Impact *from* Excellence

From atoms to systems

Tyndall
National Institute
Institiúid Náisiúnta

ANNUAL REPORT 2017

tyndall.ie

Contents

Front Cover Image

Gold coupons in the desert

Tyndall Annual Scientific Image Competition Winner; see page 54/55 for details

TYNDALL NATIONAL INSTITUTE
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From atoms to systems

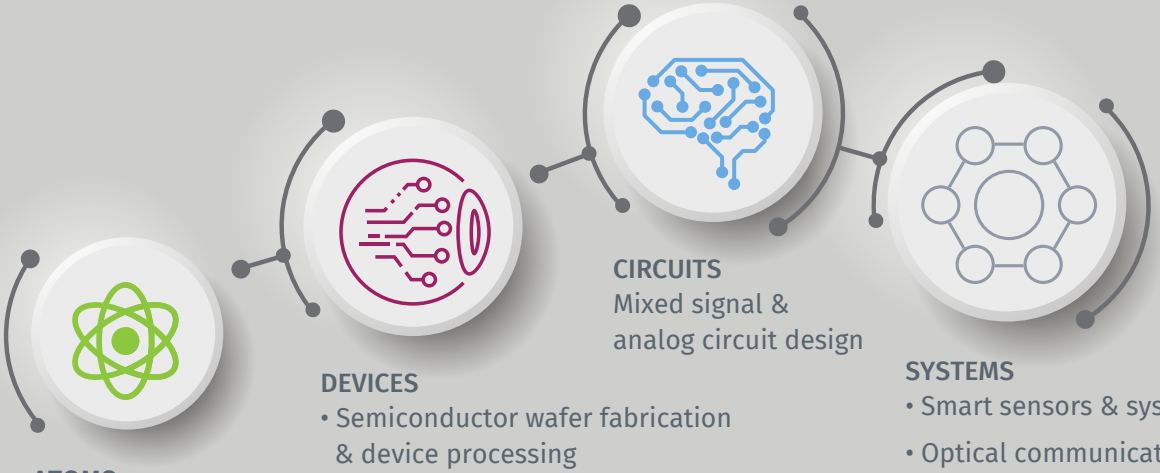
VISION

To be the premier ICT research institute worldwide in generating economic impact through excellence in research.

MISSION STATEMENT

Consistent with national socio-economic policies and priorities in Science, Technology, Engineering and Innovation, we will deliver economic impact from excellent research, systems development and graduate training, delivering innovative and disruptive ICT solutions and highly trained people, creating opportunities in areas of high jobs potential, particularly in communications, energy, health and the environment.

We are globally leading in our core research areas:



ATOMS
- Nano materials
- Growth & analysis

DEVICES
- Semiconductor wafer fabrication & device processing
- Electronic & photonic devices

CIRCUITS
Mixed signal & analog circuit design

SYSTEMS
- Smart sensors & systems
- Optical communication systems
- Microelectronics & photonics integration

Message from our Chairman & Acting CEO Eoin O'Driscoll

Eoin O'Driscoll
Chairman & Acting CEO

2017 has been a very interesting and challenging year personally, combining the role of Board Chairman with that of acting CEO in anticipation of the appointment of a new CEO. The role of acting CEO has given me a real opportunity to engage further with staff in Tyndall, and to appreciate the high quality of their work. Excellent research, driven by dedicated staff, is the foundation for our success and is the basis for our impact.

Research at Tyndall spreads from atoms, through systems, to applications. The research highlights section of this report takes examples from our 270 publications in 2017 to overview our strength across this full spectrum. Highlights range from fundamental understanding of superconductivity developed by Prof. Seamus Davis while on sabbatical at Tyndall, through to the world's most advanced demonstration of a new, highly scalable optical access network architecture, and applications that spread from medical and smart agriculture devices through to analysis of the chemistry of medieval Gaelic velum manuscripts. All of this research is built on the work of over 450 staff and students, in turn providing them with an ideal multidisciplinary training environment to develop skills critical to Ireland's future well-being.

Tyndall is a major partner in two new SFI Research Centres that were announced in 2017: Confirm, which aims to transform Ireland's manufacturing industry to become a world-leader in smart manufacturing, and VistaMilk, which has similar aims for the dairy sector, with Tyndall's smart sensor capabilities key to both centres.

Significant effort was also put into the preparation of the proposal for the second phase of the SFI-funded Irish Photonic Integration Centre (IPIC) which we lead. The proposal received very positive review by an international panel in December 2017. We await the outcome, which we are confident will allow IPIC continue to go from strength to strength. The preparation of our submission to SFI for the next phase of the CONNECT centre will be a key focus throughout 2018.

2017 delivered another strong outcome in EU Horizon 2020 funding. Our overall success rates continue to be significantly higher than the EU and national averages. A notable win in 2017 was the EnABLES project, which we coordinate. This project provides infrastructure access across Europe and also research funding to create 'self-sustaining' energy solutions to 'power the internet of things' based on energy harvesting, storage, micro-power management and system integration activities.

We strive in our work not just for research excellence but also to deliver economic impact, supporting the government's objective to improve Ireland's long-term competitiveness by exploiting its national research ecosystem. Industry income in 2017 was €6m, covering a wide range

Tyndall Board

Back (l-r)
Steven Ringel, *The Ohio State University*
John Mullins, *Amarenco Solar*
Richard Penty, *University of Cambridge*
Jane Williams, *Sia Partners*
Marcus Breathnach, *Department of Business Enterprise & Innovation*
Ian Quinn
Eoin O'Reilly, *Tyndall*
Anita Maguire, *University College Cork*
Seated (l-r)
Patricia Reilly, *European Commission*
Eoin O'Driscoll, *Tyndall Chairman*
Willy Sansen, *KU Leuven*
not pictured: Ann Kelleher, *Intel Corporation*

of Technology Readiness Levels (TRLs), from generating knowledge at lower levels to direct industrial application at higher levels. Related licensing activity also remained strong.

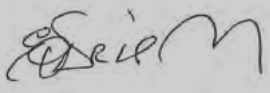
Our industry income is based both on long established multi-year interactions with companies such as Intel and Analog Devices, as well as new interactions, including a major contract agreed with Rockley Photonics to advance silicon photonics from the lab to market. We do not measure impact however just in terms of income received. Following the acquisition of our spin-out company InfiniLED by Facebook and its Oculus division in 2016, we have been very pleased to support Oculus significantly expand its operations in Cork during 2017, which is of major strategic value to Tyndall and to Ireland.

Overall, our industry interaction is strongly supported not just by our commercial development team, but also by the three related Centres that we host in Tyndall. Microelectronic Circuits Centre Ireland (MCCI), our Enterprise Ireland/IDA Ireland Technology Centre, which is due for mid-term review in 2018, now has 35 member companies, with whom it is working closely to grow the scale and impact of the microelectronics industry in Ireland. The International Energy Research Centre (IERC) developed significant traction in 2017, coordinating the new European project NOVICE and partnering in ReCO2ST. It also commenced a large number of new multi-industry partner national projects, with further such projects in the pipeline for 2018. The European Space Agency (ESA) Business Incubation Centre, established in 2016, also made its first announcements of support for start-up companies DroneSAR and Thalman Health.

The quality of Tyndall staff was widely recognised in 2017. The Wireless Sensor Network group, led by Brendan O'Flynn, won the Technology Ireland 'Outstanding Academic Achievement of the Year' for their Smart Glove work and the UCC Bridge Network "Invention of the Year" for their Kneehabilitation project. InfiniLED and its academic founders, Tyndall researchers Brian Corbett and Pleun Masskant, along with Technology Transfer Case Manager Anthony Morrissey, received the Knowledge Transfer Ireland Mature Spin-out Company Impact Award, with Brian Corbett also receiving a Leadership Award at the UCC Staff Recognition Awards ceremony. This was one of six awards to Tyndall staff at the ceremony, with Julie Donnelly (Research Support), Fatima Gunning (Research Supervisor), Alan Mathewson (Research Career), and Anthony Morrissey (Impact) all receiving individual awards. In addition, we were delighted that the Empowering Women @ Tyndall (EW@T) programme, which aims to support our female staff and students to reach their full potential, won the Frank McGrath Perpetual Award for Equality and Welfare.

We look forward now to further development and strengthening of Tyndall and its impact in the coming years. A significant upgrade and expansion of Tyndall was included by Government in the National Development Plan 2018-2027 in early 2018. We are grateful for the confidence that this shows in the work of the Institute and look forward to the opportunity it provides to greatly enhance our capabilities and economic impact. This will enable us to build upon our existing strengths in photonics and micro & nanoelectronics, supported not just by national programmes but driven also by continued international leadership and by strong engagement with industry.

I would like to thank the Department of Business, Enterprise and Innovation for their continuing critical support and valuable partnership. I also thank President Patrick O'Shea and his management team in UCC for their promotion of Tyndall and their important ongoing support. Additionally, I would like to thank outgoing board member Kevin Fielding for his valuable input over the last 8 years. Above all however, I thank our staff and students for their commitment and dedication, which underpin everything that we have achieved to date.



Eoin O'Driscoll
Chairman & Acting CEO

Scorecard

PEOPLE

Empowering Women@Tyndall team recognised by UCC with The Frank McGrath Perpetual Award for Equality and Welfare

EIGHTEEN
STUDENTS COMPLETED PHDs

Saibal Roy appointed as Research Prof. to the Physics Department of UCC; **Conor O'Mahony** as Adjunct Prof. at Chongqing Technology and Business University (CTBU), China.

3 Tyndall researchers received SFI Career Development Awards

5 Tyndall staff recognised with awards at **UCC Annual Staff Recognition Awards** night

RESEARCH EXCELLENCE

Over 270 peer-reviewed publications

26 invention disclosures made and 6 *patents filed, 3 granted*

Two new SFI Research Centres approved in smart manufacturing (CONFIRM) and in smart dairy agriculture (VistaMilk)

Wireless Sensor Network group wins **Technology Ireland Outstanding Academic Achievement of the Year for Smart Glove** and UCC Bridge Network "**Invention of the Year**" for **Kneehabilitation project**

INFRASTRUCTURE ACCESS

H2020 ASCENT and PIXAPP projects providing the international research community with access to infrastructure at Tyndall and at project partner sites

H2020 EnABLES project funded to provide access to Tyndall's capabilities in energy harvesting and power management

€10 million infrastructure refresh procurement underway

GLOBAL REACH

Funding for first SFI Ireland-China award approved in atomic layer deposition theory (Tyndall) and experiment (Jiao Tong University)

Hosted **European Photonics Venture Forum** in Dublin in May 2017

Review of EU H2020 ASCENT infrastructure project commended it as "An exemplar of how an infrastructure project should be performed"

Hosting of **IEEE NANO 2018 conference** and of **first International Workshop on Energy Harvesting in 2018**

FUNDING

112 **proposals** (SFI, EI, EU, etc.) submitted to a value of **€75m**

40 *proposals funded worth* **€28m**

Since Horizon 2020 launch, **we participate in 56 projects worth €29m to Tyndall**

€7 million H2020 project wins in 2017

23% success rate in H2020 calls

INDUSTRY ENGAGEMENT

Direct industry funding of €6m in 2017

Knowledge Transfer Ireland Mature Spin-out Award 2017 won by InfiniLED and its academic founders Brian Corbett and Pleun Maaskant

FORTY INDUSTRY STAFF, from a range of SMEs and MNCs, are based in Tyndall

Nine new EI Innovation Partnership programme projects approved

10 COMMERCIAL LICENCES/OPTIONS/ ASSIGNMENTS CONCLUDED WITH INDUSTRY

III-V Photovoltaic Cell with tethers (brown) in place ready for µTransfer Print to new substrate

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details

Impact highlights

Impact highlights

"We will deliver economic impact from excellent research, systems development and graduate training, delivering innovative and disruptive ICT solutions and highly trained people, creating opportunities in areas of high jobs potential, particularly in communications, energy, health and the environment."

An excerpt from Tyndall's Mission Statement

Rockley and Tyndall together advance silicon photonics technology

With the extraordinary growth in internet traffic and the non-stop demand for cloud-based services, data centres play a central role in meeting the demands of the petabyte-per-day data explosion. This year, Rockley Photonics (UK and USA), a fabless supplier of silicon photonics chipsets and IP designed for high volume optics applications, partnered with Tyndall to develop and deploy next generation silicon photonics technologies.

The immediate focus of the research is on high-speed III-V devices led by Tyndall and UCC Physics's Prof. Frank Peters and his Integrated Photonics team, targeting the transition to 50 Gb/s- and 100 Gb/s-per-wavelength transport rates. Fully-funded by Rockley as one of the larger direct industry engagements of 2017, the project is expected to expand into other silicon photonics technologies as the partnership develops and the technology reaches market deployment.

Dr Andrew Rickman, Founder & CEO of Rockley said that the combination of Rockley's expertise in high-density, low-power connectivity solutions and network topologies with Tyndall's infrastructure and research domain excellence will lead to groundbreaking, early stage technologies which will impact on the performance of future data centres and on the capacity and power efficiency of the internet.

In attracting silicon photonics leaders such as Rockley, the partnership highlights Tyndall's position as a global innovator in integrated photonics and we expect to continue a roadmap of activity with this partner covering photonics devices, silicon photonics and photonics packaging and systems.

Strengthening Europe's research infrastructure

Julie Donnelly, Programme Manager and Project Coordinator for ASCENT, with Mike Hayes, Coordinator for EnABLES.

The world will have 1 trillion IoT devices by 2025, all needing a power source. EnABLES, the EU Horizon 2020 research infrastructure project awarded funding in 2017 with Tyndall as co-ordinator, aims to eliminate battery replacement by developing energy harvesting solutions and/or finding ways to reduce device power consumption.

Infrastructure access available through EnABLES ranges from materials and models to devices and systems. Access providers will help users accelerate adoption and innovation in real-life applications. Launched in January 2018, the project includes leading researchers from CEA (Leti & Liten), Fraunhofer IMS, Fraunhofer IIS, imec the Netherlands, Karlsruhe Institute of Technology, Politecnico Di Torino, University of Bologna, University of Perugia and the University of Southampton. Together they aim to create self-sustaining energy solutions to power the internet of things based on energy harvesting, storage, micro-power management and system integration activities.

Simulations, data libraries, equipment, free of charge expertise and feasibility studies can be accessed in a fast-track manner via a Transnational Access (TA) programme, which will also fund Joint Research Activities (JRAs) between partners.

Strategically, this is a very important project for Tyndall in developing a European 'starting community' and positioning Tyndall as a global thought-leader and epicentre for 'powering IoT' research. This programme builds on the extensive expertise Tyndall has in offering access to its state-of-the-art facilities and expertise. Since 1999, Tyndall has hosted several European and SFI-funded access programmes which have given hundreds of researchers access to the advanced and unique research infrastructure at Tyndall.

EnABLES is one of a suite of access programmes currently running at Tyndall, along with:

ASCENT - Access to advanced nanoelectronics infrastructure led by Tyndall, with partners in imec and CEA-Leti.

PIXAPP - Open-access Photonic Integrated Circuit (PIC) Assembly and Packaging Pilot line led by Tyndall with partners in the UK, Germany, France, Belgium, Netherlands, Finland, Italy and Czech Republic.

ACTPHAST 4.0 - A unique "one-stop-shop rapid prototyping incubator" for supporting photonics innovation offering access to cutting edge technologies in Tyndall and 21 other partners across Europe.

Driving EU growth and competitiveness in global photonics industry

Netherlands-based PHIX Photonics Assembly engineers visiting Tyndall's packaging laboratories for training on advanced packaging technologies and to learn about packaging design rules.

PIXAPP is the world's first Integrated Photonic Packaging Pilot Line and was established in January 2017 with €15.6m funding from the European Commission.

The primary goal of PIXAPP is to support the transition of integrated photonic devices from prototype to production via pilot-scale manufacturing. A key objective of PIXAPP is to establish a set of packaging design standards providing users with easy access to well-defined and qualified packaging technologies which are sufficiently flexible to address a wide range of markets; from communications to medical devices and sensing. PIXAPP also provides advanced training to industry, including practical hands-on laboratory-based training using state-of-the-art packaging equipment.

PIXAPP has achieved three significant milestones during its first year of operation:

Design of standardised optical and electrical interconnects for all major European silicon, indium phosphide and silicon nitride integrated photonic foundries.

Establishment of the PIXAPP Gateway Hub at Tyndall to support incoming user requests for new packaging projects.

Establishment of a unique industry-focused training programme in advanced photonic packaging.

PIXAPP has also attended, presented at and sponsored many of the leading global photonics conferences and exhibits, and has established an internationally recognised global brand.

