

EEE RESEARCH NEWS

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Excellence In
Engineering



School of Electrical and Electronic Engineering

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Excellence In Engineering

Nanyang Technological University's (NTU) College of Engineering and School of Electrical and Electronic Engineering (EEE) have put the university on the world map again in several global school rankings. We have excellent people with the requisite experience and expertise, EEE is posed to meet new challenges and seize opportunities.

In ShanghaiRanking's Global Ranking of Academic Subjects 2017, the College of Engineering was ranked the best school globally for two subjects – nanoscience and nanotechnology; and energy science and engineering – and Singapore's best for nine subjects.

The college was the sixth best worldwide and top in Asia for electrical and electronic engineering, and third globally and second in Asia for telecommunication engineering. Both subject programmes are offered in the EEE.

The EEE was also ranked the fifth-most prolific scientific research institution in semiconductors for the period 2006-2016, ahead of the University of Cambridge in Britain, based on the volume of research papers indexed in Clarivate Analytics' Web of Science.

Professor Yoon Soon Fatt, chair of the EEE, noted: "NTU's collaborations with leading industry partners, including research partnerships with Intel, NXP Semiconductors and Mediatek Singapore, have produced results. The EEE also worked hard to recruit talented faculty and promising PhD students, among other things."

Since its establishment as one of NTU's three founding schools, the EEE has grown and become one of the world's largest schools in electrical and electronic engineering. It is today internationally renowned for its high academic standards and strong research orientation.

The school has more than 140 full-time faculty members with strong research and professional expertise, and is supported by more than 460 research staff in 50 laboratories at 12 research centres.

The faculty members' research output is widely recognised for its quality; that has enabled the school to attract some S\$96 million of research funding annually. The research outcomes are also reported in about 750 Web of Science indexed journals and 460 conference papers every year.

In 2017, the EEE also organised a mega conference combining the 12th Conference on Lasers and Electro-Optics Pacific Rim, 22nd OptoElectronics and Communications Conference, and 5th Photonics Global Conference.

In the same year, Professor Yong Ken Tye from the EEE, who is also director of its Centre for Bio Devices and Signal Analysis, won the 2017 Beilby Medal and Prize for his work in nanomaterials and biophotonics to improve healthcare and medical diagnostics.



Four other EEE professors were named the world's most highly-cited researchers by Clarivate Analytics' Web of Science: Professors Huang Guangbin, P N Suganthan, Tang Dingyuan and Xie Lihua.

School of EEE

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The world's most highly-cited researchers

Unlocking Future Communications



The next generation of communications systems, including ultrafast 5G wireless networks, will require devices that can operate at millimetre-wave bands with minimal cost and maximum efficiency.

Now, Professor Ng Geok Ing and his research team at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE) have partnered others to develop 40 nanometre gate length gallium nitride high-electron-mobility transistors on silicon substrates with the highest cut-off frequency ever recorded, at 250 gigahertz (GHz). Their invention has potential applications in high-frequency and high-power performance devices.

The researchers used metal-organic chemical vapour deposition to grow the transistor's epitaxial structure on silicon with high-resistivity. High-resistance substrates help to prevent energy losses from induced current flows in high-frequency applications.

Its ohmic source and drain contacts were made with annealed titanium, aluminium, nickel and gold, while the rectangular gate was constructed using nickel and gold. Further metalisation for the interconnects and probe pads was carried out with titanium and gold.

While other reported III-nitride devices on silicon substrates have achieved similar drain currents, the researchers said that their device design has the edge on other devices in two ways: it

has a higher mobility and thinner total barrier thickness.

Their creation's performance also compares well with gallium-nitride high-electron mobility transistors produced on silicon carbide substrates, which have smaller diameters and are much more expensive.

While their transistor has a relatively low maximum oscillation of 60 GHz, the researchers noted that this could be improved through the use of a T-shaped gate structure. They added that reducing the transistor's gate length to 20 nanometres and adopting a self-aligned process in it could improve its performance.

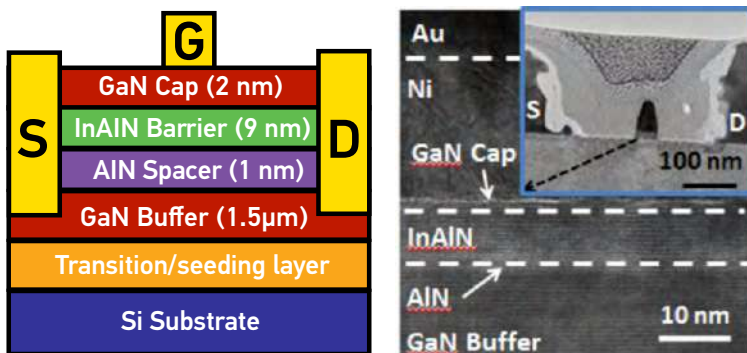


Fig. 1 Schematic diagram and TEM image (gate region) of a 40 nanometres gate length InAlN/GaN on silicon substrate

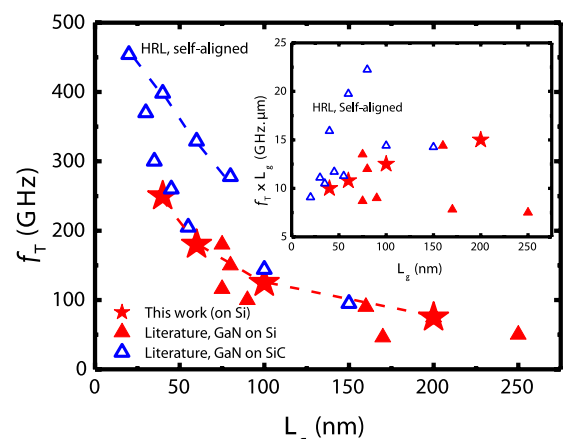


Fig. 2 Comparison of the cut-off frequencies (f_T) of GaN HEMTs on Si in this work with other reported GaN HEMTs on silicon substrates and GaN HEMTs on silicon carbide substrates. The inset shows the L_g dependence of $f_T \cdot L_g$ product

Improving Absorber

Scientists have long been seeking ways to cloak items and render them invisible for the purposes of stealth and surveillance.

Using concepts from transformation optics, in which metamaterials are designed to produce specific optical properties, scientists from Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Prof Luo Yu and Imperial College London led by Prof Sir John Pendry have proposed a theoretical flat absorber that could better absorb light to cloak objects and hide them from view.

The scientists showed that it is theoretically possible, through a series of transformations, to compact a three-dimensional structure into a two-dimensional surface without losing any of the former's properties.

Light waves that hit the two-dimensional surface are directed to singular points with sharp edges that confine the waves' energy and convert it into heat. This reduces the amplitude of reflected light waves, making the surface

less visible to observers. Furthermore, the surface will remain dark even when illuminated with white light.

The scientists proposed using a compacted layer of doped graphene as a flat absorber. In simulated experiments, the absorber had an absorption level of about 50 percent with a bandwidth of more than 10 terahertz, even in the presence of losses.

