

Growing the photonics industry at the speed of light

New developments and applications for quantum technology, metamaterials, and fiber technologies – these were just some of the fascinating topics to capture the attention of the 180 participants at the recent The Photonics Institute (TPI)-LUX Photonics Consortium Conference.

The 16-17 February event was well-attended by 20 companies and 10 non-profit organizations including the National Research Foundation, Economic Development Board, SPRING, A*STAR and the Singaporean-German Chamber of Industry and Commerce.

Said Prof Tjin Swee Chuan, co-director of TPI and chairman of the LUX Photonics Consortium, in his opening address: "Photonics research in Singapore has been growing at the speed of light and vibrantly across the Nanyang Technological University (NTU), National University of Singapore (NUS) and the Agency for Science, Technology and Research (A*STAR) research institutes."

"The Photonics Institute was set up in NTU in 2014 to synergize the research strengths and be an effective access point for industry partners to work with us. A year later, the LUX Photonics Consortium was formed to bring the research community and industry closer, with a mission to bring the latest technologies developed and research outcomes to commercialization."

He added that the event marked a good start to "a closer collaborative platform for exchange of ideas from the great minds of both worlds".

Indeed, throughout the two-day affair at NTU's Nanyang Executive Centre Auditorium, researchers and industry professionals could often be found engaging in animated discussions amidst a backdrop of novel research projects on display such as the Fiberized Infrared Nanoscope and Broadband All-optical Fiber Transistors.

Foreword

It is indeed my honour to pen this foreword for the very first issue of "Illuminate" quarterly newsletter jointly brought to you by LUX Photonics Consortium – an initiative by NTU and NUS, and supported by NRF (National Research Foundation) – and The Photonics Institute at NTU. This newsletter serves as a conduit of information reaching out to both the industry and academia members on what is happening in the local and international photonics arena.

The LUX Photonics Consortium has progressed at a rapid pace since its inception six months ago. We have since organised members' networking event, partnered with The Photonics Institute to organize the TPI Conference, and participated in our first industry event – IoT ASIA recently which received good media coverage, and now bringing you trending news in photonics. There are more in the pipeline in the coming months! All these exciting events as well as intriguing articles will be featured in this newsletter.

I hope you will enjoy reading the newsletter, just as we do in delivering innovations through this enabling technology.



*Prof Tjin Swee Chuan
Chairman, LUX Photonics Consortium
Co-Director, The Photonics Institute*

Photonics Technologies for Today and Tomorrow Conference

Addressing a rapt audience inside the packed auditorium, Emeritus Professor Sir Peter Knight – whose research focuses on theoretical quantum optics, strong field physics, and quantum information science – got the conference off to a strong start with his plenary talk titled “Quantum Technology for a Networked World”.

The Senior Research Investigator at Imperial College London and Senior Fellow in Residence at the Kavli Royal Society International Centre at Chicheley Hall touched on the many potential applications that may result from breakthroughs in quantum technology. These include communications systems that are immune to GPS jamming and quantum sensors for medical uses like cardiography and neurophysiology. His fellow plenary

speaker, Prof Yuri S. Kivshar, who heads the Nonlinear Physics Centre at the Australian National University, discussed the emerging field of nanophotonics and metamaterials, which are artificial electromagnetic media structured on the sub-wavelength scale.

Prof Kivshar shared his research on photonic, terahertz and microwave electromagnetic metamaterials and metadevices with different functionalities including the property of indefinite (or hyperbolic) dispersion.

Other notable speakers at the conference included Mr Kenneth Tai, Chairman of the Jasper Display Corporation, and Dr Lai Kin Seng, Head, Applied Physics Laboratory, DSO National Laboratories.

Mr Tai, a strong contributor to Taiwan's

information and communications technology industry over the years, spoke of how the “Silicon Island” has been integrating optics into the silicon industry.

Highlighting that the United Nations had declared 2015 the International Year of Light, he urged more start-ups to participate in the budding optical technologies industry and seize the many opportunities available there.

Dr Lai discussed his research on CW and pulsed infrared diode-pumped solid-state lasers, as well as adaptive optics as a way to correct thermal aberrations and achieve good laser beam quality.

