

## An EPIC visit

The start of the New Year proved an auspicious one for the nascent partnership between the LUX Photonics Consortium and the European Photonics Industry Consortium (EPIC), with the EPIC delegation visiting Singapore from 11 to 13 January.

It was a direct result of the Memorandum of Understanding (MOU) that LUX had signed with EPIC – an industry association that promotes the sustainable development of organisations working in the field of photonics – just last April.

The first-of-its-kind activity between the two organizations saw 15 representatives from European technology companies with a focus on photonics and optics exploring Singapore's business, technology and R&D ecosystem.

"The EPIC delegation to Singapore was amazing, it has been a great experience both from a technical/business perspective but also personal. Some of the contacts established will maybe result in accelerating our product development, or to jointly find new innovative ideas," said Philippe Gastaldo, Product and R&D Director at Unity SC, a French company dealing in inspection and metrology tools.

Other organisations in the delegation included Sweden's NorthLab Photonics, Spain's Catalan Institute of Nanoscience and Nanotechnology (ICN2), and Germany's ficonTEC, which supplies semi- and fully-automated optical device assembly and testing systems for the optical industry.

From the onset, the EPIC representatives were well-received at a welcome dinner attended by NTU



NRF CEO Prof Low Teck Seng welcoming the participants.

at the Singapore Economic Development Board (EDB) and National Research Foundation (NRF).

They also visited the facilities and the leading of Denselight Photonics, photonics manufacturer Coherent, and full-service semiconductor the company GlobalFoundries, including the latter's futuristic 300mm automated fabrication plant. All three are LUX member companies.

Group photo at NRF



LUX Chairman Prof Tjin and EPIC Director General Carlos Lee kick-off the 3 days programme at NRF.

Chief of Staff and Vice President (Research) Prof Lam Khin Yong and The Photonics Institute (TPI) Co-Director Prof Sir David Payne and Prof Tjin Swee Chuan who is also the chairman of LUX Photonics Consortium.

The delegation then got to go deep into the heart of the photonics research scene at NTU and the National University of Singapore, as well as learn about Singapore's priorities and funding models



NRF Programme Director George Loh introduces RIE2020 and 4 technology domains for economic growth and opportunities in Singapore

## Message from the Chairman/Co-director:

In January, we concluded a successful and fruitful EPIC delegation visit to Singapore that saw 12 EPIC companies from 8 countries exploring Singapore's photonics industry and ecosystem. Many contacts were made and exchanged among EPIC and LUX members; and the delegates were treated to a taste of uniquely Singapore hospitality. Our newest member Nanoveu joined us at the same time and participated in the event as well.

Recently, I was honoured to be invited by EPIC to speak at "EPIC TECH WATCH" at the W3+ (Optics, Electronics & Mechanics) trade show in Germany introducing Photonics Research in Singapore. The partnership with EPIC has indeed created many bilateral interactions between the two consortiums. To build on the momentum of this partnership, I will be attending the EPIC Annual General Meeting (AGM) in Eindhoven on 6-7 April to give a talk and warm up the connection. We are also planning a LUX delegation to Germany and possibly Denmark in October this year to learn about the photonics industry ecosystem in the 2 countries. It is my wish that some of our LUX members will be able to find links in Europe and possibly partner them in marketing or innovation. Meanwhile, we have in place a host of activities that we hope you can participate.

Firstly, TPI will be hosting the inaugural Scientific Advisory Board meeting in March that will chart TPI's strategic research direction. Next, the International Conference on Optical and Photonic Engineering (icOPEN 2017) and Manufacturing Technology Asia (MTA) 2017 trade show on 4-7 April at the Singapore Expo, where both LUX and TPI are supporting organizations together with 9 LUX member companies exhibiting their products and technology. And at the end of July, we will have our photonics mega conference – Photonics@SG – on July 31<sup>st</sup> to August 4<sup>th</sup> co-organized by TPI. For the first time, Conference on Lasers and Electro-Optics Pacific Rim (CLEO-PR), OptoElectronics and Communications Conference (OECC) and Photonics Global Conference (PGC), will be co-located at the Marina Bay Sands Singapore. LUX together with TPI will be major sponsors of this event and exhibition. We will have a pavilion to showcase TPI research centres' capabilities and a booth space for LUX member companies. Do stay tune for more exciting information coming to you in the coming months.