"The compacted, hidden dimension has a dramatic effect on the electromagnetic

properties of the system: transmission through a single sheet of graphene structured according to our prescription shows a strong broadband absorption of terahertz radiation, as opposed to the isolated absorption peaks of a conventional grating," said the scientists.

They added that while they had made a few assumptions in their simulations that will not hold up in some real life circumstances, these should not have a significant impact on the realised absorber's performance.

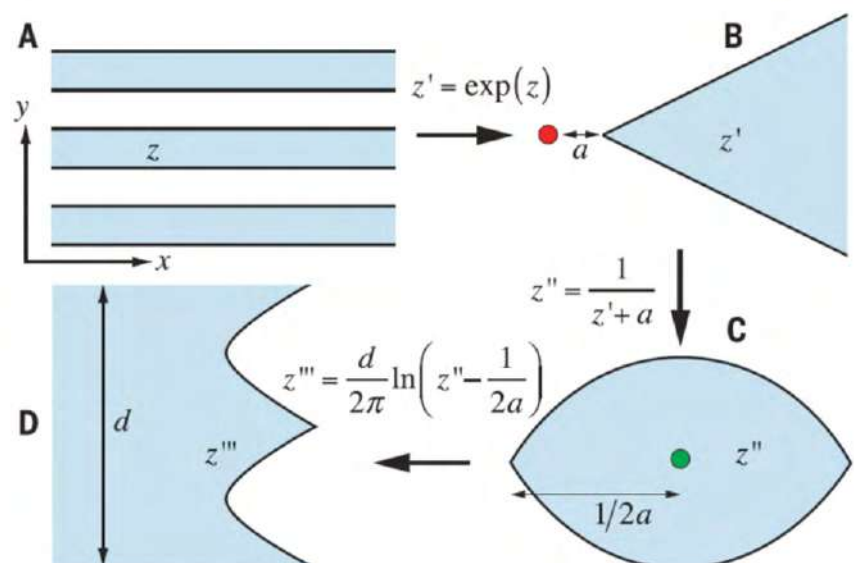


Fig. 1 A series of transformations compacts three dimensions into two dimensions. The infinite dimension along x in (A) is transformed into singular points in (D). (B) $x = -\infty$ transforms into $x' = 0$, $x = +\infty$ to $x' = +\infty$. (C) $x' = 0$ transforms to $x'' = 1/a$ and $x' = +\infty$ to $x'' = 0$. The u axis lies out of the plane.

Protecting Privacy



With more countries deploying sensors to track the elderly's health, monitor traffic and accomplish other civic goals, concerns about privacy intrusions have grown proportionately.

To help allay privacy concerns, scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Professor Tay Wee Peng have developed an algorithm to enable data collection devices to automatically decide how much and which data to send to centres that analyse the data.

Their work will prevent government agencies and corporations from using collected data to gain information about people that is beyond the stated purpose of the data collection networks.

For example, government agencies may give motion-sensing wearable devices

to the elderly to detect when they fall. The collected data, however, may also reveal information about the elderly's activities, such as when they go to the toilet or cook.

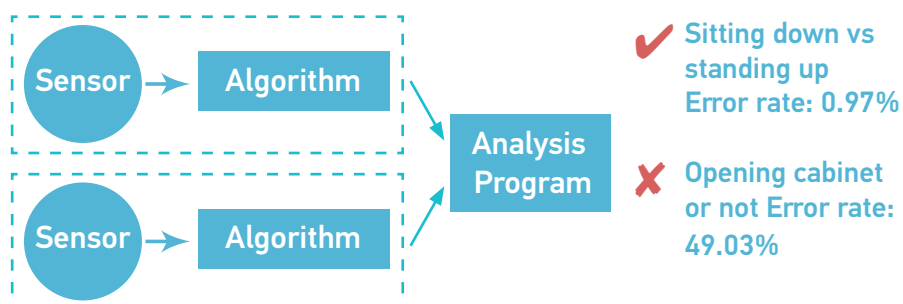
The EEE team's algorithm would go through the collected data to determine which data points are necessary for an analysis program to detect a fall, and combine or eliminate the other data points to create a 50 percent error rate for the testing of all other hypotheses.

This means that the analysis program would have enough information to accurately identify whether a fall has occurred, but would be forced to essentially guess whether the data also shows that, for example, the elderly went to the toilet at a particular time.

The EEE scientists validated their algorithm by testing it on data collected to identify when a person sat down or stood up. The data was sent from a body-worn sensor and showed acceleration speeds and gyroscope measurements in different directions.

After the algorithm processed the data, an analysis program identified with high accuracy when the person sat down or stood up but had a nearly 50 percent error rate in guessing whether the person was opening a cabinet.

"Our algorithm can learn by itself, through machine learning, how to process different datasets to achieve the desired outcomes," said Professor Tay Wee Peng from the EEE.



Making Sensors Smarter

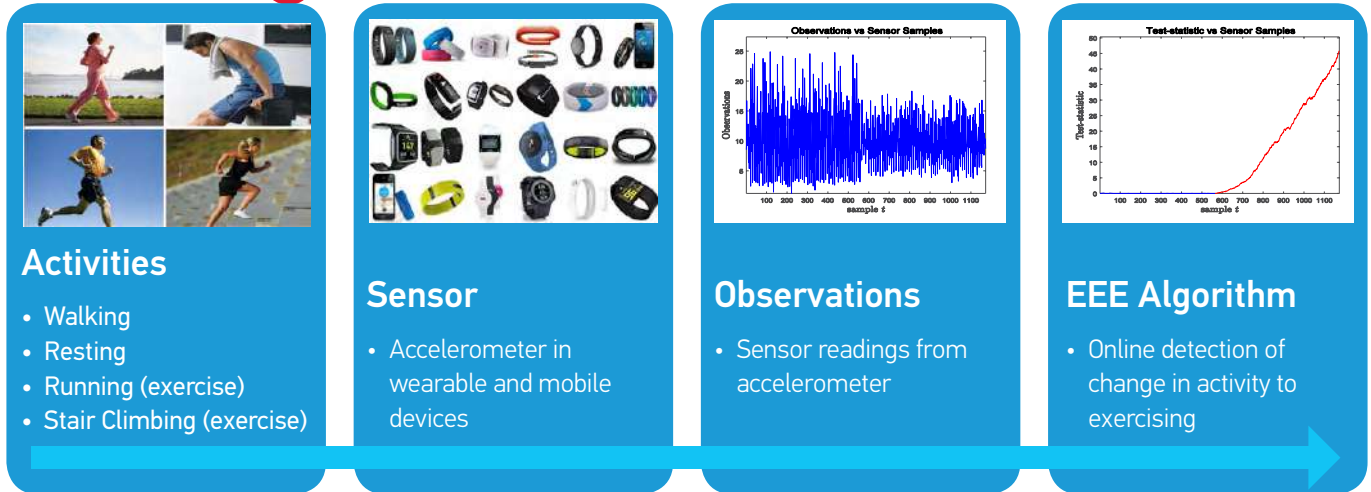


Figure 1: Application to activity monitoring.

