Nanyang-DSO Graduate Programme (NDGP) 2026

By Temasek Laboratories @ NTU (TL@NTU) and DSO National Laboratories

Research Topics

The following are the research topics available for selection:

1. Design and Fabrication of III-Nitride high-electron-mobility transistors for 5G/6G Applications

Widebandgap semiconductor materials, such as Gallium Nitride (GaN), promise to revolutionise the world of microwave power amplifiers by providing high power density, linear operation and robustness up to mm-wave frequencies (30 to 300 GHz). New applications such as gigabit point-to-point 5G/6G wireless communications or automotive radar require mm-wave power amplifiers. Researchers have demonstrated improved power density using different III-Nitride alloys (e.g: ternary, quaternary based heterostructures) by shrinking the gate (e.g: 20 to 40 nm) fabrication processes. Despite the great potential of these new technologies, they still suffer from physical and fabrication issues which may prevent devices fabricated on GaN and other III-Nitride alloys from achieving the improved device linearity and reliability levels required.

To improve the transistor linearity, it is required to design novel device structure, device simulation, device fabrication processes and its characterization. The main objective of this research topic is to explore different approaches to realize mm-wave operating devices by the optimization of device architecture design (e.g. Fin-HEMTs), device simulation, device fabrication and its electrical (DC, Pulsed I-V and RF) characterization. The measured device data can also be correlated with the in-coming HEMT epi-characteristics as well as device processing parameters.

Supervisor: Prof Ng Geok Ing (EEE)
Co-Supervisor: Dr Subramaniam Arulkumaran (TL@NTU)

2. GaN based HEMTs for high-power RF applications

Widebandgap semiconductor materials, such as Gallium Nitride (GaN), promise to revolutionise the world of microwave power amplifiers by providing high power density, linear operation and robustness up to mm-wave frequencies (30 to 300 GHz). GaN-based high electron mobility transistors (HEMTs) have emerged as a promising technology for delivering high power at high frequency power amplifiers. This may lead to increase efficiency and reduce energy consumption. AlGaN/GaN-based HEMTs were studied extensively and demonstrated power densities up to 10 W/mm at 40 GHz. Beside their great promise, technological issues still impede the full exploitation of the potential foreseen for GaN-based devices. To push the power density, researchers have explored different approaches. For example, N-Polar GaN HEMTs, Multiple-Channel GaN HEMTs, AlN/GaN HEMTs, InAlGaN/GaN HEMTs, GaN-on-Diamond and etc…

The purpose of this work is to improve the present GaN-based HEMT technology, increasing device power density and its efficiency by the optimization of device architecture design (e.g. Multi-Channel GaN HEMT or GaN-on-Diamond), deep scaling to increase the operating frequency, device passivation to suppress the current dispersion, device fabrication and its electrical (IV, Pulsed I-V, CV and RF) characterization. The measured device data can also be correlated with the in-coming HEMT epi-characteristics as well as device processing parameters.

Supervisor: Prof Ng Geok Ing (EEE)
Co-Supervisor: Dr Subramaniam Arulkumaran (TL@NTU)

3. Investigation of The Bendable Behaviour of Diamond for Thermal Management Applications

Diamond, with extremely high in thermal conductivity (TC) of beyond 2000 w/m k, it is the highest TC material and deemed to be the ultimate solution for thermal management challenge. However, it is also due to its extreme hardness and therefore, challenging to provide direct conformal contact with the heat source and not effective for heat extraction. This limitation might soon be able to overcome as recently; there is an experimental discovery that monocrystalline and polycrystalline diamond nanoneedles can be deformed reversibly to local elastic tensile strains at room temperature. By exploiting such bendable phenomenon of diamond, perfect thermal contact may soon be achievable, a game changer to the electronic world.

Herein, the objective is to investigate this new type of advance diamond that is compressible to address the need as thermal contact, without the need to sacrifice much of the TC of diamond. Various synthesis methods will be explored and examined with our state-of-the-art material characterization systems. Importantly, the thermal behavior as a function to the straining of these new diamond will be investigated. Due to the complexity and the scope of the investigation, there will also be collaboration with international diamond experts for advice, advance characterization, and validation of the materials.

Supervisor: Assoc Prof Edwin Teo (EEE/MSE)
Co-Supervisor: Dr Tsang Siu Hon (TL@NTU)

4. Advanced High Performance and Functional Fiber Materials

High performance fibers especially those with specific functionality have found a broad range of applications beyond textile and fashion. These applications include those in energy, electronics, biomedicine, environment, defence and aerospace.

