communication Prize in Optics

This Prize is open to AOS student members whose Honours, Masters or PhD research work has been accepted for publication in a refereed journal in the past year. The Prize may only be awarded once to any individual. A submission consists of a 300-word summary of the published research, written in the style of a New Scientist article or similar, explaining the significance of the applicant's research project to a casual reader outside the field. The $500 Prize is sponsored by Warsash Scientific Pty Ltd.

For more information, visit optics.org.au

STA News

Superstars of STEM: Achieving Our Mission to Shift Stereotypes

We recently announced 60 new Superstars of STEM - a group of impressive, diverse and inspiring women from across Australia. They were selected from hundreds of strong applicants, and we will work with them over the next two years to support them to become role models for the next generation of Australian girls and young women.

"When we launched the program last year, I said that the stereotypical scientist was an old man in a white coat," STA President Professor Emma Johnston AO said. "Thanks to the first 30 Superstars this is starting to change, and with 60 more announced today, we will be well on our way to permanently smashing the stereotype."

In the next few decades, we expect around 60% of new jobs created will require skills in science, technology, engineering and mathematics (STEM). As global challenges grow in scale and complexity, it's becoming increasingly urgent to nurture a strong, capable and creative STEM workforce that brings diverse perspectives to problem-solving, knowledge building and solution-seeking.

But Australia's currently failing to take advantage of our full breadth of clever and creative minds. We're struggling to attract and retain women into the STEM workforce, and the tired old 'scientist' stereotype is partly to blame. Only 21% of people speaking about STEM are women. Women who work in science and technology struggle for visibility.

Many girls cite a lack of role models as the reason for not pursuing studies in advanced mathematics and science in school, or considering STEM degrees (such as maths, physics, or computer science) when enrolling in university.

It is these two facts that inspired Science & Technology Australia to establish the Superstars of STEM program in 2017, with a remit to smash stereotypes and empower a diversity of Australian women in STEM to become proud public role models.

We selected 30 impressive scientists, technologists, teachers and entrepreneurs from hundreds of applicants for the program pilot. They've undertaken year-long training in advanced communication, and we've linked them with decision-makers and opportunities to share their stories and become hugely effective role models.

Guided by STA, a team of expert facilitators, and one-on-one mentoring by women of influence from business, politics, the media and science, the inaugural Superstars have exceeded all our expectations. They've comprehensively expanded their influence online, featured in a range of print and broadcast media, and connected directly with thousands of school students across the nation.

Some of the highlights include:

- Over 12 months, the Superstars achieved more than 1,400 media mentions globally, with an estimated advertising equivalent of $3 million in Australian media alone.
- In total, their news media stories were seen an estimated 82.5 million times.
- The Superstars' collective social media presence grew across all platforms by 53.19% – with a combined audience of 60,830 followers.

Inaugural Superstars of STEM also reported strong growth in personal confidence. On entry to the program, just 10% of participants felt confident speaking with the media. By the end, this had increased to 80%, and nine out of ten rated their media communications as proficient, advanced, or superstar.

During their time as Superstars of STEM, the group also visited 83 schools in Australia (as well as a few in Asia) and reached more than 12,000 students.

Participants were also invited to speak on a range of high-profile stages including various TEDx events, The National Press Club, the Australian Embassy in Jakarta, The NSW Chief Scientists Breakfast Seminar Series, "It takes a spark" conference key notes, and many round table discussions, podcasts, blogs and government and corporate events.

STA is proud of what our inaugural Superstars have achieved. We look forward to working with the program alumni and our second cohort of 60.

Superstars of STEM has been made possible by the generosity of our major supporter, the Department of Industry, Innovation and Science. We're also grateful to our partners who've worked with enthusiasm to build skills and opportunities for the Superstars – the Australian Science Media Centre, Women in STEMM Australia, SBS, The Conversation, and GE. And we couldn't have done it without our expert trainers and delivery partners, our generous program mentors and of course, the inaugural 30 Superstars of STEM.

To learn more about the program and read about what's coming next for Superstars II, visit the program web page.

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Subwavelength Localisation of Light without Metals

by Kirill Koshelev, Sergey Kruk, and Yuri Kivshar

For many years, subwavelength localisation of light has been governed by the physics of noble metals and surface plasmon polaritons (or plasmons). However, the recent progress in metamaterials and meta-optics associated with Mie scattering brings a novel platform into the field of nanoscale optics based on high-index dielectric nanoparticles which may support high-quality resonances driven by the exotic physics of bound states in the continuum, introduced by the pioneers of quantum mechanics almost 90 years ago.

Introduction

The field of nanophotonics describes the subwavelength localisation of light, and it is usually associated with the physics of noble metals and surface plasmon polaritons (or plasmons) supported by metal-dielectric interfaces in nanostructures and waveguides. However, the recently emerged field of resonant dielectric nanophotonics provides a novel research direction in nanoscale optics [1]. All-dielectric resonant nanophotonics employs subwavelength Mie-resonant dielectric nanoparticles as elementary units (or "meta-atoms") for creating highly efficient optical metadevices, defined as devices having unique functionalities derived from structuring of functional matter on the subwavelength scale [2]. Because of the unique optical resonances and various interference effects accompanied by strong localisation of the electromagnetic fields, high-index nanoscale structures are expected to replace different plasmonic components in a range of potential applications. Many concepts which had been developed earlier for plasmonic structures but fell short of their potential due to strong losses of metals at optical frequencies, can now be realised for low-loss high-index dielectric resonant structures.