Sensor technologies have improved to the point where they can be used to make buildings more energy-efficient, monitor the environment, check people's health and carry out countless other tasks.

With more sensors being deployed, however, the risk of false alarms may rise, and users may have to choose between prolonging the data analysis process to reduce false alarms and having a quicker alert system that also has a higher false alarm rate.

Now, scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Professor Tay Wee Peng, in collaboration with the University of Illinois at Urbana-Champaign, have invented an algorithm to help sensor systems analyse data more quickly to rule out

false alarms and alert people to anomalies. They used a semi-parametric approach that puts collected data into different virtual bins to quickly identify and confirm anomalies.

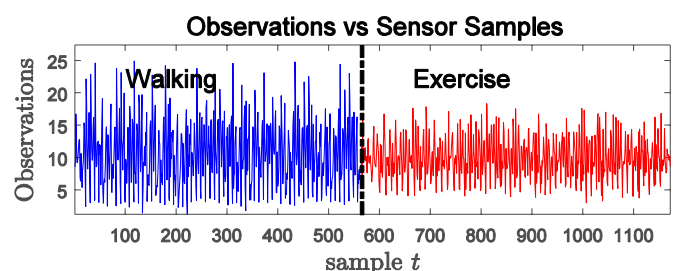
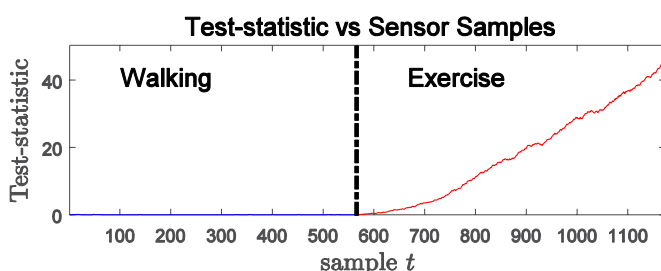
Any sensor system that collects data must contend with noisy signals. Furthermore, as sensors are deployed for more and more complex tasks such as analysing biological or physiological data, they may not know what type of anomalous data is expected.

An on-body sensor like a fitness tracker monitoring a person's physical activity will record fluctuations specific to that individual, for example. The fitness tracker maybe programmed to log the person's exercise activities, which can be considered to be "anomalous" from the idle state or when the person is performing non-strenuous activities such as walking.

The EEE algorithm looks at the data points collected by a sensor and assigns them to different virtual bins. If the accelerometer reading in the on-body fitness tracker usually fluctuates by up to 1 m/sec^2 uniformly, for example, it may create 10 virtual bins each spanning 0.1 m/sec^2 .

If the person is not exercising, the bins would be filled equally over time as the accelerometer reading goes through its normal fluctuations. If the person starts to run, however, some bins would be filled more frequently than the others.

The EEE algorithm allows sensor systems to work out, over time, what data is considered abnormal, and quickly confirm anomalies. The EEE team also validated their work by testing it on a set of activity tracking data.



Test on activity tracking data to detect when person switches from walking to an exercise activity like jogging or climbing stairs. The EEE algorithm does not need to know in advance what exercise the person is going to perform, or his or her individual characteristics. The larger the test-statistic, the more confident the test is that a switch from walking has occurred.

Going Green

Head over to Singapore's Jurong Island and you'll find a virtual laboratory of green technologies aimed at making the energy and chemical industries more sustainable and competitive.

Working with researchers from the University of Cambridge in Britain, scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE) are looking at how to improve and deploy technologies such as smart sensors, micro-grids and power electronics to make industries more energy-efficient and reduce their carbon footprint.

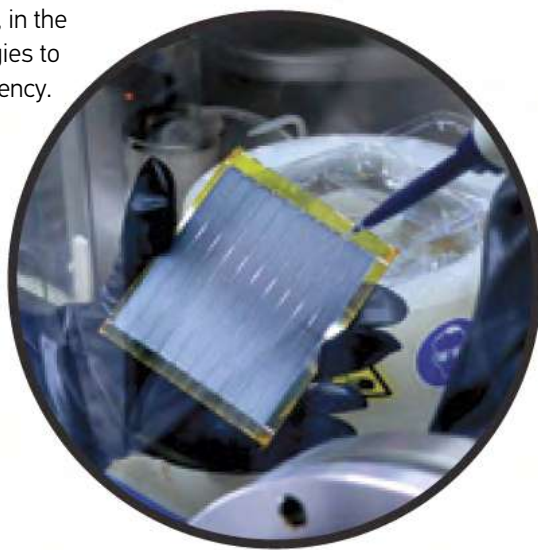
"We can use these technologies to redesign the organisation and layout of the energy network, and squeeze out inefficiencies through optimal operation and coordination of energy generation and consumption," explained Professor Ling Keck Voon from the EEE.

He and his team have created algorithms to optimise the scheduling of combined cycle gas turbines and other thermal units to reduce the machinery's fuel costs and greenhouse gas emissions. They are also investigating ways to capture and use waste heat from electricity generation for other industrial purposes.

Meanwhile, other EEE researchers have teamed up with scientists from the University of California, Berkeley, in the United States to create technologies to maximise buildings' energy efficiency.

Professor Hu Guoqiang from the EEE is leading an effort to develop data-driven methods to detect and diagnose faults in traditional energy guzzlers such as chillers and air-handling units. Resolving such faults more quickly could have a big impact on Singapore's and other countries' carbon footprint.

"We hope to contribute to Singapore's economy, as well as to Singapore being a good world citizen with regard to global warming," said Prof Ling. "While Singapore's contribution to global carbon emissions is very small compared to larger or developing countries, we believe our work can also be deployed elsewhere in Southeast Asia."



A perovskite solar cell being fabricated in a glove box at the SinBeRISE CREATE laboratory. Credit: SinBeRISE.

Boosting Wireless Charging

Team Members: Mr Goh Zhi Zhong Amo, Assoc Prof So Ping Lam

Research Centre: Centre for System Intelligence and Efficiency (EXQUISITUS)

In the near future, charging all of your personal devices could be as simple as putting them on a specially-configured wireless power transfer tablet.

Researchers at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Professor So Ping Lam, have created a wireless power transfer system that can wirelessly charge two electronic devices concurrently through a distance of two inches.

Their system sidesteps the disadvantages of other wireless power transfer systems, such as those based on inductive coupling, which suffer from a low degree of misalignment between coils and a strict single input and single output configuration.

Wireless Charging for EV

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www.eee.ntu.edu.sg

Wireless Charging System for Electric Vehicles

Project Objective

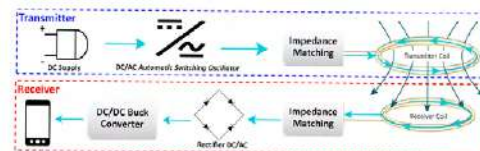
To design and develop a fast wireless charging system for electric vehicles and autonomous vehicles.

