INTRODUCTION

ABOUT US
The Photonics Institute (TPI), one of the most advanced institutes in the field today, is the culmination of over 20 years of photonic research at Nanyang Technological University (NTU). It is an interdisciplinary research institute that consolidates various research centres in the area of photonics within NTU, and is in partnership with the Optoelectronics Research Centre at the University of Southampton UK. The aim is to establish Singapore as a world leading centre of research excellence in applied and fundamental photonics. The institute is funded and supported by industry partners and various national agencies, including A*STAR, DSO National Laboratories, the Economic Development Board Singapore, Ministry of Education and the National Research Foundation, Prime Minister’s Office. TPI is led by a triumvirate of world-class directors: NTU professors Tjin Swee Chuan and Nikolay Zheludev, along with Professor Sir David Payne, Director of the Optoelectronics Research Centre, Southampton.

Research centres under the institute:
• Centre for Optical Fibre Technology (COFT)
• Centre for Disruptive Photonic Technologies (CDPT)
• Centre for Optical & Laser Engineering (COLE)
• Centre of Excellence for Semiconductor Lighting and Displays (LUMINOUS)
• Centre for OptoElectronics and Biophotonics (COEB)
Affiliated centre:
• Centre for Ilia Devices and Signal Analysis
Affiliated programme:
• Silicon Photonics

At TPI, we aim to establish a cradle of scholarship, research and innovation, making the transition from fundamental science to applied science. We help develop diverse photonics applications that have an impact on everyday life: from energy efficient lighting and revolutionary 3D displays, to ultra-high speed communications links; from subcellular medical imaging to energy harvesting and water quality sensing. These innovations and more are just the beginning of what photonics has in store.

VISION
To be the leading photonics research establishment in Asia, with an agenda embracing the entire spectrum of photonics from Electrons to Enterprise, from Invention to Innovation.

MISSION
• Consolidate and coordinate the research and innovation activities of photonics-related research centres in NTU.
• Achieve a step change in quality of research and technical relevance.
• Become a cradle of new knowledge and intellectual property.
• Be the focal point for ground-breaking applications of light-enabled technologies.
Fibre medical device for diagnosis of Coronary Artery Disease (CAD)

Using state-of-the-art fibre drawing facilities and expertise, a multi-disciplinary research team is working on developing and validating clinically viable, next generation fibre-optics technologies that are capable of obtaining subcellular resolution images of the coronary artery wall. This technology will enable – for the first time – visualisation of key subcellular and extracellular processes involved in the formation of atherosclerotic plaques. This was previously hindered by the lack of cutting-edge imaging tools capable of obtaining microscopic pathological information in living humans. This research in this area may lead to a breakthrough in the understanding, diagnostic and management of Coronary Artery Disease (CAD) – the leading cause of death in the world today. It could dramatically change clinical practice and improve patient care, while also having the potential to act as a platform for further developments in imaging technology for biomedical applications.

ABOUT COFT

The Centre for Optical Fibre Technology (COFT) is the newest centre under The Photonics Institute. Jointly set-up by NTU and the University of Southampton Optoelectronics Research Centre (ORC), COFT has state-of-the-art equipment for the fabrication and characterisation of different kinds of optical fibres, ranging from standard silica fibres to a variety of advanced special fibres, microstructured fibres and novel glasses such as chalcogenides.

Special fibres have a wide range of applications – from high power fibre lasers used for material processing (marking, welding, cutting and drilling) and spectroscopy, to sensors used for downhole measurement in oil wells and detection of bacterial contamination in foods. They are also employed in the biomedical field for endoscopy, which allows physicians to examine the interior of a hollow organ of the body, such as the stomach. Much of the Centre’s research work currently involves the use of advanced fibre technology to generate light of a desired mid-IR or UV wavelength.