In his concluding remarks for the day, Prof Sir David Payne, co-director of TPI, emphasized how photonics is “the enabling technology behind so many of today's essential products”.

He enthused: “From LED lighting to new vehicle headlamps, from navigating airliners to 3D printing – photonics marks the future. It has even been said that the 20th century was the century of electronics, while the 21st is that of photonic technologies, which are expected to grow to a S\$950 billion global market by 2020.”

“With its strengths in hi-tech manufacturing and the advent of TPI leading in photonics research, Singapore has a unique opportunity to establish major global industries in photonics components and systems.”



NTU Provost Prof Freddy Boey kicks-off The Photonics Institute (TPI)-LUX Photonics Consortium Conference with his welcome speech.

Advanced Optics in Engineering Workshop

The second day workshop presented the outcomes of A*STAR's Advanced Optics in Engineering Programme. A total of 11 projects – ranging from the design and fabrication of a cost-effective mid-infrared source to fibre-drawing nanomanufacturing – were showcased.

One of the highlights was the presentation on infrared nanoscopes by Prof Nikolay Zheludev, co-director of TPI and 2015 recipient of the Institute of Physics' prestigious Young Medal and Prize for his global leadership and pioneering efforts in nanophotonics and optical metamaterials.

Currently, the maximum resolution that can be achieved by optical microscopes is limited by the diffraction of visible light. Prof Zheludev is looking at incorporating specialized fiber and super-oscillation technologies with sub-wavelength resolution for advanced infrared imaging and nanofabrication applications.

Mr Loh Wai Mun, Director, Engineering, A*STAR, wrapped up the half-day workshop, saying: “Conducting a workshop to present the outcomes of the programme is an effective way to reach out to both industry and students to interest them in the cutting-edge research work in laser and optics that is being done in our Research Institutes and Institutes of Higher Learning.”

“It gives me great pleasure to congratulate the Principal Investigators and their teams for their achievements in the programme. I would also like to thank Prof Tjin, as Programme Manager, for running a tight, well-coordinated programme. Going forward, I encourage the PIs to engage the industry so that the value created by the positive outcomes of the programme is captured by the industry.”



The 16-17 February event succeeded in bringing together researchers and industry professionals, opening up new possibilities for collaboration.

“A highly informative and high quality conference”

Participants were united in their praise for the TPI-LUX Photonics Consortium Conference, with Dr Narendra Gawande of LUX Photonics Consortium member company *Coherent* sharing that he was looking forward to more such opportunities for interaction.

He suggested that future conferences could include more content on how companies in the photonics industry can improve the efficiency and effectiveness of their current operations, saying: “This can be done either by sharing best practices in photonics for managing cost and quality of photonics processes, parts and tools, or also by introducing new tools and technologies that can help companies to overcome these issues.”

Dr Magad of *II-VI*, another LUX Photonics Consortium member company, felt that the conference “provided an impressive overview of the explosive growth of the field of photonics with many new and extended applications, such as in high-resolution imaging, telecommunications, energy generation and conversion, and biomedical sensing”.

He added: “The focus on applied research is appropriate and bodes well to feed and meet the needs of industry to enable the faster development of new products and processes for the benefit of mankind. Engagement and collaboration with industry will undoubtedly quicken the pace of new ideas being explored, which in turn, opens up new possibilities.”

“I commend The Photonics Institute and the LUX Photonics Consortium for organizing such a highly informative and high quality conference.”

Participants got to explore the many innovative research projects, like the Fiberized Infrared Nanoscope, on display at the Nanyang Executive Centre Auditorium.



A Milestone Reached with MoU between LUX and EPIC



From left Mr George Loh, Prof Tjin Swee Chuan and Mr Carlos Lee, after signing MoU at Annual General Meeting of EPIC on 22nd April 2016.

A milestone was reached by LUX and the European Photonics Industry Consortium (EPIC) with the signing of a Memorandum of Understanding (MoU) between both regional Photonics bodies. The signing took place at the Annual General Meeting (AGM) of EPIC on 22nd April 2016. LUX was represented by Chairman, Prof. Tjin Swee Chuan and EPIC by Director-General, Mr. Carlos Lee, in the presence of Programme Director, Mr. George Loh, from National Research Foundation (NRF), Singapore.