System Overview

The automatic switching oscillator circuit converts the DC power into the high frequency AC power to generate magnetic field in the transmitter coil. Impedance matching between the transmitter coil and receiver coil maximizes the power transfer between the two coils. The receiver coil picks up the magnetic field induced by the transmitter coil to produce AC power to the rectifier. The rectifier then converts the AC power back to spatial DC power. Lastly, the DC/DC buck converter down-converts the DC voltage to charge the mobile devices.

Advantages of Wireless Charging Technology

- Electric Vehicles (EVs):**
 - Convenient fast charging method therefore promotes the use of EVs to cut down carbon emissions
 - In-motion charging suits to long distance traveling needs
- Consumer Electronics:**
 - Convenient charging method for all gadgets
 - Better water and dust resistance for mobile phones
 - Reduces wear and tear of charging port for mobile phones and tablets
 - Universal standard able to charge across devices therefore reduce electronic waste



Future Wireless Charging Applications



Wireless charging for electric vehicles and autonomous vehicles



Wireless charging for consumer electronics



In-motion wireless charging for electric vehicles

EEE SCHOOL OF ELECTRICAL AND ELECTRONIC ENGINEERING EXPO

Supervisor: Prof So Ping Lam

Project Members: Goh Zhi Zhong, Amos

The EEE team's work is based on a coupling method known as magnetic resonant coupling. A transmitter converts high-frequency alternating current into a magnetic field through a coil and transmits it through the air to a receiver. The receiver converts the magnetic field back into alternating current and passes that along to a rectifier. The rectifier turns the alternating current into direct current which then goes through a converter for final voltage regulation before it is used to power the electronic devices.

"We conducted research and experiments on different coil materials, coil diameters, coil distances and resonant frequencies before developing the current version of our wireless power transfer system," said Professor So Ping Lam from the EEE. The team also plans to investigate how their work could be used to charge electric vehicles wirelessly.

"We believe that wireless power transfer is an emerging technology that offers a convenient, safe and reliable way of charging millions of electronics devices," said Professor So. "Furthermore, its use is not restricted to consumer electronics. It can also be used for many other applications such as the wireless charging of electric vehicles and wirelessly powered pacemakers and other medical equipment."

A Tool Against Extremists



Fig.1: Diagram of the video processing pipeline.

Violent extremists are increasingly turning to the Internet to radicalise and recruit others due to some online platforms' easy access, anonymity, low cost and lack of censorship.

To help reduce extremists' and terrorists' ability to convert others to their cause through online platforms, Nanyang Technological University's School of Electrical and Electronic Engineering (EEE) has teamed up with Singapore's Home Team Behavioural Sciences Centre to develop an electronic screening tool that can flag extremist and radical propaganda videos.

Law enforcement officers, intelligence officers and analysts can use the tool to sieve out materials that they need to focus on.

To create the tool, the researchers led by Professor Justin Dauwels combed numerous extremist videos to identify audio-visual and linguistic features that would indicate that a video is extremist in nature or radical propaganda.

An object detection program was also applied to the videos to automatically

detect and extract objects that appear in them.

"For the audio track of each video, we extracted the parts where someone was speaking, cut those into two-second windows, extracted a plethora of low-level audio features from each of them and calculated the means and

standard deviations for each feature," said Prof Justin Dauwels from the EEE. Linguistic and emotive features were also extracted from the audio tracks.

The data allowed the researchers to identify which features were most closely associated with extremist videos, and train algorithms to automatically determine whether a video fell into that category (see Fig.1).

Prof Dauwels said: "Our preliminary results suggest that there are significant differences between extremist and non-extremist videos that can be automatically detected and extracted. The screening tool will lead to more effective and efficient information sifting for counter-terrorism efforts. We are looking forward to continue this collaboration with the Ministry of Home Affairs and potentially overseas intelligence agencies as well, in an effort to improve the accuracy of the system."

Fighting Parkinson's Disease



Parkinson's disease is a chronic disease that affects hundreds of thousands of people globally, including three in 1,000 Singaporeans aged 50 and above.

Using an electrode to stimulate a tiny part of the brain called the subthalamic nucleus (STN) is an effective treatment for patients with Parkinson's disease, but current methods to map the STN and determine the ideal placement of the electrode are time-consuming and require significant expertise.

Scientists from Nanyang Technological University's School of Electrical and Electronic Engineering, led by Prof Justin Dauwels are collaborating with the neurosurgical team Dr Nicolas Kon and resident Dr Wan Kai Rui from the National Neuroscience Institute of Singapore under the NNI-NTU fellowship program to develop a faster, more accurate and automated way to perform this task.

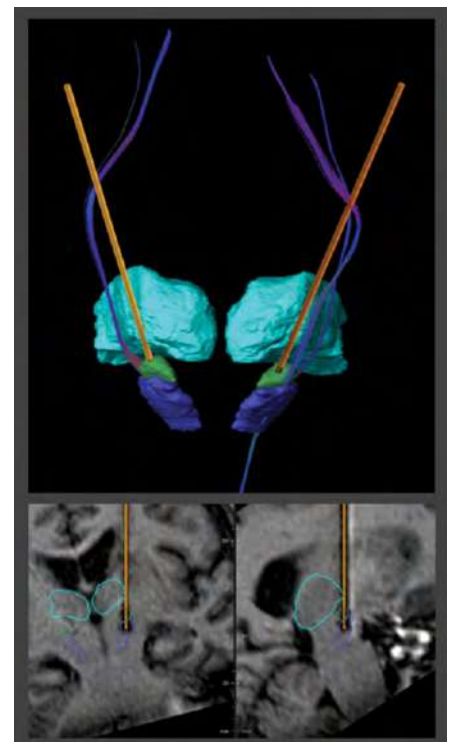
Currently, neurosurgeons and neurophysiologists have to map out the STN manually, which measures just 4 to 6 mm on average, through the use of microelectrode recording and test stimulations in the patient, who remains awake throughout the surgery.

While this process is considered the gold standard and necessary to ensure the precise targeting of the STN, it is extremely time-consuming and requires significant expertise on the part of the neurosurgeon and neurophysiologist to interpret the neuronal firing patterns accurately.

To date, there is no real-time system in clinical practice that can automatically detect and inform the neurosurgeon when the electrode is in the ideal location.

"Our collaboration aims to use machine learning classification procedures to build a three-dimensional physiological brain map based on the different types of signal patterns produced by different brain nuclei. Our research would be able to automatically determine the STN's borders as well as the optimal site for placement of the electrode," said Professor Justin Dauwels from the EEE.

He added: "We believe that our work will be able to reduce not just the durations of operations, but also potential morbidities due to human error, thereby leading to better clinical outcomes."