In this project, the candidate will be working with an interdisciplinary research team to explore the design, fabrication and applications of new generation of fiber materials based on advanced polymers, carbon nanomaterials, ceramics and/or composites. The objectives of this PhD thesis are (i) to develop fiber precursor materials with desirable thermal-mechanical properties, fiber spinnability, and other functional properties such as electric and thermal conductivity, (ii) to establish the fabrication feasibility of micro- or nano-fiber spinning with advanced various spinning techniques, e.g., wet-spinning, dry-spinning and electrospinning, and (iii) to explore these new fiber materials in engineering applications. The cross-disciplinary knowledge gained in the study will help in-depth understanding of the critical relationships among chemical structures, micro-/nano-architecture, fabrication processes and functional properties. The project may also include an element of sustainability and green fabrication. New knowledge, technology and capabilities will be developed through innovation towards synthesis, fabrication and application of next-generation fiber materials.

This project plans to build upon the on-going collaboration initiatives with RICE University, Hebrew University of Jerusalem, and/or University of Manchester. Candidates having passion in innovative research and holding a good degree in a relevant science and/or engineering discipline are encouraged to apply.

Supervisor: Prof Hu Xiao (MSE)
Co-Supervisor: Assoc Prof Edwin Teo (TL@NTU)

5. Multiscale Engineering of Functional Structural Materials

To deliver mission-critical capabilities under a wide variety of environmental conditions, advanced systems need to be lean, efficient and adaptable, like a human body, with each module capable of carrying out multiple tasks simultaneously. The skin, for instance, acts as a physical barrier to absorb shear stresses, keep out micro-organisms, conduct thermo-regulation and sense pressure and heat. In contrast, current engineering design continues to rely on the paradigm of "1 system for 1 task", resulting in highly segmented and specialized solutions that are prone to over-engineering and have no backups.

The aim of the project is, therefore, to design and develop multifunctional structural materials through multiscale engineering from macro (> 1mm) to nano (~ 100nm) scales. To achieve this, the project will make use of advanced multiscale simulation methods driven by first-principles calculations and custom Machine Learning/ Artificial Intelligence (ML/AI) models, as well as unique multiscale manufacturing systems developed within our labs that combines nanofabrication with additive manufacturing techniques to derive new scientific and engineering insights into multifunctional material systems.

Supervisor: Asst Prof Lai Changquan (MAE)
Co-Supervisor: Dr Seetoh Peiyuan Ian (TL@NTU)

6. Mode-preserving fiberized laser beam delivery at kilowatt levels

Optical fibers have transformed our lives. They are the primary physical channel for exchanging information in global communication networks, supporting cutting-edge speed and bandwidth. They are widely used in optical sensing of mechanical stress and strain for structural health monitoring in buildings and other infrastructures. Another sector that has seen tremendous growth by adopting optical fibers is the high-power laser industry. The fiber form factor is ideal for thermal cooling that is critical for increasing the lasing power. Moreover, the fiber platform guides the light along its mechanically flexible path and removes the need for beam alignment, offering exceptional operational stability and beam quality. Hence, fiber lasers have been the main driver in high-power laser domain in the last decades.

One of the key features that makes the fiber laser so versatile is the ability to deliver the output beam via fiber, transporting the laser beam directly on to the target. However, at high beam powers, the delivery fiber may exhibit strong nonlinear effects, such as the thermal mode instabilities, which can severely impact the beam quality. Many approaches have been proposed and tested to reduce the nonlinear effects, but most entail introducing other undesired effects, such as the onset of multiple spatial modes that deteriorate the focusing power of the laser beam.

A promising solution to this challenge is hollow-core optical fibers, which guide light in their central hollow region, assisted by microstructured cladding surrounding the hollow core. They have been under active development in the past decade, with the latest breakthroughs demonstrating lower transmission losses than telecommunication-grade fibers. By guiding the laser beam in the hollow region, we can bypass the nonlinear effects induced in the waveguide material, enabling distortion-free high-power laser beam delivery.

In the Thesis, the candidate will develop a kilowatt-level laser beam delivery system using hollow-core fibers, which has the potential to disrupt the high-power fiber laser industry. This will involve designing, fabricating, and characterizing low-loss hollow-core fibers that are mode-matched to the laser output fiber. The design will require numerical simulations based on finite-element modelling. Fabrication will be carried out at our local fiber fabrication facility. Furthermore, a strategy to reliably and repeatably integrate the delivery fiber into the high-power laser through thermally resistive, mode-matched fusion splicing will be developed.

Supervisor: Asst Prof Chang Wonkeun (EEE)
Co-Supervisor: Dr Charu Goel (TL@NTU)

7. Crystal Fiber Technology As a New Frontier For High Power Lasers

The rapid evolution of high-power laser systems demands fiber technology that overcomes the limitations of conventional silica-based optical fibers. While silica fibers are well-established, they suffer from fundamental constraints such as nonlinear effects, material damage at high intensities, and thermal limitations. This project focuses on the development of crystal fiber technology—an emerging class of optical fibers with superior thermal handling and enhanced nonlinear performance, making them ideal for high-power laser applications.