Tyndall leadership to play key role in two new SFI research centres

CONFIRM SFI research centre launch; pictured front row (l-r) are Dr Mary Shire, Vice President Research, The University of Limerick (UL); Minister of State for Training, Skills, Innovation, Research and Development, John Halligan TD; CONFIRM Director, Conor McCarthy (UL); CONFIRM Deputy Director, Graeme Maxwell, Tyndall; Dr Mark Southern, Senior Research Fellow, (UL) and Prof Tiziana Margaria, Co-Principal Investigator, Lero.

In 2017, Tyndall welcomed the approval of CONFIRM and VistaMilk, two new Science Foundation Ireland research centres for manufacturing of the future and for precision pasture-based dairying, respectively.

Adding active intelligence to manufacturing is critical for the long term competitiveness of Irish industry. CONFIRM will enable research in smart products, manufactured by smart machines, underpinned by smart production systems, and all integrated through smart supply chains. Led by Prof. Conor McCarthy, University of Limerick, with Tyndall's Head of Specialty Products and Services, Graeme Maxwell, as Deputy Director, the CONFIRM Centre will contribute to the global advancement of Smart Manufacturing.

Within CONFIRM, Tyndall will help develop new technologies to enable Ireland become a world leader in smart manufacturing across multiple sectors. We see this as an exciting addition to our research portfolio and strengthening the opportunities for Tyndall to embed the smart technologies we develop into the manufacturing floors of the future.

The VistaMilk Centre is to be a world leader in the Agri-Food technology sector through innovation and enhanced sustainability across the dairy supply chain, positively impacting the environment, animal well-being and the health of consumers.

The advances developed in the VistaMilk centre, will apply to dairy systems in many countries and will be a catalyst for global growth in the Agri-Tech sector. VistaMilk represents a unique collaboration between Agri-Food and ICT research institutes and leading Irish/multinational food and ICT companies.

The new centre will be hosted by Teagasc, the national agency with responsibility for agriculture and food research, in partnership with Tyndall, the Telecommunications Software and Systems Group at Waterford Institute of Technology and the Insight Centre for Data Analytics at University College Dublin. Within VistaMilk, Tyndall will develop smart sensor systems that will enable the Irish research and industry communities to be uniquely positioned to address future market opportunities in the emerging sectors of precision agri-food and environmental monitoring.

Awards success for Smart Glove and Kneehabilitation

left Tyndall's Dr Brendan O'Flynn demonstrating the smart glove which transports people's hands into the virtual world, providing a fully-immersive, touch-sensitive experience.

right Declan O'Mahoney, Tyndall Entrepreneur-in-Residence; Michael Lucey, PurdyLucey; Salvatore Tedesco, Kneehabilitation Principal Investigator; Anthony Morrissey, UCC Technology Transfer Office; and Cormac Harrington, Tyndall COO with the Bridge Network Invention of the Year award.

Tyndall's Wireless Sensor Networks team, led by CONNECT-funded investigator Brendan O'Flynn, was recognised in 2017 for two distinct areas of their work in wearable smart sensing systems.

At the 2017 Technology Ireland Software Awards, Dr O'Flynn received the 'Outstanding Academic Achievement in the field of Digital Technology' award from IBEC on behalf of the researchers behind the Smart Glove – Haptic Human Computer Interface System for VR/AR and robotics.

Developed in a collaborative project in conjunction with Waterford Institute of Technology's Telecommunication Software and Systems Group, the smart glove is a culmination of over a decade of research in the development of motion sensing for the human body and incorporates the latest sensing technologies needed to bridge the human and digital worlds of Augmented/ Virtual Reality and robotics. The glove incorporates sensors and novel data fusion algorithms to give precise information in real time regarding hand biomechanics, position and movement.

Salvatore Tedesco received the Bridge Network "Invention of the Year" award sponsored by PurdyLucey for the team's rehabilitation-focused system, Kneehabilitation. The Kneehabilitation project was informed by, and developed in conjunction with, expert clinical partners. It is focused on delivering a real time solution to monitoring the knee, enabled by the use of proprietary Wireless Inertial Measurement Unit (WIMU) technology developed within the Wireless Sensor Networks team.

Nanowires of Germanium Antimony Telluride

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details

Research excellence

Research excellence

Tyndall's vision is to be the premier ICT research institute worldwide in generating economic impact through excellence in research.

Our research is performed within three closely linked centres – Micro & Nano Systems, Photonics and Specialty Products & Services, with the activities spanning from fundamental concepts and analysis through to novel systems and applications. The Micro & Nano Systems Centre at Tyndall focuses on modelling and development of materials, devices and systems for integrated information and communications technology (ICT) applications.

This section presents highlights of Tyndall research during 2017 – "from atoms to systems" – starting with novel materials research, and then moving on to describe work on devices, circuits and systems with world-leading capabilities, and finally presenting examples of recent applications-focused research with real impact in communications, energy, health and the environment.

Further information on many of the highlights can be found by clicking on the hyperlinks in the online version of this report.

Advanced/novel materials

Davis' research leads to superconductivity breakthrough

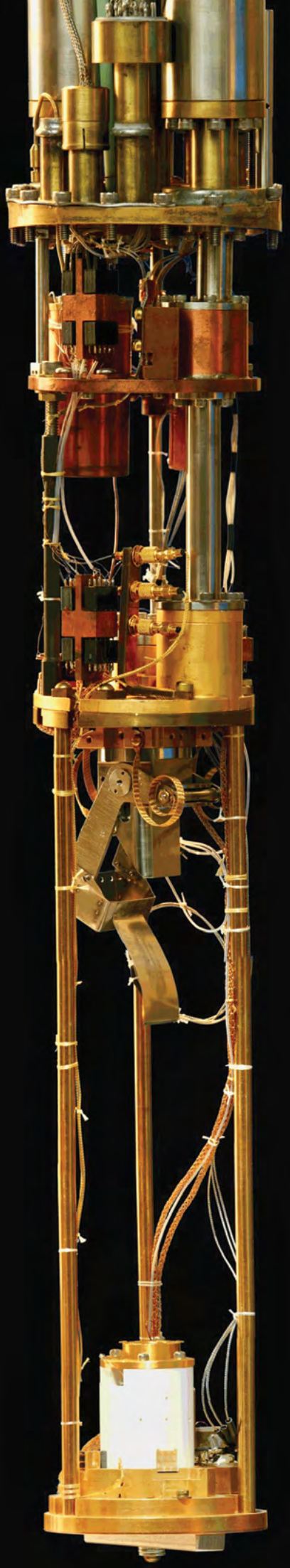
left J. C. Séamus Davis.
right Quantum microscope.

Initially, all high temperature superconductors (HTS) were based on doped copper-based alloys, for which the undoped phase is a robust Mott insulator, in which electron-electron interactions prevent current flow in a material where conventional theory would predict the material to be a good conductor.

Recently, iron-based HTS materials have been demonstrated, for which the undoped phase is not an insulator. Thus, proximity to a Mott insulator appeared **not** indispensable or universal to HTS. However, theory has long indicated that iron-based materials could still be governed by strong electronic correlations proximate to a Mott insulator if an orbital selective Mott phase (OSMP) exists.

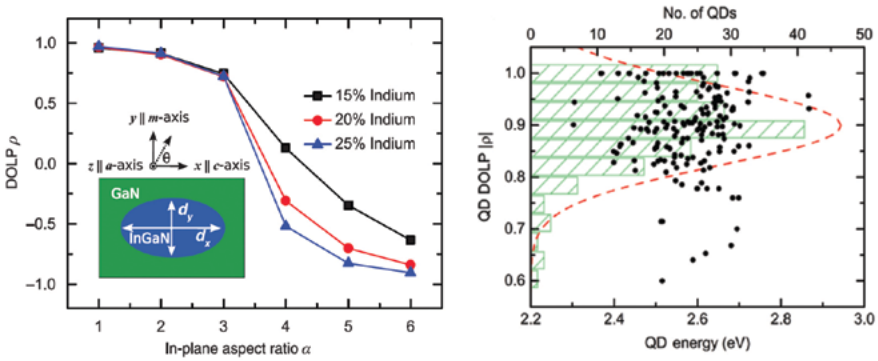
While on sabbatical at Tyndall, Prof. Seamus Davis (Cornell University and Brookhaven National Laboratory) completed analysis of the canonical iron-based superconductor FeSe, using an orbital resolved electronic visualization technique that his group invented.

These results, published in *Science*, reveal that orbital selective superconductivity does exist in FeSe. If this discovery can be generalised to other iron-based superconductors, strong electron-electron correlations occurring in proximity to a Mott insulator would once again be found universal and key to HTS.



Advanced/novel materials

Direct generation of linearly polarised single-photon sources from nitride-based quantum dots



above Dr Stefan Schulz, Staff Researcher, Photonics Theory Group.

GRAPHIC
Degree of optical linear polarisation (DOLP) in a (nonpolar) indium gallium nitride quantum dot. left: Theoretical calculations of the DOLP for different quantum dot shapes. right: Experimental results for the DOLP measured in 180 quantum dot structures.

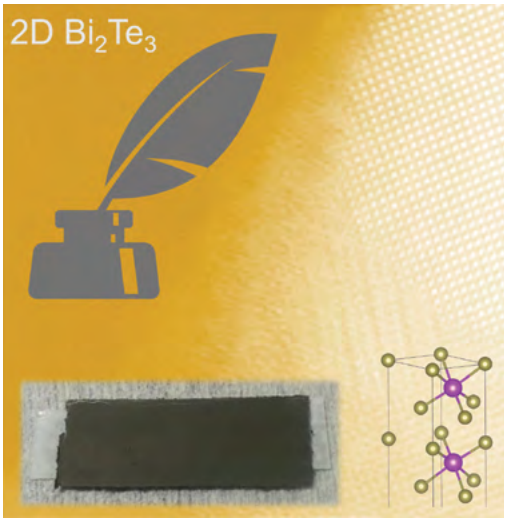
Polarised single-photon sources are essential for applications in quantum information systems, such as quantum key distribution. To develop these non-classical light sources, semiconductor nanostructures, such as quantum dots, have been of strong scientific interest. Here, nitride-based materials have attracted considerable attention since their fundamental properties put room temperature single-photon emission within reach.

However, a major drawback of conventional nitride-based systems is their inability to produce single-photons with a deterministic polarisation axis. The theoretical work by Saroj Kanta Patra and Stefan Schulz at Tyndall, published in *Scientific Reports* in collaboration with experimental groups from University of Oxford, University of Cambridge and Toshiba Research Europe, has shown that this problem can be circumvented when realising nitride-based quantum dots on novel growth planes, while keeping the benefits of the nitride material system.

These novel structures are excellent candidates to achieve single-photon emission near room temperature with a deterministic polarisation axis. This presents a notable advantage over single-photon emitters based on other material systems, which only operate at cryogenic temperatures.

Advanced/novel materials

2D Nanosheet paint



left Prof. Colm O'Dwyer, School of Chemistry, Tyndall National Institute, and Environmental Research Institute, University College Cork

right Aberration-corrected high angle annular dark field scanning transmission microscopy image of the atomic structure of a 2D Bi_2Te_3 material, developed into an ink suspension that can be painted onto surfaces.

In the search for innovative coating methods for 2D materials, the nano community requires a method that allows conformal coating over any form of surface, with minimal processing, that exploits the unique properties of 2D materials. Ideally, the process should not mask the intrinsic properties of the 2D material.

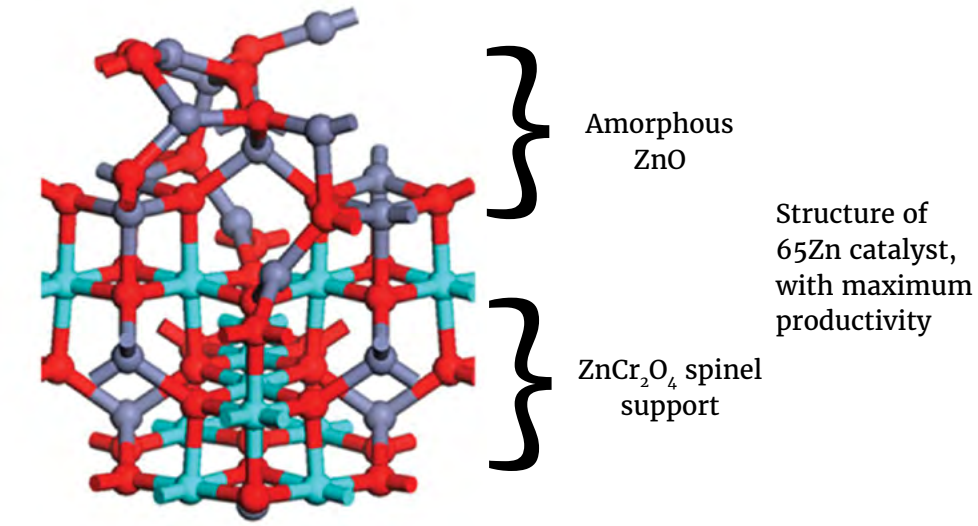
Embedding 2D layered materials into polymers and other materials has enabled production of ultrasensitive pressure sensors, tunable conductive stretchable polymers, and thermoelectric coatings. Bismuth telluride, a layered compound, has not been examined in detail by solvent exfoliation, despite its critical importance in many applications, particularly in thermoelectrics. Work by Colm O'Dwyer and colleagues in *Chem. Mater*. has shown several advantages for polymer functionalized 2D Bi_2Te_3 ink painted onto a surface.

In comparison with other deposition, printing, or writing methods for 2D materials, their technology has potential to be applied on large and on curved surfaces. The painting direction and the film aspect ratio define the film's conductivity, which cannot be achieved when conductive additives are used, and may be a general phenomenon for films painted from inks of 2D semiconductors.

Process and device physics and engineering

Design of catalysts for methanol production for fuel and energy applications

above Dr Michael Nolan, Senior Staff Researcher, MNS (Materials & Devices)



right The atomic structure of the best performing catalyst as determined by simulations.

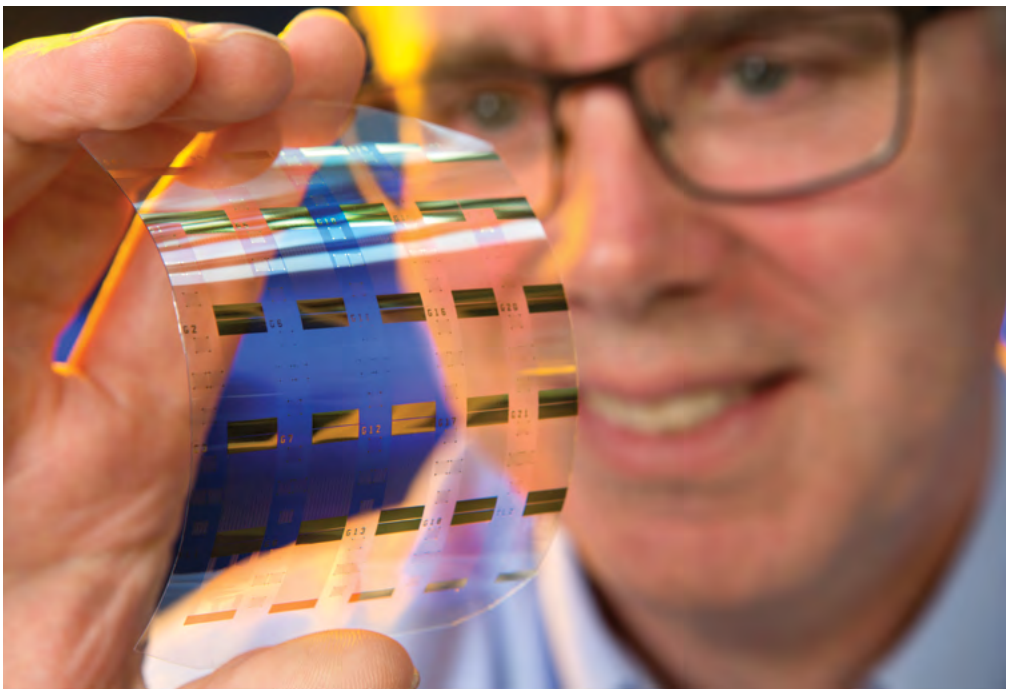
In 2017, Tyndall led the activities on design of catalysts for biomass conversion to methane, methanol and fuels in the FP7-NMP project BIOGO. The key step is production of methanol, from which liquid fuels can be produced.

Working together with one of Europe's leading catalysis groups at Ruhr-University Bochum, Germany, the materials modelling work of Michael Nolan and John Carey unravelled for the first time the precise atomistic structure and the origin of the activity of the mixed zinc-chromium oxide catalyst used for methanol synthesis.

Tyndall's theoretical work, published in *ACS Catalysis*, showed that a composition with 65% zinc and 35% chromium forms an amorphous, active zinc oxide outer layer and it is this ultra-thin layer that is responsible for the high activity of the catalyst for methanol production, as observed in the experimental work of BIOGO partners, thereby providing a route to more efficient methanol production for fuel and energy applications.