Light blue colour: Thalamus
Green colour: STN
Purple colour: Substantia nigra
Orange colour: Electrode

A Better Camera

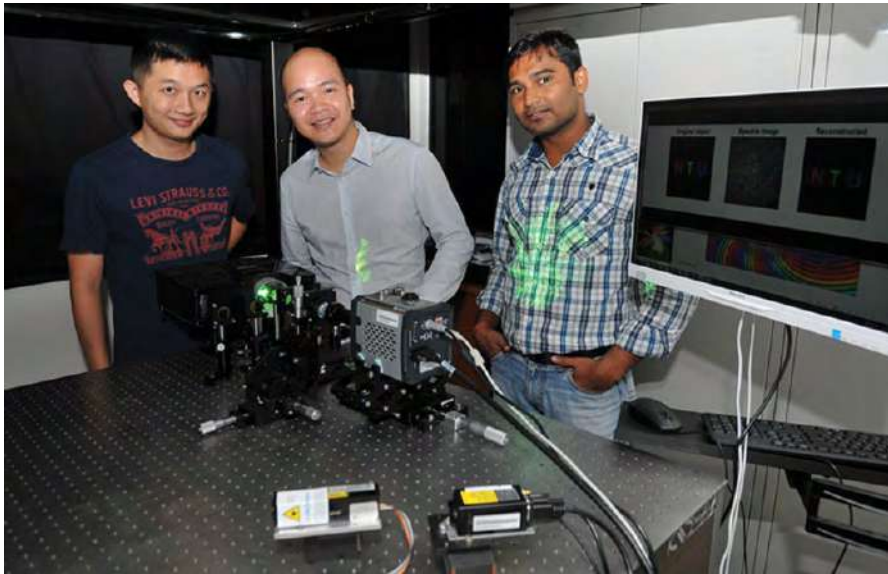


Fig 1 Speckle Imaging Group: (from left) Dr. Dongliang Tang, Asst. Prof. Cuong Dang, and Dr. Sujit Kumar Sahoo

Cameras that can see and separate multiple wavelengths which are even invisible to the human eye, such as infrared and ultraviolet light, have revolutionised biomedical imaging, surveillance and many other fields.

Users of such multispectral cameras have to choose between spectral resolution and range, or between multi-shot and spatial resolution, however, the trade-off between these parameters is pre-set and fixed when the cameras are manufactured.

Now, scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Professor Cuong Dang have developed a multispectral imaging technique that is low-cost, simple and allows more flexible trade-offs between spatial and spectral information. Users can also choose the spectral range and resolution to be captured and retrieved from a single shot image. The invention could make multispectral imaging in medicine and other fields more affordable and powerful.

The EEE method uses a single monochromatic camera which produces grey-scale images, and a scattering medium, which is any material that scatters light passing through it.

When light passes through a scattering medium, it scatters and produces a speckle pattern that is captured by the

camera. Different types of light produce different, measureable patterns.

If you know how ultraviolet light will scatter after it passes through the scattering medium, for example, you can analyse an image, identify the speckle patterns produced by the light and reverse-engineer the original photographed scene to highlight regions of strong, moderate and weak ultraviolet light – which is how the EEE method works.

Dr. Sahoo added that their method would work for all types of light, provided that the camera sensors can detect them. Users need only calibrate how each type of light scatters after it passes through their choice of medium, to use that knowledge for subsequent image analyses.

Professor Cuong Dang from the EEE said: "Unlike other multispectral imaging techniques, our camera can be used to do single-shot spectral imaging of any spectral band within a broad range just by replacing a lens with a glass diffuser, and it is also least affected by optical alignment issues as there are no moving parts and no focusing optics."

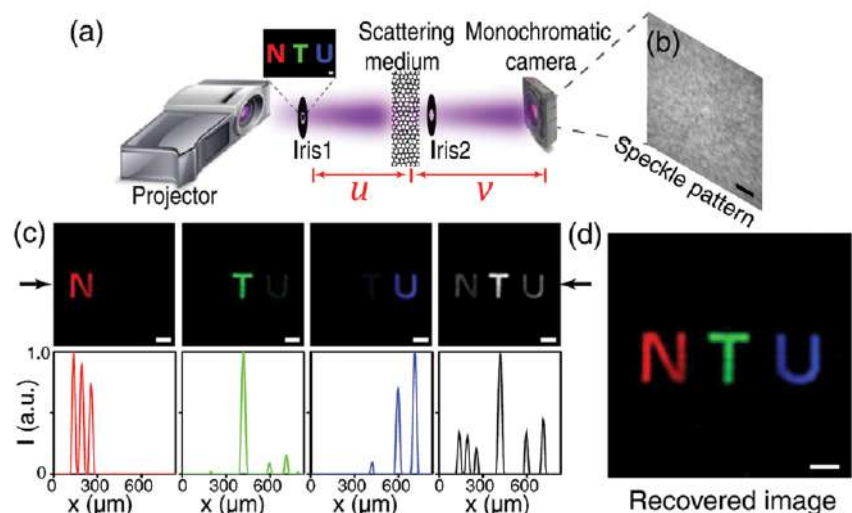
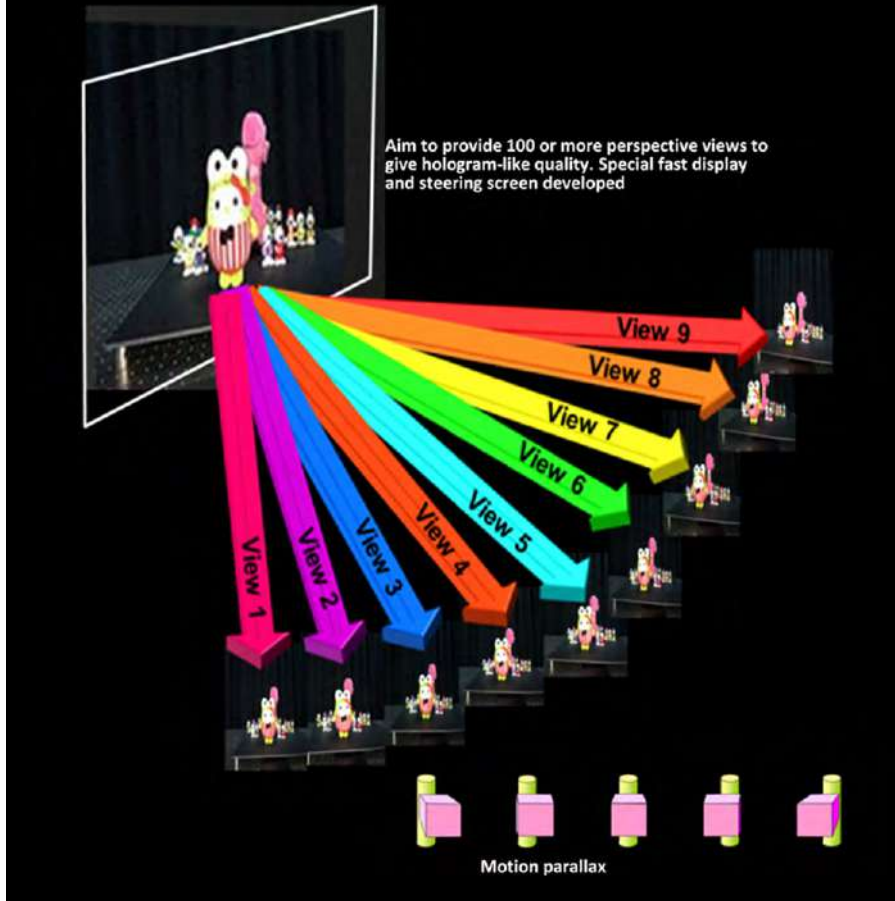


Fig 2 Experimental setup and the reconstructed multispectral images.