High power mid-IR source from silica hollow-core fibres

Mid-infrared lasers (4-5 μm) are in great demand for a variety of applications, including plastic and polymer processing, spectroscopy, healthcare, laser surgery, remote sensing, fibre communication, and scientific research. Current lasers for mid-IR consist of a bulk crystal, glass or gas gain-medium pumped by a flash lamp, diode laser or electrical discharge. Fibre lasers are supplanting the traditional solid state laser in many areas. Unfortunately, conventional silica fibres cannot transmit wavelengths greater than 2.4 microns. Thus novel approaches are needed to overcome these challenges and meet the increasing demand for mid-IR laser sources. We are developing a silica-based, low-loss, hollow-core fibre for the delivery of laser light in the mid-IR wavelength range (up to 5 μm). The fibre will be used to explore the nonlinear properties of various gas media in the IR region to make a compact, high-power, mid-IR source at 3 μm for material processing and healthcare.
CENTRE FOR Disruptive Photonic Technologies

“(...) generates a knowledge base for new light-based technologies with a 10+ year outlook”

ABOUT CDPT

CDPT is a leading Nanophotonics Centre in Asia and the main centre of Nanophotonics and Metamaterial research in Singapore. It complements the more applied research agenda of A*STAR institutions DSI and IMRE.

CDPT develops radically new nanotechnology-enabled artificial, dynamic, and reconfigurable photonic materials and components that provide ground-breaking solutions for telecoms, energy, light generation, imaging, lithography, data storage, sensing, medicine, security and defence applications. Using novel material structures, the Centre advances the physics of control, guiding and amplification of light in nanostructures through new nanofabrication techniques and methods of growth, hybridisation and integration into waveguides and fibres. CDPT aims to develop disruptive technological solutions for ultra-high-density integration, low energy consumption for high speed optical switching, and data processing.

There are three deeply interlinked research strands that aim to generate a knowledge base for new technologies with a 10+ year outlook:

• Reconfigurable, dynamic and quantum metamaterials
• Reconfigurable micro/nano-fibers and cognitive photonic systems
• Nanolasers, spasers and nano-metamaterials for electromagnetic technologies

Reconfigurable, dynamic & quantum metamaterials

We study interactions of atomic and plasmonic systems in Quantum Atomic Metamaterials, and investigate fundamental aspects of Quantum Optics and switching in Plasmonic Metamaterials. We explore novel functionalities in Topological Insulator Metamaterials, as well as mould electromagnetic waves flow via Transformation Optics and Electromagnetic Energy Management.

Nanolasers, spasers & nano-metamaterials for electromagnetic technologies

We explore fundamental aspects of Nanolasmonic Luminescence and Light Localization to realise miniaturised Nanoparticle Light Sources through novel, two-dimensional, visible and infrared nanophotonic materials and devices. We implement advanced nanophotonic structures and reconfigurable metamaterials.

Reconfigurable micro / nano-fibers & cognitive photonic systems

We explore new dimensions of network systems through Cognitive Reconfigurable Photonics Networks and Topological Phenomena in Photonic Networks. We study the inherent bandwidth limits for free-space and fibre optics communications via Coherent Femtosecond Data Processing with metamaterials, as well as integration with in-line light sources such as fibre Nano-Spasers.
CENTRE FOR Optical & Laser Engineering

ABOUT COLE

COLE was launched in 2013 with support from the Economic Development Board (EDB), and School of Mechanical and Aerospace Engineering, NTU and the Optics and Photonics Society of Singapore. Its mission is to conduct research and develop a platform to train people and support the growing local industry in optical and laser engineering.

COLE has four major focus areas – research, education, industry and outreach. COLE researchers conduct applied research that has resulted in a spin-off company and numerous high impact journal publications. On the education front, a new Master’s specialisation in Optical Engineering is offered to working professionals and engineers for skills enhancement and training. Strong industrial partnerships have been established with various companies that has enabled technology licensing and collaborative research projects. Outreach activities such as conferences and workshops are an on-going strength of COLE.

Computational Optics: Optical Design, Quantitative Phase and Light Field Imaging

COLE researchers have developed several patented phase imaging systems to explore applications in Microsystem Metrology and Bio-imaging. Notable among these are the Compact Digital Holography for MLMs and Microsystem Metrology and d'Blamerger camera module for quantitative phase measurement. Both systems are licensed to d’Option Pte Ltd. – a local start-up.

Biomedical Optics and Imaging

Optical Coherence Tomography system can enable multimodal imaging for diagnostics. A high-speed and high-resolution OCT scheme for biomedical diagnostic applications has been developed.

COLE researchers also work closely with the Singapore Eye Research Institute to investigate high-resolution diagnostic monitoring of open and closed angle in glaucoma patients and development of trans-corneal imaging systems, providing clinicians with objective information in the detection of primary angle closure glaucoma.