Prof Tjin Swee Chuan  
Chairman, LUX Photonics Consortium  
Co-Director, The Photonics Institute (TPI)



An initiative of both Nanyang Technological University (NTU) and National University of Singapore (NUS), supported by National Research Foundation (NRF), Singapore.



Group photo at Coherent

Group photo at GLOBALFOUNDRIES

Group photo at DenseLight



Facility tour at DenseLight



Lab tour at The Photonics Institute, NTU



Facility tour at NUS

Benefiting from this visit too were the member companies, with their senior executives and key decision makers having the opportunity to network with the EPIC delegates at the various venues.

Said Coherent Singapore's General Manager, Mr HT Goh: "The event allowed for interaction between two continents and opened the door to connect to Photonics-related companies. As strengthening our ecosystem is key, this exchange can provide opportunities for collaboration in advanced manufacturing, supply chain and other development areas."

"It was also an opportunity to showcase our capabilities in Operational Excellence, Customer Intimacy and Innovation. This not only promotes Coherent's branding but Singapore's – as a small but progressive nation with a significant photonics presence. Hopefully, this small effort will help connect more dots and open doors for more collaborations and partnerships that are mutually beneficial."

Knowledge-sharing was high on the agenda, with a total of 32 presentations made, including by NRF, EDB, SPRING Singapore, TPI, LUX and its member companies, and the 13 EPIC companies,

Prof Tjin Swee Chuan, LUX Chairman and TPI Co-Director spoke about Asia-Pacific as an emerging market for photonics and shared how investment in research & innovation in Singapore continues to grow under its Research, Innovation & Enterprise 2020 plan.

He also shared how the public-private partnership model continues to go from strength to strength here, with LUX – powered by more than 30 faculty members from NTU and NUS, its 18 member companies, and the support of the National Research Foundation – aiming to be a "seamless bridge" for such partnerships.

Twelve LUX member companies presented too, including the newest, Nanoveu, a leading provider of thin film-based nanostructures that shape our vision when viewed through high-resolution smart devices.



SPRING Singapore Manufacturing & Engineering Director John Lu talked about Singapore's SME landscape and business opportunities for precision engineering.



EDB Head of Electronics Goh Pei Sheng pitched to the companies about the strength of Singapore as their next business and/or R&D centre.



But it was not all work and no play, as a "Uniquely Singapore" social programme for the delegates saw them visit the Night Safari as well as the Marina Bay Sands' SkyPark.

Said Mark Lutkowitz, Principal at fibre optic consultants fibreReality: "In my almost 35 years in the optical business, I have never been a part of such an extraordinarily unique opportunity for networking and collaboration."

"The planning by EPIC in coordination with groups in Singapore (LUX Photonics Consortium) could not have been more meticulous. I heartily look forward to being an EPIC delegate to many other parts of the world."

Indeed, it was certainly a fruitful visit in which several objectives of the MOU – such as encouraging direct contact and cooperation between the two consortiums, including the exchange of information and contacts – were met.

*The presentations can be downloaded from the LUX Photonics Consortium website.*

Facility tour at Coherent



(from left) NRF Programme Director George Loh, NTU Chief of Staff & VP of Research Prof Lam Khin Yong, TPI Co-director Prof Sir David Payne



EPIC Director General Carlos Lee and JDC Rone Chiu



NRF CEO Prof Low Teck Seng mingling with EPIC participants.