Process and device physics and engineering

Transparent metal meshes on plastic



Dr Aidan Quinn, Deputy Head, MNS (Materials & Devices), and Head of the Nanotechnology Group with a set of transparent electrodes on a plastic substrate.

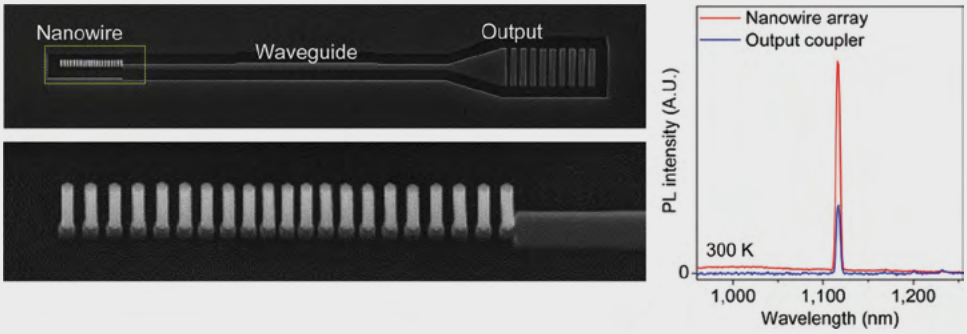
Transparent electrodes are everywhere - the most common example is the touchscreen in your mobile phone. The conductive oxide materials commonly used for these products have a number of drawbacks. They are brittle and also need high process temperatures during fabrication, making them unsuitable for emerging products such as touchscreens or displays on flexible plastic substrates.

Metal mesh patterns are a promising alternative for flexible transparent electrodes. Mícheál Burke and colleagues within the Nanotechnology group at Tyndall have developed a new class of transparent metal meshes on plastic.

These asymmetric meshes are based on a new class of pentagonal tiles recently proposed by a US researcher. Bending tests showed that these asymmetric metal mesh electrodes showed better performance after repeated bending cycles compared to electrodes based on symmetric shapes (squares, hexagons or circles). This work, published in *ACS Applied Materials and Interfaces* opens the way for design of future transparent electrodes optimised for both electrical efficiency and mechanical flexibility.

Process and device physics and engineering

Nanowire array lasers



Nanowire array laser *(left)* and Single-mode output spectrum *(right)*. Chip-scale integrated light sources are a crucial component in a broad range of photonics applications. III–V semiconductor nanowire emitters have gained attention as a fascinating approach due to their superior material properties, extremely compact size, and capability to grow directly on lattice-mismatched silicon substrates. Although there have been remarkable advances in nanowire-based emitters, their practical applications are still in the early stages due to the difficulties in integrating nanowire emitters with photonic integrated circuits. Here, we demonstrate for the first time optically pumped III-V nanowire array lasers monolithically integrated on silicon-on-insulator (SOI) platform. Selective-area growth of InGaAs/InGaP core/shell nanowires on an SOI substrate enables the nanowire array to form a photonic crystal nanobeam cavity with superior optical and structural properties, resulting in the laser to operate at room temperature. We also show that the nanowire array lasers are effectively coupled with SOI waveguides by employing nanoepitaxy on a pre-patterned SOI platform. These results represent a new platform for ultracompact and energy-efficient optical links and unambiguously point the way toward practical and functional nanowire lasers. *Nano Lett. 2017, 17, 3465–3470*

A collaboration between Tomasz Ochalski's team from the Cork Institute of Technology (CIT) CAPPA group at Tyndall and colleagues from the University of California and the Cardiff University has demonstrated a new type of nanowire array laser on silicon-on-insulator (SOI) that has the potential to transform chip-scale integrated photonics.

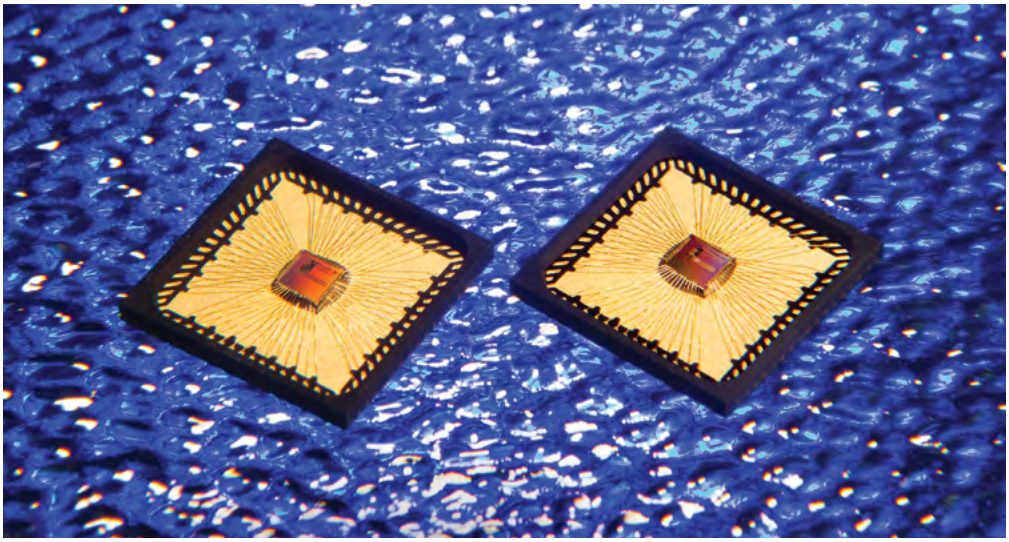
The SOI platform exploits silicon fabrication technologies developed for the microelectronic industry to make compact, low cost integrated photonic devices such as optical transceivers and sensors. However, due to the indirect bandgap of silicon, SOI lacks one key component – an efficient laser light source.

Consequently, a co-integrated direct bandgap III-V laser is required. However, it has proved difficult to grow sufficiently defect-free III-V material directly on silicon due to the large lattice constant mismatch between the two materials.

This new work, published in *Nano Letters*, has shown how selective-area growth can be used to fabricate tiny nanowire arrays which relax the strain sufficiently to enable efficient laser operation at room temperature.

Circuits and systems

Supporting solutions for IoT edge devices



Packaged CMOS chips, consisting of an Ultra-low Power SAR ADC to enable next-generation deployed IoT Sensor nodes, developed in conjunction with S3 Group under the Enterprise Ireland Innovation Partnership Programme.

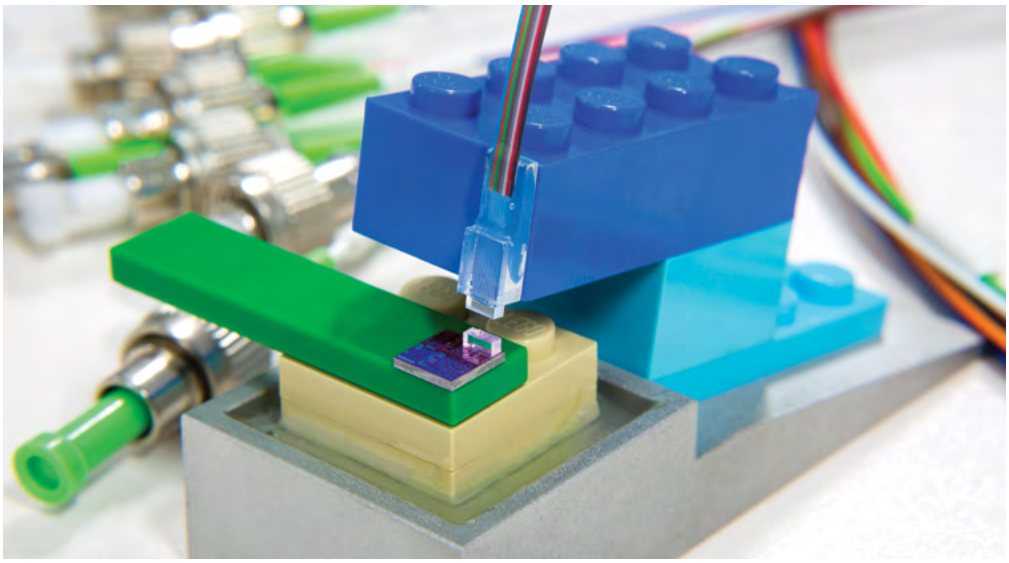
Research in Microelectronic Circuits Centre Ireland (*MCCI*) focuses on Analogue, Mixed-Signal and RF Circuits that are disruptive and always driven by application impact. The growth of the Internet of Things (IoT), along with wearable devices and new biomedical applications are creating new use cases for sensors deployed in environmental monitoring, sustainable agriculture, medical technologies and lifestyle devices.

A key highlight of MCCI research in 2017 was its engagement with S3 Group to design a low power successive-approximation-register (SAR) analog-to-digital converter (ADC). The design and realisation included several novel aspects, including an ultra-low power (ULP) ADC being developed that can operate at 5 µW or less. The research explored both novel architectural and circuitry topology improvements to extend the current state of the art in this space. The circuits included a reference and input buffer, which were optimised to work in conjunction with the ADC.

This work is already finding application in solutions for edge devices supporting IoT. Engagements such as this provide industry partners with the opportunity to undertake high quality research and leverage the research capability within MCCI, while also allowing MCCI to address current challenges with high impact.

Circuits and systems

Pluggable coupler



Pluggable multi-channel single mode optical connector to silicon photonic integrated circuit.

Silicon photonics is emerging as a potential platform for low-cost sensing and point-of-care medical diagnostics. Using established CMOS technologies, the silicon-on-insulator (SOI) architecture allows for highly compact photonic integrated circuits (PICs) that can be fabricated in reasonable volumes (i.e. 1,000 – 10,000 PICs per 200 mm wafer).

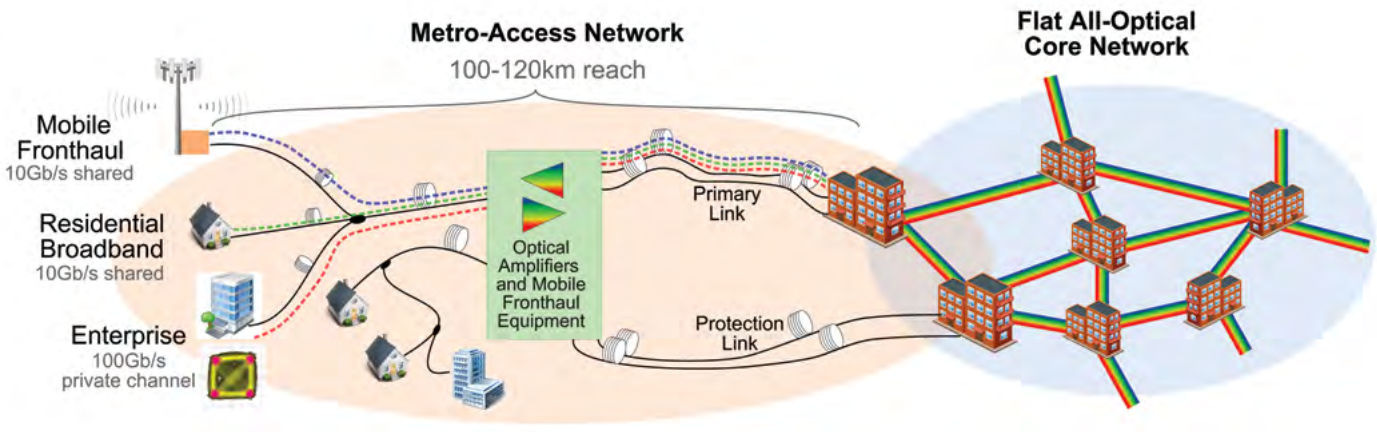
However, “packaging” PICs into photonic systems incorporating optical fibres is technically challenging, involving a slow and costly active alignment and bonding process, because of their submicron-level alignment tolerances.

Peter O’Brien’s Photonics Packaging group have recently shown in *IEEE Photonics Technology Letters* how this problem can be solved by employing a pair of micro-lens arrays; one on the silicon PIC and the other on the fibre-array. The technique enables high fibre-to-PIC grating-coupling efficiencies of 68% with a relaxed alignment tolerance of ± 30 µm (for 20% power loss).

Such relaxed tolerances give significant opportunities for cost reduction, as the team were able to demonstrate via a highly-reproducible “pluggable” multi-channel Fibre-to-PIC connection made using simple toy building bricks.

Circuits and systems

Dynamically reconfigurable high capacity optical access network



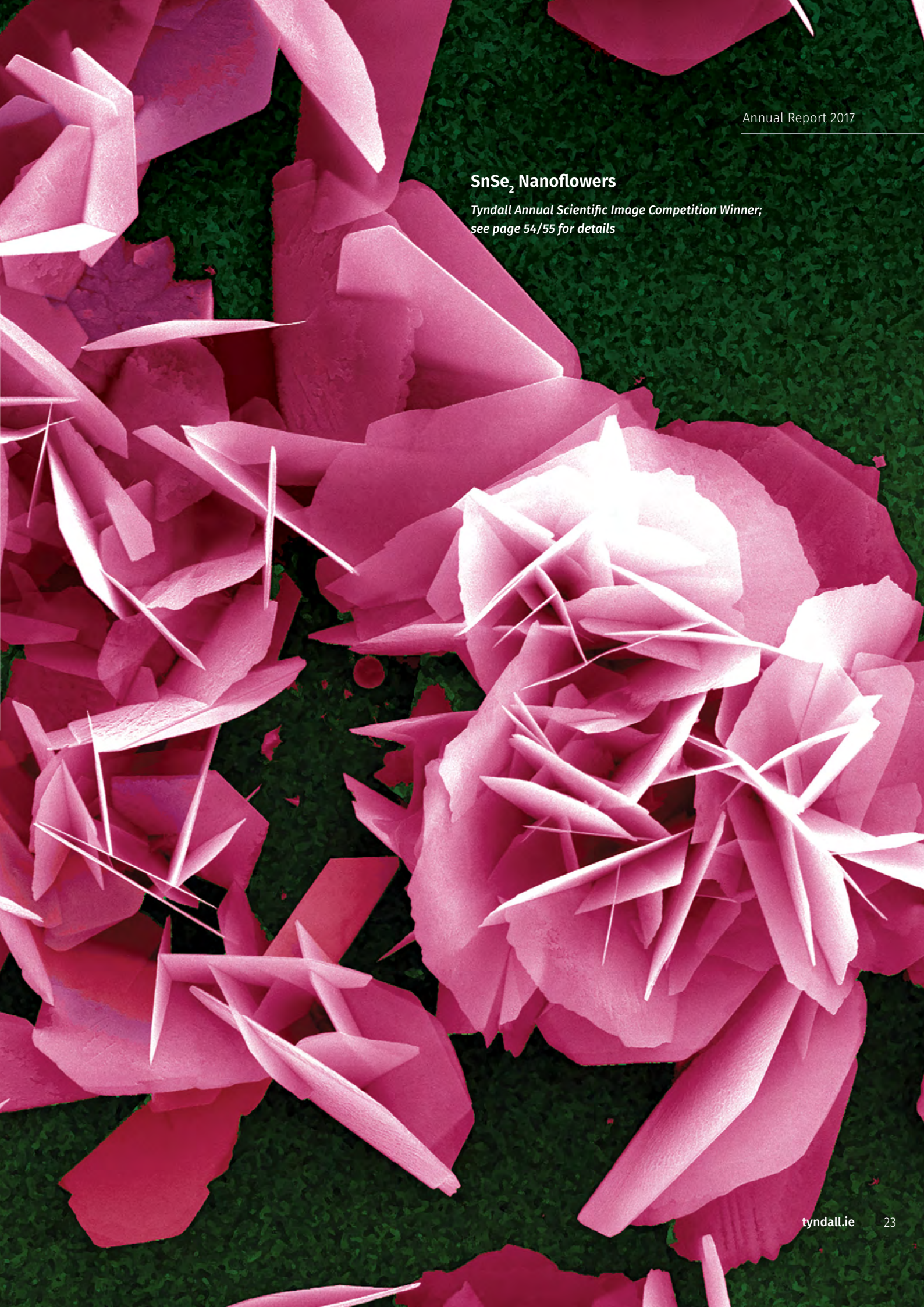
Schematic diagram of the new network architecture comprising combined metro-access and flat all-optical core.

A collaboration between Tyndall's Photonic Systems Group, Trinity College Dublin and industry partners Nokia Bell Labs and Polatis has developed the world's most advanced demonstration of a new, highly scalable network architecture based on long reach fibre access networks.

The demonstrator showcased how fibre access systems can enable network service convergence by incorporating dynamic wavelength channel allocation, with the potential to support fixed home and business users as well as mobile wireless users, all on the same network.

