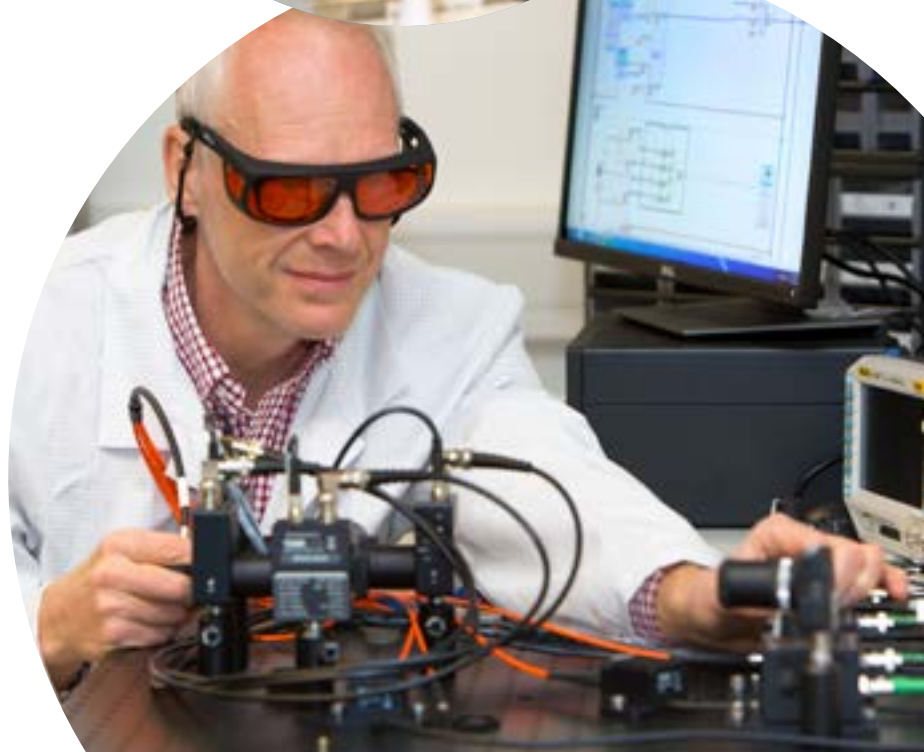


# 2016

## Annual Report



Impact from Excellence







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# Chairman's message

In Ireland, we are at an interesting point in our economic development as we continue to recover from recent global shocks, and we now again have over two million people at work. As an open economy, Ireland has benefited greatly from globalisation. However, greater geopolitical uncertainty and the direct impacts of Brexit and US economic policy will challenge the existing model.

Faced with such uncertainty, our success in building and sustaining a strong economy will increasingly be based on our competitiveness and the ability to innovate. Tyndall National Institute continues to play an important role using our world class research outputs to create strategic and innovative advantages for both indigenous and multinational companies.

Excellent research is the foundation for our success and is the basis for our impact. We are proud of our research and constantly seek validation through external benchmarks including awards and publications. 2016 was a good year for Tyndall. Positive affirmation of our progress is reflected in our staff performance in University College Cork's (UCC) annual research awards, winning UCC Information and Communication Technology (ICT) Invention of the Year (Kafil Razeed), Research Team of the Year (Peter O'Brien's Photonics Packaging team), Research Career Award (Eoin O'Reilly) and Commercial Impact Award (Brian Corbett et al - InfiniLED). In 2016 Tyndall continued to achieve excellent success in Europe's Horizon 2020 (H2020) programme and also importantly continues to expand the number of Irish SMEs and MNCs it brings into proposals.

Translation of research outputs to industry is a priority in the Institute, executed through research programmes and direct industry contracts. This aligns well to the government's objective to improve Ireland's long-term competitiveness by exploiting its national research ecosystem. As always we seek to span a wide range of Technology Readiness Levels (TRLs), from generating knowledge at lower levels to industrial application at higher levels. We also continue to explore opportunities to develop stronger Research Technology Organisation (RTO) capability to fulfill an identified need in the Irish research ecosystem.

Partnerships with multinationals and indigenous companies continue to increase, with particular success in 2016 in developing a number of client interactions with key corporate accounts similar to our long-standing relationship with Intel. Our Researcher-in-Residence programme remains strong with expansions by X-Celeprint and new resident partner Johnson & Johnson demonstrating the advantage companies see in co-located research. Licensing activity also continued to be strong, in particular in the circuit design space.

Ultimately small open economies like Ireland will succeed or fail depending on the quality of its people. At Tyndall, we provide graduate students with the opportunity to work on leading edge research, within multi-disciplinary expert teams while using our state-of-the-art research infrastructure. The Tyndall-led PhD (Engineering Science) is our fastest growing programme and 2016 saw 25 new PhDs granted across all fields.

As ICT transforms sectors like agri-food, communications, energy, environment and health we are confident that new high calibre graduates will join our existing alumni in transforming our world.

Following the renewal of the formal agreement between Tyndall, UCC and the Department of Jobs Enterprise and Innovation (DJEI) at the beginning of 2016, we have made a significant contribution as a UCC research flagship and National Institute. In particular we have shown national leadership in EU Horizon 2020 success. We are looking forward to supporting new UCC President Prof. Patrick O'Shea as he defines a new vision and strategy for the University.

I would like to thank President Michael Murphy who has completed his term as UCC President. His support for the agreement between UCC and DJEI has allowed Tyndall to continue to make a critical contribution to the Irish economy.

I would also like to wish Dr Kieran Drain the very best as he prepares to depart Tyndall and move back to the USA in 2017. Kieran has been a huge asset to Tyndall over his term where he led institute growth while keeping a strong focus on delivering impact through research excellence. Additionally, I would like to thank outgoing board member Lisa Amini, and welcome incoming board members Prof. Richard Penty and Jane Williams.

As part of Tyndall's plan for the next ten years, we will seek to strengthen our research base while continuing to be a primary support for Irish industry. We will continue to build depth in our core technical areas and selectively add expertise in newer evolving sectors such as agri-tech and advanced manufacturing technology. Increased emphasis will be placed on new company creation and support using vehicles such as the European Space Agency Business Incubator.

An important focus will be the enhancement of our capital infrastructure and the attraction, development and retention of talented people. Our ambition is to achieve many more successes like the recent Facebook acquisition of our spin-out company InfiniLED.

**Eoin O'Driscoll**  
Chairman



# CEO's message

From advancing quantum computing to helping keep cows healthy, 2016 has been an exciting year for us at Tyndall National Institute. I'm proud to say we delivered real impact through our research excellence in line with the objectives set out in our five-year strategic plan. Throughout this report you will see examples of just some of our many achievements including my top five highlights for 2016. Picking just five was a difficult task.

## Research excellence



While our activities are vast and varied, research excellence continues to be at the core of everything we do. Our research expertise was recognised this year as seven of our senior staff were awarded a prestigious Science Foundation Ireland (SFI) Investigator Award. These awards accounted for almost a quarter of all Investigator Awards issued by SFI in 2016.

Our publications increased by 15% to 270, and half of those were in journals ranked in the top 20%. These include papers in *Nature*, *Physical Review Letters*, *Advanced Materials* and a paper in *Proceedings of the National Academy of Sciences (PNAS)* by Séamus Davis who was on sabbatical at Tyndall and UCC. 25 PhD viva voce examinations were completed in 2016, continuing a significant output from our energised and diverse graduate student community.

Using public science databases to benchmark our performance against leading European RTOs, it is clear we are achieving a higher intensity of academic publications and a greater focus on graduate education while still maintaining a broad TRL spread of research activities. We also received an excellent assessment grade and very positive review in UCC's external research quality review process.

We continue to compete for the next round of SFI centres and have active participation in three of the eight bids that progressed to phase two - external peer review. Our centre proposals demonstrate our smart sensor capabilities in advanced manufacturing, precision agriculture and biopharmaceuticals.

## Commercial activity

We enjoyed another strong commercial performance in 2016 with industry income increasing to €5m. Intel renewed its commitment as a strategic industry partner and we've seen growth with other key corporate partners who we hope to move to similar multi-year research engagements.

An exciting development on the start-up front was the acquisition of our photonics spin-out company InfiniLED by Facebook and its Oculus division. The InfiniLED employees are now integrated into the Oculus Research & Development team and the company plans to retain and expand its operations in Cork. We see this as a key strategic opportunity.

In further support of start-up activity we launched the European Space Agency (ESA) Space Solutions Centre Ireland during 2016 which incorporates a business incubator. We host this national centre in partnership with Athlone Institute of Technology, Maynooth University and the Irish Maritime and Energy Resource Cluster. We were also successful in securing the European Photonics Venture Forum for Ireland in May 2017. This forum brings together approximately 40 photonics start-ups from across Europe with investors in a two day event.

Our commercial team was strengthened with the appointment of Peter Smyth as Commercial Director. Peter has extensive experience in microelectronics and systems having worked in large R&D organisations and is a founder of a number of start-ups.

## Agency-funded centres

Our SFI research centre, the Irish Photonic Integration Centre (IPIC) continues to go from strength to strength in technical achievements, national coordination, international reach and major funding wins. Our new SFI Professor in Biophotonics, Stefan Andersson-Engels, is now fully on board and is actively building his substantial research team.

Microelectronic Circuit Centre Ireland (MCCI), our Enterprise Ireland/IDA Ireland Technology Centre, is focused on growing the scale, quality and industry relevance of microelectronics research in Ireland. In 2016 it enjoyed significant growth in scale and impact and successfully completed five silicon tape-outs, cementing the team's credibility in execution and delivery of deep sub-micron IC designs.

The International Energy Research Centre (IERC) came through its mid-term review with a clear challenge to reposition itself to deliver its mission of providing technology solutions to industry in the demand-led energy space. The centre has significant industrial membership traction and will develop a new business plan to secure its longer term operation.

## Horizon 2020

Our Horizon 2020 performance continues to strengthen. Our success rates have been higher than both the Irish and EU averages since its launch. 13 proposals with a total value of €10m were funded in 2016 and to date we participate in 39 projects, of which we co-ordinate six.

Significant wins include the European photonics packaging pilot line PIXAPP, and a significant InterReg Medtech programme CALIN. This strong performance is credit to our EU team building international consortia, influencing calls, and raising our profile within the European Commission.

## Partnerships

In line with our strategic plan, we generated new and strengthened our existing strategic partnerships. We signed a Memorandum of Understanding (MOU) with Wuhan East Lake Hi-Tech Development Zone, People's Republic of China. Ranked third among 105 hi-tech development zones across China, it is the only one focused on optoelectronics.

Another important MOU was signed with Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT. Building on this MOU, EMFT has partnered with us in our SFI centre bids and joined with us in a number of EU Horizon 2020 proposals.

The existing MOUs with Cork Institute of Technology, Telecommunications Software Systems Group at Waterford Institute of Technology and Teagasc, the agriculture and food development authority in Ireland, also continue to yield opportunities.

## Empowering Women @ Tyndall

We were delighted to launch the Empowering Women @ Tyndall (EW@T) programme in 2016, with the aim of supporting our female staff and students to reach their full potential. We enjoyed an exciting line-up of talks from inspiring leaders including Ann O'Dea from Silicon Republic, Maeve Lankford from the Leadership Foundation and Margie McCarthy from Science Foundation Ireland. The



EW@T committee, a gender diverse group from all areas of Tyndall, has defined a three-year plan to involve, engage and support diversity across the institute. The EW@T initiative was presented at our Technology Days event where attendees from a wide variety of organisations expressed an interest in collaborating with us on further developing the programme.

## The future

Looking forward to 2017 and beyond, we are optimistic for the future. As one of Europe's recognised Digital Innovation Hubs, we will build upon our strengths in photonics and micro and nanoelectronics to capitalise on opportunities arising from the European digitalisation agenda. The completion of our submission to SFI for the next phase of IPIC will be a key focus in early 2017. As we move into the latter stages of our five-year strategic plan, we will define a longer term vision for Tyndall and respond to the identified national gap in supporting industry in higher TRL work.