Welcome cocktail session at SkyPark Marina Bay Sands



Welcome dinner hosted by LUX Photonics Consortium

(from left) TPI Co-director Prof Sir David Payne, NRF Programme Director George Loh, LUX Chairman & TPI Co-director Prof Tjin Swee Chuan



(from left) NUS ILO Dave Tay, LUX Photonics Consortium Soo Choi Pheng, Northlab Photonics Per Karlsson

## Featured Research Capability - COLE

### Shedding light on new scientific ground

Smart windows that are voltage controllable to adjust opacity in the blink of an eye, enhancing the lives of office workers, drivers and homemakers. A device that detects explosives from afar, decreasing the risks of counter-terrorist officials in their day-to-day work. A diagnostic tool that can uncover diseased cells at infant stages, saving millions of lives every day as people get early treatment for potentially deadly illnesses. A spin-off company providing the next generation tools for RIE2020.

These are just a few innovative projects that are currently being undertaken in the Centre for Optical and Laser Engineering (COLE) in Nanyang Technological University (NTU) – a research centre where a strong pool of qualified researchers and scientists come under one roof to collaborate on cutting edge technology in the area of Optical Engineering.

Housed under the auspices of the School of Mechanical and Aerospace Engineering in NTU, COLE's vision is to become the regional hub in Optical Engineering, with the aspiration of growing into a global research centre.

#### About COLE

- Established through an EDB grant and co-funded by NTU with a startup funding of \$20 Million in 2013
- More than 15 million dollars in competitive funding primarily from Industry
- 50 Investigators, Researchers and PhDs
- Over 70 Masters students from local industry (part time students) as well as full time students.
- 300 metre square of research labs, cleanroom and offices
- More than 250 journal publications in the first 6 years
- More than 200 conference presentations including Keynote and Plenary, and invited talks

COLE is helmed by renowned researcher Professor Anand Asundi, who has an illustrious career in the field optical engineering, having held tenures in universities like Virginia Tech. and the University of Hong Kong. Professor Asundi has also published over 400 papers in peer-reviewed journals and as plenary and invited talks. He has also organised international conferences, workshops and courses all over the world. He is a Fellow of SPIE, the International Society of Optical Engineers, and the founding Chairman of the Optics and Photonics Society of Singapore.

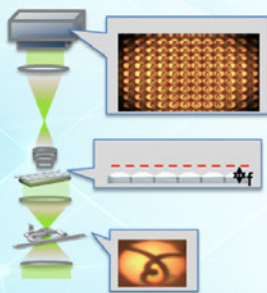
COLE was built on the four pillars of research, education, industry and outreach to help take the established Precision Engineering sector to the next level.

## Research and Industry

Research within COLE preceded the formation of the centre with members active in areas of Optical Metrology and Testing aimed towards Precision Engineering Measurement and Non-destructive Inspection. Since the formation of the COLE, research has progressed along four fronts – Computational Optics, Metrology and Testing, Laser Processing and Structuring and Biomedical Imaging. Industrial partnership and applications for industry are a vital aspect of the research at COLE. Research in COLE is closely linked to industrial demands and many projects have a near term industrial application. Following are highlights of some projects within this group:

## Computational Optics

COLE has developed novel technologies for 3D and 4D imaging using structured light systems, digital holographic and transport of intensity equations as well as Light Field imaging, with the aim of revolutionizing microscopy and precision metrology. Light Field can be thought of as the incoherent counterpart of Holography, since it provides both depth and perspective from a single image. Thus this would simplify measurements as it does not need laser illumination that is done for interferometric methods. In addition, novel systems for objects as large as the human body to as small as single cell have been developed and are being validated by our collaborators.



Light Field Microscopy

## Optical Metrology

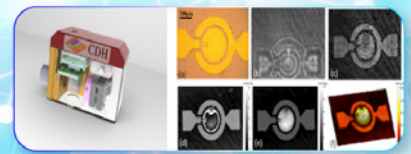
An important function of Optical Engineering deals with its application in defence and security areas, an area that Dr Fu Yu is an expert in. He focuses on the research and development of a multi-beam laser coherent detection system using a single detector, finding new ways to beef up counter-terrorist techniques and equipment. The basis behind this is the single-probe, multi-point and long distance laser Doppler vibrometer (LDV), with applications in a wide variety of industries, such as microstructure, data storage, automotive, aerospace, transportation, steel industry and mechanical engineering.