It is well known that high-index dielectric meta-atoms support electric and magnetic Mie-type resonances which can be tailored by the nanoparticle geometry [1]. Mie-resonant semiconductor nanoparticles have recently received considerable attention for applications in nanophotonics including metasurfaces and nonlinear frequency generation [3]. Importantly, the possibility of resonant enhancement of magnetic fields in dielectric structures enables simultaneous excitation of strong electric and magnetic multipolar resonances which can result in constructive or destructive interference with unusual spatial scattering characteristics [4], thus driving many novel effects in both linear and nonlinear nanophotonics.

All-dielectric nanostructures offer many advantages over their plasmonic counterparts, in particular enabling both passive and active nanophotonic elements and devices, and - depending on the material choice - CMOS compatibility. For active nanophotonics, the dielectric material itself may be used as a source of light, or localised light sources such as quantum wells or quantum dots can be placed inside the dielectric material of the nanoresonator, where the near-field enhancement is usually the largest. An ultimate goal is to create active dielectric nanoantennas with optical resonances at the wavelength of the material emission, thus providing a pathway for the realisation of novel types of light sources and nanolasers.

Resonances in all-dielectric nanophotonics

Resonances and interference effects play a crucial role in all-dielectric nanophotonics because they allow for a substantial enhancement of both electric and magnetic fields and tailor light-matter interaction at the nanoscale. The physics of high-index dielectric nanostructures relies on the geometric Mie resonances and interference between different modes of resonators that can drive novel effects such as unidirectional scattering of light, Huygens' metasurfaces, and bound states in the continuum.

Traditionally, Mie resonances are associated with the exact solutions of Maxwell's equations for spheres (see e.g. reference [1] and references therein). However, optical Mie-type resonances can exist for any geometry of high-index dielectric nanoparticles and they can also be employed to control light below the free-space diffraction limit in many functional nanophotonic devices [3]. For spherical geometry, each Mie solution is exactly determined by a single multipole, which makes the representations of electromagnetic field in terms of eigenmodes and multipole series identical. Despite the fact that for resonators of an arbitrary shape individual solutions are simultaneously characterised by an infinite number of multipoles, for many common configurations only one leading multipole dominates other terms in the expansion and allows easy distinction between various Mie resonances.

Importantly, dielectric nanoparticles of simple geometries can support both electric and magnetic type resonances of comparable strengths. A strong magnetic dipole (MD) resonance occurs due to a coupling of incoming light to the circular displacement currents of the electric field, owing to the field penetration and phase retardation inside the particle. This occurs when the wavelength inside the high-index material of the particle becomes comparable to the particle's spatial dimension, namely $2R \sim \lambda/n$, where n is the refractive index of the particle's material, R is the nanoparticle's radius, and λ is the wavelength of light. This is a type of geometric resonance that requires that a nanoparticle should have a large refractive index in order to support strong MD resonances in the subwavelength regime. Similarly, a dielectric nanoparticle can support resonances dominated by the electric dipole and other high-order multipoles such as electric quadrupole and magnetic quadrupole resonances. Mie resonances are usually associated with localisation of the incident electromagnetic field inside the particles suggesting at least two-orders-of-magnitude enhancement of many optical effects observed with high-index dielectric nanoparticles, in comparison with nonresonant cases [3].

Bound states in the continuum (BICs)