To remain competitive internationally, significant additional capital funding is vital to enhance our capabilities and critical fabrication facilities. By providing access to the best infrastructure and equipment, we can continue to attract world-leading research, engage with key industrial partners, and ensure a positive impact on the Irish economy.

I would like to thank the Department of Jobs, Enterprise and Innovation for their continuing critical support and valuable partnership. I would further like to thank President Michael Murphy and his management team in UCC for their important ongoing support. I would also like to thank our chairman, Eoin O'Driscoll, who continues to challenge our balance of ambition and impact versus scientific discovery.

Finally, I would like to thank our staff and students for their commitment and dedication to excellence and hard work. You continue to drive Tyndall's many achievements and have made 2016 a truly successful year.

Regrettably for family reasons I have decided to step down as CEO of Tyndall in early 2017. It has been a real privilege to work at Tyndall and I appreciate the positive support that I have received from everyone from the very first day I arrived. I am proud of our many accomplishments, not only in 2016, but over the last four years. Tyndall is a world class Institute that is a product of its excellent people who will continue to move Tyndall forward on its current positive trajectory.

**Kieran F. Drain, PhD.**  
CEO

*Members of the Empowering Women @ Tyndall committee Anthony Morrissey, Michelle Farrell, Cian Ó Mathúna, Niamh Kavanagh, Karen Twomey, Eilis Mulcahy, Fatima Gunning and Hugh Smiddy. Missing from photo: Peter O'Brien and Patricia Vazquez.*



# Scorecard:

## People



- 105 PhD and 16 Master's degree candidates pursued their studies
- 25 students completed PhDs
- SFI Professor in Biophotonics now building his team
- Multiple initiatives to support entrepreneurs (Entrepreneur-in-Residence, Makerspace, IPIC Bootcamp, CorkBIC)

## Research excellence



- A record six SFI Investigator Awards received
- More than 270 peer-reviewed publications
- Highest ranking achieved in UCC's five-year research quality review

## Infrastructure access



- ESA Space Solutions Centre Ireland launched including a business incubator with start-up access to a Tyndall-led consortium
- SME access enhanced by EU InterReg project Calin and EU pilot line PIXAPP
- €7.5m infrastructure funding received from SFI
- H2020 ASCENT project providing the international research community access to Europe's leading nanofabrication research facilities at Tyndall (Irl.), imec (Bel.) and Leti (Fra.)

## Global reach



- European Photonics Venture Forum 2017 secured for Ireland (Dublin)
- Successful hosting of ALD 2016 with over 800 attendees (>400 from industry)
- MOU with Administrative Committee of Wuhan East Lake Hi-Tech Development Zone, People's Republic of China (WHEDZ)

## Funding



- €10m H2020 project wins in 2016
- Since Horizon 2020's launch, we participate in 39 projects worth €22m to Tyndall
- 20.5% success rate in H2020 calls
- 131 proposals (SFI, EI, EU, etc.) submitted to a value of €100m. 45 proposals funded worth €42m

## Industry engagement



- Total industry income increased to €5m
- Successful launch of the third cycle of Intel's three-year research contract
- Signed a three-year contract worth \$1m with Analog Devices
- Delivered on major commercial integrated magnetism projects with global partners
- Five Enterprise Ireland Commercialisation Fund Awards won at a value of €1.6m

*Outgoing UCC President Dr Michael Murphy with incoming UCC President Prof. Patrick O'Shea and Kieran Drain, CEO Tyndall National Institute.*



# Highlights





## Tyndall spin-out InfiniLED acquired by Facebook

Defined by a diameter of less than 10 microns,  $\mu$ LEDs (micro Light-Emitting Diodes) have attracted attention from LED manufacturers due to their outstanding luminous efficiency compared to competing technologies. This makes them suitable for use in displays for wearable and mobile devices because they are brighter and use less battery power than traditional LED-backlit Liquid Crystal Display (LCD) screens.

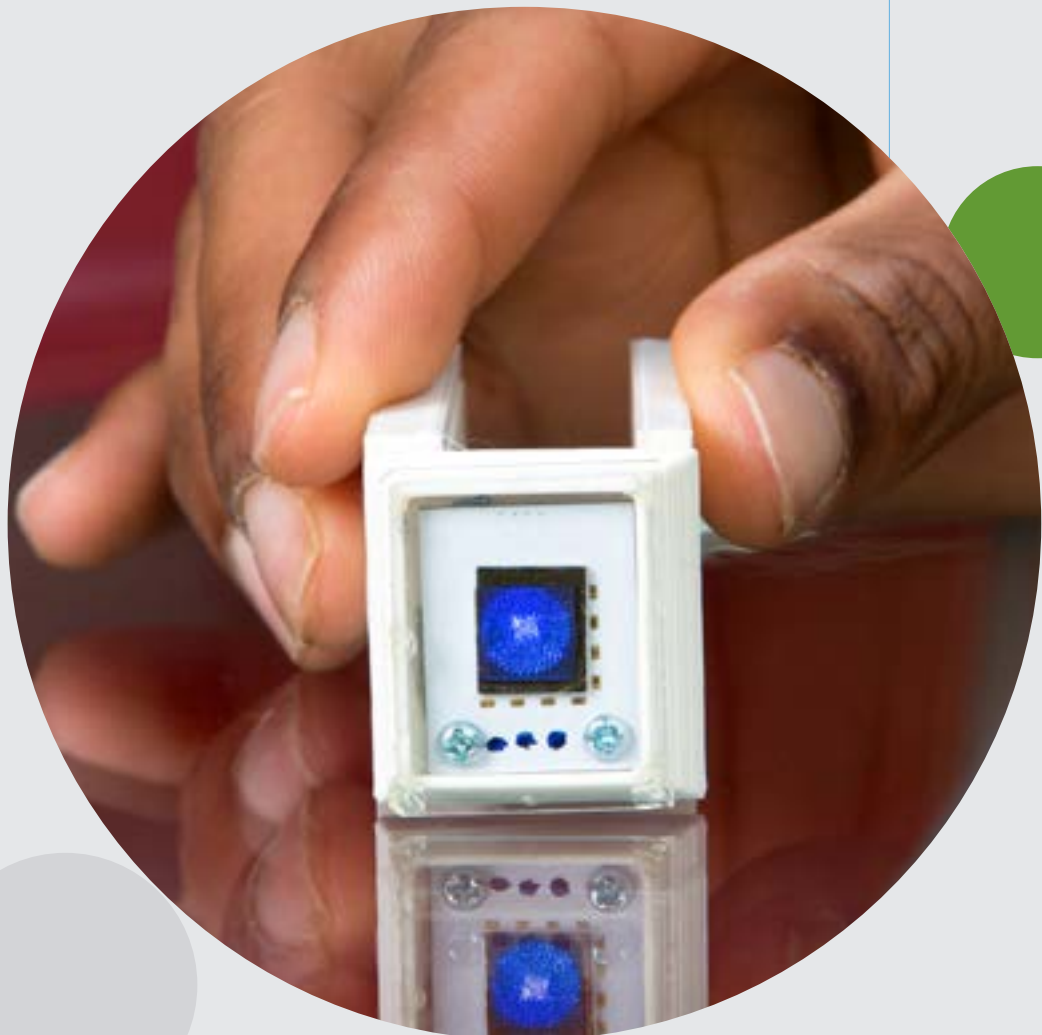
World-leading  $\mu$ LEDs developed by Brian Corbett and his team were commercialised through Tyndall spin-out InfiniLED, which was acquired by Facebook during 2016 for further technology development by its subsidiary, Oculus.

This new generation of LED technology can create high quality displays with reduced power consumption, extending the battery life for portable devices such as cameras, mobile phones, laptops and VR devices. The InfiniLED displays can consume substantially less power than normal LCD and Organic Light-Emitting Diode (OLED) displays and are capable of producing bright images with much improved contrast due to the quasi-collimated light.

The patented technology employs a parabolic reflector which is etched into the semiconductor material during the fabrication process, thereby placing an optical component at the best location for efficiently capturing and collimating the generated light.

The underlying  $\mu$ LED technology in InfiniLED displays was supported and funded by Enterprise Ireland.

*Micro-display with over 8,000 addressable micro-LEDs.*



## Breakthrough step towards quantum computing

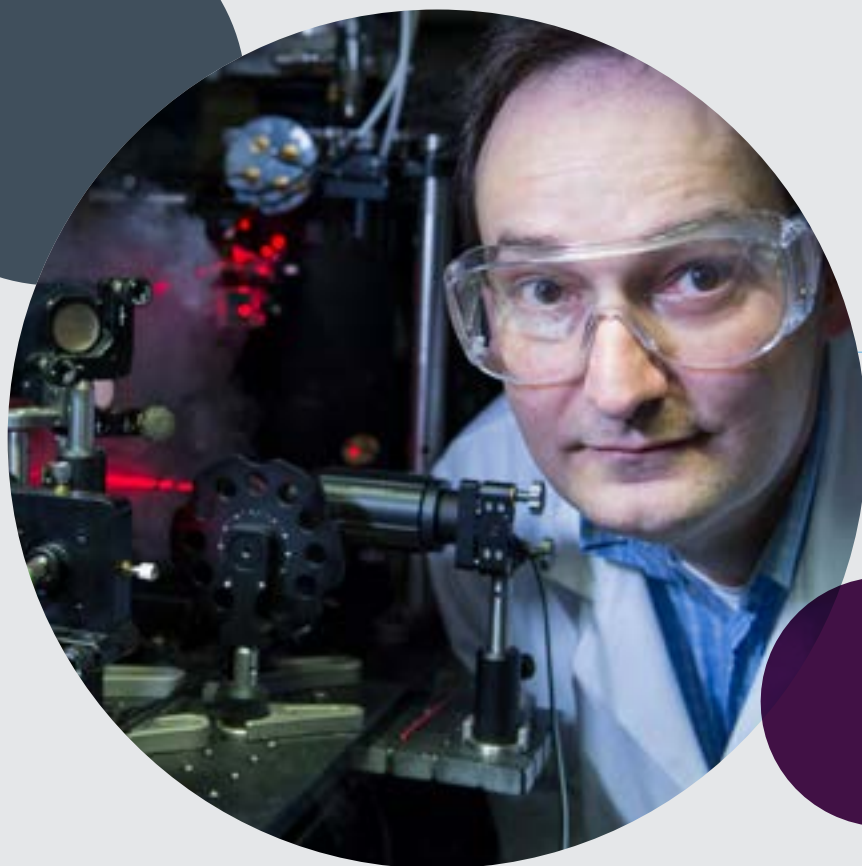
Quantum computing technology is regarded as the next revolution in global computing and will enable greater speed and efficiency to power our future computing needs. Conventional digital computing uses 'on-off' switches and Boolean algebra, but quantum computing looks to harness quantum states of matter (such as entangled photons of light or multiple states of atoms) to encode information. In theory, this can lead to much faster and more powerful computer processing, but the technology to underpin quantum computing is currently difficult to develop at scale.

In 2016, a research team led by Dr Emanuele Pelucchi made a 'quantum leap' by developing a technical step that could enable the use of quantum computers sooner than expected. The team made the significant breakthrough by making quantum dot light-emitting diodes (LEDs) that can produce entangled photons, theoretically enabling their use to encode information in quantum computing.

The team engineered a scalable array of electrically driven quantum dots using easily-sourced materials and conventional semiconductor fabrication technologies. This method allowed the team to direct the position of these sources of entangled photons. Being able to control the positions of the quantum dots and to build them at scale are key factors to enable more widespread use of quantum computing technologies as they develop.

This is an important step towards the realisation of integrated quantum photonic circuits designed for quantum information processing tasks, where thousands or more sources would function in unison.

Details of the development were published in Nature Photonics.



*Dr Emanuele Pelucchi in his quantum optics laboratory at Tyndall.*

## Tyndall accelerates the commercialisation of magnetics-on-silicon

Our magnetics-on-silicon technology platform is based on validated research with key innovations along the entire supply chain of integrated magnetic passive component solutions including design and modelling, magnetic materials, process/fabrication technology and test/characterisation. This multi-disciplinary approach and capability is unique in the research space and has been referenced by the electronics industry as a global benchmark in the development of the future and emerging area of power supply on chip (PwrSoC). Tyndall is internationally recognised as a key partner in accelerating the commercial scale-up of the magnetics-on-silicon technology through research and licensing contracts.