Biomimetic Optical Systems

Current autofocus smartphone cameras are driven by a voice coil motor (VCM) which is power hungry and can cause lens fluffing. COLE researchers have developed a electroactive-polymer actuated lens design which mimics the lens of the human eye.

Precision Optical Metrology

Motivated by the technological stimulus of ultra-short pulse lasers, COLE researchers are improving the precision of remote sensing and control capabilities for future space missions. Taking advantage of the superior characteristics of these lasers, such as fine temporal resolution, high peak power, high repetition rate, high frequency stability and broad spectral bandwidth; absolute distance metrology, multi-functional spectroscopy, precision time transfer and optical clocks are being investigated for the next generation space missions.

Laser Optical Patterning & Processing: Nanolithography by Surface Plasmon Interference

Novel concepts of laser interference, surface plasmon interference, nanolithography and other near-field microscopy techniques are being utilised at COLE to fabricate nano-scale periodic structures, with potential applications ranging from solar cells to bio-sensing.
CENTRE OF EXCELLENCE FOR Semiconductor Lighting & Displays

ABOUT LUMINOUS!

LUMINOUS investigates the science and technology of next-generation semiconductor lighting and displays forultrahigh efficiency and performance. It has astrong team of pioneering scientists and young researchers, together with world-class equipment and state-of-the-art facilities for semiconductor epitaxial growth and colloidal synthesis.

The core competencies and cutting-edge technologies developed at LUMINOUS include:
• InGaN/GaN LEDs
• White LEDs
• Organic LEDs
• Nanocrystal LEDs
• Nanocrystal lasers
• Nanocrystal quantum dot nanophosphors
• Emerging lighting technologies and advanced displays.

LUMINOUS! Flagship programme: World-class expertise & capability for II-nitride LED epitaxy & chip fabrication

LUMINOUS! looks at further development and exploitation of LED technologies, such as adaptive artificial lighting (photon-dynamic therapy, lighting for food storage, mercury-free lighting for clean water purification, surgical theatre lighting etc), each of which has specific operational requirements and needs custom design of the LED suitable to UV to achieve high efficiency and high performance. Next generation displays will be flexible, fully transparent and have high colour purity. We are developing proprietary manufacturing processes and device solutions for energy-saving lighting and information displays.

LUMINOUS! houses state-of-the-art facilities for semiconductor device epitaxy, fabrication and testing, including: nano-005200050005050000-sheath III-N Metal-Organic Chemical Vapour Deposition (MOCVD). The Center provides full capability for the epitaxial growth of III-N for high efficiency and high quality solid-state lighting, displays and other optoelectronic applications.

LUMINOUS! also has a full line for LED fabrication (including laser lift-off and laser scribing) and material-to-device characterization. The latter includes thickness, sheet resistance and photoluminescence mapping, fluorescent lifetime imaging, electroluminescence and LED absolute efficiency measurements using integrating spheres.

LUMINOUS! high-efficiency & high-quality colloidal optoelectronic material & device platform

LUMINOUS! has state-of-the-art soft-material synthesis, material characterization and device fabrication systems. Our team studies these materials from synthesis to property characterization and device applications, enabling the team to establish world-class expertise and generate new technologies spanning from materials to systems. Targeted applications are color-enrichment for displays, quality indoor lighting, spectrally-enhanced outdoor lighting, flexible and bendable displays, and tunable lasers. LUMINOUS! has developed the capability to synthesize various types of colloidal Quantum Dots (CdSe, CdS, etc.) and III-V material systems (InP). Colloidal QDs can be synthesized using a simple and cheap set-up, as compared to expensive instruments for epitaxially grown semiconductor QDs. We are equipped with high standard QDs synthesis setups (both manual and automatic) which enable us to explore the unique features of these nano-material systems. We benchmark and investigate the performance of these hybrid materials and devices with state-of-the-art characterization tools, including fluorescent lifetime imaging microscopy, absorption, photoluminescence and quantum yield measurement.
CENTRE FOR OptoElectronics & Biophotonics

ABOUT COEB

Established in 1994, COEB is a research centre for advanced photonics looking at fundamental science as well as novel technology and applications. We conduct research in areas such as very-high-capacity optical communications, nanophotonics, biophotonics, optical sensors for environmental science and personal healthcare, together with other related broadband information technology systems.