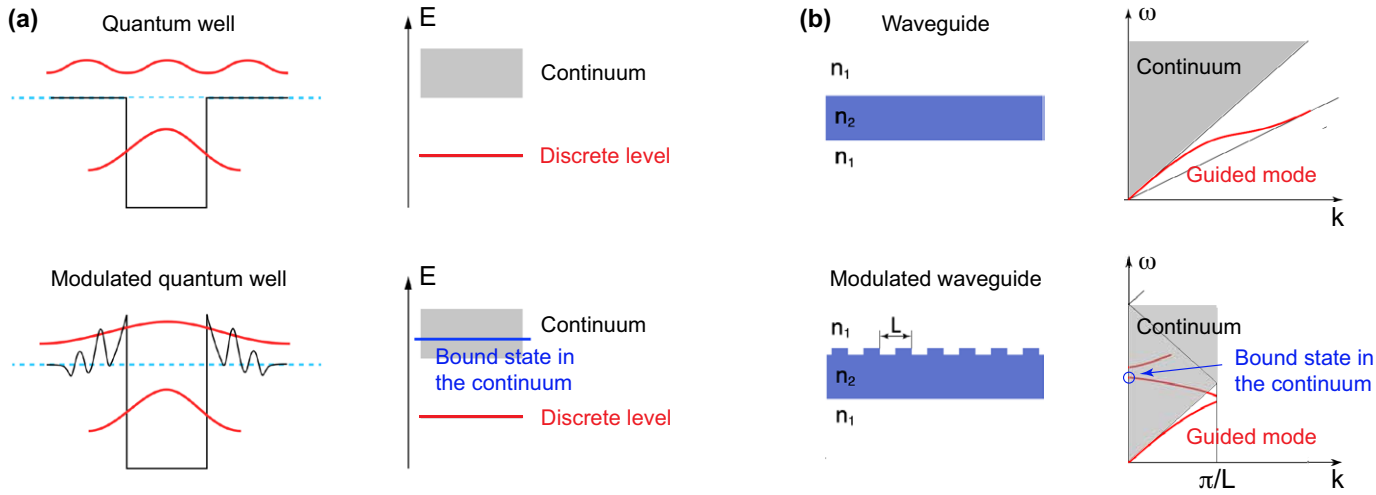

Figure 1. a) A sketch of a conventional box-like energy potential in quantum mechanics supporting a discrete bound state (top) and an exotic potential supporting a bound state localised within the radiation continuum (bottom), with the energy levels shown schematically at the right. **b)** A sketch of a conventional dielectric function distribution for an optical waveguide (top) and for a modulated waveguide such as a photonic-crystal slab (bottom), with the frequency dispersion shown schematically at the right.

originate from coupling between the modes in dielectric structures such as photonic crystals, metasurfaces, and isolated resonators [5]. BIC solutions were introduced in quantum mechanics 90 years ago by J. von Neuman and P. Wigner [6], while in photonics they were re-discovered only in 2008 [7, 8]. The physics and origin of such exotic states in quantum mechanics is summarised in figure 1(a), while figure 1(b) shows how BICs can be achieved in simple photonic structures due to a periodic modulation.

Importantly, a true bound state in the continuum is a mathematical object with an infinite value of the quality factor (Q factor) and vanishing resonance width, and it can exist only in ideal lossless infinite structures or for extreme values of parameters [9]. In practice, a quasi-BIC, also known as a supercavity mode [10], can be realised when both the Q factor and resonance width remain finite and approach the mathematical condition of a BIC asymptotically. The BIC-inspired localisations of light make it possible to realise high-Q modes in many systems, including optical cavities, coupled optical waveguides, periodic chains of spheres and discs, and photonic crystal slabs [5].

In connection with meta-optics, many metasurfaces composed of arrays of dissimilar meta-atoms with a broken in-plane symmetry can support high-Q resonances directly associated with the concept of bound states in the continuum [11]. This includes, in particular, broken-symmetry pixelated dielectric metasurfaces suggested for surface-enhanced sensing [12].

Recent discoveries revealed that even a single subwavelength resonator made of a high-index dielectric can be tuned into the regime of a supercavity mode and can support quasi-BICs. This can be achieved by varying the geometrical parameters of a nanoparticle when the radiative losses are almost suppressed due to destructive interference of leaky modes [10]. We discuss this case below in more detail for the example of an AlGaAs cylindrical resonator.

High-Q resonances in isolated nanoparticles

Subwavelength confinement of light and high-Q factors of optical resonators are crucially important for many applications in photonics. Conventional ways to enhance the Q factor are to increase the size of a resonator, to employ whispering gallery modes and cavities in the engineered structures such as photonic crystals, or to arrange several resonators in space and exploit their mutual interference. Recently, a completely different approach was proposed based on the concepts of quasi-BICs and supercavity modes which allows the subwavelength confinement of light in all-dielectric high-Q resonators [9, 10]. The physics of a substantial growth of the Q factor is directly associated with quasi-BICs: in open resonators radiative losses are suppressed dramatically when the radiating tails of several leaky modes cancel each other out via destructive interference [10].

Figure 2 summarises the physics of the quasi-BIC formation in isolated subwavelength high-index resonators. A nanoparticle shown in figure 2(a) is a nanodisc made of AlGaAs (20% Al fraction) placed in a homogeneous background with refractive index 1. The realistic values of permittivity and loss of AlGaAs are taken from the data for the wavelength around 1,600 nm.

The eigenmodes of a finite-length nanodisc can be roughly divided into two families, namely, radially oscillating and axially oscillating modes. The radial resonances originate from the resonances of an infinitely long cylinder as Mie-like modes and the axial modes can be linked to the Fabry-Pérot-like modes. A pair of low-frequency Fabry-Pérot-like and Mie-like modes undergoes strong coupling via continuous tuning of the nanodisc aspect ratio r/h producing the characteristic avoided resonance crossing feature, as shown in figure 2(c). Since the nanodisc represents an open resonator, the radiative lifetime of interacting modes is also strongly modified leading to the generation of a quasi-BIC with an enhanced Q factor up to 120. This value is one order of magnitude higher than the Q factor of conventional MD resonances.