During 2016, our Integrated Magnetics team demonstrated world-leading results with the highest efficiency (>90%) of integrated coupled-inductor technology, a key component of power management systems for microprocessor power delivery. This is a disruptive technology enabling demonstration of the first power converter system on a passive interposer with step-function performance improvements (>81% efficiency - the highest reported in literature), energy savings, size (smallest power supply-in-package reported) and cost in application areas including smartphones, IoT, wearables and augmented/virtual reality.

A key research highlight in 2016 was Zoran Pavlovic's advanced magnetic device characterisation system to accurately measure the magnetic core and device performance with large ac (0.6 A), dc (4A-dual phase) signals and test frequencies up to 120 MHz. The advanced characterisation system is capable of measuring at conditions that are close to the actual application conditions in a power converter. A key output from the system is accurate core loss data which includes all mechanisms within the magnetic material including eddy currents, hysteresis and anomalous. This key data allows the establishment of an accurate design/optimisation window for the material and device, which is critical for overall system optimisation.

A strategic highlight for 2016 was securing research funding of over €1m per year for the next four years to explore novel ideas in device designs, magnetic materials, MEMS/NEMS processing and circuit topologies to advance the state-of-the-art in this emerging area. The funding, which will double the size of the team, includes two SFI awards, two EU Horizon 2020 projects and an EI Innovation Partnership. This record funding will contribute to the demonstration of novel device constructions with new material systems and will move our existing technology up the TRL scale, making it available for high-volume manufacturing in products forecast to be on the market in 2018/19.

*Zoran Pavlovic demonstrating the large-signal electrical characterisation of on-silicon coupled inductors for future Power-Supply-on-Chip (PwrSoC).*





## SFI Awards

### Investigator Awards:

Seven of our leading researchers received SFI Investigator Programme Awards in 2016. This programme supports world-class research that will improve our society and economy. The awards fund outstanding people with innovative ideas and strategic partnerships that can demonstrate potential economic impact.

### The awardees are:

#### Martyn Pemble

Martyn Pemble and his team will fabricate thin film materials based on micro and nano length scales using methods designed to directly simulate real world manufacturing conditions. This will demonstrate the commercial viability of the novel coating technologies to be employed.

Specifically, roll-to-roll systems for colloidal assembly, atomic layer deposition (ALD) and the deposition of other, liquid based thin film systems will be used to create thin films that possess enhanced anti-microbial properties under normal room lights with improved transparency and conductivity.

In addition a spool-to-spool coating system will be established for the coating of fibres while a spray or lamination system for the production of antimicrobial surfaces will be constructed and the resulting materials tested in a clinical environment.

Funding: €1.8m

#### Paul Hurley

Paul Hurley and his team will investigate a range of open scientific and technological questions related to the use of 2-dimensional Transition Metal Dichalcogenides (TMDs) materials. This class of semiconductor materials exhibit considerable promise for emerging applications in information and communication technologies, sensors, photonics and for the devices which will underpin the 'Internet of Things'. However, the majority of research to date has been conducted on hand-crafted devices fabricated using individual exfoliated flakes.

The team will investigate large-scale growth, functionalisation and contacting of TMDs building on the expertise in Tyndall and Trinity College Dublin for the formation, processing and electrical characterisation of alternative semiconductor materials. Through large area growth, characterisation and integration into hybrid devices using nanoscale-processing techniques, the team will aim for a realistic performance evaluation of TMD films for a broad range of electronic applications.

Funding: €1.5m



SFI IvP awardees: Paul Hurley, Ivana Savić, Eoin O'Reilly, Cian Ó Mathúna, Martyn Pemble, Stephen Fahy and Emanuele Pelucchi.

### Stephen Fahy and Ivana Savic

Thermoelectric materials can convert heat into electrical power or cool devices using electrical current. This SFI-DEL (Department of Education and Learning Northern Ireland) supported collaboration of teams at Tyndall and Queen's University Belfast will explore hidden atomic instabilities to improve the efficiency of certain thermoelectric materials. The team will use large-scale computer simulations to guide them to the best candidates, and synthesis and measurement to verify their properties and applications.

Funding: €1.4m

### Emanuele Pelucchi

Emanuele Pelucchi and his team will develop an improved scalable source of quantum light with the aim of making quantum computation a reality in the near future. The SFI-DEL award is an "all Ireland" collaboration aimed not only to optimise existing device structures, but to expand the family of quantum phenomena (or, as they are called, generalised quantum correlations) that can be exploited effectively to achieve large-scale quantum information processing.

Funding: €1.2m

### Cian Ó Mathúna

Over the next decade, the concept of Power Supply on Chip or 'PwrSoC', a term coined by Cian, will facilitate a paradigm shift in power management for ICT. Cian and his team will develop innovative solutions for integrated power supplies encompassing:

- Magnetic materials
- Thin film fabrication
- Design & characterisation
- Circuit topology
- System integration

The development of nano-scale inductor structures on silicon with high power densities and efficiency will provide a disruptive solution which will effectively make the magnetic components in a power converter disappear onto the silicon power management integrated circuits.

Funding: €1.2m

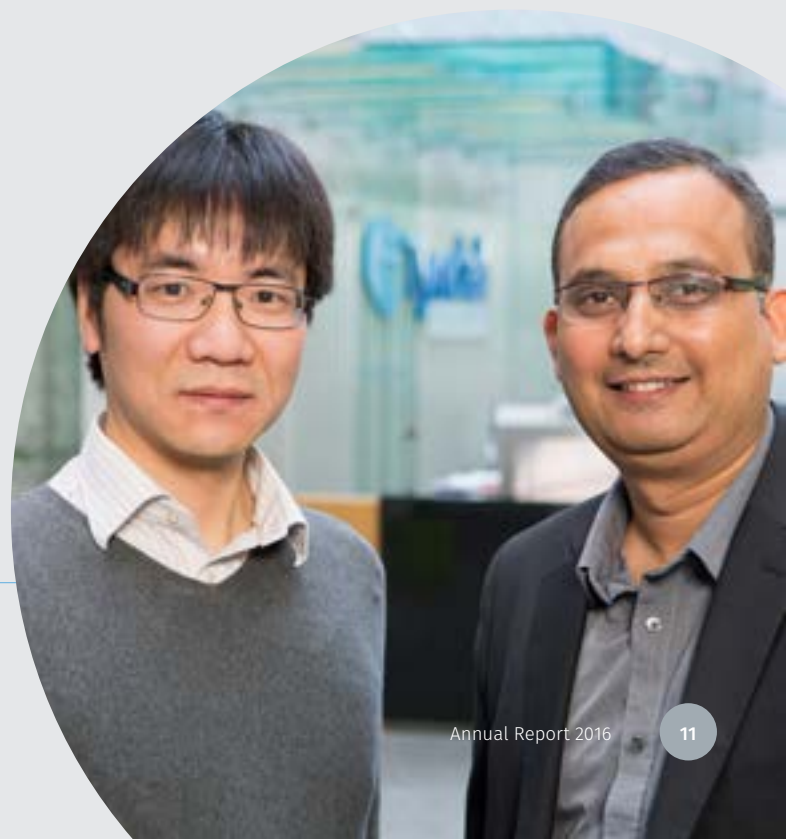
### CDA and SIRG Awards:

In addition to the SFI Investigator Awards, two of our researchers received SFI individual research awards.

**Jian Zhao** was awarded an SFI Career Development Award (CDA) of €0.9m to research flexible high-capacity optical networks.

**Santosh Kulkarni** was awarded an SFI Starting Investigator Research Grant (SIRG) of €0.6m to research advanced magnetic materials for high efficiency power supplies.

*SFI Career Development Award  
recipient Jian Zhao and SFI Starting  
Investigator Research Grant Award  
recipient Santosh Kulkarni.*



## Lift-off for ESA Space Solutions Centre Ireland

In 2016, we launched the European Space Agency (ESA) Space Solutions Centre Ireland. The centre supports entrepreneurs with innovative ideas for using space technologies to create new products and services in a non-space environment. The centre will provide technical expertise, business-development and funding support to 25 start-ups and 10 technology transfers by 2021.

The centre is one of 16 ESA BICs (Business Incubation Centres) throughout Europe which inspire entrepreneurs to convert space-connected business ideas into commercial companies. Technologies originating from Europe's space programmes have already given us more efficient transportation, better medical instrumentation and improved pollution control systems.

Funded by ESA and Enterprise Ireland, ESA Space Solutions Centre Ireland is a partnership between Tyndall, Athlone Institute of Technology, Maynooth University and the Irish Maritime and Energy Resource Cluster.



*David Gibbons, Manager of ESA Space Solutions Centre Ireland; Minister for Jobs, Enterprise and Innovation, Mary Mitchell O'Connor TD and Franco Ongaro, ESA's Director of Technical and Quality Management pictured at the launch of the ESA Centre.*



# Research

A photograph of two scientists, an older man and a younger man, both wearing white lab coats and safety goggles. They are in a laboratory setting, with shelves of bottles and containers in the background. The older man is leaning over a laptop, and the younger man is holding a small electronic component over a green circuit board. Both are wearing blue nitrile gloves. The word "Research" is overlaid in a blue circle in the top left corner.

# Electronics

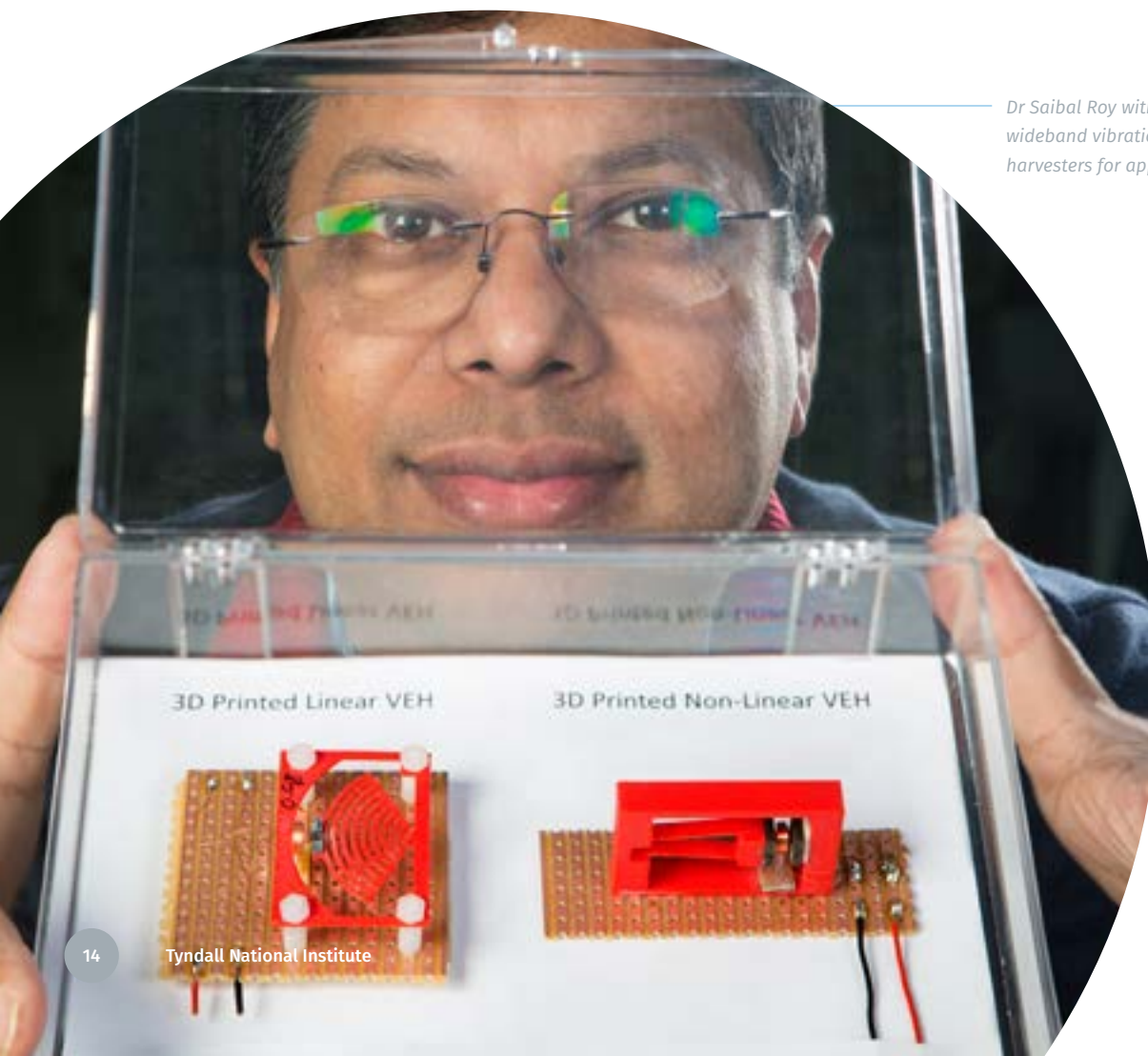
## Vibrational energy harvesting to power smart things for the IoT

With the development of low-power electronics, the search for reliable, ambient 'green' sources of energy has increased significantly in the last decade. This has led to a surge in research into latent environmental mechanical vibrations. Vibration energy harvesting is a technology which converts ambient mechanical energy into usable electrical power.