(a) A common projector without a magnification lens generates 2D multispectral objects on the plane of iris-1 (the object plane), which blocks any stray light from projectors. The light path is scrambled by a scattering medium (optical diffuser) then goes to a monochromatic camera after passing through the second iris, which plays the role of aperture in our imaging system. (b) The raw speckle pattern captured by the monochromatic camera. (c) Reconstructed multispectral images (upper half) and the intensity of their central rows (lower half), respectively. Two arrows mark the central row of the images. (d) A composite multispectral image is constructed by superimposing three individual RGB spectral images in (c). Scale bars: 1000 μm in (b) and 100 μm in others.

3D – Without Glasses



The EEE scientists' multi-layer light field displays use three liquid crystal display (LCD) screens that are placed in front of one another. Professor Zheng Yuanjin said: "We use algorithms to generate different light rays in each direction from the same point of the screen. Each LCD layer contains a different pattern, and the whole stack can approximate the light field of a given scene and recreate the scene with a hologram-like appearance."

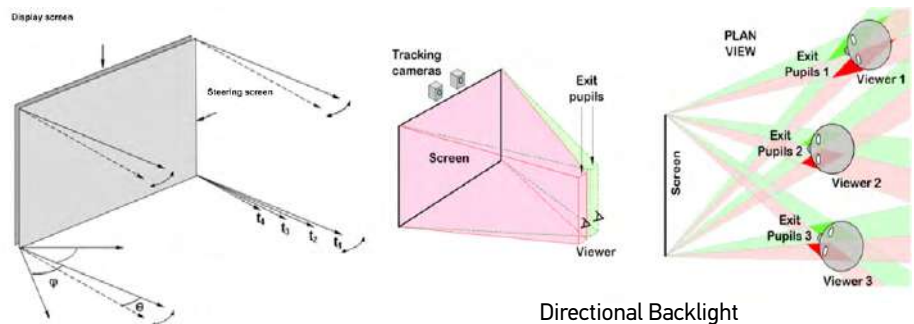
The directional backlit displays form exit pupils in the viewing field where either a left image or a right image is seen across the entire screen. The use of a head position tracker ensures that the pupils are always located in the regions of the viewer's eyes.

In the super multi-view displays, steering screens deflect the output from the display screen by a small angle. Professor Zheng added: "We obtain a high view density by scanning viewing zones in the regions of the viewers' eyes and rapidly updating the perspective views. Full resolution is obtained, and the high view density gives images a good depth of field."

In the near future, you may be able to watch three-dimensional (3D) videos without having to wear special glasses.

generate a 3D view. All 3D displays send different signals to each eye from the same point on the screen.

Scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Professor Zheng Yuanjin are working on three types of glasses-free 3D display sets: multi-layer light field displays; directional backlit displays; and super multi-view displays.



Directional Backlight

Currently, people have to wear special glasses to watch 3D videos. This is because we have two eyes that are separated by a few centimetres, and each eye has a slightly different view.

In real life, the brain combines the views to create a natural 3D image. In conventional 2D screens, both eyes see the same image so there are not enough spatial cues for the brain to



Tensor Display



Pico-projector Array for SMV Display

Novel Millimetre And Terahertz Wave Photodetectors

Photodetectors sense light and other electromagnetic energy, and are used in a wide range of technology. Long-wavelength photodetectors, especially those that operate in the millimetre and terahertz wave ranges, in particular, have many applications in many fields.

Now, scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), Professor Zhang Dao Hua and his team members Dr Tong Jinchao and Dr Xu Zhengji, together with Professor Huang Zhiming and his team members Dr Zhou Wei and Qu Yue at Shanghai Institute of Technical Physics, Chinese Academy of Science, have invented new long-wavelength photon detectors. Their creation could be used to improve technologies in many other fields, especially in security checking technologies. In addition to filing a patent, the related work has been published in Nature Communications (NatureCom 8, Article number: 1660, 2017).

Long-wavelength photodetectors that are now commercially available include Golay cells, pyroelectric elements, bolometers and Schottky barrier diodes.

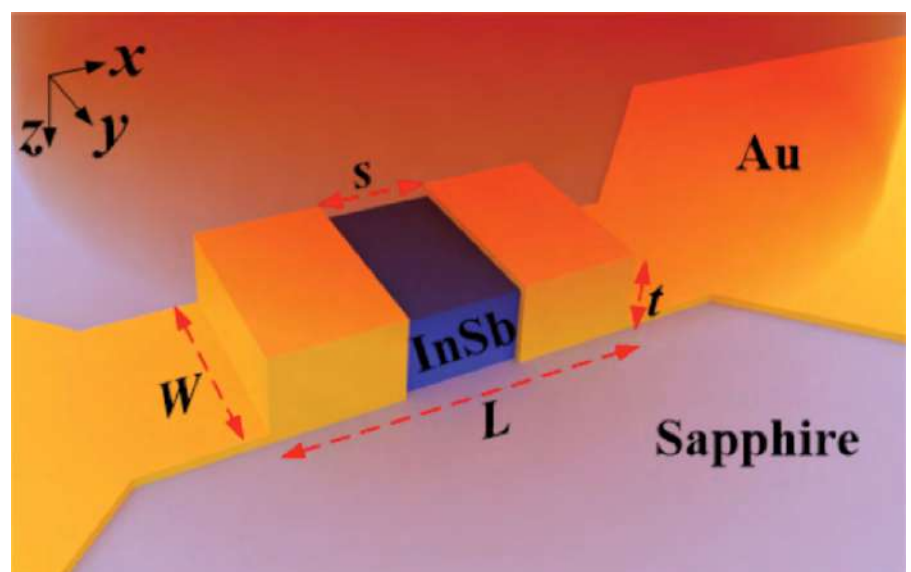
The first three, however, suffer from a slow response or require cryogenic cooling if they are used in thermal-sensing applications.

Meanwhile, the diodes, which are widely used in radio-frequency and microwave ranges, are high-speed but require advanced fabrication and material growth techniques.

The EEE scientists developed an antenna-assisted sub-wavelength ohmic metal-semiconductor-metal structure, made of gold and indium antimonide (InSb), that can detect photons in the millimetre and terahertz wave ranges.

Under transverse magnetic polarised illumination, the gold planar dipole antenna efficiently couples photons into the structure. Localised surface plasmon polaritons (SPPs) are excited by the coupled photons within the InSb semiconductor, especially near the semiconductor-metal interfaces on the top facet.