The electric field profile and far-field distribution of the high-Q mode for the aspect ratio in- and out of the quasi-BIC regime are shown in the cases A, B, and C of figure 2(b). Away from the quasi-BIC condition the far-field distribution of the high-Q mode is dominated by the MD contribution. Since both Fabry-Pérot-like and Mie-like modes are characterised by the MD radiation pattern, their hybridisation leads to sufficient suppression of the MD component enabling the next allowed multipole – a highly symmetric magnetic octupole mode. The high-Q quasi-BIC mode can be efficiently excited from the

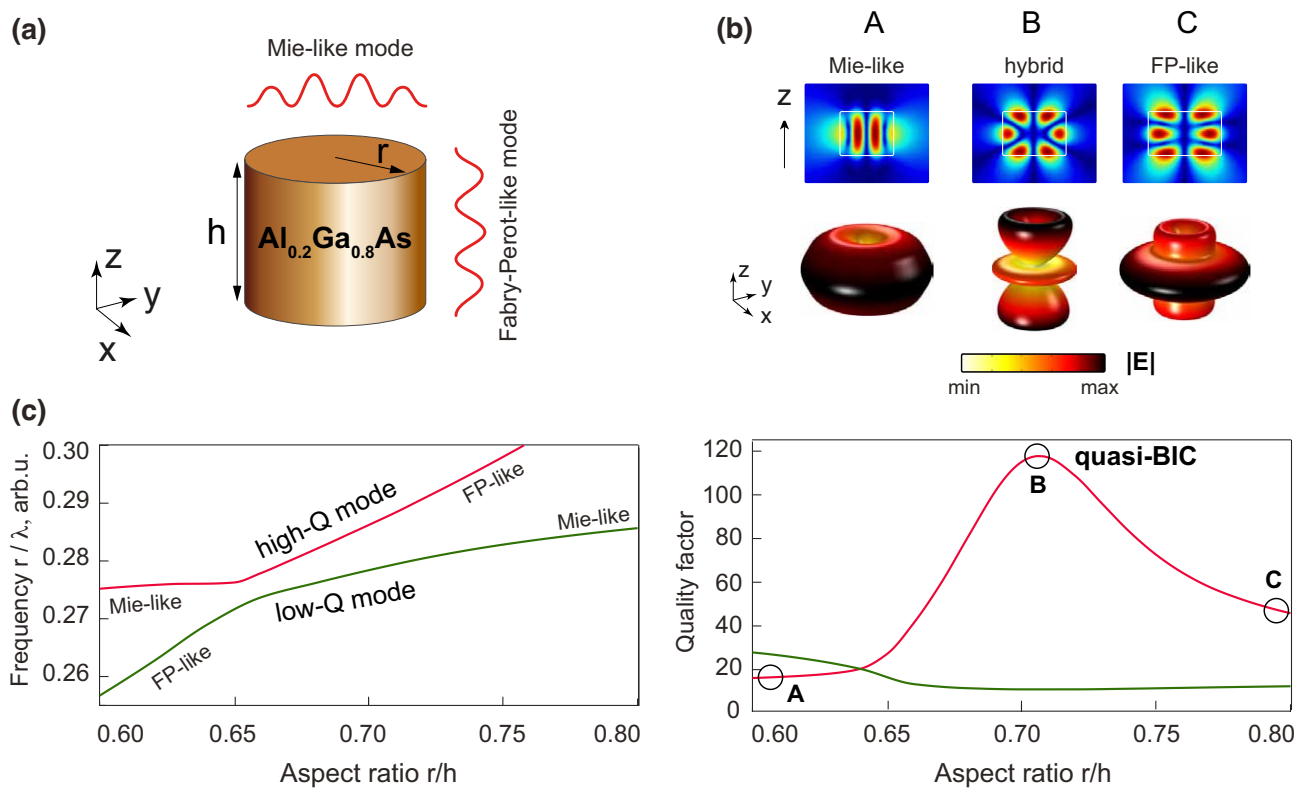

Figure 2. The physics of quasi-BIC resonances in an isolated subwavelength nanoparticle (adopted from reference [9]). **a)** Geometry of an AlGaAs cylindrical resonator with radius r and height h. **b)** Upper panel: Near-field distributions of the electric field at points A, B, and C. Lower panel: Transformation of the radiation pattern for the high-Q mode while passing the avoided resonance crossing. The quasi-BIC supercavity mode condition corresponds to the magnetic octupole mode. **c)** Strong coupling of two resonator modes resulting in the emergence of a quasi-BIC. Left: Mode frequencies vs. aspect ratio of the nanoparticle. Right: Mode Q factor vs. aspect ratio. Points A, B, and C mark the mode structure from panel b).

far-field by structured light: a focused, azimuthally polarised vector beam.

A new era of nonlinear nanophotonics

A large enhancement of the Q factor of high-index dielectric nanoscale resonators offers a paradigm shift in nonlinear optics, opening up new horizons for nanoscale nonlinear metadevices. The reason is that nonlinear optics at the nanoscale is governed by strong field confinement and the resonant response is not limited by phase matching. As a result, the processes of high-order harmonic generation can be boosted dramatically since they scale as $(Q/V)^n$, where n is the process order and V is the mode volume. Therefore, a giant increase in generation efficiency is expected in isolated subwavelength nanoparticles tuned to the quasi-BIC regime, as was recently predicted for second-harmonic generation (SHG) in AlGaAs nanodiscs [13].

For almost half a century, nonlinear nanophotonics has remained of mainly academic interest with only a few examples of interdisciplinary applications and technology transfer such as SERS dating back to 1973. The main reason is the low efficiency of nonlinear processes at the nanoscale as traditionally light is required to propagate over a long distance inside a material to build up a detectable nonlinear signal.