Dr Saibal Roy and his research team have developed a novel, low-cost, miniaturised and high performance energy harvester, operating over an ultra-wide frequency range. Along with a power conversion module and wireless sensor node this could provide an alternative energy solution for next generation electronics enabling the connected smart world, moving us a step closer towards realising the 'Internet of Everything'.

The results of this research were published in Physical Review Letters, one of the leading journals in physics, and the team has also filed a global patent protecting this emerging technology for niche applications.

*Dr Saibal Roy with non-linear wideband vibrational energy harvesters for applications in IoT.*



## Probing the atomic-scale origins of thermoelectric materials

A number of intriguing material properties originate from the interaction of electrons with vibrations of atomic nuclei, for example superconductivity, topological phases and related phenomena. This interaction also determines how efficiently thermoelectric materials convert waste heat into electricity or vice versa, which can be used to power wireless sensors or cool electronic devices.

In collaboration with the experimental team of Prof. David Reis from SLAC National Accelerator Laboratory at Stanford University, using the world's most powerful X-ray laser, the Linac Coherent Light Source (LCLS), and using computer simulation at facilities in Tyndall and the Irish Centre for High-end Computing (ICHEC), the team studied the interaction between electrons and lattice vibrations in lead telluride, which is one of the most efficient thermoelectric materials currently known. Lead telluride exists near a crystal structure transformation and has a tendency to distort without fully transforming - an instability that is thought to play an important role in its thermoelectric behaviour.

By exciting electrons in lead telluride with a brief pulse of infrared laser light, and then using LCLS's X-rays to determine how this burst of energy stimulated lattice vibrations, we found that the light pulse excites particular electronic states that drive lead telluride towards instability through coupling with lattice vibrations. It's hoped that uncovering this mechanism will help us find other thermoelectric materials that are more abundant and less toxic than lead telluride.

*Prof. Stephen Fahy and Dr Ivana Savic in Tyndall's high-performance computing facility.*





## Smart knee device aims to improve post-surgery recovery

Recuperation from knee surgery, such as arthroplasty or knee replacement, can take some time, varying from three months to one year depending on the patient. In 2016, scientists at Tyndall and an SME from Nissatech Innovation Center in Serbia developed a new smart knee device that could improve and accelerate recovery from knee surgery.

The smart knee system remotely monitors the patient's progress through a knee movement sensor developed at Tyndall, and based on the progress the patient makes, the rehabilitation programme can be adapted and personalised to the patient. The data provided to the physician is invaluable in the recovery process, which is the real value of the smart knee system.

The smart system is just one of many innovations that are being shared with the international SME community through Gateone, funded through the European Horizon 2020 programme. Encouraging small and medium sized businesses to take advantage of world-class technologies, Gateone is sharing a concept portfolio with SMEs across Europe and providing funding to help bridge the gap from R&D to market-ready products.

We selected four of our key technology platforms to be part of the Gateone portfolio, including wearable technologies, micro-needle-based transdermal delivery systems, energy management systems and electrochemical sensors. The smart knee is the first of our demonstrators to be provided to an SME for real environment trials and leverages work developed by Salvatore Tedesco and the Wireless Sensor Networks team.

The smart knee generated significant interest from potential users, SMEs and MNCs who are keen to exploit the technology, as well as considerable media attention from diverse media such as thejournal.ie, Engineer's Journal, Medical Independent and UTV.

*Thomas Healy and John Barton demonstrating the smart knee device.*



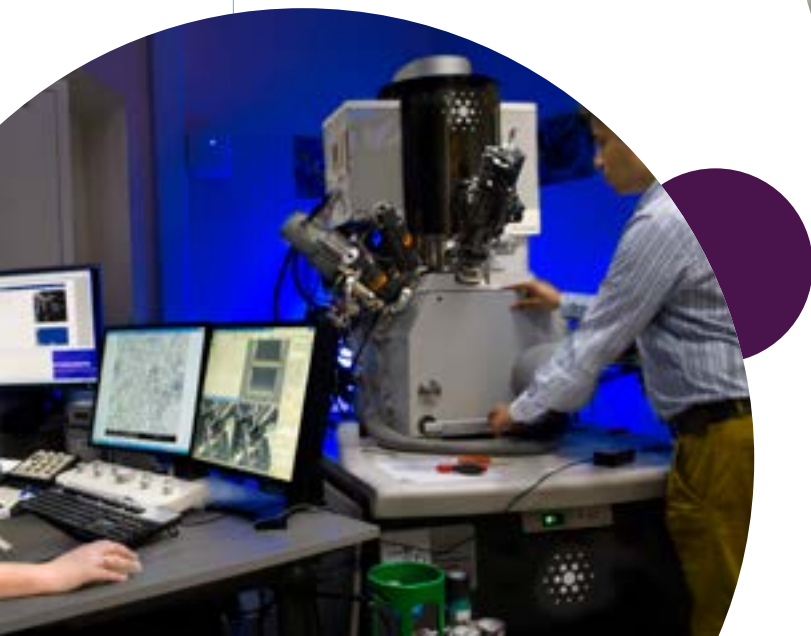
## Research breakthrough in enabling faster, smaller and greener electronic devices

A major obstacle to the introduction of group IV elemental semiconductors Si and Ge in photonics, optoelectronics and in band-to-band tunnel FETs (TFET) is their indirect bandgap. Prof. Justin Holmes and his research group have created a simpler process to produce direct bandgap germanium-tin (Ge<sub>1-x</sub>Sn<sub>x</sub>) alloy nanowires with large (at least 9 atomic %) tin content, much higher than the equilibrium solubility of tin in germanium.

The nanowires were grown from a simple, cheap and scalable bottom-up process where third-party metal catalysts were used to guide the non-equilibrium incorporation of tin atoms into the Ge bi-layers during Ge nanowire growth. The tin (Sn) atoms become trapped with the deposition of successive layers, thus giving an extraordinary tin content in the germanium nanowires. The development of non-equilibrium nanoscale alloy was key to achieving direct bandgap in the group IV semiconductor system.

This research breakthrough, published in the prestigious scientific journal Nature Communications, is vital in potentially enabling the production of faster, smaller and greener electronic devices. The nanowires produced are expected to lead to electronic devices that are up to 125 times more power efficient than conventional devices due to the unique electrical and optical properties of germanium-tin nanostructures.

*Jessica Doherty and Dr Subhajit Biswas determining Sn incorporation in Ge<sub>1-x</sub>Sn<sub>x</sub> alloy nanowires in Helios Nanolab scanning electron microscope.*



## Supercapattery: A new class of energy storage device for powering pacemaker

Researchers in the Advanced Energy Materials team are developing an energy storage device by bringing together the best of the supercapacitor and battery worlds.

Led by Dr Kafil M. Razeeb, the team has developed a hierarchical NiO-In<sub>2</sub>O<sub>3</sub> microflower (3D)/ nanorod (1D) hetero-architecture as a supercapattery electrode with excellent cyclic stability for powering the next generation of implantable pacemakers that should be able to survive inside the human heart for 20 years.

The team is now working on ways to improve the capacity of this supercapattery device and has already achieved nearly 50% of the capacity of commercial Li-ion batteries.

A symmetric device fabricated using this hybrid electrode showed excellent power density and retained 79% of its initial capacity after a remarkable 50,000 charge-discharge cycles. In comparison, state-of-the-art Li-ion based batteries can only survive for 1,500 cycles with the same retention.



*Dr Kafil M. Razeeb checking the nano-heterostructured electrodes for supercapattery fabrication.*

# Photonics

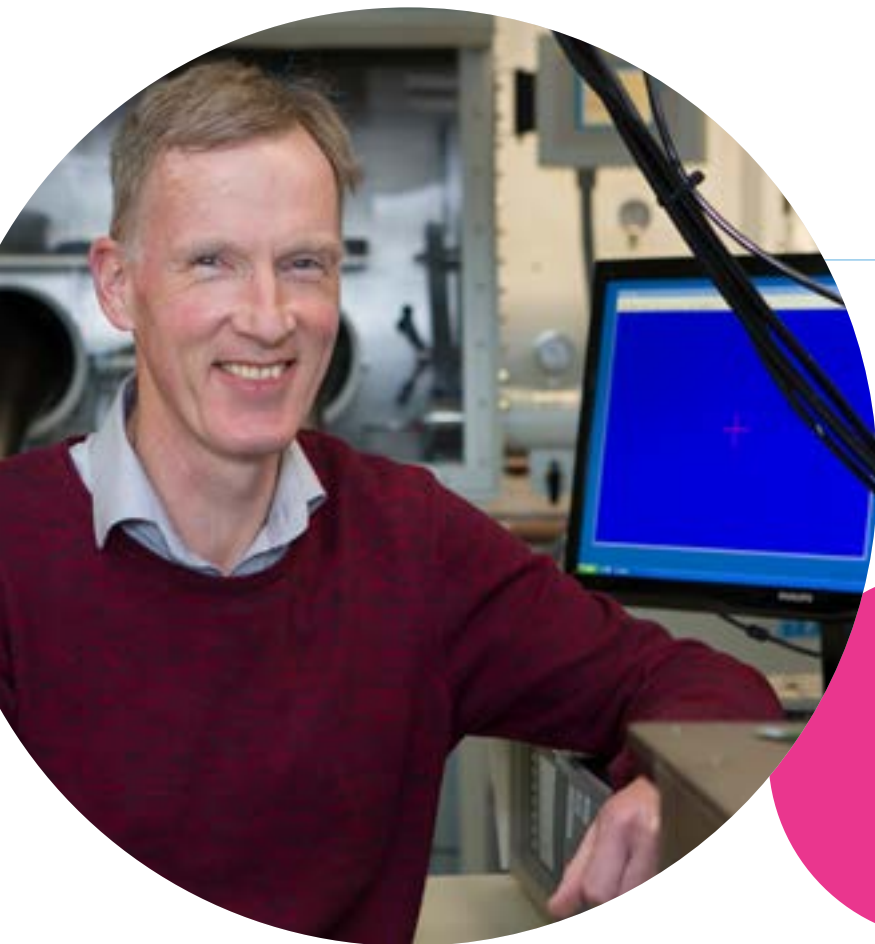
## World's first integrated plasmonic platform

Miniature, highly-sensitive sensor systems which are cheap and small enough to be installed in our phones could enable us to use our mobile devices to test air quality, or even measure blood sugar levels.

Optical techniques can be used to detect and measure the concentration of a selected molecular species with great accuracy, compactness and convenience by using chemical attachment. Laser light can be made to travel along a metal surface, enhancing its interaction with the species under investigation and therefore increasing the sensitivity. These high frequency surface electromagnetic fields are termed plasmons.