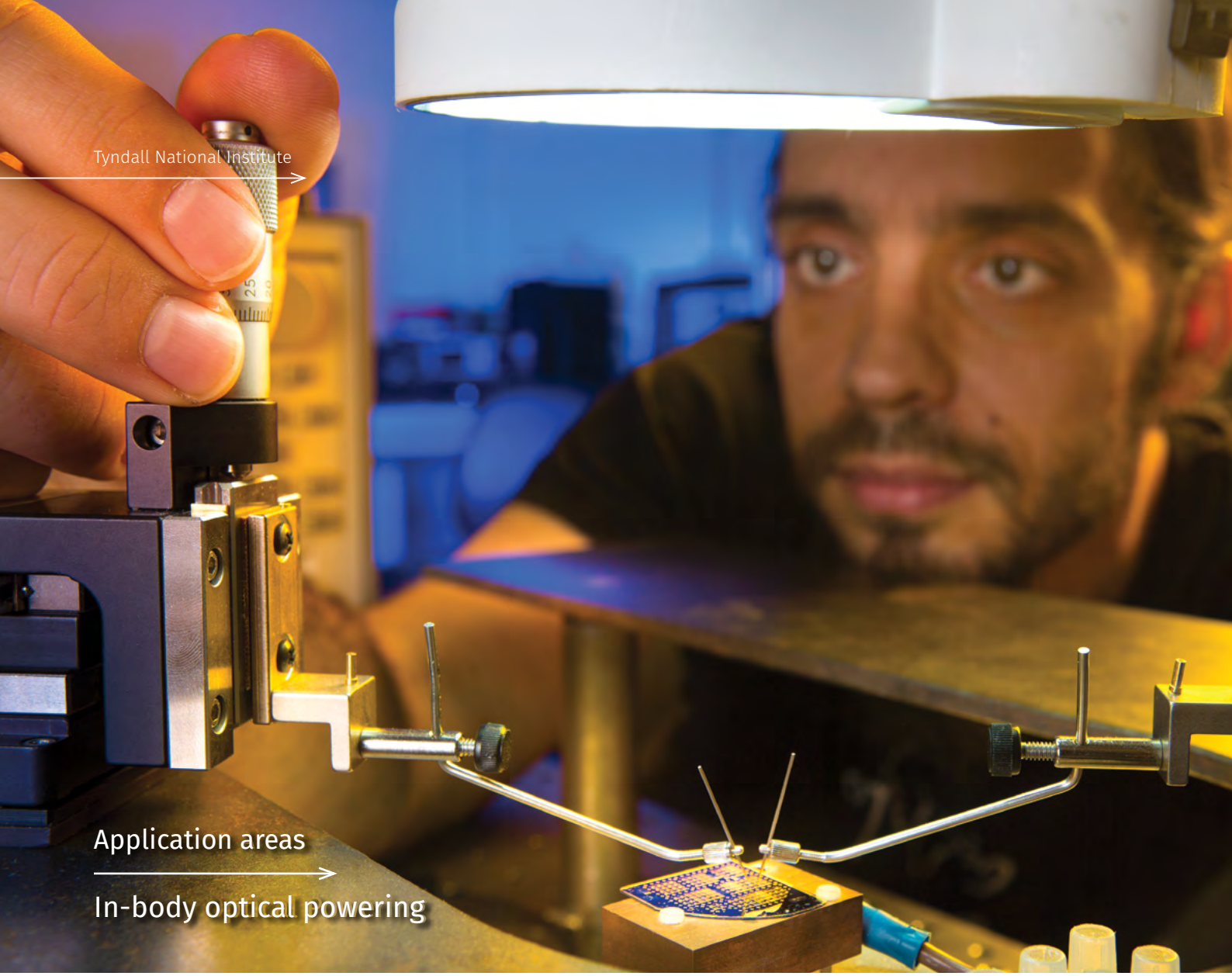
By growing the access network to metro-scale reaches of approximately 100km, the novel access network concept will also enable the use of a flat all-optical core network, where electronic switching and routing is confined solely to edge nodes.

Compared to today's networks, this enables a factor of 50 reduction in the number of such nodes, greatly reducing network power consumption and costs. The team's results led to two invited papers in leading *IEEE* communications journals and six other peer reviewed publications in leading journals and conferences in 2017.



$SnSe_2$ Nanoflowers

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details



Application areas

In-body optical powering

In-body controlled nerve stimulation using implantable devices is an important technique for the treatment of significant neurological disorders. Today, such systems use electrical wires to power the stimulating electrodes. However, this limits the use of imaging techniques such as MRI for patient monitoring, as the powerful electromagnetic fields generated by MRI can interact with the wires causing potentially hazardous effects such as heating.

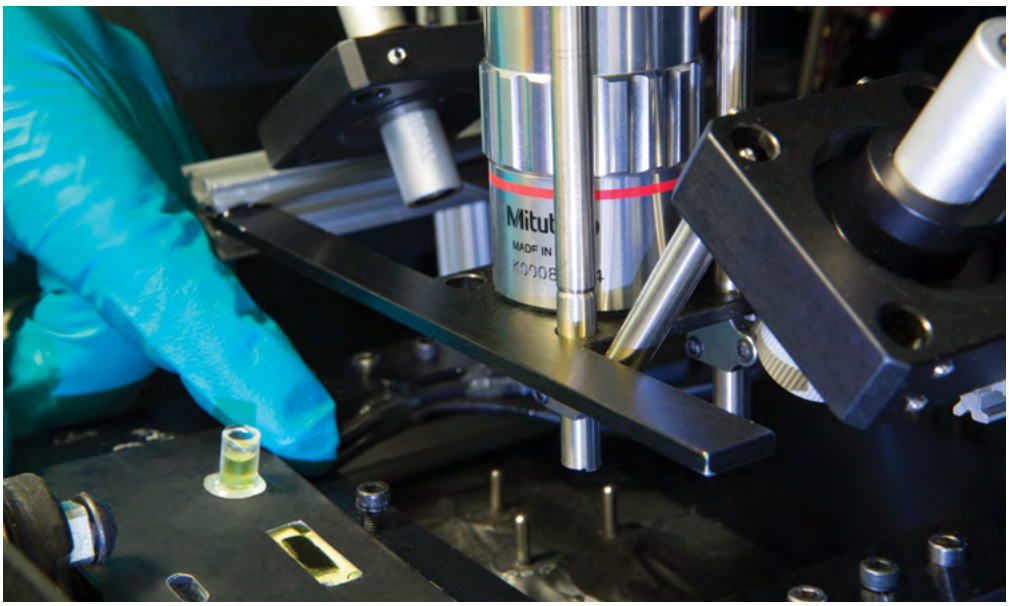
Photonics researchers at Tyndall are working with start-up company Synergia Medical to address this problem by developing an optical fibre-based alternative, incorporating an optimised laser and laser power converter chain.

The team have developed GaAs photovoltaic (PV) cells with a power conversion efficiency of 58% at the targeted laser wavelength, which is close to the world record, and demonstrated the complete application-specific powering concept for the first time. The work spanned from design and growth of the GaAs materials, through fabrication and characterisation of the PV cells to the design and integration of the complete power chain.

Dr Jérôme Garnier, Researcher, Photovoltaics, probing the electrical characteristics of GaAs-based laser power converter devices in one of the Tyndall photonics laboratories.

Application areas

Improving health with ICT



Disposable microfluidic test cartridge incorporating lyophilised PCR reagents inserted onto instrument to implement (i) sample heating, (ii) fluid handling and (iii) fluorescence detection. These steps implement the CT molecular diagnostic assay, including cell lysis and realtime PCR amplification.

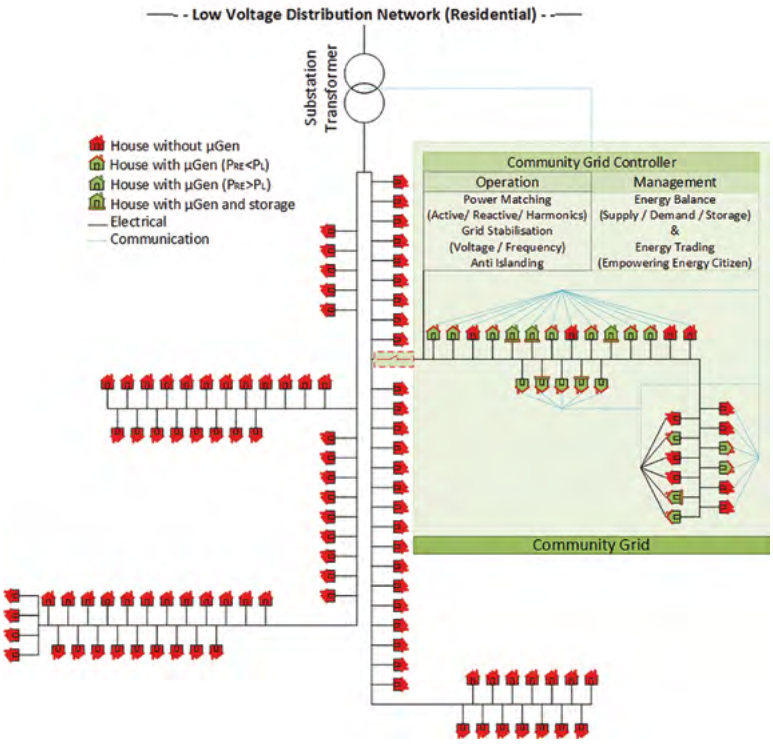
Tyndall's *ICT for Health* programmes leverage key enabling technologies in photonics, electronics, materials and biotechnology, to deliver innovative solutions in health-tech for diagnostics, connected health, therapeutic systems, cardio and neural interfacing/modulation, surgical instruments and smart manufacturing.

Working with leading academic, business and clinical researchers, Tyndall's ICT for Health programmes are focussed on novel health-tech with clinical utility and commercial opportunities. Over the last decade, the prevalence of infectious disease, e.g. Chlamydia trachomatis (CT), has increased worldwide, and point-of-care diagnostics plays a key role in early detection and treatment. The Enterprise Ireland Commercialisation Fund project POC4STI, led by Tyndall and involving collaborating researchers in NUI Galway, developed a fast (< 1 hour) molecular diagnostic test screening for pathogens (e.g. CT) directly from a biological sample (e.g. urine), without the need for sample clean-up or nucleic acid (i.e. DNA) pre-concentration.

The test achieved good sensitivity (>80%) and selectivity (>80%) enabling low detection limits (<10 cells), comparable to benchmark tests, on 163 clinical samples. This is the first time that a direct urine CT molecular PCR test was demonstrated, requiring only thermal lysis, followed immediately by realtime amplification. The assay was demonstrated on a two chamber disposable microfluidic cartridge, distinguishing between positive and negative clinical samples. Future work will focus on further clinical evaluation and incorporating additional pathogen targets into the test panel.

Application areas

Enabling energy citizens to become prosumers



left Senior Researcher, Dr Shafi Khadem, with researchers Dr Mohamed Bahloul and Dr Ankur Majumdar.

right Example of a Community Grid System.

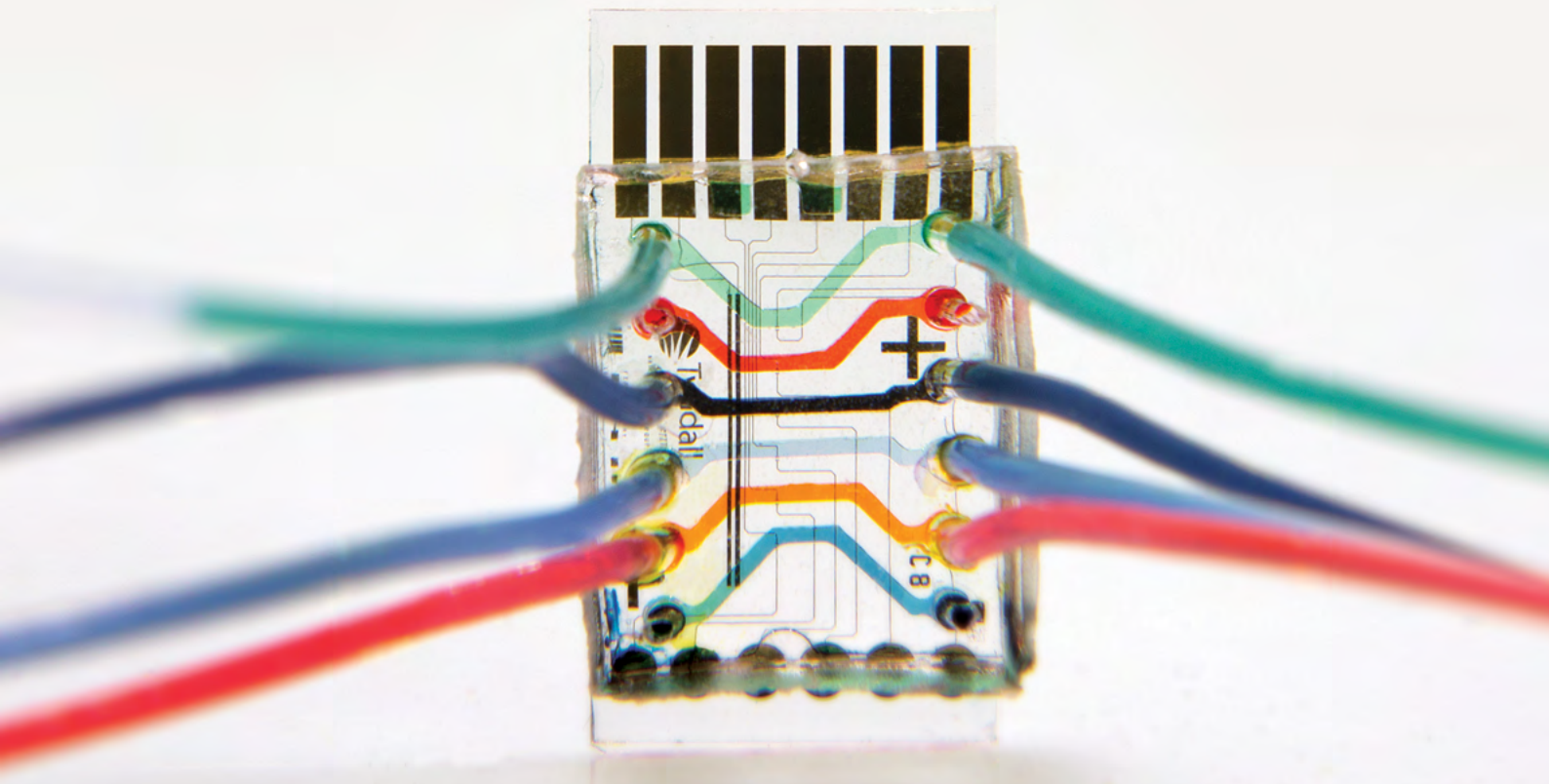
Over the last decade, the placement, integration and functionality of distributed generation systems in the electricity network has seen a reformation from the centralised grid into a more complex and distributed one, using local energy resources with consumers' active participation in energy management.

These complex systems present interesting opportunities for technology innovation, integration and energy trading models, all of which have direct impact to the citizen, the market and other actors in the network. The *IERC EDGE group* has presented a novel community grid structure that addresses the competing challenges of robustness and flexibility. This structure allows new technologies to be integrated along with flexible methods for energy trading, without reducing the grid network stability.

It also enables increased participation of energy citizens as prosumers, providing an inclusive platform around which a community can build and maintain a robust yet efficient, affordable and sustainably clean energy based network.

Application areas

On-farm analysis to identify bovine disease



Integrated nanosensor chip coupled with a microfluidic sampling device used to deliver rapid disease detection in cattle.

Bovine respiratory disease is a multifactorial disorder in cattle caused by a combination of bacterial and viral pathogens.

A key challenge to disease eradication and treatment is that the current turnaround time for disease detection, by analysis of serological samples using lab-based diagnostic processes, can be more than 72 hours.

Consequently, new diagnostic devices, suitable for on-farm analysis, that deliver rapid and early identification of animal disease states, are required. To this end, we have developed *novel nanowire-based immunosensors* that demonstrate label-free and multiplexed disease detection from whole serum in under 20 minutes.

These devices could provide real-time data and thus provide an informed decision-making capability concerning appropriate treatments to veterinarians while at the farm.

Application areas

From arsenic to zinc: the chemistry of Gaelic manuscripts

Prof. Pádraig Ó Macháin of the Dept of Modern Irish, UCC, with Dr Daniela Iacopino of Tyndall.

For the first time X-ray fluorescence (XRF) analysis was performed on late-medieval Irish manuscripts of the vernacular vellum and paper traditions with the aim of shedding light on the work of Irish scribes across the paper-vellum transition.

This work was the result of a collaboration between Tyndall's Dr Daniela Iacopino, UCC's Prof. Padraig O'Machain and XGlab, and was made possible by the cooperation of the National Library of Ireland and the Royal Irish Academy.

The XRF analysis revealed a large presence of iron derived from iron gall ink. Calcium was also found, from egg white used as binding agents and from chalk used to reduce the greasiness of vellum skins in preparation for writing. Gum arabic was also identified from the presence of zinc. Lead- and mercury-based pigments were identified in rubricated letters whereas yellow decorations occurring in large letters were identified as orpiment, a mineral compound of sulphur and arsenic. Overall, this work highlights the exotic, and at times toxic infrastructure that lies beneath the work of the scribes of late medieval Ireland.