Multi-point Laser Doppler Vibrometer for Car Body Vibration Measurement

Assoc Prof Murukeshan is developing fast, precise and non-invasive optical metrology tools for modern industrial production. One of them is the Digital Speckle Pattern Interferometer (DSPI), which is capable of measuring surface deformation, vibration and surface profile.

Prof. Asundi has expanded on his works on Photomechanics and Fiber Optic Sensor with the development of novel tools such as the Phase Shift Reflectometer for measuring specular objects, Low birefringence polariscopes for residual stress measurement which is finding renewed interest in injection molded optics and microfluidic channel inspection and digital hologscope for MEMS and Microsystems inspection and Characterization.



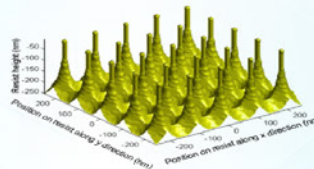
Digital Hologscope for MEMS and Microsystem Metrology

## Laser Structuring and Processing

From an Optical Engineer's perspective, 3D printing has evolved from the laser printing process and uses many of the same concepts. However, with the need for higher precision and printing of smaller structures, there is an increased push towards novel solutions for 3D printers. Assoc Prof Murukeshan and Asst Prof Kim at COLE have been exploring new but distinct approaches for laser patterning, processing and structuring.

Asst Prof Kim's work explores using Ultra-fast, femto-second (10-15 s) lasers to process and pattern materials. The very short pulse time does not allow the material to react, hence resulting in much cleaner structures without any heat affected zones.

Assoc Prof Murukeshan has come up with novel near-field and interferometric lithography tools which are capable of patterning sub-wavelength structures with novel properties. In addition, he is researching a new concept called "Speckle Lithography", for fabricating random hydrophobic or hydrophilic surfaces. Both approaches have also garnered significant interest and funding from companies.

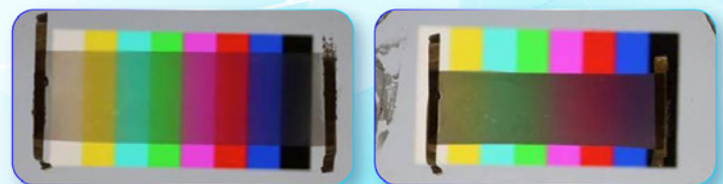


AFM image of pattern created using interference lithography

Optical MEMS has also been an area of active research at COLE and its affiliated micromachines centre, with current research targeting light field spectrometer for pollution determination by Asst Prof Miao Jianmin, and a novel smart window project led by Asst Prof Lau Gih Keong.

Current technologies – based primarily on polymer-dispersed liquid crystal (PDLC) and electrochromic glasses – have many drawbacks, such as cost, incomplete and slow response and high power requirements. Hence, they are only suitable for small windows, with far from perfect performance as in the Boeing Dreamliner.

Led by Asst Prof Lau, COLE's Smart Window Project team is working on a novel smart window based on micro-wrinkling technology. This window is made of low cost materials – transparent conductive oxides (TCOs), which are nanometric thin zinc oxide film coated on a pre-stretched elastomer membrane. The nanometric TCO thin film forms micro-wrinkling when it is compressed biaxially upon a release of the pre-stretched elastomer membrane, or mechanical stretch which unfold and flatten these micro-wrinkles – a phenomenon similar to the blinds on windows.



Tunable transmission using electrically activated wrinkling of thin film on glass

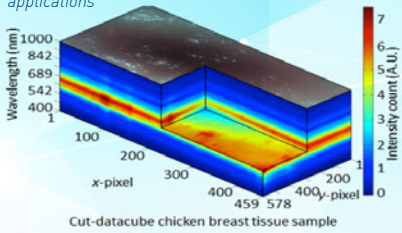
Simply put, the membrane is clear when the surface is flat, and becomes 'opaque' when surface is roughened, or 'wrinkled'. This regulates the amount of light allowed to pass through the surface, making it ideal for smart windows.