EPIC is an industry association that promotes the sustainable development of organisations working in the field of photonics. EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial

advancement. It currently represents 250 companies across 28 countries.

Under the MoU, LUX and EPIC will co-operate in pursuing the following:-

- Encourage direct contact and cooperation between the two consortiums, including exchange of information and contacts
- Be the platform for members of a consortium to reach the other's relevant government representatives, public funding bodies and other entities in the region
- Co-host visits of delegates of each consortium's commercial trade missions and business events
- Exchange of information, including exchange of market studies, technology reports and newsletters

Researchers work on a micro-Optical Coherence Tomography imaging system, which can be used for the early inspection of cancer. Such high spatial resolution imaging has not been achieved by commercial systems.

Shedding new light on photonics

Assoc Prof Wang Qijie became interested in the field of photonics around the turn of the century, when he discovered how the technology allowed an “unprecedented level of high-speed and high-transmission capacity for fiber-optic communications systems”.

He says: “It has led to the Internet we have today, which has, in turn, greatly changed the world and how we live. My interest sparked me to pursue a PhD in the field of photonics for fiber-optic communications.”

It also started a journey that led the then-Bachelor of Engineering (Honours) in Electrical Engineering graduate from the University of Science and Technology of China to our little red dot.

Having learnt of the top photonic research centres at NTU, Assoc Prof Wang had no hesitation in signing up with the university’s School of Electrical and Electronic Engineering (EEE) to pursue his PhD.

A stint as a postdoctoral researcher at the School of Engineering and Applied Sciences at Harvard University then followed before he returned to NTU to serve as a Nanyang Assistant Professor at EEE and the School of Physical and Mathematical Sciences. The Nanyang Assistant Professorship is an elite scheme for top young researchers and scholars that comes with a start-up research grant of up to S\$1 million.

Today, he is paying it forward by shedding new light on photonics as Director of the Centre for OptoElectronics & Biophotonics (COEB) at EEE. Established in 1994, and formerly known as the Photonics Research Centre and the Network Technology Research Centre, it is NTU’s oldest research centre for advanced photonics, and looks at fundamental science as well as novel technology and industry applications.

Meet the Centre for OptoElectronics & Biophotonics

One of five research institutes under The Photonics Institute (TPI), the centre’s research is divided into four programmes: Novel Photonic Materials & Devices; Photonic Nano-structures & Applications; Mid-infrared Photonics & Optoelectronics; and Biophotonics.

Says Assoc Prof Wang: “One of our focus areas is developing high-performance semiconductor, ceramic, solid-state, and fiber lasers for various applications in communication, sensing and spectroscopy, and industrial laser processing.”

He adds that his colleagues has successfully demonstrated semiconductor lasers with a broad tuning range in the near-infrared and mid-infrared regimes, and ultra-short pulsed solid-state and fiber lasers mode-locked by graphene. They have also constructed a micro-Optical Coherence Tomography (micro-OCT) imaging system.

Their work has meaningful real-world applications. For instance, the micro-OCT technology can be widely used in hospitals and clinics for disease analysis, such as early inspection of cancer.

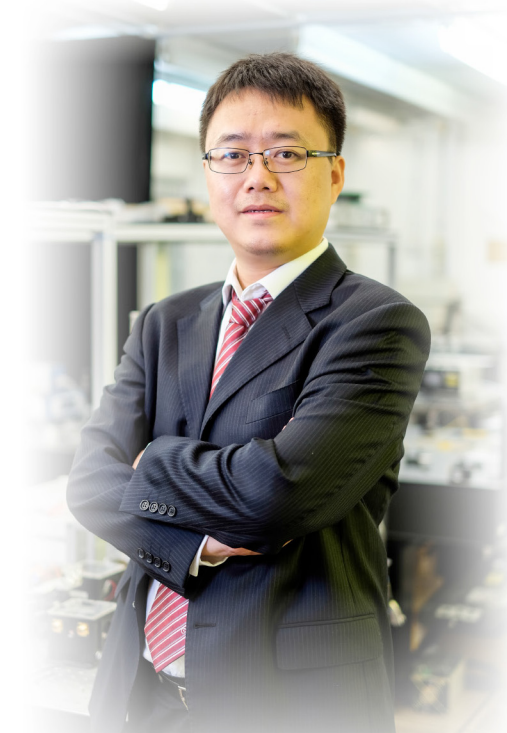
Assoc Prof Wang highlights the development of nanostructured photonic devices by Prof Zhang Dao Hua as “one of the centre’s biggest achievements by far”.