At Tyndall we have introduced a compact vertical-cavity surface-emitting laser (VCSEL) as an electrically pumped source and detector of plasmonic signals when operated in forward and reverse bias respectively. We developed the VCSEL-based plasmonic platform where the light, instead of being emitted from the laser, is coupled to the plasmonic waveguide using an integrated grating. This is a radical change in concept as it avoids the need for separate components and their alignment. The resulting system is compact, cheaper, powerful and requires smaller amounts of material to be investigated.

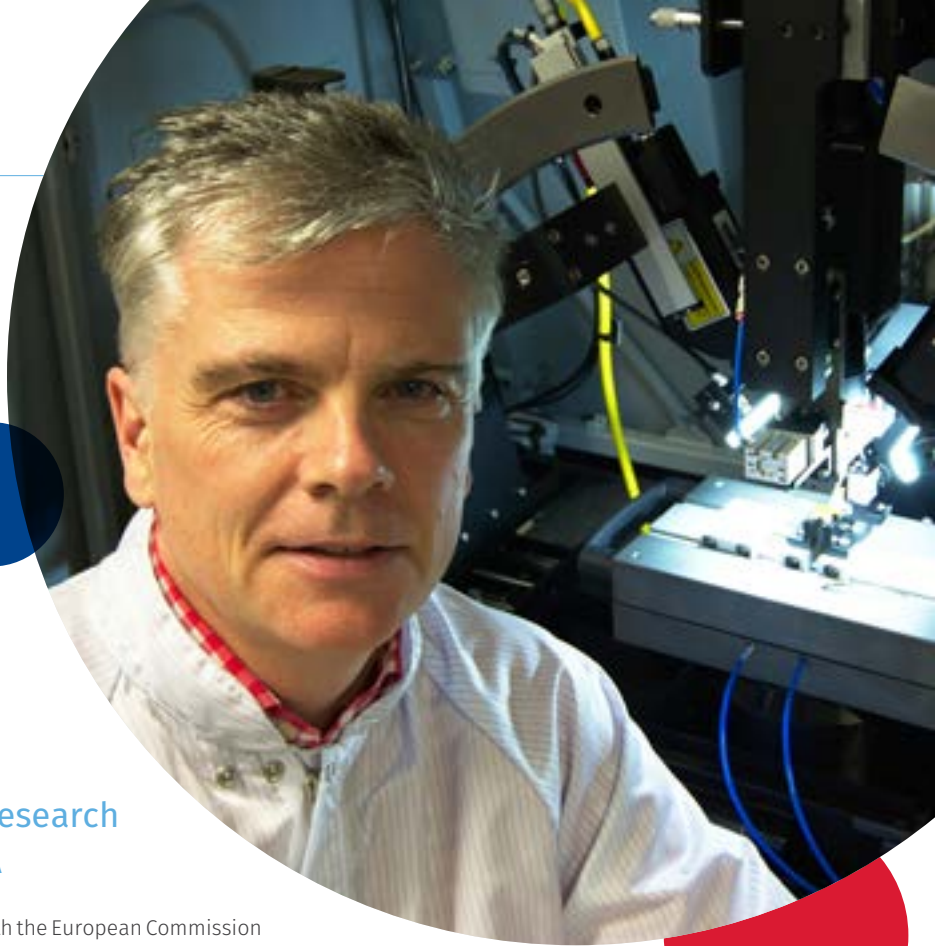
Our colleagues at King's College London have experimentally demonstrated the surface plasmon excitation, its ability to propagate in a waveguide, frequency conversion and detection. The findings of our research were published in Nature Communications.



*Brian Corbett, Head of III-V  
Materials and Devices group.*



*Dr Peter O'Brien, PIXAPP Pilot Line Director  
and Head of Photonics Packaging group.*



## Tyndall's integrated photonics research expands across Europe and USA

2016 was a significant year for photonics packaging with the European Commission committing a €15.5m investment in a new international consortium called PIXAPP, to be led by Tyndall. The investment will provide Europe with a unique state-of-the-art infrastructure, supporting the industrial development and manufacture of Photonic Integrated Circuits (PICs).

PIXAPP is the world's first open-access PIC assembly and packaging pilot line, combining a highly-interdisciplinary team of Europe's leading industrial and research organisations. With leadership from Tyndall, partners in Germany, France, Belgium, Netherlands, UK, Italy, Czech Republic and Finland will bring their expertise to support SMEs to make use of the breakthrough advantages of PIC technologies. Packaging PICs can represent up to 80% of the cost of photonics components so it is a critical focus area for the industry.

Separately, during 2016, Tyndall's global leadership in integrated photonics extended through collaborations with a number of researchers in US universities. These collaborations, initiated by Dr Peter O'Brien and funded through a joint Science Foundation Ireland and National Science Foundation programme, include Prof. Ming Wu (UC Berkeley), Prof. Alex Scherer (California Institute of Technology), Prof. Keren Bergman (Columbia University), and Profs. Nasser Peyghambarian and Dan Kilper (University of Arizona).

Outputs from this research resulted in a number of joint publications and the demonstration of highly functional photonic devices. These include demonstration of a fully packaged MEMs silicon photonic optical switch for use in data centres. The key benefits of the device over competing technologies include fast switching speed; an extremely high density of switching functionality within a small chip area and ability to scale to even higher levels of switching densities; and ability to manufacture and package devices in high volumes.

In addition, Peter O'Brien was awarded an Adjunct Professorship at the Optical Sciences Centre (OSC), University of Arizona. OSC is the largest optics institute in the US and has had three Nobel prizes awarded to its faculty.



*PhD student Alison Perrott in our  
Photonics Characterisation Lab.*

## New Tyndall multi-wafer project process for III-V PICs

The fibre-optic links that currently form the backbone of the internet carry massive amounts of information encoded on multiple (typically up to 80) wavelengths of light. As demand for information capacity continues to grow, it is becoming increasingly critical to integrate the semiconductor lasers that generate these wavelengths onto a single photonic integrated circuit, or PIC, in order to achieve the required footprint, cost and performance targets. In this case, the laser resonator can no longer be formed by the reflective cleaved facets of a single semiconductor device, but instead must be made with multiple on-chip mirrors as well as ancillary devices such as data modulators.

In 2016, the Integrated Photonics group led by Prof. Frank Peters developed a new internal multi-wafer project process that enables many variants of these complex devices to be simultaneously designed and fabricated in a very short timeframe. Using the process, the team was able to reduce fabrication times from many months to a record time of just 6 days. As a result the team was able to realise a number of novel laser and PIC designs leading to six accepted publications in high-impact photonics journals including IEEE Photonics Technology Letters and Optics Express.

## Nanostructured III-N materials with record fill factors

III-N semiconductor alloys are unique in their ability to support light emission across the visible and UV spectral range that is required for critical applications such as energy-efficient solid state lighting. However, the lack of suitable large-area growth substrates is still a major hurdle. For example, the high 12% atomic spacing difference between the standard substrate material sapphire and AlN, leads to high threading dislocation densities that generate current leakage paths which degrade or even prevent light emission in LEDs.

One attractive solution is to nanostructure the material to form arrays of nanorods. The large surface-to-volume ratio of a nanorod compared to bulk III-N allows for very efficient lattice relaxation and hence defect-free materials to be created. However, most arrays of semiconductor nanorods suffer from having relatively low densities (or “fill factors”) and a high degree of non-uniformity, especially when produced by self-organised growth. Ideally an array of nanorods for an efficient optoelectronic emitter should have a fill factor close to 100%, with uniform rod diameter and height.

Prof. Peter Parbrook’s team, in collaboration with Prof. Justin Holmes’s team and co-workers from AMBER, have demonstrated a unique “space-filling” approach for forming defect-free arrays of AlN nanorods, whereby the separation between each rod can be controlled to 5 nm due to a self-limiting growth process. These arrays of pyramidal-topped AlN nanorods formed over wafer-scale areas by metal organic chemical vapour deposition provide a defect-free semi-polar top surface, for potential optoelectronic device applications.

The team have achieved the largest ever fill factor of 98%, which was reported in the high impact journal, ACS Nano. Crucially, the new approach opens the possibility to engineer new growth substrates with reduced surface electric fields. This is critical for reducing piezoelectric effects that can otherwise cause changes in semiconductor bandgap and hence emission wavelength which are deleterious for device applications.

*Prof. Peter Parbrook, SFI Stokes Professor  
and Head of III-Nitride Materials group.*



Dr William Whelan-Curtin



## Making faster internet speeds a reality

Burst mode receivers are critical enabling components in Fibre-To-The-Home (FTTH) networks where the losses between individual users and the network operator's central office can vary dramatically depending on the network architecture.

Optical burst switching provides more bandwidth flexibility than traditional routing technologies. In other words, you can dynamically increase or reduce the bandwidth a particular home or business has for real-time traffic and as a result the network can quickly adapt to the changing demands of each user. However, it requires faster switching and control technology which is the challenge that we are addressing.

Patented in 2016, our linear burst mode receiver (LBMRx) technology is unique in that it maintains the linearity of the input waveform during equalisation, enabling additional dynamically-reconfigurable filters to be used to compensate the effects of fibre dispersion and other impairments. It will mean faster internet speeds for the end user and a cost-efficient way for service providers to offer more reliable broadband.

The IPIC team has used the LBMRx for world-leading 'long reach' FTTH demonstrations at the premier optical communications conferences, ECOC and OFC, and in recent years has also published results in four invited papers in OSA/IEEE journals. The technology is now receiving significant industry interest from market-leading communications companies.

## ERC grant holder moves research group to CIT@Tyndall

European Research Council Grants are recognised as being the most highly regarded source of funding for "frontier research" in Europe and represent the most significant part of the "Excellent Science" pillar of the new Horizon 2020 framework, both in terms of scale and prestige. They are awarded to the best researchers in Europe based solely on the criterion of excellence, and are highly competitive. Equally, the competition between European institutes to host ERC grant-holders, with the accompanying prestige and "stamp of excellence", is very intense.

Dr William Whelan-Curtin is one of the leading authorities on disorder and loss in photonic crystals and has designed and realised the world's best slowlight waveguides to date. These have applications in areas such as next-generation telecommunications and energy efficient data centre interconnects.

He received his PhD from the University of St. Andrews in 2005, in the group of Prof. Thomas Krauss, and has worked in Stanford University in the group of Prof. David A.B. Miller, a world-renowned expert in semiconductor physics. He also co-founded and runs NanoPIX, a foundry service for nanophotonic devices which supplies research teams across Europe with bespoke samples. He has authored or co-authored more than 80 journal papers and currently receives over 400 citations per year, with an h-index of 32.

Dr Whelan-Curtin's decision to relocate his research group and ERC grant to Cork is an indication of the internationally competitive strength of photonics research in Ireland and in particular the Cork institutes - CIT, Tyndall and UCC. The excellent fabrication facilities available were a key factor that motivated his decision.

Dr Giuseppe Talli explaining the network demonstrator system.







## EU activity continues to increase

The goal of the EU Programmes Office is to enhance our EU collaborative research across the whole innovation chain, thereby achieving industry growth and benefitting all of society.

As a research and technology organisation, we have taken a proactive role to double Europe's research investment in Ireland, and to work with technology adopters to bridge the so-called 'valley of death', taking laboratory demonstrators and maturing them into technology platforms ready for manufacturing and industry uptake.

Our extensive network builds on partnerships with over 400 organisations to deliver value across several European programmes including Horizon 2020, Public-Private-Partnerships and the European Regional Development Fund. Since the launch of Horizon 2020 in 2014, we have participated in 39 projects with a total value of over €250m of which the European Commission contributes 70%. The balance is largely matched by industry partners.

The investment in our research and innovation activities within these projects is valued at over €22m. An additional €18m funding to our Irish partners, including €11m to industry, has resulted in 50 jobs over the projects' lifetime.