## Biomedical Optical Engineering

The changes in tissues at early disease stages are often subtle and only occur beneath tissue surface. For most cases, conventional types of medical imaging may not be able to detect these minute changes. What's more, each imaging modality has its own advantages and limitations, which creates a problem when a diagnosis requires more than one modality. As such, there is a need for multi or hybrid modality imaging technology that integrates all advantages into one setting.

This is where Biomedical Optics comes in. It is an interdisciplinary

*Hyperspectral Imaging for Biomedical applications*



branch, which uses optics to develop technology for early disease diagnosis. Through this research, basic understanding of biological processes can be improved, enhancing the diagnostic efficiency and treatment of human diseases. Currently, Prof. Murukeshan is working

on a multi-modal imaging platform, which combines optical, multi-spectral and hyperspectral, and photo-acoustic imaging modalities for colon, breast and eye disease diagnoses. In addition, Prof. Anand Asundi has developed a 4D camera, which can be coupled to any microscope to provide 3D topography of live cells over time without the need for staining. The system is commercialised by d'Optron Pte Ltd, a spin-off company from COLE. In fact, d'Optron recently bagged the Association for Sensors and Measurement (AMA) Innovation Award 2016 in Germany.

## A super fibre-based light source for medical imaging, biotech and communications systems

The work done by The Photonics Institute (TPI) researchers from NTU's Centre for Optical Fibre Technology (COFT) on the area of supercontinuum generation has not gone unnoticed by the industry. A research paper by the TPI researchers and their counterparts at the Technical University of Denmark (DTU) was featured in the February issue of *Electro Optics*, which looks at the photonics business, applications and technology. Their research, which successfully demonstrates mid-infrared supercontinuum generation using highly-developed GeO<sub>2</sub> doped fibres, was mentioned in an article about how the supercontinuum sector "is developing and moving into the commercial world".



Supercontinuum light sources have been described as broad as a lamp – in terms of wavelength – and bright as a laser. This allows them to be applied to a range of applications including medical imaging (e.g. coherence tomography), optical microscopes, biotechnology (e.g. flow cytometry), and optical fibre communications systems. The findings by DTU and COFT have commercial viability as Ge-doped silica fibres have a lower loss above 2  $\mu\text{m}$  compared to conventional silica fibres, and increasing the doping further lowers the loss. COFT's Dr Sidharthan Raghuraman told *Electro Optics*: "This, together with high nonlinearity, makes it a good candidate for supercontinuum generation."

"To the best of our knowledge, this is the record power, ultra-broadband, and all-fibre supercontinuum light source based on silica and germania fibre demonstrated to date."

## Education and Outreach

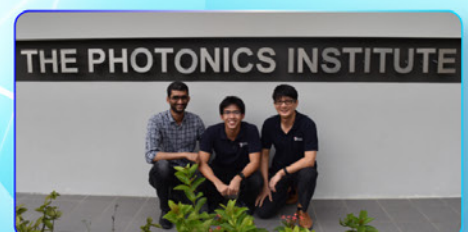
Education and Outreach is an important aspect of Optical Engineering that enables working engineers, budding researchers and scientists to understand the technologies and capabilities of Optical Engineering. Towards this end, COLE and MAE have developed the one and only specialization in Optical Engineering at the Master's level. This specialization is available to working engineers as well as fresh graduates. Over the course of the last 5 years COLE has graduated about 100 "Optineers", as they are called. In addition, these courses fit in well for the research of PhD students in NTU who need to fulfil course requirements. For company personnel who do not have the time to take the two-year MSc programs, COLE along with the Optics and Photonics Society of Singapore (OPSS) and the Workforce Development Authority organises short course and a Masterclass in Optical Engineering.

With regards to outreach activity, COLE actively engages students from high school and polytechnics and provides them with projects and internships to attract them to this growing field. Once again, with funding from OPSS, COLE has developed an OpticsKit for students, which is unlike any optics kit available. This kit first gets the students to play with systems built by Optical Engineers, which gets them interested in this area before highlighting optical principles and techniques used. This enables them to see the final product before understanding basic technologies.