As part of this research, the Laser Heated Pedestal Growth (LHPG) technique will be explored for crystal fiber fabrication. LHPG provides unique advantages in tailoring fiber properties, and the student will have the opportunity to contribute to its development and optimisation. Crystal fibers, particularly those made from sapphire, offer significant benefits such as higher damage thresholds, low phonon energy, and tailored dispersion properties, making them promising candidates for next-generation fiber laser systems.

A promising solution to this challenge is hollow-core optical fibers, which guide light in their central hollow region, assisted by microstructured cladding surrounding the hollow core. They have been under active development in the past decade, with the latest breakthroughs demonstrating lower transmission losses than telecommunication-grade fibers. By guiding the laser beam in the hollow region, we can bypass the nonlinear effects induced in the waveguide material, enabling distortion-free high-power laser beam delivery.

This research will drive advancements in optical fiber technology, high-power laser development, and applications that rely on high-intensity laser systems. The project offers an exciting opportunity for students passionate about laser technology, fiber optics, and advanced materials. Through a combination of experimental work, computational modelling, and collaboration with leading academic and industrial partners, students will gain invaluable expertise in high-power laser technology and next-generation fiber development.

Supervisor: Assoc Prof Yoo Seongwoo (EEE)
Co-Supervisor: Dr Charu Goel (TL@NTU)

8. Multicore Fiber Design: Overcoming Challenges in High-Power Lasers Via Beam Structuring

High-power fiber lasers are transforming industries, from advanced manufacturing to defence and medical technologies. However, conventional fiber designs face critical challenges, including nonlinear effects, transverse mode instability (TMI), and thermal limitations, which restrict power scaling. This PhD project will investigate multicore fiber architectures as a novel solution, utilising structured fiber design to manipulate light propagation, and overcome these limitations.

Multicore fiber architectures offer a promising solution due to their ability to distribute light across multiple cores, reducing the intensity per core and mitigating nonlinear effects. The research will focus on innovative multicore fiber geometries, such as coupled-core and aperiodic designs, to optimise mode control, suppress nonlinearities, and mitigate TMI, a major bottleneck in high-power fiber lasers. By combining advanced numerical modelling with hands-on experimental fabrication and testing, this project aims to develop scalable, high-performance fiber solutions for next-generation high-power laser systems.

Candidates will work within a collaborative and innovative research environment, gaining expertise in fiber optics, laser physics, and computational photonics. They will have access to state-of-the-art fiber fabrication facilities, providing a unique opportunity to engage in the practical aspects of fiber design and development. This project offers a unique opportunity to contribute to breakthroughs in fiber laser technology, with significant implications for both academic research and industrial applications.

Supervisor: Assoc Prof Yoo Seongwoo (EEE)
Co-Supervisor: Dr Charu Goel (TL@NTU)

9. High power and high brightness on-chip grating stabilized semiconductor diode lasers

Semiconductor based high power laser diodes (HPLDs) have been widely used in many application fields. These semiconductor HPLD modules are compact in size, reliable, cost effective, as well as efficient in optical-electrical conversion. Recently, much attention has been paid to the brightness of the HPLDs. High-brightness, high-power laser diode could be used for optical pumping of solid-state lasers and fiber amplifiers, material processing, free space communications, and medical treatment with improved performance. In addition, wavelength stabilization is another critical aspect for high power laser diode.

This project aims to develop high power, high brightness, and low cost on-chip grating laser diode. With these aspects, i.e., simultaneous high beam quality, high power and wavelength stabilization, the HPLD performance can be improved. The bulky coupling and wavelength stabilizing optics can be removed. Therefore, high power, high performance, low weight, and small size HPLDs could be achieved.

Tapered waveguide and laterally inhomogeneous waveguides laser diode is a promising concept for the combinations of high-power and nearly diffraction-limited beam quality in order to obtain high brightness. In addition, on-chip grating is beneficial to the wavelength stabilization. Therefore, in this project, the major scope of work will cover following.
(1) Large optical cavity (LOC) quantum well laser structure will be designed for high power and low divergence angle;
(2) to design tapered waveguide structure (with LOC) for high brightness;
(3) to design internal grating for Distributed feedback (DFB) laser; to design high order grating on the semiconductor for wavelength stabilization to avoid the re-growth;
(4) Optimization of the fabrication of waveguide, flare angle, laterally inhomogeneous waveguides.
(5) Optimize and fabrication of the grating structure.