The SPPs then induce non-equilibrium electrons by transferring energy to electrons in the semiconductor. With zero bias, the SPP-induced electrons have a symmetric distribution. When a bias is applied to the structure, however, the electrons will flow through the semiconductor, leading to a photocurrent.



The EEE invention worked successfully in simulations and experiments. The scientists also achieved a noise equivalent power of $1.5 \times 10^{-13} \text{ W Hz}^{-1/2}$ with a device with a spacing of 10 micrometres under a DC bias current of 3.5 mA for a beam of 0.151 meV photons at room temperature.

A Light Disinfectant

Deep ultraviolet light can be used as an extremely efficient, non-chemical and safe method to disinfect surfaces because the light attacks and kills bacteria and viruses.

Filling a gap in the disinfectant market, scientists at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE), led by Professor Hilmi Volkan Demir, together with their partner Lightlab Sweden have developed a proprietary deep ultraviolet light (UV-C) technology, based on cathodoluminescence on-chip, to kill bacteria and viruses.

Their small light chips can be manufactured at low cost and outperformed other disinfection technologies, including mercury lamps and UV-C light-emitting diodes (LEDs), in germicidal experiments.

Mercury arc lamps are most commonly used for disinfection purposes in water plants, but mercury is very toxic to people and harmful environmentally, so they cannot be used safely at large scale for consumer products such as refrigerators and dishwashers.

While UV-C LEDs have been considered as an alternative, their performance has been poor and efficient systems are unlikely in the near future.

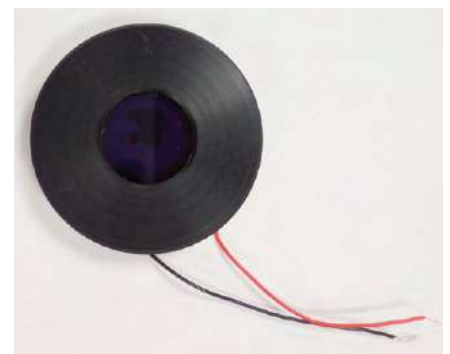
The NTU EEE and Lightlab team's invention is both mercury-free and highly-efficient. It also works instantly once switched on, unlike mercury lamps that take several minutes to warm up and radiate UV-C, can be used in both low-temperature and high-temperature operations, and has a long operational lifetime in intermittent applications.

In germicidal experiments, the chip reduced bacteria by about 99.99999 percent, two orders of magnitude better than mercury lamps, four orders of magnitude better than nano-silver

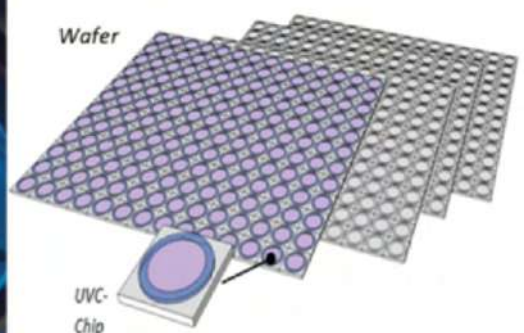
antibacterial technology and five orders of magnitude better than UV-C LEDs.

"We developed the chip technology with low cost and high volume in mind, so it can be manufactured using wafer-scale technology principles, where a vast number of devices can be manufactured at the same time," said Professor Demir.

He added that these light chips could be integrated into home appliances to disinfect surfaces; air-conditioner filters to disinfect air; and dishwashers and washing machines to disinfect filters and surfaces.



UVC-Chip



UVC chips – a new paradigm in UV light sources

App-ing Your Way To A Better Diet

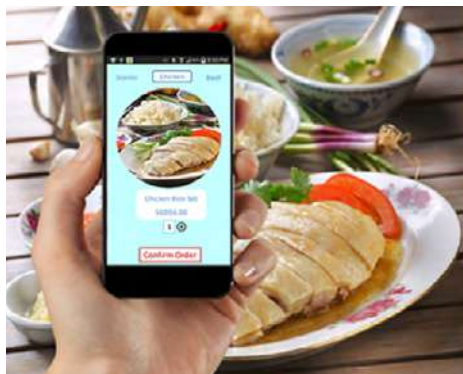


Fig 1 An overview of the proposed system. Visual analytics is used to populate the food pyramid based on what the individual is eating.

A poor diet can cause serious illnesses such as cardiovascular diseases, diabetes and obesity.

To help people cultivate and maintain a healthy lifestyle, Professor Yap Kim Hui and Professor Alex Kot, together with their team at Nanyang Technological University's School of Electrical and Electronic Engineering (EEE) have created a mobile app that can visually recognise dishes and log them into a personal food diary for users.

The app is linked to a visual analytics platform that will automatically record data about the dishes, including their carbohydrate, protein and fat content, based on standard Singapore serving sizes, alert users if they exceed daily dietary limits or fall short of goals, and make food recommendations.



Fig 2 Some representative dishes from our NTUIndianFood dataset are shown.



Fig 3 Screenshots from the developed diet monitoring mobile application. The app can automatically detect the food and compute calories and major macro-nutrients based on standard serving sizes.

By snapping photos of the dishes that they are eating, users of the app can build a record of their food history, analyse their food preferences and keep track of their diet. The app can also make food recommendations based on the

individual's preferences, fitness goals and health conditions.

"Such a system will enable long-term monitoring of one's dietary habits with the ultimate goal of improved physical

fitness. The technologies developed in this project will also benefit Singapore academically, economically and societally," the EEE researchers said.

They have so far constructed a dataset of Indian food with more than 63,000 annotated images. They have also developed a compact and personalised food recognition engine that can recognise dishes listed in the dataset with an accuracy of 95.6 percent.

They noted, however, that the recognition engine currently runs on a server with a graphics processing unit. "We are working on efficient network architectures that can achieve high food classification accuracies with low memory and energy footprints. Such networks will work better for the app's deployment on mobile devices," they said.

"We are also developing strategies to better incorporate an individual's dietary history and food diary for personalised dish recognition and recommendation," they added.