COFT, the newest of five centres under the TPI, was founded to develop core capabilities and technologies for specialty optical fibre fabrication and characterisation. The centre is the only optical fibre fabrication facility in Singapore. It also has strong ties with the University of Southampton's Optoelectronics Research Centre (ORC), which is well-known for its expertise in fibre technology and photonics. Dr Raghuraman is one of eight COFT research staff to have trained at the ORC. The local fabrication facility is pushing fibre technology toward new frontiers, including this supercontinuum source.

The experiments with the Ge-doped fibres achieved an output of 1.42W for a broad spectrum from 700 to 3,200nm and 6.4W for 800 to 2,700nm while being pumped by a broadband four stage erbium fibre-based master oscillator power amplifier. While there remain challenges, such as the need to increase the pump source power, the next item on the agenda is the development of mid-infrared laser sources, including supercontinuum sources. Dr Raghuraman shared with *Electro Optics*: "In continuation of the work reported in the paper, we are working towards scaling the power and extending the spectrum well beyond 3.5  $\mu\text{m}$ ." This will offer a robust compact industrial grade high power light source operating in mid-IR, directly from a single fibre.

*The team behind the Ge-doped mid-infrared supercontinuum fibre are (from left) Dr Sidharthan Raghuraman, Mr Daryl Ho and Asst Prof Seongwooo Yoo from COFT.*



# Industry News

## Nanoveu applies itself well



Nanoveu CEO Mr Alfred Chong (left) receives the "Most Innovative Technology" prize from Dr Omkaram (Om) Nalamasu, senior vice president and chief technology officer for Applied Materials.

New LUX Photonics Consortium member company Nanoveu took home the "Most Innovative Technology" prize at the inaugural *Ventures Day*, organised by Applied Materials, Inc., a Fortune 300 company and the global leader in materials engineering solutions. Its venture capital arm, Applied Ventures, invests in early-stage technology companies that can advance or complement Applied Materials' core expertise.

A provider of thin film-based

nanostructures, Nanoveu impressed at the event held at Fusionopolis last October and stood out from other startups involved in areas such as 3D printing, display, genomics, robotics, advanced materials and wearables/IoT.

The company's signature product, the EyeFly3D, is able to deliver 3D with the impression of depth, on high-resolution mobile phones and tablets – all without the need for 3D glasses. Its latest product EyeFyx seeks to correct a range of vision aberrations on smart devices.

## Pitch fever

This 2017 edition of the prestigious *SPIE Startup Challenge* saw homegrown optical engineering company and LUX member d'Optron named one of eight semi-finalists for the "Biophotonics, Point of Care" track.

The annual challenge sees new entrepreneurs pitching their light-based technology business plan to a team of business development experts and venture capitalists, with two from each track going on to the finals held at SPIE Photonics West in San Francisco. The other tracks are "Imaging, Display, Lasers, Semiconductors" and "Sensors, Wearables, IoT".

d'Optron was shortlisted for the d'Biomager, a 4D microscope camera that can be attached to any existing light microscope, allowing for the the size and volume of cells to be tracked 'live'.

Previously, d'Biomager had helped d'Optron – a spinoff company from NTU – clinch the "Young Enterprise" special award at the AMA Innovation Award 2016 organised by the AMA Association for Sensors and Measurement.

## A smart camera for autonomous vehicles

Regular optical cameras can be blinded by bright light and are less able to make out details in low visibility – a huge drawback when they are used for self-driving cars and drones.

Enter the Celex® camera, an ultrafast high-contrast camera for autonomous vehicles.