In the recent past nonlinear nanophotonics was dominated by metallic nanoparticles. Metals were an attractive choice as they exhibit extremely high intrinsic nonlinearities. In addition, the support of plasmon resonances allows for light confinement and local intensity enhancement near electric field hot spots. However, the overall efficiency of nonlinear frequency conversion in plasmonic nanostructures remained very small, being of the order of ~10^{-10} W^{-1} (see Table 1 and reference [14]). Efficiencies are usually limited by Ohmic losses, small mode volumes confined to metal surfaces and low laser damage thresholds. All-dielectric nanostructures with magnetic dipole Mie resonances have recently been suggested as an important pathway to enhance the nonlinear efficiency beyond the limits associated with plasmonics. The efficiency of nonlinear processes in Mie-resonant nanoparticles was reaching 10^{-6} W^{-1} (see Table 1 and references [15-16]).

Very recent theoretical proposals and experimental observations on quasi-BIC nonlinear nanoparticles demonstrate breakthrough conversion efficiencies on the order of 10^{-3} W^{-1} (see Table 1 and references [13, 17]). Figure 3 summarises our recent numerical results and experimental data on the enhancement of SHG efficiency for individual dielectric nanodiscs in the quasi-BIC regime. As shown in figure 3(a), the resonator is excited by an azimuthally polarised Gaussian beam providing perfect mode matching with the high-Q resonance, whose electric field is uniform with respect

Platform	Resonance	SHG Efficiency, W^{-1}	Reference
Au	Plasmonic modes	5×10^{-10}	[14]
GaAs-on-AlOx	MD mode	1.5×10^{-8}	[15]
AlGaAs-in-insulator	MD mode	6.4×10^{-6}	[16]
AlGaAs	Quasi-BIC	$10^{-2} \sim 10^{-3}$	[13,17]

Table 1. Comparison of SHG conversion efficiencies in plasmonic and all-dielectric nanoparticles driven by the specific resonant modes (data taken from references [13-17]).

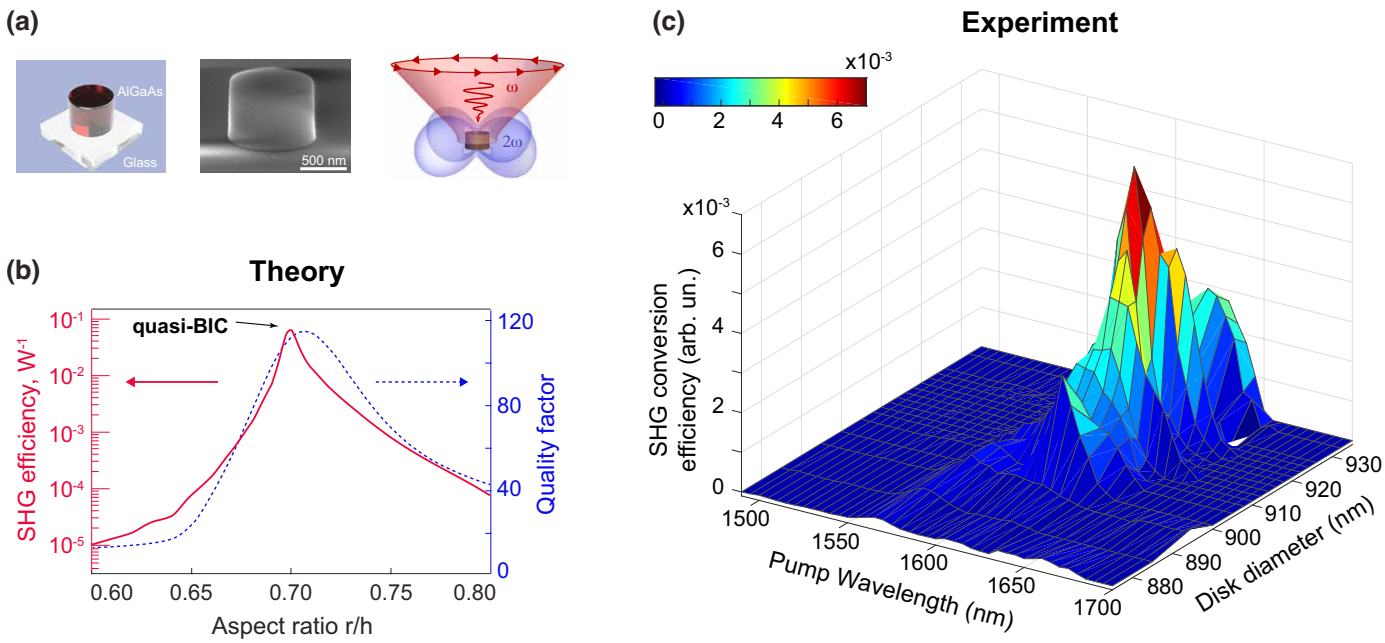

Figure 3. Giant SHG from an AlGaAs nanoparticle tuned to BIC conditions. **a)** Left to right: Schematic image and electron microscope image of a subwavelength resonator; an illustration of SHG in a resonant particle under vector beam excitation [13]. **b)** Dependence of the SHG conversion efficiency (solid red curve) and mode quality factor (dashed blue) on the nanodisc aspect ratio r/h in the vicinity of the quasi-BIC resonance [9]. **c)** Experimental SHG generation efficiency (in dimensionless units) vs. pump wavelength for a high-Q resonator with the diameter of 915 nm [17].

to the azimuthal direction. For numerical calculations presented in figure 3(b), we assume a diffraction-limited beam waist and the value of second-order nonlinear susceptibility of 290 pm/V.