Several major projects were funded in 2016. These aim to create high-impact innovations, and include the PIXAPP Photonics Packaging Pilot Line, the CALIN Wales-Ireland platform for industry-driven innovation in Advanced Life Sciences, the Factories of the Future project COMPOSITION, and two collaborative actions under the ECSEL Joint Technology Initiative.

*EU Programmes team – Martin O'Connell,  
Giorgos Fagas and Aoife O'Brien.*



A woman wearing a light blue hijab with floral patterns, red-rimmed glasses, and a white lab coat is working in a laboratory. She is wearing blue nitrile gloves and using a white and blue pipette to transfer liquid into a small glass vial held in a metal clamp. The background is a blurred laboratory setting with shelves of equipment. In the bottom left corner, there are two overlapping circles, one green and one dark grey.

# Industry engagement



As one of Europe's leading research Institutes, Tyndall engages with global leaders in the agri-food, communications, energy, environment and health sectors. The role of the commercial team is to maximise the impact of our research for our partners and the communities they serve through accelerated deployment to market of defensible technology.

We have always had a strong impact ethos and this aligns well with the global focus on increased economic return from research. From SMEs to large multinationals, visitors to our state-of-the-art facilities recognise that delivering impact through research excellence is at the heart of the Institute's activity. As a result, we're seeing an increase in the number of long-term, collaborative research engagements which enable us to align our core research activity to industrial problem statements.

We work closely with our colleagues in Ireland (Science Foundation Ireland, Teagasc, Enterprise Ireland and IDA Ireland) and overseas (H2020 and ESA) to secure valuable leveraged funding for pre-competitive research, and then switch to direct funding when the client requires restricted disclosure and greater IP control.

One aspect of our uniqueness is the ability to work 'from atoms to systems'. Working with companies such as Analog Devices, Intel, Stryker and Sunstar, to name just a few, many of the application challenges we address require our researchers to change the architectural approach, right back to the fundamental material science. It is now common for our chemistry, materials, physical devices, engineering and manufacturing teams to collaborate on a specific challenge for an optimal outcome. With all disciplines working together, this 'domain convergence' is solving some of the world's most challenging problems in our focus sectors. Some of these are highlighted in this report. It is also noteworthy that, as relationships with our core ICT partners strengthen, engagement with clients in non-traditional ICT sectors (such as medical devices and agriculture) is accelerating.

The success of our annual industry-focused Tyndall Technology Days event is validation of our commercial strategy. The 2016 event attracted 300 attendees from 100 global organisations, including Directors, Chief Executive Officers and Chief Technology Officers. We are also delighted with the impact our Empowering Women @ Tyndall initiative made at the event. We look forward to raising the bar again at our 2017 event which will take place on Wednesday, 25 October 2017. See [www.tyndalltechnologydays.com](http://www.tyndalltechnologydays.com) for more information.



*Peter Smyth, Commercial Director.*

## Key commercial highlights 2016

- € Industry income up on previous years at €5m
- Handshake icon 30% of business from new industry partners
- Magnifying glass icon 20% of commercial research activity in med-tech
- Globe icon New world-leading industry partners include Huawei Technologies and Johnson & Johnson

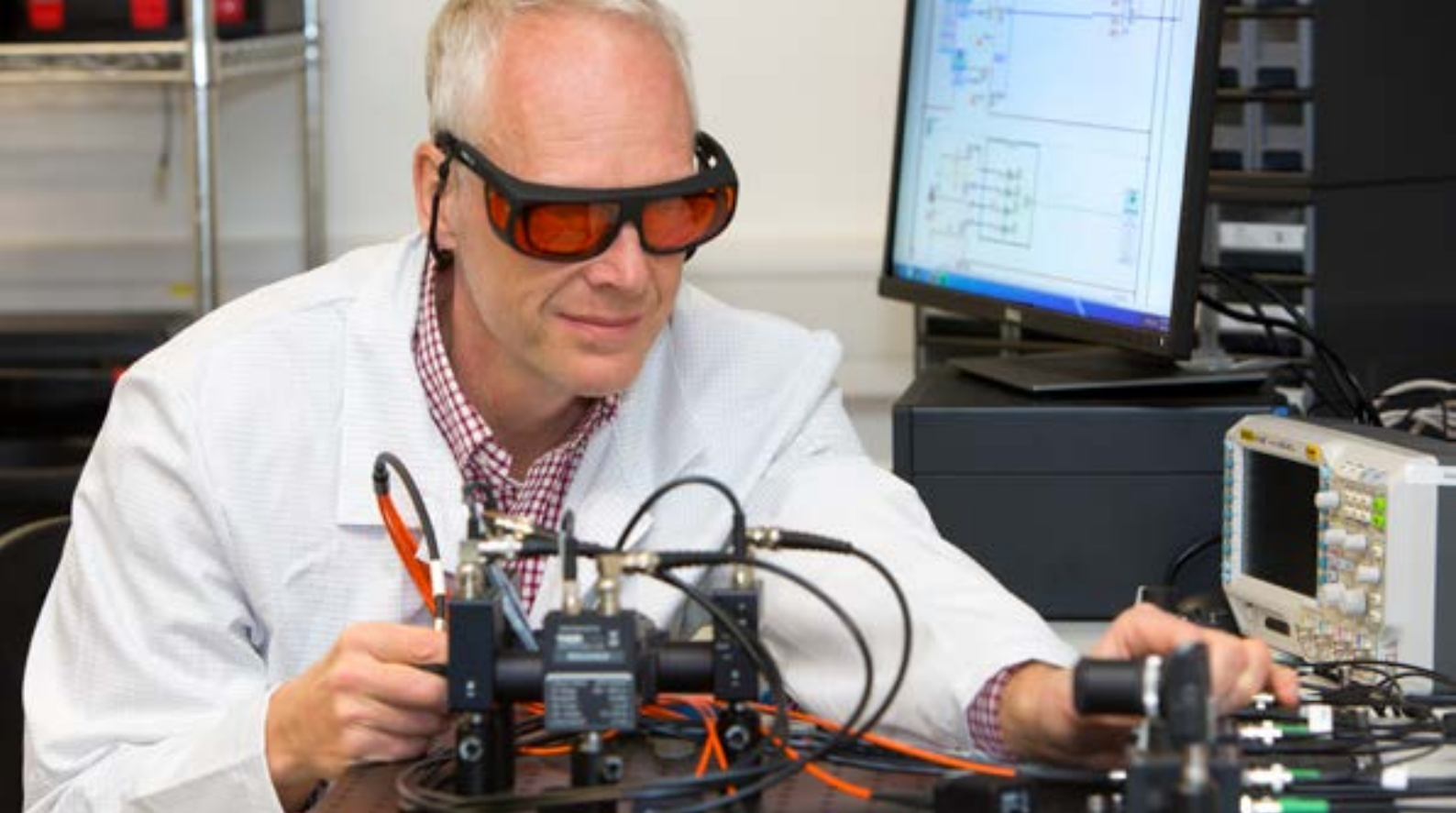




# Licenses and IP Assignments

Company	Technology
<b>Boston Scientific</b>	Instrumentation Amplifier for Implantables
<b>Boston Scientific</b>	Low Power (Nanowatt) Clock Oscillator for Implantable Devices
<b>Boston Scientific</b>	Analog to Digital Converter
<b>Grasp Wearable Technologies</b>	Design of Custom Integrated Circuit for Grasp's Run System Product
<b>Fleming Medical</b>	Smart Wound Dressing
<b>Intel</b>	Photonic Device Designs
<b>Faz Technology</b>	Interconnect Package for Photonics Integrated Circuits
<b>Lake Region Medical</b>	Optically Integrated Guidewire for Medical Applications
<b>Oculus</b>	US Patent 7,518,149 MicroLEDs With High Aspect Ratio
<b>Oculus</b>	US Patent 9,472,594 Light Emitting Diode Chip
<b>Oculus</b>	US Patent 9,515,238 MicroLED Arrays With Filter





## Patents

### Single Crystal High Dielectric Constant Material and Method for Making Same US Patent 9,240,283

**Inventors:** Scott Monaghan, Ian Povey

This granted US patent relates to a single crystal, high dielectric constant material. In particular the invention relates to a low-temperature deposited, high-k, single crystal, dielectric material for Metal-Insulator-Metal (MIM) capacitor applications with an additional application in Metal-Insulator-Semiconductor (MOS) systems. Integration of this MIM capacitor for an ADC (Analog-to-Digital Converter) would increase the speed of the ADC and of its application. The high-k also allows for reduced area capacitors, enabling on-chip integration and a greater density of IC circuitry.

### MicroLED Array with Filters US Patent 9,515,238

**Inventors:** Pleun Maaskant, Brian Corbett, Bill Henry

US patent granted for the integration of an emission filter onto an LED source at the point where the light emerges from the chip. The filter is coated directly onto the exit face of the source and is therefore in the closest possible location to the light generation point. This invention can improve LED performance by reducing the emission full width half maximum (FWHM) and/or the emission tail.

### Linear Burst Mode Receiver European Patent 2,577,865

**Inventors:** Peter Ossieur, Paul Townsend

Following on from a granted US patent in 2015, this patent is now also granted in Europe and is based on a receiver for passive optical networks that can process data at rates in excess of 10Gb/s. This technology has already been utilised as part of the European project DISCUS, which has demonstrated an advanced 'long reach' Fibre-To-The-Home (FTTH) network.

# Case studies



## Rambus and Tyndall CONNECT

Rambus creates cutting-edge semiconductor and IP products, spanning memory and interfaces to security, smart sensors and lighting. Its products are integrated into tens of billions of devices and systems, powering and securing diverse applications including Big Data, Internet of Things (IoT), mobile, consumer and media platforms.

Rambus collaborates with industry and partners with leading ASIC and SoC designers, foundries, IP developers, EDA companies and validation labs. Among its partners is Tyndall.

Within CONNECT, the SFI research centre for future networks and communications, Tyndall's team is working with Rambus to develop the next generation of optical sensing systems focusing on the potential to use the technology in wearable microsystems for gesture recognition and human computer interfacing.

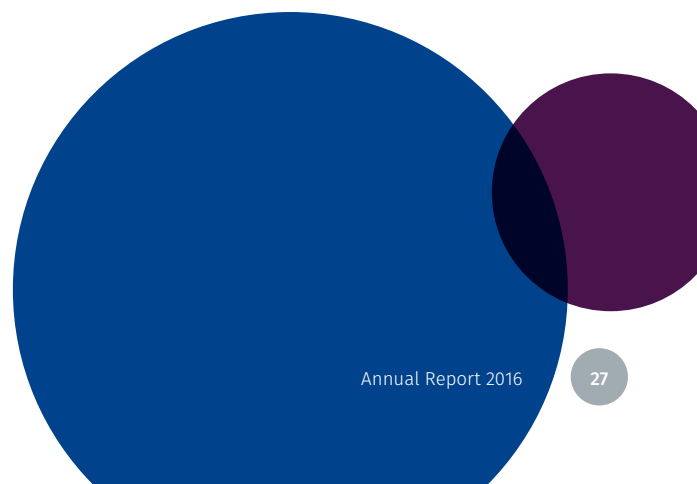
As seen by the recent development of VR systems such as Oculus and Kinect, there is a significant drive for users to be able to interact with the augmented "smart world".

The Tyndall CONNECT team, led by Brendan O'Flynn and the Wireless Sensor Networks group, is developing the data analytics and algorithms for data acquisition and point tracking based on the next generation lens-less optical sensors being developed by Rambus which will enable low-power consumption location-aware tracking systems.

Rambus had worked with Tyndall prior to the CONNECT programme. As a former Rambus employee, Tyndall CEO, Kieran Drain was responsible for connecting the two organisations, knowing there was a positive overlap between Tyndall's capabilities and the ambitions of Rambus.

"Tyndall has much broader capabilities than my smaller team at Rambus and it is good to access and leverage that expertise to work on our programme," said Mark Kellam, Technical Director at Rambus.

Mark describes the interaction with Tyndall as fruitful and positive. As he sees it, "This is just the beginning. We will continue to develop breakout products and services in a collaborative, synergistic way with our customers and partners, while continuing to look far into the future to solve the difficult technology challenges of tomorrow."