Application areas

Horizon 2020 success

€29 MILLION investment in Tyndall out of **total project value of €370m+**

€12.14m supporting **16 Irish SMEs** & **7 Irish-based MNCs**

Success rate in 2017 **double** EU and National averages

European leaders in ICT with high added-value projects & top performance

56 projects overall since H2020 launch, 16 new projects in 2017

Martin O'Connell (EU Programmes), Julie Donnelly (Access Programmes), Giorgos Fagas (EU Programmes).

Our goal is to generate excellent research and enhance EU collaborative research across the whole innovation chain. We have taken a proactive role to work with technology adopters to bridge the so-called 'valley of death', thereby achieving industry growth and benefiting all of society.

Since the launch of Horizon 2020, Tyndall has participated in 56 projects with a total value of ca. €370m including significant co-funding by industry partners. The investment in Tyndall activities within the projects is valued at €29m, with an additional €20m funding to our Irish partners, including €12m to industry which supports over 50 jobs during the projects' lifetime.

There were 16 new projects funded in 2017. Some high-added value wins were the EnABLES project which provides access to Research Infrastructure for powering the IoT and fosters an emerging community; the Actphast4.0 and KET4CleanProduction projects that act as co-investment platforms for demonstrators towards high-impact innovations; the NexPho21 Coordination and Support Action for the next strategic research agenda in Photonics; and significant involvement in large-scale initiatives in quantum technologies.

$SnSe_2$ nano-waves

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details

Industry engagement

Industry engagement

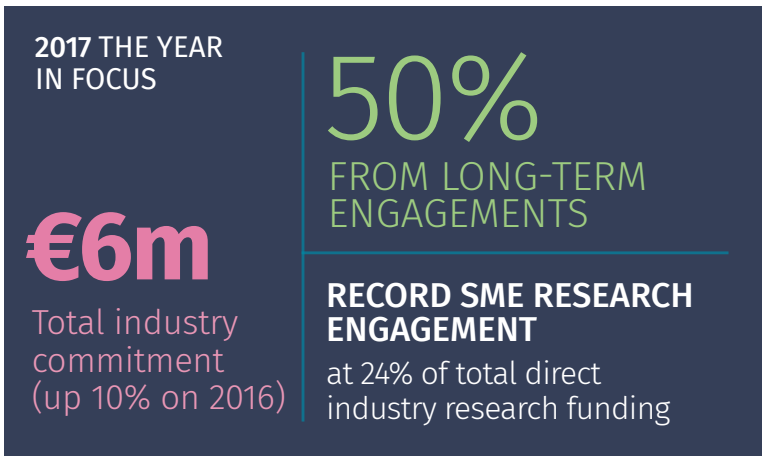
The Commercial Team; Maria Rohan, Eimear O'Mullane, Hugh Smiddy, Peter Smyth, Anthony Morrissey (UCC TTO), Ann Heffernan.
not pictured: Michelle Farrell, Janine Galvin and Carlo Webster.

In 2017, Tyndall continued to expand its impact in industrial client engagement, including the number of industry-led programmes, the profile of our industry partners and the contribution of these programmes to our research income. In turn, these programmes deliver broader impact through our clients' adoption of Tyndall technologies.

This past year saw the highest number of industry-funded programmes and industrial income in Tyndall's history.

Small-to-medium enterprise (SME) collaborative activity also reached record levels, while our start-up supports and technology transfer programmes also delivered outstanding results.

Industrial research activity overview



Tyndall kicked off almost 50 new industry-driven research programmes in 2017. New funding commitments from these activities exceeded €10m, of which more than 50% came from industry partners, with the balance coming from funding agencies (primarily Science Foundation Ireland, IDA Ireland and Enterprise Ireland). Two particular highlights of 2017 were increases in the number of programmes initiated by industry partners and increased SME research spend.

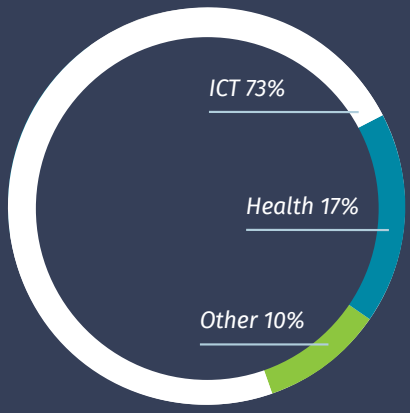
Six industry partners accounted for 20 of the 50 new programme starts, endorsing Tyndall's role as a long-term, strategic research partner to industry. In all, 50% of the industry funding commitment came from a small number of these collaborations.

There was also a significant increase in research spend by the SME sector, which reached a new high of almost a quarter of the total of the direct industry research funding commitments. The high-speed data communication and space technology sectors showed significant growth for SMEs this year.

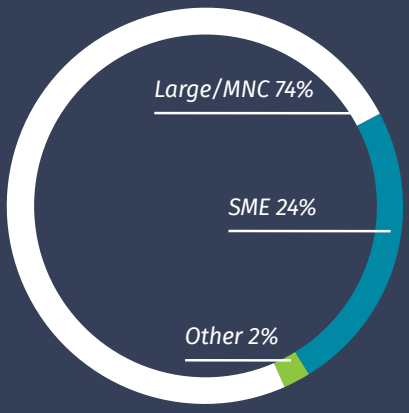
Average spending per programme was up in 2017, with 50% of programmes involving industry spend of more than €200,000 per programme. In technology terms, Photonics research represented 49% of the total, with the remainder comprising micro & nano systems and specialty products and services. Information and communications technology remains the strongest application segment, representing 74% of all industry research (with agri-food and medical technology comprising the remainder).

2017 THE YEAR IN FOCUS

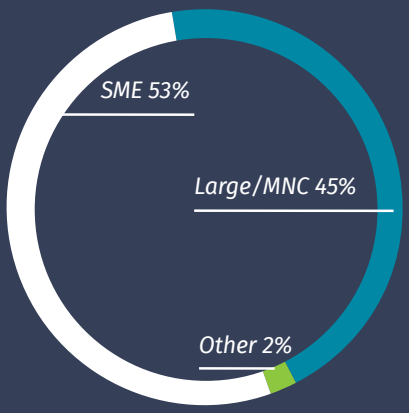
New industry research spending commitment 2017 by application sector



New industry research spending commitment 2017 by company size

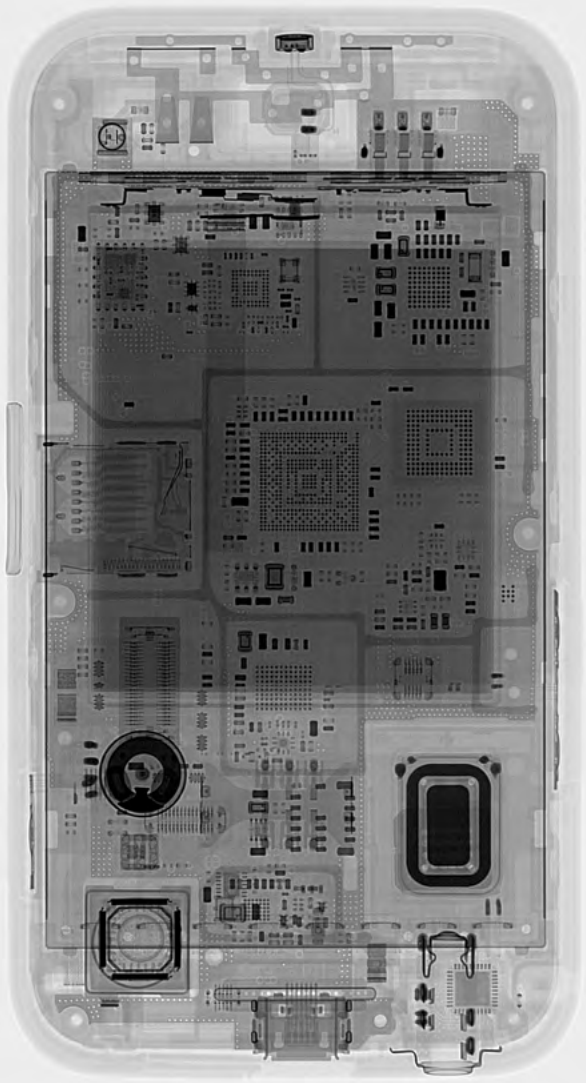


Number of industry clients 2017 by company size



SME: Small to Medium Size Enterprise

MNC: Multinational Corporation

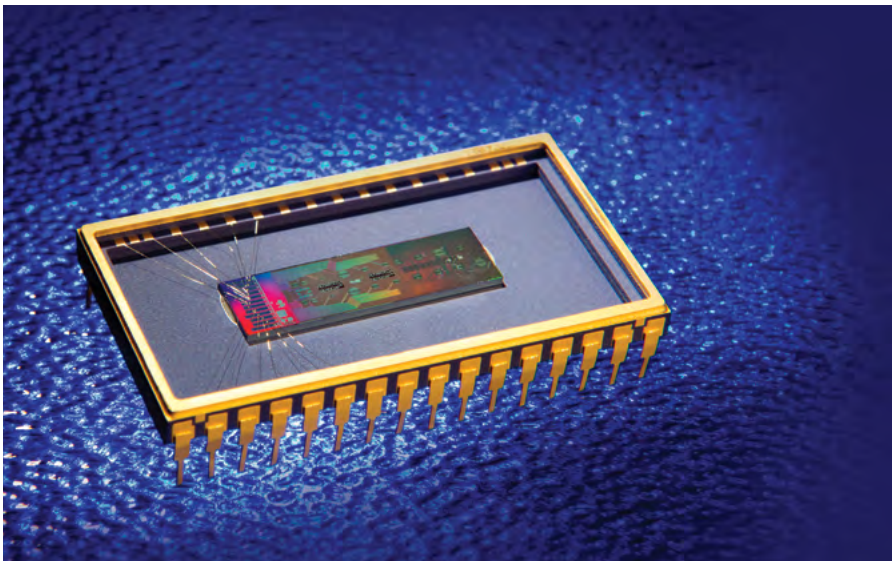


Demonstration of Tyndall's X-ray and CT scan imaging capabilities using a smart phone as a sample

2D X-ray view

Long-standing services to industry continue to expand in the Specialty Products & Services Centre (SP&S). In 2017, this activity accounted for over 15% of industry engagement.

Of note in 2017 was an increase in the number of test and characterisation clients in the space technology sector, demonstrating Tyndall's return on infrastructure investment and the value of its space standards certification. It is noteworthy that SME engagement is at its highest for these services. As Tyndall continues to expand its offering to space clients across Europe, we expect this upward trend to continue.



Packaged CMOS sensor silicon chips demonstrated a next-generation CMOS diagnostics platform developed under the Enterprise Ireland Innovation Partnership Programme, in conjunction with Altratech.

Tyndall's ICT-for-Health Programme

For many years Tyndall has recognised the importance of market sector focus in maximising impact for clusters of industry partners. This strategy continues to bear fruit with the ICT-for-Health Strategic Programmes group, which is working to meet the needs of our med-tech clients, accounting for 17% of the total industry commitment to research in 2017.

Five Enterprise Ireland Innovation Partnership projects commenced under the ICT-for-Health Programme during the year. These partnerships involve four Tyndall Principal Investigators – John Buckley (WSN), Conor O'Mahony (LSI), Salvatore Tedesco (WSN), and John Barton (WSN).

Tyndall's ICT-for-Energy Efficiency Programme

The strong impact of the Strategic Programmes approach is now delivering impact to the energy sector with strong growth in ICT for energy efficiency initiatives. These include an agreement between Tyndall and TEL Magnetic Solutions Limited (TELMS) for high frequency sputtered laminated magnetic cores.

Focus on future start-ups

Tyndall's start-up supports programme is a collaboration of Tyndall's Entrepreneur-in-Residence, UCC's Technology Transfer Office and the Tyndall commercial centre. The objective of this programme is to generate investable teams and technologies, primed for commercial success, and thus further deliver on Tyndall's mission to generate economic impact from research excellence.

An active pipeline of 12 teams and technologies was supported through the programme in 2017, securing a total of almost €3m in Enterprise Ireland funding. A selection of these 'unincorporated start-ups' has benefitted from ongoing mentoring, project management, access to potential investors, intellectual property (IP) clinics and various training programmes.

A further seven technology-driven potential start-ups, mainly led by Tyndall researchers, are being tracked with a view to support during 2018.

As part of its development programme for technology start-ups, Bank of Ireland recognised Tyndall's role as a leading source of ICT talent with a new commitment of commercialisation funding. This funding will be used to help establish new start-up supports for Tyndall's highly differentiated potential tech start-ups.

In addition to Tyndall's in-house pipeline of start-up opportunities, the ESA Space Solutions Centre Ireland, which incorporates ESA Business Incubation Centre (BIC), is an ESA-funded consortium led by Tyndall and includes University College Cork, NUI Maynooth, and Athlone Institute of Technology.

Through this incubation centre, which aims to support start-ups adapting space technologies for high-growth terrestrial markets, four new early stage businesses received €200,000 in funding commitments and three additional SME applicants were approved for ESA technology demonstrator awards.

Anthony Morrissey receiving the UCC Impact Award 2017 from UCC President Prof. Patrick O'Shea.

Impact from intellectual property generation

UCC's Technology Transfer Office (TTO) supports Tyndall's objective of delivering economic impact through the excellence of its research programme. During 2017, Tyndall delivered a record 10 technology transfer licences, options and assignments (LOAs). This is reflective of the high level of industry engagement in 2017, and the resulting IP pipeline for the future is very strong. The involvement of the TTO in this success resulted in Dr Anthony Morrissey, TTO Commercialisation Manager for Tyndall, being chosen as the winner of the UCC Impact Award for 2017.

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Licences, options and assignments

Licence of **Bandpass Filter** circuit which enables a reduction in the power requirements of the active elements of electrical circuits for the acquisition of bio-potential signals in implantable devices, resulting in longer battery lifetimes.

Assignment of **Photonics Packaging** designs to Irish SME to enable improved packaging of its photonic integrated circuits, with improved fibre clamping and reduced stress.

Licence of **Thoracic Impedance IC** to measure the electrical activity of the thorax and thus enable a device, e.g. a pacemaker, to calculate and integrate the patient's respiratory rate and thus to pace accordingly.

Assignment of designs for **Magnetic Films for Coupled Inductors** for application in Power Supply on Chip (PwrSoC) products.

Licence of **Voltage Reference IC** for implantables, which provides a known reference voltage and thus a known reference current, ensuring correct biasing of all active blocks, a known problem for such devices.

Assignment of **Data Modulation 96QAM/64QAM** scheme for extending the transmission reach of 200Gbit/s terrestrial Wavelength Division Mutiplexing systems while maintaining sufficiently high spectral efficiency to accommodate optical filtering effects using commercial wavelength-selective switches.

Assignment of **Data Modulation 8-dimensional PCTW** scheme for long-haul transmission in submarine applications.

Licence of **MEMS component** for use in aerosol applications, such as medical devices including inhalers.

Option to license a range of low power circuitry to drive biosensor arrays for various diagnostic and other medical applications.

Licence of a patented "smart wound dressing" for chronic wound care which contains multiple sensors that monitor the status of a wound dressing, including temperature and exudate transport.

Tyndall Technology Days 2017

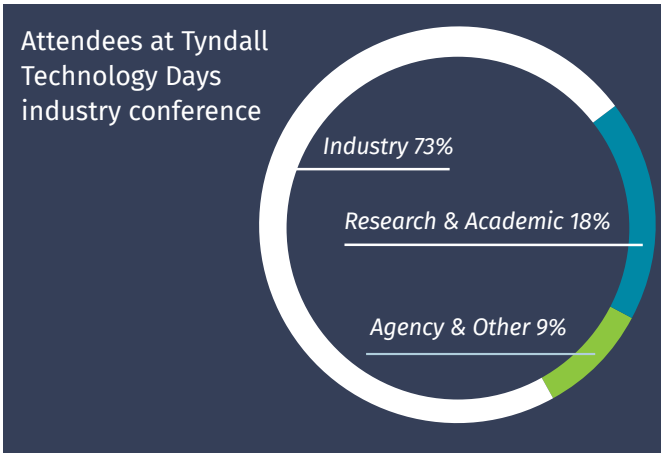
An Tánaiste and Minister for Business, Enterprise and Innovation, Frances Fitzgerald TD, Dr Cian O'Mathúna, Tyndall Strategic Programmes, Marco Belcastro, Marco Sica and Davide Alfieri, Tyndall Wireless Sensor Networks.

On 17 October 2017, 300 attendees enjoyed a day of essential networking and technology sessions at Tyndall's annual Technology Days industry conference.