We fabricate resonators of various radii from AlGaAs layers grown epitaxially on GaAs wafer. We employ electron-beam lithography and sequential ion etching. The resonators are then transferred to a glass substrate from the GaAs wafer [see figure 3(a)]. In our experiment, we pump the resonators with 300 fs pulses in the spectral range from 1490 to 1700 nm by an optical parametric amplifier MIROPA-fs-M from an Australian start-up company Hotlight Systems. To couple efficiently to high-Q modes, we employ light structured with a home-made silicon metasurface. We use an infrared Ophir power meter to measure pump intensity, and a visible Ophir power meter together with a Trius 694 camera for nonlinear measurements. Nonlinear spectra are checked with the Ocean Optics spectrometer QE Pro.

Figure 3(c) shows the experimental results for SHG intensity as a function of both pump wavelength and resonator diameter [17]. We observe a pronounced peak in second-harmonic intensity for the 915 nm resonator at 1615 nm wavelength for azimuthal pump polarisation. In our experiments we estimate the overall conversion efficiency of $I_{SH}/I_{pump} = 10^{-3}$ in a sub-optimal experimental arrangement. The system holds promise to demonstrate higher efficiency in our ongoing research. This is a record high conversion efficiency achieved by now for any nanophotonic resonator, as summarised in Table 1 based on the data from on references [13-17].

Concluding remarks

Resonant dielectric nanoparticles and metasurfaces provide an alternative solution to enhance the performance of many nanophotonic structures and metadevices that employ metallic elements and plasmonics effects. The study of resonant dielectric meta-optics has become a new research direction in metamaterials and nanophotonics, and it is expected to complement or substitute some of the plasmonic components in a range of potential applications. The unique low-loss resonant behaviour makes it possible to reproduce many subwavelength resonant effects already demonstrated in nanoscale plasmonics without essential energy dissipation.

In the past three years, we have witnessed a major breakthrough in the field of passive meta-optics and metasurfaces: by switching from metallic to all-dielectric designs we are able to achieve near unity transmission efficiency with phase and polarisation control. All-dielectric metasurfaces are rapidly establishing themselves as a new technology evidenced by a growing number of patents, start-up companies, and industry engagements. This rapid progress stands on (direct or indirect) theoretical progress in the physics of Mie-resonant dielectric metasurfaces driven by optically-induced magnetic response. We anticipate that the novel physics originating from the 90-year-old concept of bound states in the continuum will provide a new twist to both active and nonlinear nanophotonics in a way similar to how Mie-theory has shaped passive all-dielectric resonant nanophotonics.

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References

[1] A Kuznetsov et al, Science **354** (6314), aag2472 (2016).
[2] NI Zheludev and YS Kivshar, Nature Materials **11**, 917-924 (2012).
[3] S Kruk and Y Kivshar, ACS Photonics **4**, 2638-2649 (2018).
[4] W Liu and Y Kivshar, Optics Express **26**, 13085-13105 (2018).
[5] CW Hsu et al, Nature Review Materials **1**, 16048 (2016).
[6] J von Neuman and P Wigner, Phys. Z **30**, 467-470 (1929).
[7] DC Marinica, et al, Phys. Rev. Lett.

100, 183902 (2008).
[8] EN Bulgakov and AF Sadreev, Phys. Rev. B **78**, 075105 (2008).
[9] K Koshelev, A Bogdanov, and Y Kivshar, Science Bulletin (2018); https://doi.org/10.1016/j.scib.2018.12.003
[10] MV Rybin et al, Phys. Rev. Lett. **119**, 243901 (2017).
[11] K Koshelev et al, Phys. Rev. Lett. **121**, 193903 (2018).
[12] A Tittl et al, Science **360** (6393), 1105-1109 (2018).
[13] L Carletti et al, Phys. Rev. Lett. **121**, 033903 (2018).
[14] M Celebrano et al, Nature Nanotechnology **10**, 412 (2015).
[15] S Liu et al, Nano Letters **16**, 5426-5432 (2016).
[16] S Kruk et al, Nano Letters **17**, 3914-3918 (2017).
[17] First presented at 7th NANOMETA 2019 (Seefeld, Austria): S Kruk, K Koshelev, JH Choi, EV Melik-Gaykazyan, D Smirnova, HG Park, and Y Kivshar (paper FRI4f.35)

Mr. Kirill Koshelev, Dr. Sergey Kruk, and Prof. Yuri Kivshar are with the Meta-Optics and Nanophotonics Group of the Nonlinear Physics Center, Research School of Physics and Engineering, Australian National University. Dr Sergey Kruk is the recipient of the 2017 Geoff Opat Early Career Award of the Australian Optical Society, and Prof. Yuri Kivshar is the recipient of the 2017 W.H. (Beattie) Steel Medal of the Australian Optical Society.