The centre’s research strengths are divided into four thematic programmes:

1. Novel Photonic Materials & Devices
2. Photonic Nano-structures & Applications
3. Mid-infrared Photonics & Optoelectronics
4. Biophotonics

Novel Photonic Materials & Devices

We focus on discovery, design and development of novel photonic materials in both organic and inorganic materials, nano-material structures, silicon photonics and novel photonic devices for next-generation communications, defence, green energy and bio-medicine.

Photonic Nano-structures & Applications

We focus on surface plasmonics, tunable and active metamaterials, metallic and dielectric nonlinear metamaterials, acoustic metamaterials, metamaterial light sources and detectors, super and hyper-lenses, and surface plasmon sensors for imaging and sensing applications.

Mid-infrared Photonics & Optoelectronics

We are developing innovative mid and far-infrared lasers, and graphene/novel material optoelectronic devices (waveguides, detectors, and modulators) for a broad range of applications, such as sensing & spectroscopy, biomedical sciences, communications, quality control of food, environmental monitoring and process control, imaging and security screening.

Biophotonics

The mission of the program is to improve human healthcare through basic, translational and clinical research in photonics. We focus on micro/nano-imaging, optical and endomicroscopy, fibre medicine, biosensors, CARS/SBS, and low-cost optical medical devices.
SILICON PHOTONICS Programme

The Silicon Photonics Programme focuses on the development of photonic devices and photonic integrated circuits (PICs) on a silicon (Si) platform. By leveraging the silicon micro and nano-fabrication technologies in the Nanyang NANOFabrication Centre (NAFC) in NTU, researchers and students under the programme are working on the development of CMOS compatible silicon photonic devices and ICs for high-speed optical communication and sensing. The ultimate goal of the programme is to enable large scale and high-density integration of optical functions in silicon wafers, integration of III-V compound semiconductor photonic devices on the Si platform is also a key research area.

CAPABILITIES

- Fibre fabrication, such as multi-kW laser fibres, microstructured & hollow fibres and nano-wire fibres.
- New class of LED that can be engineered to emit at desired wavelengths for specific applications, such as greenhouse lighting, fresh produce storage, light therapy and smart lighting.
- Micro-optical sensors for environment and intelligent homes, and biomedical monitoring for personal healthcare. Fibre-based photonic systems for power generation and energy delivery.
- Mid-IR photonics such as mid-IR fibre, mid-IR photodetectors based on III-V and graphene used in sensing, imaging, and communications applications.
- Biophotonics technologies like micro/nano-imaging, intravascular optical microscopy, endomicroscopy for early cancer detection, fibre medicine, fibre biosensors, super-resolution microscopy, and photo-acoustic imaging for the biomedical and healthcare industry.
- Novel solutions for high-speed wireless indoor communication via visible light using LEDs.
- Integrating fibre grating inscription on the fibre draw towers using ultra-fast laser technology.
- Computational optics in digital holography, optical metrology, 3D measurement, imaging and display.

FACILITIES

State of the art facilities include:

- Fibre drawing tower capable of silica, hollow and soft glass fibre.
- Modified Chemical Vapour Deposition system.
- Preform index profiler for special fibre fabrication such as microstructured fibre, softglass fibre for applications in fibre sensors and fibre lasers.
- Fibre Bragg grating system, sputtering system, Cytoviva microscopy for photonic III-V materials, photonics nanofabrication, mid-IR and THz photonics and optoelectronics applications.
- MOVCVD, Laser lift-off system, integrating spheres for Lighting and Displays applications.
- Near-field nanophotonics lab, quantum plasmonics lab, transformation optics lab.
- Optical design, laser manufacturing, precision machining and MEMS manufacturing.
- Silicon and III-V material full fabrication and characterization facilities for mid-IR Si-photonic devices and circuits.

CONTACT US

The Photonics Institute
Nanyang Technological University
St-86b-02.5a Nanyang Avenue Singapore 639798
Email: d-tpi@ntu.edu.sg  Website: http://tpi.ntu.edu.sg

Photo Credit: DARA, The Customer; Windows: TSI, The Optical Society of America; Photos Credit: MERED, IBM Research; Photonic.com, Emmetek, Retinos, Laser and Tech World