Held at the new Páirc Uí Chaoimh stadium and conference centre in Cork, this year's theme was *Innovation for Industry*, with emerging trends in future communications, smart manufacturing, energy management and medical technology covered during the event.

The keynote was delivered by **Dr Ann Kelleher, Corporate Vice President and General Manager of the Technology and Manufacturing Group at Intel Corporation**. Speakers included scientists and business leaders from companies such as **BT, Philips, Nokia Bell Labs, Analog Devices, Johnson & Johnson** and **United Technologies Research Centre**. More than 75 senior management representatives attended the event at Director, CXO and GM level.

Tyndall research staff were on hand to demonstrate new technologies, including a new portable system to detect nerve agents in real-time; wearable technology platforms for health monitoring; and sensors that inform farmers and food producers of animal, soil, crop and water conditions in real-time.



"Tyndall is leading the way in preparing not only Irish businesses, but global businesses to meet the challenges and opportunities ahead of us. Through research excellence and deep industry engagement, institutes like Tyndall are advancing Ireland as a world-leading centre of innovation and research,"

An Tánaiste and Minister for Business, Enterprise and Innovation, Frances Fitzgerald TD, part of opening address at Tyndall Technology Days 2017.

What our partners say

Huawei

"This visit is an opportunity to demonstrate some of the leading innovations that Huawei and Tyndall are jointly researching, and areas we will be closely collaborating on in the future to discover key breakthrough technologies. Over the next 20 years, we aim to bring industry and academia together in ever-closer collaboration, and by the use of new technologies to build a better connected world."

Guo Ping, Huawei Deputy Chairman of the Board

Guo Ping, Huawei Deputy Chairman of the Board and Rotating CEO with Prof. Eoin O'Reilly, Tyndall.

PIXAPP

"In the past, it has been very expensive to manufacture high volumes of PICs, and more expensive and challenging again to package them. This is creating a bottleneck for production, which is impacting the potential for growth in the photonics industry. I am confident that Tyndall National Institute's leadership will deliver market success for Europe and drive our competitiveness across the communications, medical, automotive, energy, safety and defence sectors globally."

Jose Pozo, Director of the European Photonics Industry Consortium (EPIC) commenting on PIXAPP

AbbVie

The aim of this project is to produce a highly miniaturised wearable demonstrator device for precision diagnosis of neurological diseases with machine learning algorithms which can assist in monitoring disease progression and aid in the adjustment of medication doses.

"There is now a strong and mutually beneficial working relationship between both organisations, where AbbVie understands the market problem statements and Tyndall understands Information and Communication Technology (ICT) based solutions; this makes for a very strong partnership."

Jeff Redmond, Device Technical Manager, AbbVie

Setanta College

Limitations in current technology are causing problems in the assessment of elite athlete performance monitoring and assessment. Tyndall is working with Setanta to utilise micro-electromechanical systems (MEMS) to capture a range of metrics not currently available in order to assist coaches and athletes to make training and performance related decisions in real-time on-the-field.

"Having a world leading research centre such as Tyndall as our research partner gives a small company like Setanta credibility on the global stage."

Dr Liam Hennessy, Director, Setanta College

European Space Agency & Thalman Health

Jan Woerner, Director General of the European Space Agency and Minister of State for Training, Skills, Innovation, Research and Development, John Halligan TD., welcoming the announcement of Thalman Health joining the ESA BIC said:

"Tyndall has a 30 year history of working with ESA and providing access to a range of capabilities and expertise, including testing technology intended for use in the harsh environment of space. With the addition of companies like Thalman Health, Ireland continues to strengthen and advance its role in the space sector".

PHIX

"Offering packaging services requires both processing and state of the art equipment knowledge. With Tyndall, we have found a partner that has a broad range of processing knowledge for PIC assemblies complementary to our expertise,"

Albert Hasper, CEO of PHIX.

"We are delighted to be involved with this multidisciplinary project in collaboration with Teagasc and Tyndall National Institute. It will allow us to develop a highly novel antibody-based sensor that can address pathogen detection in crops of major significance to Irish agriculture and to train researchers in the latest technologies used in rapid, sensitive and specific diagnostic platforms,"

Prof Richard O'Kennedy, School of Biotechnology, Dublin City University.

Sanmina

Tyndall worked with Sanmina on a new low power, low frequency antenna for wearable sensors which could have applications for on-body wearable systems and a range of biomonitoring devices.

"The interaction with Tyndall is very relevant in today's world of research and innovation where the coming together of expert building blocks is critical to enabling innovation to deliver both human and economic impact."

Robert Newberry, Director of Engineering at Sanmina

renew Group Private Limited

This project will design and develop a wearable device for the detection of bruxism, a condition involving excessive teeth grinding or jaw clenching. The device will replace expensive lab-based diagnostic solutions in use today to make a more user-centric quantitive measure for detecting bruxism.

"The combination of our expertise with Tyndall's track record in technology integration is helping us to develop an intelligent, wearable bruxism detection device. Having access to Tyndall's knowledge, infrastructure and its people provides Renew Group with leading edge technology to drive new innovative products into the market place."

Declan Cassells, Managing Director, Renew Group

West Pharmaceutical Services

Combining intelligent systems, wireless communications and embedded sensors that may allow for future generations of wearable injection devices that are self-aware and capable of monitoring dosage rates, detecting adverse events and communicating with patients, clinicians and the wider healthcare eco-system.

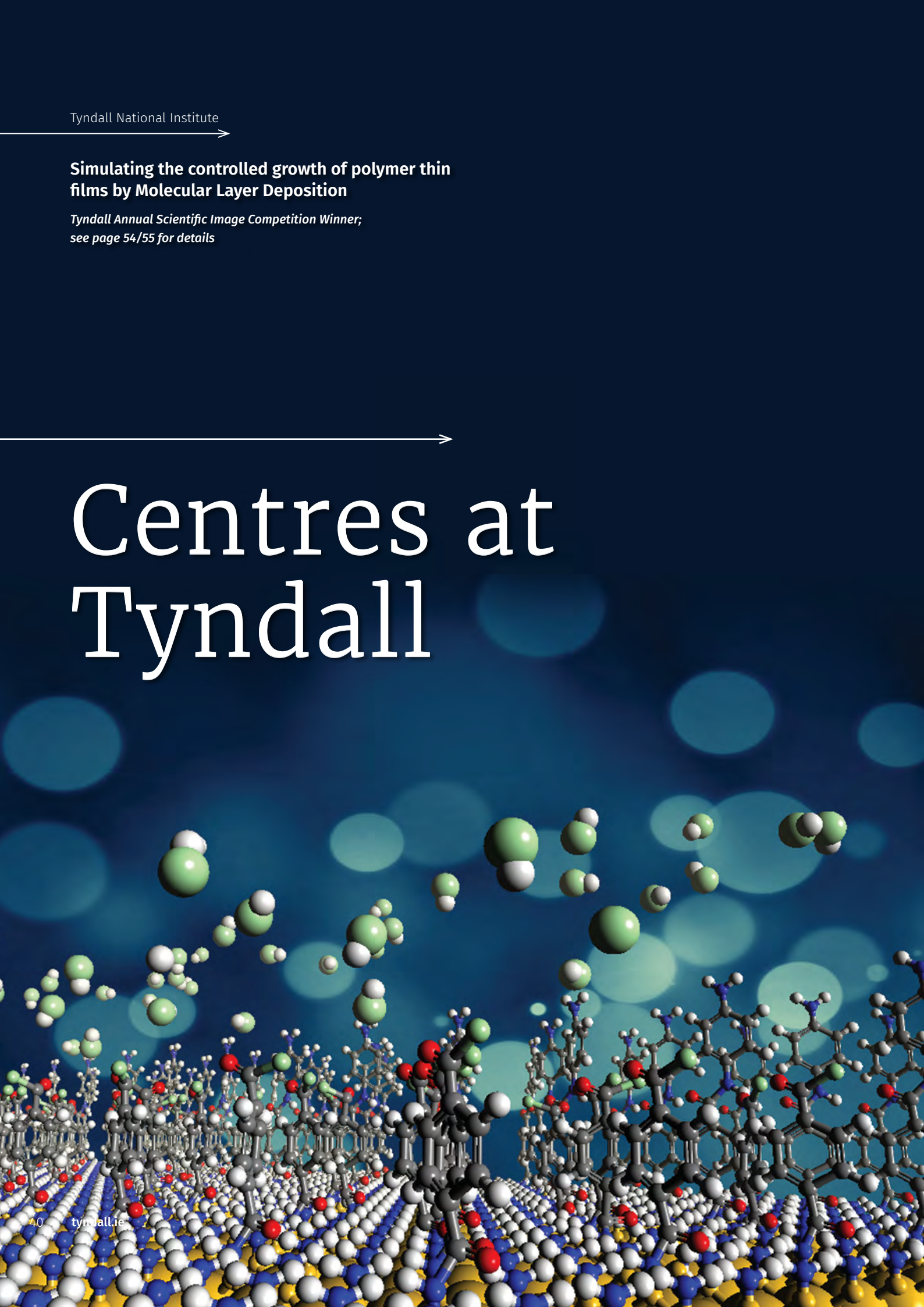
"The partnership with Tyndall – Ireland's national ICT laboratory – will allow us to explore what is possible with cutting-edge electronics, communications and sensors that they are developing for applications in future generations of wearable drug delivery devices. This will help ensure that we maintain our position as a world-leading supplier in innovative delivery systems for injectable therapies."

Dr Alex Lyness, Manager, Research & Technology, Innovation, West Pharmaceutical Services

Simulating the controlled growth of polymer thin films by Molecular Layer Deposition

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details

Centres at Tyndall



Centres at Tyndall

Tyndall delivers market-needs driven research. Our agency-funded research centres develop technology solutions for the communications, energy, health, agriculture, food, marine and environment sectors. These include:

>> Centre for Future Networks and Communications (CONNECT);

>> European Space Agency (ESA) Space Solutions Centre Ireland;

>> International Energy Research Centre (IERC);

>> Irish Photonics Integration Centre (IPIC);

>> Microelectronic Circuits Centre Ireland (MCCI).

During 2017 two new SFI research centres were funded, that will involve Tyndall collaborating with other Higher Education Institutions and Industry; the CONFIRM Centre for Smart Manufacturing and VistaMilk for precision pasture-based dairying.

This section describes the activities of each centre, as well as highlighting key areas of impact during 2017.

Irish Photonic Integration Centre

Seated: Brian Murray, PhD student in the Photonics Systems Group
Standing: (L-R): Prof. Paul Townsend, IPIC Director and Head of Photonics; How Yuan Hwang, PhD student in the Photonics Packaging Group; Yuliya Verbishchuk, M.Sc. student in the Photonics Systems Group.

IPIC is now firmly established as one of Europe's leading photonics integration research centres with 150 researchers producing over 100 publications per year and securing substantial European and industry funding annually.

The centre is ideally positioned between the academic and industrial worlds, delivering leading edge research and PhD training, while also advancing our science from the lab to high technology readiness levels (TRLs), providing prototypes and low volume manufacturing to our industry partners. 2017 saw the first outputs, in the form of publications, from our recently established biophotonics research programme and the initiation of a number of projects with some of the world's leading clinicians and largest medical device companies. These seek to tackle challenges such as how to safely monitor the lungs of premature infants using light.

"International review panel scores of 92% (progress) and 94% (future plan)"

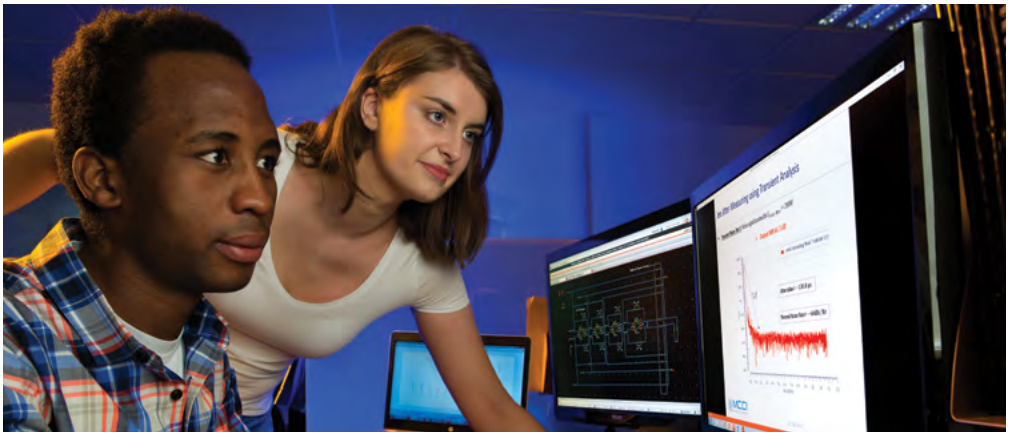
2017 highlights

Multiple new innovations spanning from materials to systems, including:

- High speed (25Gb/s) III-V electro-absorption data modulators designed for integration with silicon photonic circuits
- Novel glass-based cost-effective interposer enabling the combination of both optical and electrical interconnects
- Ultra-low linewidth (10kHz) optical frequency comb source using feed forward heterodyne optical linewidth reduction
- Launched the "Little Book of Photonics Careers" to highlight the exciting career opportunities open to graduates and to encourage students to consider pursuing their education in subjects such as physics, engineering and ICT
- Continued the expansion of the Photonics Ireland National Technology Platform (NTP) which is now 1 of 12 NTPs from across Europe supporting the Photonics21 European Platform, and its public-private partnership with the EC, through NextPho21.

Our primary objective for 2018 is to secure renewed funding from SFI for the period 2019 to 2025 that will also see IPIC expand by 50% to over 200 researchers.

Microelectronic Circuits Centre Ireland



MCCI's Ian Assom and Kathy Hanley

"€7.5m in annual research funding, 87 researchers & engineers, over 50 publications, and 14 IP licences"

MCCI was established in 2010 under the EI and IDA Technology Centres Programme to deliver high impact microelectronics research for the global semiconductor industry. It is hosted by Tyndall and includes University College Dublin, University of Limerick, Cork Institute of Technology, Maynooth University and Carlow Institute of Technology.

MCCI works with industry partners to deliver application-driven research, and currently have 52 research projects underway with 35 member companies. A key highlight in 2017 has been the growth in the level of funding MCCI generates for microelectronic research. From a core grant of €1m, the centre generated a further €6.5m in funding through industry partners, and other public funding sources. It also completed 6 IP licences, in Medtech and SmartAgri applications, which were in highly innovative projects. Publication output was 21 papers and conference presentations, well ahead of its annual target. In addition the centre won several early-stage research grants in disruptive technologies and future communications.

2017 highlights

- Central to MCCI's strategy is the development of its researchers into future leaders for the thriving semiconductor industry in Ireland. 2017 saw the 43rd researcher transfer to industry and reaffirms the centre's strength as a talent pool for sought-after microelectronics graduates.
- A further 6 IP licence agreements were completed in 2017, primarily in ultra-low power, implantable, biomedical circuits for cardiac care, bringing the total licences completed to date to 14.
- In addition, 3 patent applications were filed, including a joint application with an industry partner who have engaged on a collaborative research project.
- Selected from a globally competitive call for a research commercialisation to participate in a bootcamp run jointly by SFI and the NSF in the US.

2018 will continue to be a year of growth and scaling for the centre, in terms of engagement and research funding generated. Research commercialisation will also be a focus in the coming year, having secured a number of funding grants to bring research to market.

International Energy Research Centre

Dr Matthew Kennedy, Head of Strategy and Business, Dr Beth Massey, Head of Research, and Prof. Tony Day, Executive Director of IERC.

The International Energy Research Centre (IERC) is the industry-driven research centre working at the interface between energy, the environment and the total built environment.

Working in collaboration with industry partners that include utilities, multi-national companies and small-medium enterprises, the IERC works to translate industry-identified needs into research objectives while also supporting national policy objectives for energy efficiency and low carbon energy services. 2017 was the most successful year to date for IERC as it focused on delivering commercial impact for its core industry members. This was realised through delivering 9 collaborative projects and partnerships with industry to develop new IP and commercial offerings, securing €1M in European and €4M in industry funding.

"Engaging 40 industry collaborators to deliver €8.1M in research value"

2017 highlights

- The IERC, through its engagement with over 40 new industry partners and potentials, formally commenced five new collaborative projects with Irish industry representing a total research value of €5.3M.
- The IERC's international standing in research excellence was strengthened and recognised with the award of two Horizon 2020 projects (one on buildings energy-efficient retrofit and one developing a new business model to increase the ESCO market in both Ireland and Europe), representing a value of €1M to the IERC, and representing Ireland to the International Energy Agency in its technology partnership initiative.
- The breadth of the IERC also expanded to include new engagements with 7 academic partners (employing 18 researchers) and a research output of 8 journal papers.