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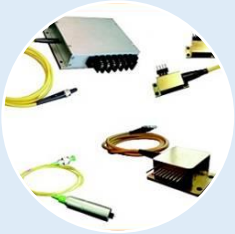

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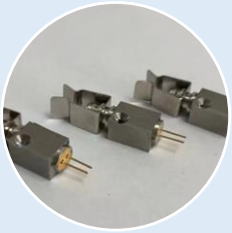

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Optics in Everyday Life: The Human Eye as a Photon Detector

by Tony Klein

More than a 100 years before Planck's 1901 paper on the black body spectrum or Einstein's 1905 paper on the photoelectric effect, it would have been possible to show experimentally that light was quantised, i.e. that it consisted of a stream of photons, using only the human eye as a detector.

I came across this intriguing proposition in an old book on Biophysics [1] which discusses the sensitivity of the eye. In order to estimate the order of magnitude of what we are talking about, we may start with the proposition that stars of the 8th magnitude are just visible. This corresponds to about 10^{-16} Joule/sec which, at a wavelength of 510 nm (the peak sensitivity of the rods in the retina) would correspond to about 100 or so photons in a flash of light. Of these about 5 are reflected by the cornea; another 45 or so are absorbed in the aqueous and vitreous media before reaching the retina, and 80% of the remainder are absorbed in the non-sensitive portions of the retinal structure. Thus, one can conclude that about 10 photons would constitute a detectable flash of light. (All data from Reference 1).

In a practical experiment to measure the actual number, dark-adapted subjects were exposed to flashes of light attenuated by a large number of identical absorbers, the number of which corresponds to logarithmically increasing attenuation factors. One records the percentage of the time that the flash of light was seen or not seen. If light were a continuous stream of energy, one would expect a fixed intensity threshold above which the flash would be visible all the time, or below which it would not be seen at all. However, if light were to be regarded as quantised, one would expect a fluctuation in the number of photons per flash and hence a variation in the percentage of the time that the flash of light would be perceived. (These alternatives are shown in Figure 1 as the "Simple model" and "Fluctuation model" respectively).

In the Fluctuation model, above a certain number of photons in the flash, it would be seen all the time. But as the number of absorbers were to be increased and thus the *average* number of photons per flash decreased, the percentage of time that the flash would be perceived would decrease according to the statistics of the fluctuation. The crux of the matter is that the fluctuations would follow the statistics of small-numbers, i.e. a *Poisson distribution* which would look something like the curve in Figure 1. Theoretical calculations for different numbers are quite sensitive to the actual numbers, as shown in Figure 2.

One such experiment, among many, was performed as long ago as 1942 [2] and showed results corresponding to around 6 photons as the average number per flash, with some variations between subjects that correspond to a number of photons between 5 and 7, as shown in Figure 3.

The punchline, expressed in my lead paragraph, is that such an experiment could have been performed a very long time ago, long before quantum physics was invented! A steady source of light, such as a standard candle, plus a mechanical shutter defining a short flash, plus a large number of identical attenuating sheets, could have been used along with any number of very patient, dark-adapted subjects, whose yes/no answers could have been recorded and analysed by hand. The mathematics of the Poisson distribution had long been in existence before, of course. Note that the actual value of energy per photon is not actually required; the total energy per flash could have been measured by classical calorimetry, as could the attenuation factor per absorbing sheet, hence the energy per photon could have been deduced. (Planck's constant could also have been

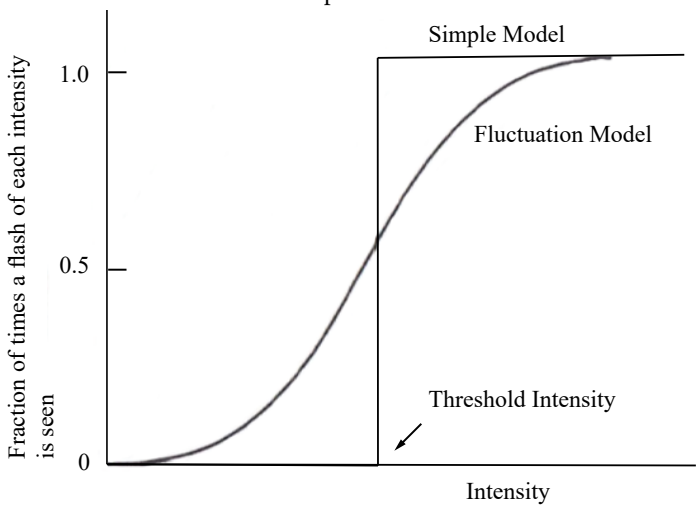

Figure 1. Schematic representation of the fraction of times that a flash of light might be detected plotted against the intensity of the light for two models: intensity as continuous (Simple Model) or quantised (Fluctuation Model). Image credit: Reference 1.