## eblanaphotonics

### Eblana Photonics – a home grown success story

Eblana Photonics is an Irish SME success story with origins in advanced research programmes in photonics, involving Ireland's leading research centres including Tyndall.

"While Eblana has developed and enhanced the original licensed technology, resulting from a collaboration between Tyndall and Trinity College Dublin, everything we sell today still has its basis in that original technology," said Jim Somers, CEO of Eblana Photonics.

Over the years Eblana has developed a range of products focused in two key fields, namely telecommunications and data, and laser gas-sensing detectors.

Eblana is to the forefront of global technological developments in photonic systems for advanced communications and other sectors. Meanwhile, its single mode lasers are used extensively for high-sensitivity detection of gases such as Carbon Dioxide (CO<sub>2</sub>), Methane (NH<sub>3</sub>), Ammonia (CH<sub>4</sub>) and Hydrogen Fluoride (HF). Eblana's technology platform delivers unrivalled wavelength uniformity and stability which is critical for these applications.

Jim Somers reported, "We have grown into a very profitable company and while much of that success is down to our own staff, we also acknowledge that Tyndall's resources and researchers have contributed to Eblana's growth."

Eblana is now one of the global players in low-power lasers for industrial applications. "We are probably the largest supplier into the industrial laser-based sensing market today, from a start position just five years ago," said Somers.

Eblana has experienced an average 30% revenue growth per annum over the past five years and now employs 20 people, two thirds of whom are at doctorate level. It has identified telecommunications as an area of high future growth and opportunity, and while Eblana is a small player in this area today, it has aggressive plans for growth in that sector.

According to Somers, "We continue to work with Tyndall because of its expertise in laser physics and semiconductor device fabrication. Tyndall's capabilities and facilities have improved, especially in photonics and photonics integration. The research work that Tyndall has carried out for us in the area of photonics is critical."

The relationship is set to continue with Eblana signing a new agreement with SFI research centre IPIC at Tyndall, starting in 2017. The purpose is to leverage the significant specialised equipment, together with IPIC's photonic manufacturing capabilities, to help develop future products.

"Many researchers within Tyndall and IPIC are highly regarded experts in their fields worldwide, and to be able to tap into this level of expertise, on our doorstep, is very significant for a growing company such as Eblana. It's a great testament to government investment in research facilities," concluded Somers.



## Boston Scientific - Enabling smaller implantable pacemakers in the future

Boston Scientific began working with the Tyndall-hosted microelectronic circuits technology centre MCCI in 2013, on what Michael Kane, Process Development Fellow at Boston Scientific, describes as a 'significant project' to seek alternative architectures for implantable medical devices.

"We are world leaders in ultra-low power medical devices and we needed a partner to research the possibilities of leveraging and applying emerging mobile technologies to medical applications. It was a large and complicated project, with funding just shy of €1m."

He also points out that there were constraints around this project, for example much as Boston Scientific respected the people at Tyndall they had to be cautious and could only give enough information to let the Tyndall engineers design and manage their own solutions.

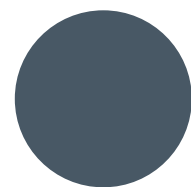
Kane is very positive in his praise for the team he worked with at MCCI and suggests that, "MCCI is a standout, high functioning group in terms of technology leadership and outputs."

In response to the brief from Boston Scientific, MCCI developed an ultra-low power, custom ASIC (Application-Specific Integrated Circuit) that contains all the sense channels and stimulation circuitry required, that fits within a 10-year battery lifetime window.

The prototype chip which supports pacemaker and neuro-stimulation therapy applications, also incorporates a novel instrumentation amplifier to allow pacemaker devices to more effectively sense bio-potential signals.

MCCI combined the pacemaker and other novel circuits into a single chip in order to make them smarter, more sensitive and more power-efficient.

The programmable IC uses separate channels on a single chip for sensing the activity of the heart and for setting the pace of beating. This research will enable smaller implantable pacemakers in the future, which would result in less invasive implant procedures, while devices would need to be replaced less frequently.





## Henkel and Tyndall – understanding needs.

Henkel has had a presence in Ireland since 1966, and in 1974 it became one of the first multinational companies to build a research and development centre here.

According to Matthew Holloway, Technical Director of Henkel's Technology Centre in Dublin, "Henkel has probably one of the largest material science R&D centres in Ireland, with up to 120 people working in our R&D Centre, with over 50% PhD qualified. We are very committed to R&D and while in the past we had a strong focus on machinery adhesives and super glue, our conventional core chemistries, more recently we are looking to evolve into other areas of interest and have sought opportunities to collaborate with researchers in the field of 3D printing and printed/flexible electronics."

When Matthew Holloway joined the Dublin operation in 1994, Henkel already had a long standing relationship in place with Tyndall. "We consult with Tyndall when we require electronics expertise. We have a strong interest in the materials side of research while Tyndall can add electronics expertise - that's our overlap."

For example, Tyndall worked for Henkel on a major project focussed on MLD (Molecular Layer Deposition), a subset of ALD (Atomic Layer Deposition) an activity in which Tyndall is regarded as a world leader. This is an area of relevance for Henkel within its global electronics business."

When that project concluded in 2013, Henkel went on to sponsor a PhD student who is focused on research in MLD of acrylates. This utilised Cyanoacrylates which are a key chemistry in adhesives sold under the Henkel Loctite brand.

Holloway finds that having a researcher in situ at Tyndall is a good way to continue to build the relationship. "We have quarterly reviews as part of that sponsorship. These are face-to-face reviews either at Tyndall or Henkel that provide a great opportunity to discuss what's going on more generally within our organisations. The communication channel is kept open."

"A key benefit of working with Tyndall is that they have a strong understanding of what our future research needs are, and how they align with market trends. One of these is the convergence of ICT into the healthcare market. Ireland is an excellent location to develop new innovation and products for the healthcare industry given the scale of its medtech and pharmaceutical industries. Tyndall has been very astute in targetting this through its ICT for Health programme."





## An enduring and strengthened relationship with Applied Materials

Applied Materials is the leader in materials engineering solutions used to produce virtually every new chip and advanced display in the world.

Its expertise in modifying materials at atomic levels and on an industrial scale enables customers to transform possibilities into reality. With its diverse technology capabilities, Applied Materials delivers manufacturing equipment, services and software to the global semiconductor, display and related industries.

Applied Material's long-term growth strategy requires continued development of new materials engineering capabilities and over the last five years the company has spent an average of 15% of net sales in research, development and engineering.

They engage Tyndall to discover and assess relevant emerging technologies and disruptive approaches to long-standing challenges.

Applied Materials Ireland joined the Science Foundation Ireland-funded Strategic Research Cluster FORME (Functional Oxides and Related Materials for Electronics) in 2011, with the support and encouragement of the IDA. The research cluster, led by Tyndall, focused on the development of materials and processes to enable the production of faster, smaller, more power-efficient logic processors for computing and associated memory and data storage applications.

"We were impressed with both the results and capabilities demonstrated by Tyndall during this engagement," said Dr Paul Ma, Senior Director of Process Engineering at Applied Materials.

As part of this programme, Applied Materials provided and installed multi-chamber state-of-the-art Atomic Layer Deposition (ALD) equipment at Tyndall.

In addition, James Connolly from Applied Materials Ireland serves as a Researcher-in-Residence working directly alongside Tyndall academic and industry partners. This really helped to enhance the value of the ongoing engagement with Tyndall.

"Since 2011 we have increased our engagement with Tyndall both on ALD-related topics and other areas of interest where Tyndall demonstrates world-class research capabilities, and this collaboration has gone from strength to strength," said Michael Hill, Applied Materials Ireland Country President.

# Agency-funded centres



*Prof. Paul Townsend, Director of IPIC,  
Head of Photonics Centre, Tyndall*

## What is your centre's mission?

IPIC's mission is to deliver excellence in photonics research and advance and miniaturise photonics integration science in order to develop leading-edge technologies and products.

## Why is it important?

Our work focuses on developing the next generation of highly-compact and miniaturised photonics technologies in order to tackle some of society's greatest challenges, especially in the areas of ICT and health. This includes:

- Revolutionising the speed of data transfer for the continued growth of the internet
- Delivering new smart medical devices for improved patient outcome
- Developing highly compact instrumentation for point-of-care diagnostics and wearable devices
- Developing systems for process and environmental monitoring

## How has your mission progressed in 2016?

At the end of 2016, IPIC's third year of operation, the centre's research programmes are delivering IPIC's three target outputs of scientific excellence, the development of high skilled trainees and economic impact. This is demonstrated by the 227 publications associated with IPIC to date and over 38 projects with industry partners.

Also, IPIC Deputy Director, Dr Peter O'Brien is leading Horizon 2020 funded project PIXAPP which will establish the world's first open access Photonic Integrated Circuit (PIC) assembly and packaging pilot line.

## What was your key highlight?

The recruitment of Prof. Stefan Andersson-Engels who is establishing a new, 15 person-plus biophotonics group with funding from SFI under his recent Research Professorship Award.

## What are you excited about for 2017?

IPIC and Tyndall are hosting the third edition of the European Photonics Venture Forum (EPVF) which will take place on 10 & 11 May 2017 in Dublin. The event will ensure photonics becomes a pillar of local regional development plans, mirroring the European strategy and driving more support and funding to the sector.



*Dr Alan Mathewson, Assistant  
Director & PI, CONNECT Centre*

## What is your centre's mission?

CONNECT is the SFI research centre for future networks and communications. In this context, 'networks' refers to the end-to-end system including responsive things, which is the area in which Tyndall is contributing expertise in smart sensors, energy storage and energy harvesting.

## Why is it important?

Communications networks are now a vital part of society's critical infrastructure. CONNECT research, in collaboration with over 35 industry partners, is connecting and sensorising everyday things, leading to new products and services including improved healthcare and food production, these are applications which will benefit us all. The Internet of Things is a burgeoning field of research and we expect significant job creation as a result of Tyndall-CONNECT success.

## How has your mission progressed in 2016?

The Tyndall CONNECT team worked on several industry projects, delivering excellent results in all cases. Platform research blossomed with a new cohort of staff and students reflecting an increase in publications and presentations in 2016. Information on the research has been provided at all levels and our outreach and public engagement programme has helped enhance the public perception of our work within the centre.

## What was your key highlight?

In 2016, work from different research groups was brought together to create a new and innovative system for disease detection in farm animals. The funding available from SFI enabled the different components to be integrated together to create a new and innovative product which was awarded an innovation award at the 2016 National Ploughing Championships.

## What are you excited about for 2017?

Follow-on and new industry projects are ahead of schedule for 2017, and more new researchers will be hired on foot of these funding successes. The additional staff will add to the breadth of work in line with our long-term strategy, and will result in more demonstrable impact from the funding that we receive through the creation of jobs in Ireland and new and innovative products. These will be announced as they arise as part of our public engagement programme.



*David Gibbons, Manager, ESA  
Space Solutions Centre Ireland*

### **What is your centre's mission?**

To inspire and facilitate the use of space technology, systems and know-how for space and non-space applications.

### **Why is it important?**

We will boost the Irish "space" industry and the Irish economy by identifying new business opportunities for providers of space technology and systems as well as enhancing its know-how and competitiveness. We will create jobs, invest in start-ups and support sustainable innovation.

### **How has your mission progressed in 2016?**

ESA Space Solutions Centre Ireland was launched in September 2016, with a lot of interest from industry, media and the general public.

### **What was your key highlight?**

The highlight for 2016 was the official launch by Minister for Jobs, Enterprise and Innovation Mary Mitchell O'Connor TD and Franco Ongaro, the head of ESA's ESTEC facility along with over 200 guests from industry, academia, media and government agencies. This resulted in a significant number of enquiries about the centre and generated a lot of media attention, establishing the centre in the nation's infrastructure and generating a very positive response to the centre's existence.

### **What are you excited about for 2017?**

Maintaining the momentum from the launch and establishment of the Space Solutions Centre, this will progress with the first Tender Evaluation Board sitting in January 2017 and the selection of the first two companies for the ESA Business Incubator Centre (ESA BIC).