In summary, this PhD topic is focused on the simultaneous realization of high power, high brightness, wavelength stabilization for high power semiconductor diode lasers, which is important for their applications. The above proposed research field will be well fitted for NTU's dynamic world level cutting-edge program. In addition, the proposed topic on high power laser diode also has great significance in both commercial and defence applications. For example, in commercial application, to name a few, high power lasers can be used for Optical pumping, Biomedical and Analytics Instrumentation, Materials Processing, Optical communication, Lidar, Printing, Imaging, and many others. For defence application, high power laser diodes can be used as Laser weapon, Night Vision, Laser Designation, Range Finding, Target Designation, Illuminators, Solid State & High Energy Laser Pump Sources, and so on. Obviously, improved high power laser performance to be achieved in this exciting PhD project can better enhance their use in above mentioned application fields.

Supervisor: Assoc Prof Wang Hong (EEE)
Co-Supervisor: Dr Liu Chongyang (TL@NTU)

10. Hardware Security Analysis of Advanced Microchips through Failure Analysis Techniques

Nowadays, electronic devices have become an integral part of daily life, storing sensitive data such as personal privacy and banking information. Therefore, the security of data stored within microchips is a critical concern. Over the past decade, a range of non-invasive and invasive techniques has been reported that attempt to retrieve secret data from secure integrated circuits (ICs). Among these, the use of laser beams is considered one of effective approaches for injecting faults into ICs with high precision or directly probing data.

In response, several protective techniques and designs have been developed, such as current sensor monitoring and the use of fully depleted silicon-on-insulator technology in chip fabrication. These measures are designed to fortify advanced ICs against methods like laser probing, significantly enhancing the security of data storage. However, while these security measures are effective against known attack techniques, it remains uncertain whether they can withstand emerging attack methods, especially those combine traditional approaches with artificial intelligence.

The main objective of this project is to strengthen the hardware security of advanced microchips. By employing both existing and newly developed semi-invasive and/or invasive attacks, as well as advanced microelectronics failure analysis techniques (such as electron probing and imaging) and intelligent image processing, we aim to simulate potential threats posed by hackers attempting to access confidential data. The insights gained from studying these attack techniques will aid chip designers and manufacturers in enhancing the protective capabilities of current and future electronic devices, ensuring a higher level of security against evolving threats.

Supervisor: Prof Gan Chee Lip (MSE)
Co-Supervisor: Dr Liu Qing (TL@NTU)

11. Ultrafast joining of advanced ceramics for enhanced mechanical properties

Due to the challenges in fabricating large ceramic sizes, ceramics often need to be joined together directly or with metals for practical applications. Traditional joining processes such as brazing and diffusion bonding requires long-term exposure of entire assemblies to high temperature in a chamber furnace, and thus it is an energy/time-consuming process. The long-time exposure of the ceramics at high temperatures could also degrade their mechanical properties. Therefore, selective, ultrafast joining techniques with the assistance of electric field or microwave are attractive to make the process more efficient. As an emerging, novel joining process, there is still a lack of a good understanding on these joining techniques for advanced ceramics, especially 3D printed ceramics with complex architected structures.

This project aims to develop an ultrafast bonding technique using electric field and/or microwave to promote more localized heating and material diffusion processes so as to realize a strong joint at the ceramic interfaces. The joining interfaces with unconventional topology will be designed and 3D printed to further enhance the bonding strength. The effects of the filler material, energy input, and interface structures on the mechanical and thermal properties of the joined ceramics will be systematically studied. The application of the optimized joining technique to large size ceramic and ceramics with complex architected structure will also be explored.

Supervisor: Prof Gan Chee Lip (MSE)
Co-Supervisor: Dr Du Zehui (TL@NTU)

12. Ultrafast joining of advanced ceramics for enhanced mechanical properties

Due to the challenges in fabricating large ceramic sizes, ceramics often need to be joined together directly or with metals for practical applications. Traditional joining processes such as brazing and diffusion bonding requires long-term exposure of entire assemblies to high temperature in a chamber furnace, and thus it is an energy/time-consuming process. The long-time exposure of the ceramics at high temperatures could also degrade their mechanical properties. Therefore, selective, ultrafast joining techniques with the assistance of electric field or microwave are attractive to make the process more efficient. As an emerging, novel joining process, there is still a lack of a good understanding on these joining techniques for advanced ceramics, especially 3D printed ceramics with complex architected structures.

This project aims to develop an ultrafast bonding technique using electric field and/or microwave to promote more localized heating and material diffusion processes so as to realize a strong joint at the ceramic interfaces. The joining interfaces with unconventional topology will be designed and 3D printed to further enhance the bonding strength. The effects of the filler material, energy input, and interface structures on the mechanical and thermal properties of the joined ceramics will be systematically studied. The application of the optimized joining technique to large size ceramic and ceramics with complex architected structure will also be explored.

Supervisor: Prof Gan Chee Lip (MSE)
Co-Supervisor: Dr Du Zehui (TL@NTU)