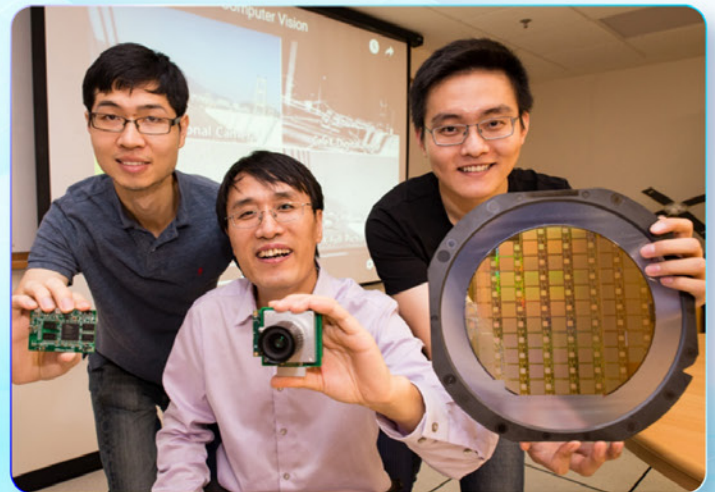
Developed by Hillhouse Technology, a LUX member company and start-up incubated by NTUitive, it is able to record changes in light intensity between scenes at nanosecond intervals.

High-speed video cameras usually have several million pixels, or sensor sites that record light information and are used to form a resulting picture. A camera that records up to 120 frames or photos per second would generate gigabytes of data, which would then have to be processed by the autonomous vehicle so it can "see" its surroundings.

In contrast, Celex® records the changes between light intensity of individual pixels at its sensor, thus reducing the data output. This also avoids the need to capture the whole scene like a photograph, increasing the camera's processing speed.

Further, a built-in processor in the sensor allows it to instantly analyse the flow of data to differentiate between foreground objects and the background, giving autonomous vehicles more time to react to any oncoming vehicles or obstacles.

In February, a prototype of the camera was unveiled at the 2017 IS&T International Symposium on Electronic Imaging (EI 2017) in the United States to positive feedback from the conference attendees, who include academia and top industry players. It is designed by Asst Prof Chen Shoushun from NTU's School of Electrical and Electronic Engineering.



Part of the team behind the ultrafast Celex® camera: Asst Prof Chen Shoushun (centre) and research engineers Li Wanlong (far left) and Yang Wenlei. Photo credit: NTU Singapore

# 9 Reasons to attend/exhibit at Photonics@SG

## 1. One ticket to access 3 prestigious photonics conferences in the Region.

- Conference on Lasers and Electro-Optics Pacific Rim (CLEO-PR)
- OptoElectronics and Communications Conference (OECC)
- Photonics Global Conference (PGC)

**CLEO**  
Laser Science to Photonic Applications



**PGC 2017**

## 4. Supported by two major photonics society The Optical Society and IEEE Photonics Society.

**OSA**  
The Optical Society

**IEEE Photonics Society**

## 2. Located at Singapore's iconic landmark Marina Bay Sands.



Photo credit: foundtheworld.com

## 5. Record number of paper submissions and expecting 1500-2000 participants from more than 55 countries.

## 6. Ground-breaking research findings to be revealed for the first time...

## 7. Welcome reception at the World's Largest Aquarium in Sentosa.



Photo credit: bydeals.net

## 3. Featuring world renowned speakers such as :



**Professor William E Moerner (Nobel Laureate)**  
Physical chemistry and chemical physics of  
single molecules, single-molecule biophysics,  
super-resolution imaging and tracking in cells

**Professor Sir John Pendry**  
Metamaterials, Negative refraction, Cloaks,  
Transformation Optics, Perfect lens



**Eric Swanson**  
Optical Coherence  
Tomography, Adaptive Optics

**Professor Kent Choquette  
(IEEE PS President)**  
Microelectronics and Photonics,  
Optoelectronics, Semiconductor lasers



**Professor Eric Mazur  
(OSA President)**  
Ultrafast Optics, Nanophotonics

## 8. Industrial exhibition from 1<sup>st</sup> - 3<sup>rd</sup> August, exhibition space of 3000sqm.

## 9. LUX-TPI pavilion and workshop showcasing technologies from local photonics industry and research performers.

Photonics@SG

Conference registration:

[http://photonics2017.org/reg\\_guide.php](http://photonics2017.org/reg_guide.php)

For Booth space with  
TPI/LUX Photonics  
Consortium Pavilion and  
LUX's Photonics Tech Talk,  
please email to:  
[LUX\\_Chairman@ntuitive.sg](mailto:LUX_Chairman@ntuitive.sg)