He says: “Photonic nanostructures have recently become a main research focus due to their unusual properties which cannot be found in any naturally-formed material. I believe that the next photonic revolution will be fuelled by photonic nanostructures and their integration with active media and devices.”

And he is optimistic that the centre will continue to light up the photonics

COEB's research strengths are divided into four thematic programmes:

- Novel Photonic Materials & Devices
- Photonic Nano-structures & Applications
- Mid-infrared Photonics & Optoelectronics
- Biophotonics



Assoc Prof Wang Qijie, the centre’s director, believes that being under The Photonics Institute’s umbrella will give the COEB more opportunities to collaborate with members of the global photonics industry, including other leading photonics research institutes.

research scene, especially now that it is under the TPI umbrella. “We will have more opportunities to collaborate with other top photonic research institutes around the world, such as the Optoelectronics Research Centre at the University of Southampton in England.”

“Thanks to TPI, we are also connected with the LUX Photonics Consortium supported by the National Research Foundation. This will help us to better tie the research we do at the university to the industry’s needs, and ultimately contribute to Singapore’s economic growth.”

NTU – the *perfect* environment for research

On a personal front, Assoc Prof Wang – whose key research contributions have been in the field of mid-infrared and Terahertz photonics and optoelectronics – is grateful for the opportunities he’s had at NTU to further his research interests.

He says: “After my postdoctoral experience in the US, I realized that any research, especially experimental applied physics research, needs sufficient funding support and the right infrastructure.”

“NTU has provided me with the perfect environment. Most of all, the Nanyang Assistant Professor programme really enabled me to start my own independent research project smoothly.”

Indeed, his work has seen him win numerous awards including the prestigious Young Scientist Award by the Singapore National Academy of Science in 2014 and the Special Recognition Award at the World Cultural Council 30th Award Ceremony in 2013, while he has also published/co-published more than 100 papers – including 9 invited papers – in top international journals like *Nature Photonics*, *Nature Materials*, and *Nature Communications*.

Notably, he and his research group also invented a broadband and high photoresponse graphene photodetector that can cover up to the mid-infrared range. Their research can potentially be applied to satellite imaging, or IR, consumer and traffic cameras.

The centre’s advanced semiconductor fabrication facilities include the Metal-Oxide Chemical Vapour Deposition system, which produces nanoscale semiconductor layers such as InP for high-performance optoelectronic devices like semiconductor lasers and photodetectors.

Bright future for Singapore’s photonics industry

Looking ahead, Assoc Prof Wang is excited about the potential for growth in Singapore’s photonics scene. He cites the world-class photonic research facilities that have sprung up here – and particularly in NTU – thanks to the “generous funding from the Singapore government over the years”.

He enthuses: “At our centre, we have a number of advanced semiconductor fabrication facilities such as Metal-Oxide Chemical Vapour Deposition and Molecular Beam Epitaxy dedicated to different material systems such as InP, GaAs, GaN and InSb, plus state-of-the-art cleanroom processing equipment.”

“With these high-end photonic facilities and top talent from around the world, such as China, India, France, and the United Kingdom, we are able to tackle many challenges in the photonics field.”

Assoc Prof Wang believes that, for the Singapore photonics scene to continue scaling new heights, partners from the research community, industry and government agencies must be brought closer together through regular conferences or workshops like the recent TPI-LUX Photonics Consortium Conference.

He says: “In this way, the research community can be made aware of real-world critical industry needs, while they can also showcase their research capabilities to their industry partners.”

As for the COEB, he hopes that the next five years will see it continue to cultivate world-class research and human capital for Singapore’s vibrant knowledge-based economy.

Says Assoc Prof Wang: “With the government’s new Research, Innovation and Enterprise 2020 plan in mind, we are aiming to tackle challenges in the fields of advanced manufacturing, precision engineering and healthcare, as well as help Singapore to attain its vision of being a Smart Nation. The centre will also continue to be aligned with NTU’s mission of creating a global university of excellence.”