A Hub For Trailblazing Research

Centre for Infocomm Technology (INFINITUS)

In the Centre for Infocomm Technology, our researchers and engineers are working together on translational projects for the Singapore Smart Nation Programme. The centre combines our in-depth research in the areas of digital data processing, communication, data analytic, and Internet-of-Thing (IoT), with our engineering expertise in turning research outcomes into tangible solutions for the government agencies and deployment in the real world. Together with our industry partners, we are pushing ahead with several new IoT initiatives that will help to propel the education and R&D activities in NTU.

www.infinitus.eee.ntu.edu.sg



Centre for OptoElectronics and Biophotonics (COEB)

The science of light, and how to control it for various uses, is at the heart of COEB. Its research areas include optoelectronics which studies of electronics and light converge through semiconductor technologies, and biophotonics which uses light to image, detect and manipulate biological materials. Integrated optics at various wavelengths and biomedical imaging are among the key research directions in COEB, apart from the development of high performance semiconductor, fiber, solid-state, and ceramic lasers. COEB has partnered with many top institutions such as Harvard, MIT, Imperial College London, A*STAR, and various companies.

www.optimus.eee.ntu.edu.sg



Centre for Micro-/Nano -electronics (NOVITAS)

NOVITAS, Centre of Micro-/Nanoelectronics, conducts research and development in micro/nanoelectronics. It has three research groups: (1) advanced silicon device and integration technologies; (2) compound semiconductor devices and ICs and (3) Nanotechnologies. The centre has 26 faculty members, 44 researchers and more than 32 PhD students. Their research interests cover electronic material syntheses and characterizations, micro-/ nano-electronic device design and fabrication, device performance evaluation, simulation and physical mechanism study, etc. NOVITAS collaborates extensively with local and global academic and industrial partners and it holds 46 on-going research projects with a total fund of S\$27.3million.

www.novitas.eee.ntu.edu.sg



LUMINOUS! Centre of Excellence for Semiconductor Lighting and Displays

LUMINOUS! developed and demonstrated full capability for the epitaxial growth of III-N for high-efficiency and high-quality solid-state lighting, displays and other optoelectronic applications. The new advanced knowledge, proprietary know-how and technologies developed under this centre enabled superior performance for packaged LED chips while also changing their cost structure. LUMINOUS! flagship programme on energy-saving quality lighting has been attracting a high level of interest for the technology transfer of different modules in the LED growth and fabrication in the international arena. LUMINOUS! scientific research work, together with strong innovation in LED material and device design, has generated a strong IP portfolio at NTU and is in the commercialization phase. LUMINOUS! semiconductor optoelectronic solutions strengthen the national capabilities in Singapore and international industries in the region.

www.luminous.eee.ntu.edu.sg



Centre for Bio Devices and Signal Analysis (VALENS)

Striving to uncover the human body's workings and improve people's health, VALENS has four research priorities: lab-on-a-chip; bio-imaging; e-Health, which includes wearable devices to monitor health; and neurotechnology, where scientists develop methods to detect and predict neurological disorders. A recent collaboration with Massachusetts General Hospital and Harvard Medical School, for instance, resulted in a computer program to help doctors quickly diagnose epilepsy. VALENS also works with many Singaporean hospitals and international institutions.

www.valens.eee.ntu.edu.sg



VIRTUS, IC Design Centre of Excellence

An integrated circuit (IC, 'microchips') usually embodies millions of transistors and functions as the 'brain' of the myriad of electrical and electronic devices in our modern society – the major driver in humanity's third wave of invention and economic disruption. Research at the VIRTUS - IC Design Centre of Excellence encompasses most areas in IC design, ranging from contemporary areas to emerging areas, including organic/printed electronics on flexible substrates, the Internet-of-Things, Terahertz circuits and systems, satellite electronics, III/Von-CMOS, Point-of-Care devices, etc. VIRTUS collaborates with major research universities, including MIT, Caltech, Cornell, etc., and with major industry players, including NXP, Infineon, Huawei, Mediatek, etc.

www.virtus.eee.ntu.edu.sg



Centre for System Intelligence and Efficiency (*EXQUISITUS*)

EXQUISITUS develops core technologies to make complex engineering systems smarter and improve their performances. Main research areas in the centre include control and optimization, machine learning, data analytics, autonomous systems, intelligent systems and robotics, power systems and power electronics, smart grid technologies, smart building technologies, and smart manufacturing technologies, etc. Over the years, *EXQUISITUS* has worked with many universities and organisations including MIT, UC Berkeley, Cambridge University, Technological University of Munich, Rolls-Royce, Singapore Power, ST Engineering, Delta Electronics, Building and Construction Authority of Singapore, and Land Transportation Authority of Singapore, etc.

www.exquisitus.eee.ntu.edu.sg



Centre for Optical Fibre Technology (*COFT*)

The Centre for Optical Fibre Technology (*COFT*) gathers fibre-based technology and applications in Singapore under one roof hosted by the school of EEE, NTU. Being equipped with state-of-the-art facilities, the centre is well-placed to fabricate optical fibres - both standard as well as specialty fibres. The centre aims to become a centre of excellence in the advanced research of optical fibres and their related technologies, developing core capabilities and technologies for specialty optical fibre fabrication and characterisation. *COFT* has also partnered the overseas universities and research groups to develop ways to manufacture special optical fibres and related technologies. *COFT*'s goal is to become a hub for optical fibre fabrication and fibre-based devices research.

www.coft.eee.ntu.edu.sg



Electromagnetic Effects Research Laboratory (*EMERL*)

Though invisible to the naked eye, electromagnetic fields are all around us and can interfere with electronic devices. *EMERL* – short for the Electromagnetic Effects Research Laboratory – researches and measures electromagnetic effects on military and commercial electronic systems. Spearheaded by NTU and Singapore's defence organisation DSO National Laboratories, *EMERL*'s goal is to achieve the safe and innovative use of electromagnetic fields in new technologies. Its research could lead to increasingly compact electronic systems with high immunity to electromagnetic fields.

www.emerl.eee.ntu.edu.sg



Rapid-Rich Object Search Lab (*ROSE*)

In Internet searches, a picture could be worth a thousand words. The Rapid-Rich Object Search or *ROSE* Laboratory is a collaboration between NTU and China's Peking University to boost the efficiency and effectiveness of visual search from mobile devices or over the Internet. In particular, the lab is focusing on the classification, recognition, retrieval, and tracking of visual objects in images and videos. The *ROSE* Lab is working with Internet giants (e.g. Tencent) and industry leaders (e.g. Accenture, NVIDIA, and OMRON) in social media, e-commerce, digital advertising, image forensics, and surveillance to commercialise its research.

<http://rose.ntu.edu.sg>



Satellite Research Centre (*SaRC*)

The Satellite Research Centre or *SaRC*'s high-flying research includes putting into space Singapore's first locally-built satellite, the X-SAT, in 2011. Since then, it has developed and deployed six more satellites. Its researchers are also pushing the frontiers of satellite technology with innovations such as a fault-tolerant electronic system, precision navigation hardware, sensors, advanced control and electric propulsion system etc. In 2009, it started training students in various fields including advanced payload and satellite development from pico- to micro-satellites. Its goal is to become a centre of excellence in small satellite technology.

www.sarc.eee.ntu.edu.sg



Silicon Technologies, Centre of Excellence (*Si-COE*)

Silicon is found in virtually all electronics and has transformed every aspect of our economy, including information technology, transportation, energy production, and national security. The Silicon Technologies, Centre of Excellence or *Si-COE* aims to find new uses for it in sectors from multi-purpose healthcare wearables to energy efficient sensors for Internet of Things. Its four research focuses are the use of silicon in advanced sensors and non-volatile memories, new silicon chips intermixed with compound semiconductors, advanced packaging, and innovative solutions to dissipate heat in microchips. It has established research partnership with multinational corporations like GLOBALFOUNDRIES, Infineon, Hewlett Packard as well as Institute of Microelectronics in Singapore.

www.sicoe.ntu.edu.sg



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