The focus for 2018 is to secure renewed funding from the Department of Communications Climate Action and the Environment from 2019-2021, win additional Horizon 2020 projects and grow our industry membership by 25% which will see the IERC expand by 50% to 40 researchers.

ESA Space Solutions Centre Ireland / ESA BIC Ireland

Minister of State for Training, Skills, Innovation, Research and Development, Mr John Halligan TD, Director General of the European Space Agency, Mr Jan Woerner, Manager of ESA Space Solutions Centre Ireland, David Gibbons, and Co-Founder and Head of Operations of Thalman Health, Ian Kerins, welcoming the announcement of Thalman Health joining ESA BIC.

"4 Companies selected for the ESA BIC and 3 Technology Transfer demonstrators supported"

Launched in September 2016, and including UCC, AIT and NUIM as partners, the centre has quickly established a focus for the use of space technology in downstream terrestrial applications.

2017 Highlights

- 2017 proved a successful year in getting significant interest in the activities of the centre, resulting in a number of applications with four companies selected to join the ESA BIC:
  - DroneSAR a company specialised in search and rescue utilising drones and earth observation data in emergency situations,
  - Thalman Health whose ground breaking technology allows noninvasive monitoring of core body temperature,
  - ApisProtect safeguarding beehives and the habitat of bees allowing increased honey yields,
  - Intelligent Implants whose technology allows increased bone growth through electrical stimulation.

3 of the 4 companies will be incubated at Tyndall.

- In addition three technology transfer projects have been supported:
  - Paperless Vessels, through the application of the International Space Station's (ISS) procedural control software into the marine shipping industry.
  - ISS-developed software also being utilised in the high reliability qualification and customer support industry targeting the aerospace sector.
  - The development of a geo-fencing safety control system for port container terminals.

The centre's activities will further grow in 2018, with the increased awareness of ESA Space Solutions and the ESA BIC.

CONNECT

Dr Alan Mathewson, Prof. Cian Ó Mathúna, Dr Alan O'Riordan, Alida Zauers, Ré Ó Cinnéide, Dr Brendan O'Flynn, all from Tyndall and CONNECT, hosting an information event for industry in Cork. Also pictured (seated) are Prof Linda Doyle, Trinity College Dublin and Cllr Declan Hurley, Mayor of Cork County.

Founded in 2015, CONNECT is the €60m SFI research centre for future networks and communications led from Trinity College Dublin. CONNECT staff in Tyndall (29 team members) lead the centre's 'Low Energy Network' theme, researching smart systems, smart sensors, energy generation and energy storage technology.

In 2017, CONNECT passed its SFI 2-year progress review with flying colours. Tyndall researchers made significant technical contributions during the process. Our researchers have also embraced the SFI EPE (education and public engagement) mandate with vigour and enthusiasm, surpassing expectations during the year, and communicating the impact of their research in multiple creative ways to non-STEM audiences. While also enjoyable, the process has informed our research and occasionally provided inspiration from unexpected sources.

CONNECT's 2-year Progress Review, conducted by an international panel of academic experts, returned the highest ranking available: "outstanding project in all respects; deserves highest priority for continued funding."

2017 highlights:

- Observation of complete inversion of the hysteresis loop in a bimodal magnetic thin film, which could be used in magnetic sensors.
- Development of a novel technique for surfing the high energy output branch of nonlinear wideband vibrational energy harvesters.
- Successfully completed the SFI/NSF I-Corps programme.
- Development of an “algorithm for human motion tracking with low power wearable vision and inertial sensor technology” incorporating: efficient 3D pose detection - position and orientation in space, multi-modal multi-sensor data fusion in a wearable platform with subpixel point detection.
- Simulations and preliminary experimental results indicate highest power capability to date for thin film lithium cobalt oxide battery cathodes for wireless sensor applications.
- 20 invention disclosures were submitted in the area of smart sensors and energy harvesting for the internet of things.

Plans for 2018 and beyond include:

- Several ‘Marie Sklodowska-Curie’ postdoctoral fellows will join the team in 2018, which will allow us to expand our research in making and powering smart things for the emerging internet of everything. This new research will focus on atomistic modelling and applications in precision agriculture.
- CONNECT-funded research is attracting attention from industry. We expect several licences in the energy harvesting and/or the electrochemical sensor space. There is also growing interest in a potential start-up company in the area of smart sensor systems for applications in environment monitoring or smart agriculture.
- CONNECT’s 2018 EPE programme is already well underway with Alida Zauers coordinating a variety of outreach activities.

SEM image of as-deposited SbBiTe thin films

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details

Supporting research and industry

Supporting research and industry

The Specialty Products & Services Centre (SP&S) offers a portfolio of industry services covering the spectrum from CMOS and III-V device fabrication, materials and device analysis, reliability and failure analysis to device and system-level test and characterisation.

This year has seen the first phase of a significant roll-out of replacement equipment for Tyndall's cleanroom processing and metrology equipment and to enable processing on 200mm (8 inch) wafers. This unique national research infrastructure is a strategic asset, and is being upgraded to drive future innovation in ICT research and industry in Ireland. The ability to process on 200mm wafers is a key requirement for many of our industrial stakeholders and brings with it a higher TRL capability. Some of the key tools selected in 2017 are:

- A new Elionix ELS-G100 100 kV Electron Beam Lithography System;
- Two new MA8 contact mask aligners from Karl Suss;
- A new electron beam evaporator from Temescal – UEFC 4900;
- A nanoindenter T1 Premier from Bruker;
- A Dimension Icon-PT AFM system from Bruker.

We expect to see this roll-out continue in 2018 and beyond as part of our strategic plan. We have found – through our engagements throughout Europe – that Tyndall's USP is in being able to offer a flexible fabrication facility that brings together the increasingly exotic materials needed for future devices, for example 2D materials, topological insulators, semimetals, III-V for advanced electronics and photonics applications - that are excluded in many 'classical' CMOS facilities. Tyndall has developed tooling lines and protocols that enable this flexible approach to heterogeneous integration of materials in an increasingly complex landscape, and will continue to operate in this way with the upgraded infrastructure.

Innovative graduate education

Tyndall has a diverse and energised graduate student community. This diversity is reflected in the multi- and inter-disciplinary nature of the graduate projects and programmes, gender diversity, and a broad spectrum in the nationalities of the students studying at Tyndall.

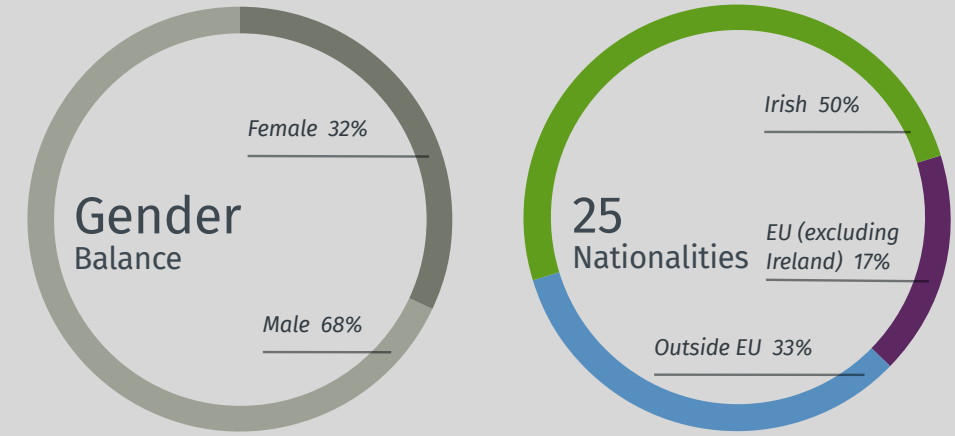
At the end of 2017, there were 105 PhD and 18 Master candidates pursuing their degrees at Tyndall for a total graduate student population of 123—comparable to levels as at the end of 2016. 18 PhD students successfully completed their studies in 2017.

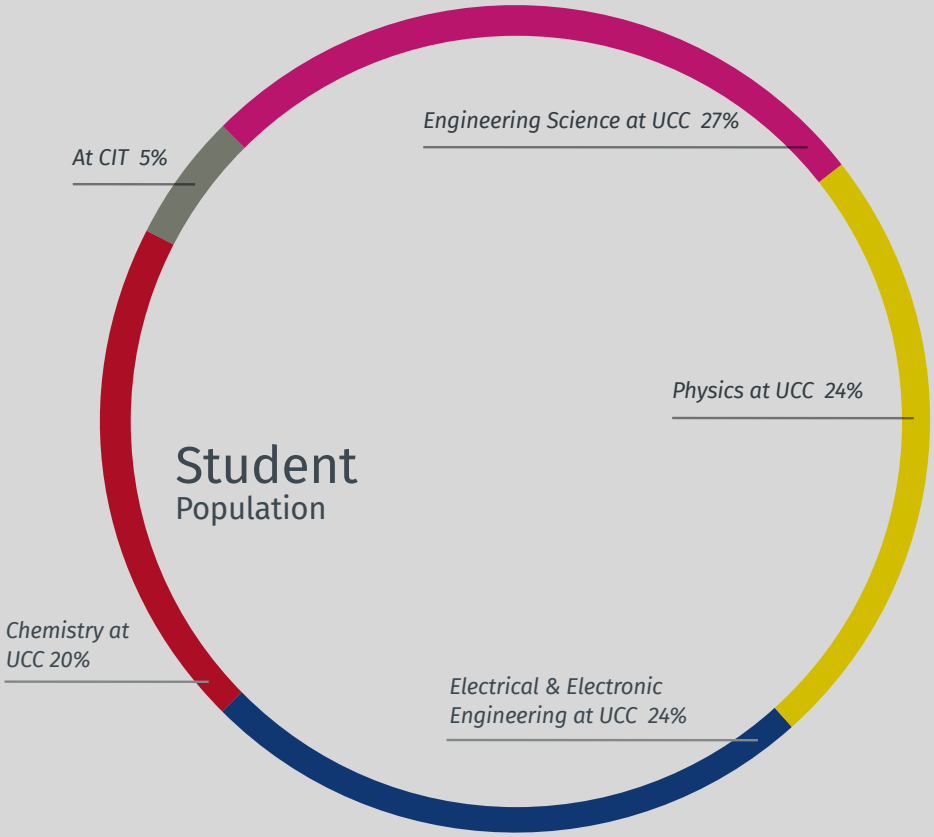
The Tyndall-led PhD Engineering Science structured PhD programme became the largest PhD programme on which students are registered in 2017. This programme has proven to be a highly flexible programme that matches Tyndall's education mission. Students take a minimum of 6 taught modules from a range of advanced technical modules, transferable skills modules and innovation, commercialisation and entrepreneurship (ICE) modules.

Students choose advanced technical modules from a wide range of multi-disciplinary topics offered across UCC's Science and Engineering Departments. Transferable skills modules in areas such as graduate information literacy skills and scientific training for enhanced postgraduate studies enables students to gain relevant skills in generic areas relevant to their personal and professional development.

In addition to multi-disciplinary technical training and transferable skills training, the PhD (Engineering Science) programme enables students to study for a level 9 postgraduate certificate in innovation, commercialisation and entrepreneurship (ICE) alongside their PhD. The ICE modules are provided through collaboration with the UCC College of Business & Law.

Tyndall's vibrant, multi-cultural student population:





STUDENT POPULATION DECEMBER 2017

105 PhD Students

18 Master Students

in 2017
18 students successfully completed their PhD

Tyndall OSA/SPIE student chapter, including Natalia Canes Estrada, President of the SPIE chapter; Brian Murray, President of the OSA chapter; Prof. Stefan Andersson-Engels, academic advisor and members of the OSA/SPIE Tyndall student chapter.

A new Tyndall/UCC student chapter from OSA and SPIE Societies was formed in 2017. The aims of the student chapter are to enhance professional development, participate in outreach activities and to increase optics and science learning through participation in events at our institutions and the local community.

ICE Graduates 2017, Jan Kegel and Amandeep Kaur with Dr Brian O'Flaherty, programme director Cork University Business School (CUBS) and Orla Slattery, graduate studies coordinator, Tyndall. *Missing from photograph:* ICE Graduate 2017, Louise McGrath.

The novel postgraduate certificate in innovation, commercialisation and entrepreneurship continues to attract Tyndall students, three of whom received the Level 9 Certificate in 2017.

Awards and Prizes 2017

BOC Bursary

The BOC Bursary is an annual award presented by BOC Gases to outstanding Tyndall students. In 2017, the award was presented by Andreas Bieringer, MD of BOC Gases to **Marco Dallasanta**, Photonic Systems, for his research into next generation technologies for access optical networks.

Tyndall's students continually showcase their research at national and international events and the range of prizes won by our students in 2017 is a testament to their quality and dedication as well as the academic expertise and support provided by our supervisors.

left Organisers of Tyndall student poster competition

right Student recipients of awards and prizes 2017.

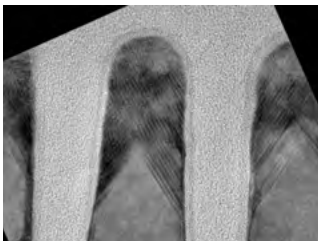
Annual Student Poster Competition

The 2017 annual student poster competition was organised by the Tyndall postgraduate student committee and the OSA and SPIE Tyndall/UCC student chapters.

The competition attracted 32 entries and is judged by an internal panel as well as Tyndall board members. The enthusiasm and dedication shown by the organising group ensured the success of the competition which provides an excellent showcase of the research being undertaken by our students across all Tyndall research areas.

First prize was awarded to **Andrea Pacheco**, Biophotonics, for her poster on "*Optical Assessment of Lung Function in Newborn Infants*". Andrea also presented a poster on this topic at the INFANT research day 2017, for which she was awarded third prize. **Marcelo Nogueira**, Biophotonics, received second prize for his work on "*Optical spectroscopy and imaging for gastrointestinal interventions*". A joint third prize was awarded to **Louise McGrath** and **Melissa McCarthy**. Louise, Electrochemical Materials and Energy, presented a poster on "*Ionic Liquid Based Electrolytes for Next Generation Li-ion Microbatteries*". Louise also received third prize at the Tyndall internal conference for her STEM demonstration. Melissa, Advanced Materials and Surfaces, presented a poster on "*Highly Efficient Perovskite Solar Cells using Atomic Layer Deposited Electron Transport Layers*". **Sanjeev Kumar**, Wireless Sensor Networks, and **Ian Seymour**, Electrochemical Materials and Energy, were also finalists in the student poster competition.

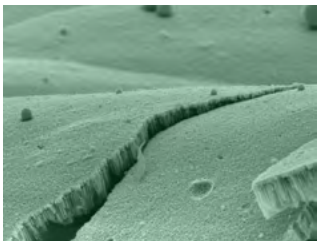
Tyndall Annual Scientific Image Competition Winners



Crystal damage in tight-pitch silicon nanowire devices

This test structure is representative of silicon transistor technology, currently used in billions of smartphones worldwide. The problem here is that doping by ion implantation, used to modify the properties of silicon locally, leads to many unwanted crystal defects. Specifically in the TEM image we see the effect of phosphorus ion implantation performed at room temperature at 45° tilts left and right. The implant is partially amorphising, and the crystal has recrystallised during the thermal treatment, but with many {111} type defects. Note the tops of the nanowires are rounded due to sputter erosion during the ion implant.

Ray Duffy, senior staff researcher, MNS (Materials and Devices) - Nanoelectronic Materials and Devices

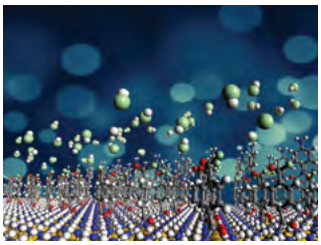


Unexplored highlands

This SEM image shows a nanowire array of magnetic $Ni_{45}Fe_{55}$ alloy deposited in a porous template of anodic aluminium oxide following oxide removal. The nanowires were deposited from a chemical solution using electroless plating. The nanowire array was investigated as an alternative to thin film planar vacuum based deposition with the ultimate goal of fabricating high energy density microinductors for integrated magnetics applications.

The image was acquired with an FEI Quanta 650FEG SEM at a magnification of 3000X.

Ricky Anthony, Ph.D student, Electrochemical Materials & Energy and ICT for Energy Efficiency groups

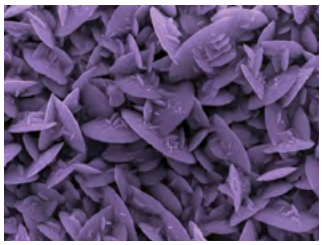


Simulating the controlled growth of polymer thin films by molecular layer deposition

This designed image shows molecular layer by layer growth of one cycle poly (p-phenylene terephthalamide) thin film reaction scheme. Molecular layer deposition (MLD) is a gas phase thin film deposition technology based on self-limiting surface reactions of alternating precursor exposures. Desired functionalities can be embedded into the films by varying the backbone of the organic or inorganic monomer and thus adjustment of thin film novel properties.