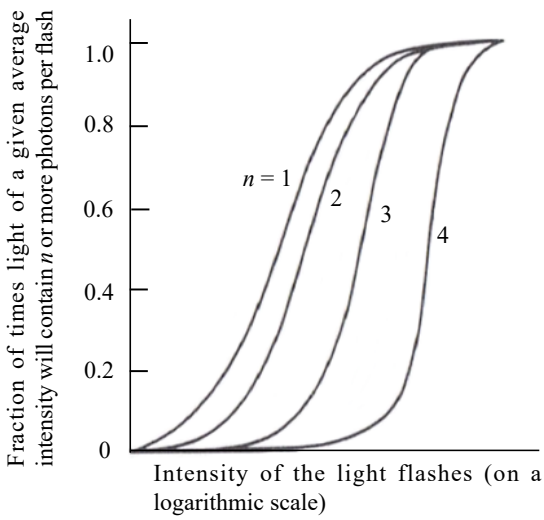

Figure 2. Calculated curves for the fraction of times that a flash of light may be detected, depending on the number of photons in the flash, plotted against the intensity of the flash, on a logarithmic scale, assuming Poisson distributions. Image credit: Reference 1.

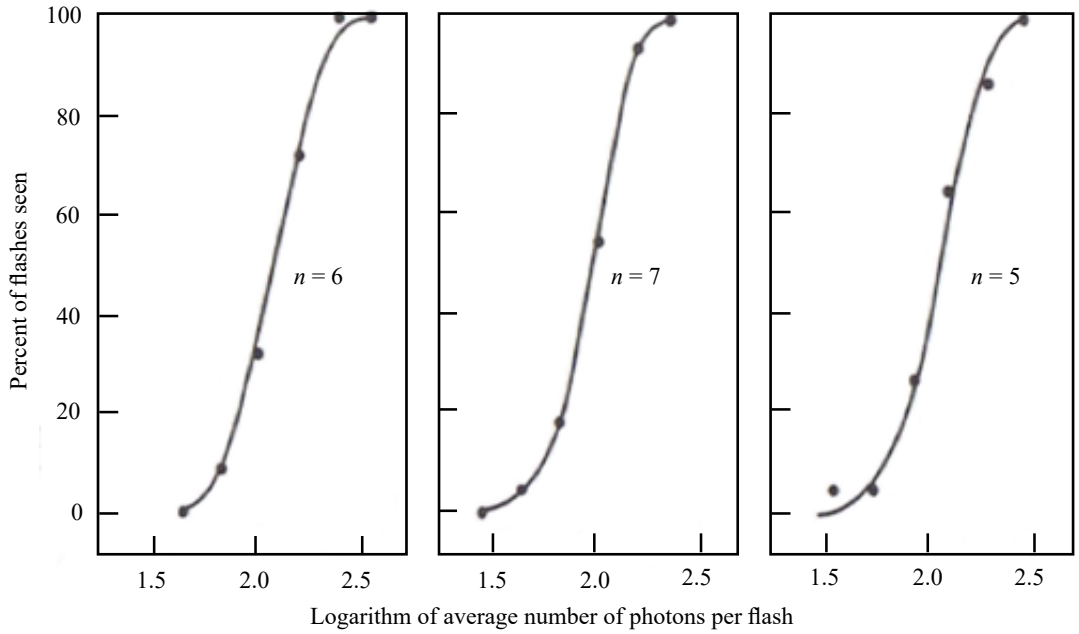

Figure 3. Experimental findings from Reference 2 showing very good fits to theoretical expectations for 6 (as well as 5 or 7) photons per flash for 3 different subjects, against light intensity (i.e. number of photons per flash), on a logarithmic scale. Image credit: Reference 1.

deduced via the wavelength and the speed of light, hence the frequency).

In other words, the quantum nature of light could have been discovered a long, long time ago, if someone had the inspiration to perform such experiments and fit the results to the already well-known Poisson distribution.

It is interesting to note that experiments of this kind have been resurrected in more recent times in order to use human eyes in tests of quantum-mechanical phenomena using single photon sources, showing that human eyes are capable of detecting a single photon. One such recent experiment [3] published in 2016, employed similar techniques to the one described above, but used single photon sources[4] of the kind used in quantum communications (and quantum cryptography). In essence, such experiments use down-conversion in nonlinear media to produce entangled pairs of identical photons, each of which can be detected by modern methods, via its entangled twin, while the other one is the subject of the experiment with human eyes.

Thus, human eyes can be used in the most sophisticated quantum experiments. A further curious property of the Poisson distribution can also be verified, namely the question of when is the next photon likely to be detected? The answer is: right away…like the answer to the well-known question about phone calls. When should one re-dial a telephone number found to be engaged? The answer, again, is: right away, after hearing the "busy signal". (If you don't believe this, go and brush up on Poisson statistics!)

References

[1] HT Epstein, *Elementary Biophysics – Selected Topics*, Addison-Wesley Co. Inc, (1963).

[2] Hecht, Shlaer and Pirenne, J. Gen. Physiol. (Rockefeller Inst. Press, N.Y.) **25**, 819, (1942).

[3] JN Tinsley et al, Nature Comm. **7** July 19 (2016). doi: 10.1038/ncomms 12172.

[4] MD Eisaman, J Fan, A Migdall, and SV Polyakov, Review of Scientific Instruments **82**, 071101 (2011).

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