What LUX members say - Membership Testimonials

Formed by Nanyang Technological University, the National University of Singapore and research laboratories and companies, Lux Photonics Consortium seeks to encourage collaborations between institutes of higher learning and the industry, on how to harness and distribute energy from light for areas such as medicine, security and defence.

Joining the Consortium has its benefits. Today, the Consortium has 13 member-companies and membership is set to grow further. In this inaugural issue, we feature three member-companies and speak to their representatives to find out their motivation for joining the Consortium. They are Head of Applied Physics Laboratory of DSO National Laboratories Dr Lai Kin Seng, General Manager of aNexus Mr Wilson Wong Y.W, and Chairman & CEO of Jasper Display Corp Mr. Kenneth Tai.

1. Could you give us an introduction of your company and its role in the photonics industry?

Wilson: aNexus is a Singapore company that has grown quickly to be a leading supplier and service provider of major photonics R&D and production equipment, including MOCVD, plasma, rare material sources, coating, printing, measurement and characterisation.

Mr. Kenneth Tai: Jasper Display Corp is dedicated to the design, development and fielding of innovative liquid crystal on silicon (LCOS) spatial light modulators (SLM), and has successfully developed and introduced several innovative products with high resolution to the market, like Microdisplay, driver IC, SLM SDK and EDK for education. JDC is the first to introduce electro-optics platform concept to industries and also provides a mature electro-optics platform for developing innovative technologies.

Kin Seng: As Singapore's national defence R&D organisation, DSO National Laboratories creates the critical edge in defence technology to force multiply the Singapore Armed Forces' (SAF) combat capabilities and render potential threats irrelevant.

2. Why did your company join the Consortium?

Wilson: As aNexus has access to the regional market and international connections, we see this as an excellent opportunity to leverage on the high tech research investment Singapore has invested to help us move up the value chain.

Mr. Kenneth Tai: JDC aims to cooperate and build relationships with local universities and other industry members in the area of photonics-related R&D, and to attend conferences and seminars to review the latest photonics technologies. JDC would like to have access to photonics facilities, labs and instruments from local universities at

membership rate, as well as access to government's sponsorship channels.

Kin Seng: DSO has constantly pushed the frontiers of photonics R&D and being a member in this consortium allows us to engage further with local researchers and industries.

3. Could you share some of the benefits that your company has benefited as a member of the Consortium?

Wilson: aNexus has benefited greatly through direct access to Photonics R&D in Singapore, and has been a part of high-level meetings with industry players. Moving on, we see an opportunity for aNexus to move up the supply chain and move into a more value-added manufacturing sector.

Mr. Kenneth Tai: Since becoming a member, JDC has improved knowledge of the photonics industry and is in a better position to help local universities and industry partners to convert technologies into business applications. For example, JDC introduced holography-related know-how used in bio-medical applications to the Consortium.

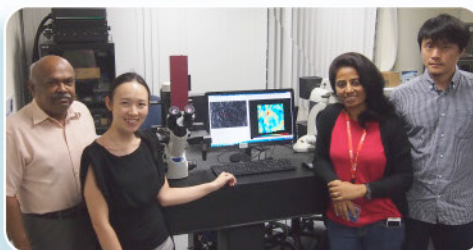
Kin Seng: The activities organised, such as seminars, have certainly been useful and interesting for DSO.

Award

d'Optron Pte Ltd, a spin-off company from NTU COLE (Center of Optical and Laser Engineering) and co-founded by NTU Prof. Anand Asundi and Rachel Wang, was recently awarded the prestigious AMA Young Enterprise Award in Germany. It is one out of five international teams nominated for the AMA Innovation Award.

This award was based on d'Biomager, an innovation that enables biomedical

scientists, for the first time, to obtain quantitative real-time 3D images of cells and tissues, with just an add-on microscopic camera.



The AMA Innovation Award has been presented since 2000 for outstanding research and development work. It is one of the most coveted awards in sensor and measuring technology. The special award for Young Enterprises is bestowed to only one company annually.

From left, Prof Anand Asundi and Ms Rachel Wang with the team and the award winning d'Biomager.