This image was selected by the Irish Research Council as one of the striking images in 2017 Irish Research.

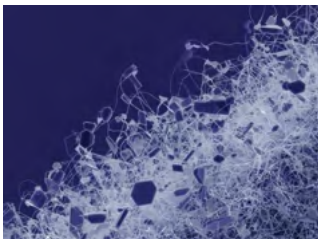
Abulaiti Hairisha, Ph.D Eng Sc. student with the Molecular Modelling for Devices group



SEM image of as-deposited SbBiTe thin films

The image depicts the as-deposited SbBiTe thin films synthesised by pulsed electrochemical technique on a Si-substrate. There are interpenetrating surfaces of SbBiTe phase, which collapses with the growth of film. SbBiTe is a p-type thermoelectric (TE) material. Here in Tyndall we grow the material using electrodeposition and measure the thermoelectric properties of the films. This material will be used in the fabrication of a micro-thermoelectric cooler/generator.

Swatchith Lal, Ph.D student, MNS (Circuits and Systems), Advanced Energy Materials



Nanowires of germanium antimony telluride

False coloured scanning electron microscope image of a sample of germanium antimony telluride (GST) nanowires and nanocrystals. This image was taken in Tyndall using the FEI Helios microscope. Germanium antimony telluride is a material of great scientific interest, with strong applications in phase change memory devices.

Fionán Davitt, MNS (Materials and Devices) - Materials Chemistry and Analysis

$SnSe_2$ nanoflowers

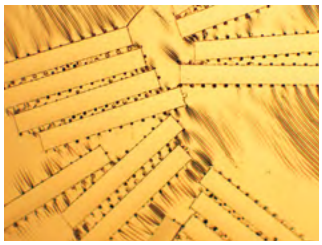
This image is a false colour SEM image of $SnSe_2$ flakes, taken using the FEI Helios here at Tyndall. These flakes were created using chemical vapour deposition (CVD), using a single source diselenoether precursor. At the growth temperature used here, flower-like structures are formed, with the petals of each flower being composed of individual $SnSe_2$ flakes. By changing the temperature in the CVD reactor, different $SnSe_2$ structures can be obtained.

Fionán Davitt, MNS (Materials and Devices) - Materials Chemistry and Analysis

$SnSe_2$ nano-waves

This image is a false colour SEM image of some disordered $SnSe_2$ flake-like structures, taken using the FEI Helios here at Tyndall. These flakes were created using chemical vapour deposition (CVD), using a single source diselenoether precursor. By changing the temperature in the CVD reactor, different $SnSe_2$ structures can be obtained.

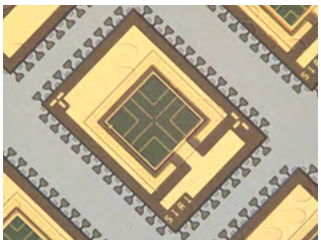
Fionán Davitt, MNS (Materials and Devices) - Materials Chemistry and Analysis



Gold coupons in the desert

These rectangular laser coupons were released from the original InP wafer, picked up by a PDMS stamp and some gold layer was evaporated at the bottom of them; the gold on the back surface of the coupons is flat. These coupons were finally printed on a Si substrate giving superior thermal and electrical conductivities.

Ruggero Loi, Ph.D student, Photonics - III-V Materials and Devices



III-V photovoltaic cell with tethers (brown) in place ready for µtransfer print to new substrate

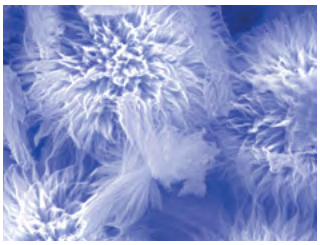
µtransfer printing is a new technique allowing the heterogeneous integration of materials/devices onto non-native substrates. Devices fabricated on native substrate are anchored in place using a tether system (brown) while a sacrificial layer in the device epitaxial structure is etched until the sample is ready for transfer. The transfer print employs a polydimethylsiloxane (PDMS) stamp which has protrusions matching the device footprint either singly or in arrays which allow scalable heterogeneous integration using Van der Waals forces or adhesive polymer layers.

John Justice, staff researcher, Photonics - III-V Materials and Devices, Photonics Sources

Nano skyscraper

The hydrothermal synthesis of zinc oxide often results in the growth of rod-shaped nanostructures. Due to the high surface area and potentially improved charge carrier transfer, the resulting nanorod arrays are investigated for their use in photo-catalysis and solar water splitting. However, unintentional growth of 3D geometries on top of these arrays may occur sometimes, leading to the formation of self-supported nanostructures such as the shown “nano skyscraper” . Thus, the image exemplifies the importance of a precise growth control but also visualizes the somewhat unexpected beauty of the zinc oxide nanorod growth.

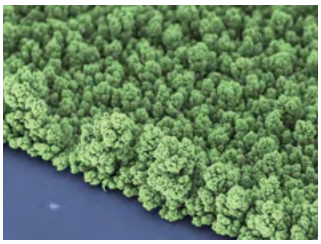
Jan Kegel, Ph.D student, MNS (Materials and Devices)



Floating flowers

Nanoflowers of cobalt oxide to build hybrid energy storage devices called supercapattery. The fibers of the nanoflower grew in all directions while connected with each other, like petals of flowers and thereby enhanced the surface area. When the structure comes in contact with the electrolyte (blue), the large surface area helps to enhance the electrochemical reactions, and thereby enabling storage of large amounts of charge for fast delivery.

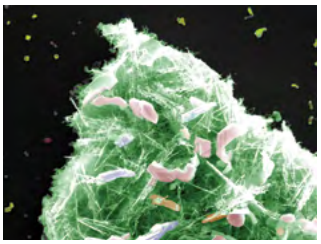
Han Shao, Ph.D student, MNS (Circuits and Systems), Advanced Energy Materials- Heterogeneous Integration



Dendritic growth of SbBiTe films

Dendritic growth of electrodeposited thin film on silicon. At Tyndall, we grow the material using electrodeposition and measure the properties. This material will be used in the fabrication of a micro thermoelectric cooler/generator.

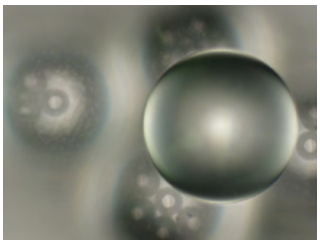
Swatchith Lal, Ph.D student, MNS (Circuits and Systems), Advanced Energy Materials



Christmas nano-tree

This is a false coloured SEM image of a “nano-tree” network of some very small germanium antimony telluride nanowires, containing microcrystal “baubles” within the network. This was grown through the use of chemical vapour deposition, and was then imaged using the FEI Helios in Tyndall.

Fionán Davitt, MNS (Materials and Devices) - Materials Chemistry and Analysis



Polystyrene spheres

These polystyrene spheres were analysed using an optical microscope in Tyndall. Polystyrene spheres can be used in applications such as electronic devices. A major challenge is developing a polymer with good stability, structural and chemical properties.

Emmanuele Galluccio, Ph.D student, MNS (Materials and Devices) - Micro-Nanoelectronics in collaboration with MCAG group, School of Chemistry UCC

Awards & Recognition

Salvatore Tedesco, Wireless Sensor Networks, is undertaking research on wearable sensors for healthcare and fitness. He won the Technology Ireland software industry award 2017 for outstanding academic achievement of the year. He also won the UCC, Bridge Network invention of the year award in the engineering, ICT and physical sciences category.

Vuslat Buk, Life Science Interface Group, received a best poster award for her poster on "*Carbon Quantum Dots Gold Nanoparticles Nanohybrid Material for Enhanced Enzyme Immobilization in Biosensor Development*" at the 69th Irish Universities colloquium. She also received a travel grant to attend the Nanobiosensors Conference.

Ekaterina Filatova, Materials Modelling and Devices, received best student presentation award at EuroCVD21 BalticALD15 Conference for her work on "*Ab initio modelling for understanding PECVD of silicon carbide and the routes towards ALD*".

Mariusz Wilk, Wireless Sensor Networks, was awarded best student paper award at the ISSC 2017 Conference for his paper on "*Sub-pixel point detection algorithm for point tracking with low-power wearable camera systems: A simplified linear interpolation*"

Natalia Canas Estrada, Photonics Systems Group, received honourable mention in the student poster competition at the Photonics Ireland Conference for her poster on "*Characterisation of IQ Modulator for a Terabit Superchannels Testbed*". Natalia was also awarded an IEEE student travel grant to attend International Photonics Conference (IPC) 2017.

Amandeep Kaur, Photonics Systems Group, is researching optical terabit superchannels. She was awarded the IPC 2017 women in photonics travel grant.

Dhiman Mallick, Micropower Systems and Nanomagnetics Group, received an IEEE student travel grant award for attending IEEE International Conference on magnetics – INTERMAG 2017.

Han Shao, Heterogeneous Integration, is working on nanostructured material based supercapattery for energy storage. She was one of only four students to be awarded a travel grant to the 231st ECS Meeting in 2017 where she gave two oral presentations and three posters on her research.

Niamh Kavanagh, Ph.D student, Photonics Systems group, with President Michael D. Higgins at the STEM reception at Áras an Uachtaráin on St. Patrick's Day.

Tyndall students have always been enthusiastically involved with public engagement and outreach events. In 2017, **Niamh Kavanagh**, Photonic Systems Group, received several awards in this area. Tyndall won a Teen-Turn host award from the SFI Smart Futures Teen-Turn initiative. This is an Irish initiative providing hands-on work experience in STEM environments to teenage girls from disadvantaged communities under the mentorship of a woman-in-STEM role model. Niamh and Dr Fatima Gunning received mentor awards for their work with Teen-Turn.

In January Niamh was selected as the Irish representative at the international week of scientific young talents in Paris. She was one of 42 young researchers and science communicators from 26 countries invited to take part. In March, Niamh was invited to Áras an Uachtaráin to a reception, hosted by President Michael D Higgins, to acknowledge the special contribution made by citizens who have excelled in science and its application to Irish life.

Niamh was recognised by Silicon Republic as a passionate supporter and advocate for diversity, inclusion and equality in STEM as well as an award winning science communicator. In 2017, Silicon Republic named Niamh as one of "10 Inspiring women in science you need to follow" and one of "The community builders: 13 women helping women in STEM".

PhD Vivas 2017

Justin Alexander, *"Low-linewidth optical comb sources based on gain-switched lasers"*

Ricky Anthony, *"Technology platform for the fabrication of micro-inductors on silicon for DC-DC conversion"*

Gerard Duffy, *"Modified screen printed electrodes for electrochemical sensing applications in food and beverage analysis"*

Abulaiti Hairisha, *"Synthesis, modelling and deposition of organic thin films"*

Lisa Helen, *"Development of a smart needle integrated with an impedance sensor to determine needle to nerve proximity for nerve blocking (anaesthetic) procedures"*

Barry Hutchinson, *"An investigation of high-k materials in metal-insulator-metal capacitor structures"*

Niall Kelly, *"Monolithic integration of photonic devices for use in a regrowth-free coherent WDM transmitter"*

Dhiman Mallick, *"Wideband vibration energy harvesting using electromagnetic transduction for powering Internet of Things"*

Hongjia Mo, *"Effective dithering of digital Delta-Sigma modulation, with applications to fractional-N frequency synthesis"*

Ronan Murphy, *"Thermoelectric properties of PbTe based materials driven near the ferroelectric phase transition from first principles"*

Xing Ouyang, *"Digital signal processing for fiber-optic communication systems"*

Pranay Podder, *"Nonlinear vibration energy harvester for powering of Internet of Things"*

Roxane Puicervert, *"Hybrid of metal meshes and CVD graphene as transparent and conductive electrodes"*

Zhiheng Quan, *"Thin film technology for optoelectronics and their thermal management"*

Dzianis Saladukha, *"Semiconductor materials and devices for 2 micron generation"*

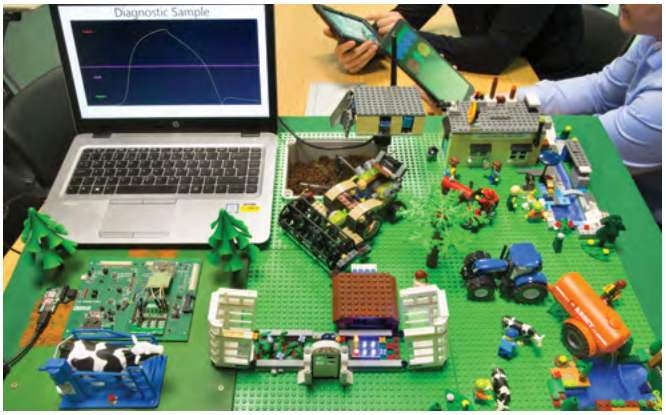
Alfonso Sanchez Soares, *"Electronic transport in metallic and semimetallic nanostructures"*

Daniel Tanner, *"Electronic properties of polar and non-polar InGaN quantum wells"*

Shiyu Zhou, *"High speed IC designs for low power short reach optical links"*

Outreach

Sinéad Ryan, education & public engagement officer, IPIC; Will Knott, teaching & outreach specialist, Graduate Studies; Alida Zauers, public engagement & outreach officer, Tyndall.



In 2017 we welcomed Alida Zauers as public engagement and outreach officer for Tyndall/CONNECT and Sinéad Ryan as education and public engagement officer for IPIC/Photonics. Under their direction, outreach activity has grown substantially over the last 12 months, with a constant stream of engaging events both internally and externally.

The overall aim of public engagement and outreach at Tyndall is to encourage the next generation of scientists and engineers, showcase our research to the general public, and develop the skills of our researchers to enable them to communicate complex science in a simple and engaging manner. Complementary to these activities, IPIC focuses its activities around the goal of strongly promoting and encouraging students to consider physics for leaving certificate and third level studies.

Our public engagement and outreach activities engage with tomorrow's scientists in primary and secondary school classrooms or during tours and workshops held at Tyndall. IPIC also promotes research careers to undergraduate students on summer internship programmes. We engage with the wider public at open days and festivals all year round and participate in science communication events to share our research in an easily understood manner.

12,000 *people participated in Cork science festival run by the Lifetime Lab, Tyndall, IPIC, CONNECT, APC, MaREI and Infant*

Engaged with approximately **1400 primary school pupils at workshops and talks**

Organised **Famelab Cork heat** - Will Knott made it through to the national finals.

2,500

Reached around 2500 secondary school students at **I Wish, careers talks** and onsite visits to Tyndall

120 *transition year students completed work experience programmes at Tyndall*

Worked with artists Susan Walsh and Leah Murphy to deliver the **'Tools of the trade project'** to **60 primary school** students.

Smart farm

Tyndall's smart farm demonstration was developed to explain the concept of smart farming and IoT to children and young adults. The colourful interactive piece consists of different sensing devices, such as water sensors to test for contaminants, soil moisture sensors in the land and light sensors enclosed within the greenhouse.

The farm also shows how disease diagnostics can be undertaken both on a hand-held unit and also in a milk line to detect, for example, mastitis. The farm was initially shown as part of the Enterprise Ireland innovation arena at the 2017 ploughing championships and attracted over 2,500 visitors to the stand. It was also used during culture night, at the Tyndall Technology Days and at school workshops during Science Week.

Little Book of Photonics Careers

A key aim for IPIC is to promote an interest in physics both as a leaving certificate subject and on into third level education where students pursue physics or electrical engineering courses. Photonics is a core discipline in physics and in an effort to give more meaning to the subject of physics, we developed the Little Book of Photonics Careers. The aim behind the book is to provide the reader with real life examples of people actively working in the photonics field. We included a diverse snapshot of individuals at all career stages across health, automotive, communications and cloud computing sectors. The common theme that these profiles share is that most of the individuals started their careers with a degree in physics. Thus, this resource ultimately goes some way to answering the question of 'What does a physicist do?'

Culture night

Tyndall opened its doors for 2 hours during culture night in 2017. During this time period over 160 members of the public had the chance to meet with 40 of our researchers and discover our cutting-edge research through a series of interactive demonstration stands. They also had a chance to explore the solar system in the star dome planetarium, attend talks by some of our researchers and witness how artists Angela Gilmour and Johnny Bugler merged art and science in an art installation.

Tyndall Financial report

Income and expenditure summary

INCOME	2017 €000s	2016 €000s
Government grant	4,500	3,500
Research	29,392	27,301
UCC contribution	2,088	2,142
TOTAL	**35,980**	**32,943**

EXPENDITURE	2017 €000s	2016 €000s
Remuneration costs	23,625	20,253
Equipment and infrastructure	1,617	2,251
Consumables and related costs	9,760	8,700
Other operating and deferred costs	978	1,739
TOTAL	**35,980**	**32,943**

Nano Skyscraper

Tyndall Annual Scientific Image Competition Winner;
see page 54/55 for details

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