*Prof. Tony Day, Director, IERC*

### **What is your centre's mission?**

The International Energy Research Centre (IERC) is working to provide world-class, collaborative and market-facing energy research.

### **Why is it important?**

The IERC has established itself as a distinctive research operation within Ireland that is capable of delivering new research solutions in a highly collaborative framework.

Projects from the IERC have covered energy harvesting, energy monitoring and auditing, heat exchange materials, human behaviour, public engagement mechanisms and community trading on the grid. Tangible project outcomes include jobs, industry collaboration, prototypes, datasets, invention disclosures and demonstrable behavioural change in consumers.

### **How has your mission progressed in 2016?**

We advanced national policy through the engagement of international experts in discussions at our conference in May. Under the theme of 'Delivering a Low Carbon Future: Transformative Technologies and Trends', sessions included contributions from research, industry and policy experts in areas such as distributed generation systems, empowering energy systems, low carbon heating and cooling and a final session on energy efficiency and carbon management. We also held a research showcase highlighting the expertise and outcomes of the work of our core team. A platform for engagement was extended to Energy Cork and ASHRAE Ireland who participated in the research showcase as exhibitors.

### **What was your key highlight?**

In 2016, we focused on developing collaborative projects with industry partners. Our key highlight was the ExpertMV project which brought together a technology company, an industrial services provider and the IERC. The main focus involves delivering a software tool that will provide a reliable approach to executing energy audits and offer a more transparent means of verifying savings.

### **What are you excited about for 2017?**

We are excited about a number of new collaborative projects ranging from the development of a renewable gas certification scheme for Ireland to the optimisation of air source heat pump applications in residential nearly zero-energy building retrofits.





*Donnacha O'Riordan, Director, MCCI*

### What is your centre's mission?

Microelectronics are at the heart of all technology and our mission is to support the growth of the industry. Our focus is on high impact research outcomes and the development of our researchers into independent thinkers and future leaders in circuit design. We will position Ireland as a world leader in circuit research, generating opportunities for new foreign direct investment and for indigenous companies to scale to a global level.

### Why is it important?

We provide key enabling technology that generates new opportunities in areas such as future communications, medical devices, smart food and smart agriculture which means our work is important to future-proof the growth of the Irish economy. Our research strategy is informed by key application and system level requirements and from our industry partners. Our ability to leverage knowledge embedded in our research hubs with Tyndall, University of Limerick, University College Dublin, Cork Institute of Technology, Maynooth University and Carlow Institute of Technology is of huge benefit to our member companies. We have the very best researchers in microelectronics in Ireland working with us to deliver high-impact research outcomes in their areas of expertise.

### How has your mission progressed in 2016?

After seven years, MCCI is running in a steady state with 31 industry members to date. We have increased overall funding to approximately €5m per annum supporting the work of 68 staff. There have been 10 commercial licenses and 28 staff transfers to industry. We had over 50 publications including 11 at tier one conferences and journals, showing the increasing research quality that has attracted world-class international talent. MCCI member companies have created over 1,000 new jobs with MCCI playing a role in over 200 of these.

### What was your key highlight?

Medtech projects continue to strengthen the core research themes for us, providing additional IP and skilled staff to be hired by semiconductor companies. We can support new and disruptive Irish start-ups in the medtech space by providing circuit research that enables new applications. This provides an environment where MCCI can increase company engagement and have a large impact on jobs and turnover.

Our successful research collaboration with Boston Scientific through a two-year Innovation Partnership grant supported by Enterprise Ireland and led by Gerry McGlinchey and Dr Ivan O'Connell was a big highlight for us. A new nanotech chip developed by MCCI in collaboration with the medtech giant will enable next generation pacemakers and neurostimulators.

### What are you excited about for 2017?

We have had a number of high profile project successes, which is attracting undergraduate students to pursue electronic engineering as field of study. We are delighted to witness the increase in students pursuing graduate studies in mixed signal circuit's design. The microelectronics research landscape has been reinvigorated through the industry-academic collaborations and dynamic business partnerships with MCCI member companies.

# Supporting Industry

2016 was an exciting year for the Tyndall Products and Services (SP&S) centre in both 'front end' device fabrication and 'back end' device forensics. New research projects were supported as we continued to deliver in piezo-electric MEMS, magnetics-on-silicon and nanowire development for next generation CMOS and novel electrochemical sensors.

The centre supported commercial activities for High Potential Start Ups (HPSUs), SMEs and MNCs in device development, materials and device analysis, advanced test and measurement, electronics packaging and pilot manufacture. It was a particularly good year for our design and technology evaluation team who successfully renewed a \$1m contract with Analog Devices for test and measurement services.

Finbarr Waldron and our Microsystems Packaging Laboratory team were awarded Irish Research Laboratory of the Year 2016 at the Irish Lab Awards recognising our capabilities and the team's work on the analysis of space grade components for the European Space Agency and development work for a large range of advanced research activities, including the packaging of magnetics-on-silicon devices.

During the year, we took delivery of new processing equipment which gives us capability in spray coating with polymers and isotropic silicon etching. The tools, an EVG 101 photoresist spray coating system and an SPTS XeF2 etch system, will be used across groups and material types. The spray coater is particularly important for MEMS devices where the surface topography on the wafer is not uniform and where normal photoresist coating techniques would not work. The XeF2 etcher allows us to isotropically etch silicon without damaging surrounding materials – this is essential where we are integrating materials together to deliver the new functionality we seek in the advanced sensors we are developing, such as piezo-electric resonators.



In 2016, we also completed an extensive audit of the fabrication facilities and as a consequence we have identified the key capabilities that require investment in the coming years to allow us to remain competitive both from an international research perspective and in terms of providing commercial services and related support to our industrial partners.

The required capital investment currently under consideration will put us in the leading position in Europe in the areas of nanotechnology and heterogeneous materials and device integration at the atomic scale. The first phase of this infrastructure upgrade is in the process of being specified and procured and we expect to see it in place by the end of 2017.

We believe it is critically important to be able to attract the highest-calibre research projects and people to Tyndall, and we can only do that by providing access to state-of-the-art infrastructure and equipment. We also know from experience that leading edge infrastructure acts as a magnet to MNCs, HPSUs and SMEs, resulting in increased commercial engagements and knowledge creation. This allows us to develop new technologies and products for these companies which translates into increased commercial activity and employment in Ireland by these organisations.

Much of the management of the access to the infrastructure within Tyndall - particularly for European SMEs and HPSUs - takes place through our EU funded infrastructure access programmes such as Ascent, Gateone and Smarter Si.

The following section showcases one such project Ascent - our largest infrastructure programme.



ASCENT provides access to the world's most advanced 14nm and beyond-CMOS nanoelectronics data and test structures in Europe's leading nanofabrication research institutes. The project is funded through the European Union's Excellent Science initiative with the objective of integrating and opening existing research infrastructures of European interest. Coordinated by Tyndall, in partnership with CEA Leti (France) and imec (Belgium), the three institutes offer:

- Fast and easy access to the world's most advanced CMOS technologies and infrastructure
- 14nm CMOS data sets, test chips and 300mm wafers for characterisation
- Flexible fabrication for non-standard nanoscale processing
- Advanced electrical and physical characterisation equipment

Launched in November 2015 ASCENT has had a very successful first year:

- 205 researchers joined the network from 35 countries
- 67 technical enquires were received
- 27 projects were approved
- 14 virtual access projects are underway
- 13 transnational access projects are in progress
- 3 Joint Research Activities have been defined that will enhance the access on offer through improved device forensic techniques, common data formats and benchmarks for new materials patterned on the nanoscale

The impact of this access, and the resulting advances that will be made, will contribute significantly to competitiveness and growth capacity in Europe's nanoelectronics industry and help to keep Europe at the forefront of global nanoelectronics development.

*ASCENT project partners Dr Valentina Terzieva (imec, Belgium) and Dr David Holden (CEA-Leti, France).*





# Skilled graduates



At the end of 2016, there were 105 PhD and 16 Master's degree candidates pursuing their studies at Tyndall. During the year, 18 PhD and 11 Master's degree candidates commenced their studies and 25 students successfully defended their PhD theses by viva voce examinations. We continue to have a diverse and energised graduate student community: 46% of our students are Irish, 23% from the EU (excluding Ireland) and 31% of our students are from outside the EU.

The PhD (Engineering Science) concluded its sixth year of student intake leading to 26 students pursuing their degrees through the programme. The flexibility of the PhD (Engineering Science) curriculum allows students to obtain skills needed to support the diversity of research projects being pursued at Tyndall - the provision of interdisciplinary training reflects well the nature of many of Tyndall's PhD and Master thesis topics.

## Emerging entrepreneurs

We continue to pilot innovative graduate education that is subsequently implemented across the university community. As a clear example, seven of our PhD (Engineering Science) students received the Postgraduate Certificate in Innovation, Commercialisation and Entrepreneurship in 2016, the first cohort of students to do so. In his first report to the UCC Governing Body, UCC President Prof. Patrick O'Shea said of the programme: "The Postgraduate Certificate in Innovation, Commercialisation and Entrepreneurship which is embedded in the structured PhD (Engineering Science) is a testament to the vision of Tyndall National Institute, and the College of Business and Law, who pioneered this progressive and novel initiative. The success of this programme, which had 7 students receiving parchments, has not gone unnoticed in UCC. The Academic Council has recently approved of rolling out this Postgraduate Certificate to all UCC students taking the structured PhD, across the four colleges in UCC. This free additional qualification for PhD students will no doubt enhance the employability of PhD students and act as a significant selling point for PhD education in UCC".



The entrepreneurial spirit of our graduate students is also reflected in the range of awards and prizes honouring their accomplishments. Our PhD and Master's degree candidates successfully highlighted the innovation, creativity and commercialisation of their research in application areas spanning agri-food, communications, energy, environment and health.

*Stefano Facchin, Karen McCarthy, Ludovic Caro, Prasanna Ramaswamy and Dimitrios Kyritsis in Tyndall's Makerspace.*

## Success for the INSPIRE national graduate education programme

The INSPIRE project, underpinning the development of Ireland's graduate education programme in nanosciences and nanotechnologies, concluded in December 2016.

Since its inception in 2008, hundreds of graduate students throughout Ireland have benefited from inter-institutional delivery of technical and transferable skills education including lecture modules and courses, national workshops on nanoscience and nanotechnology, key enabling technologies and entrepreneurship.

Scores of students availed of the INSPIRE mobility fund which enabled them to access research infrastructure at partner institutes and which also supported their participation in the various national education and training initiatives. INSPIRE led the way in introducing various new approaches to PhD education including structured PhD programmes with national accreditation mechanisms for inter-institutional graduate education modules.

Our flagship PhD (Engineering Science) degree programme formed as a collaboration between Tyndall, UCC's College of Science, Engineering and Food Science and College of Business and Law is a vibrant legacy of the collaborative vision of INSPIRE. Also, novel training facilities, enabled through INSPIRE, such as our e-learning lab, semiconductor training facility and Makerspace, continue to underpin and complement our education programmes. The INSPIRE consortium remains committed to work together on developing innovative approaches to graduate education that join different scientific and engineering disciplines through national collaboration.

Tyndall led the INSPIRE consortium consisting of leading universities and institutes of technology including: Cork Institute of Technology, Dublin City University, Dublin Institute of Technology, National University of Ireland - Galway, Trinity College Dublin, University College Cork, University College Dublin and University of Limerick.

## Tyndall Makerspace

Makerspace facilitates the development of a 'maker community' among graduate students and staff at Tyndall and provides a laboratory environment for graduate training focused at the interface between technology development and product design. The dedicated space enables us to develop a module around design and 'making' for engineers and scientists to facilitate ideation, collaboration, problem solving, prototyping and related topics. In 2016 it was used for finishing and refinement of over a dozen major projects including agency-funded centre projects. Our graduate students use the Makerspace facilities to assist their research in areas such as microneedles, flexible electrodes, integrated photonics, photonic ICs, high-speed circuits for data centre optical receivers and swept source lasers.

# Here's what our students think



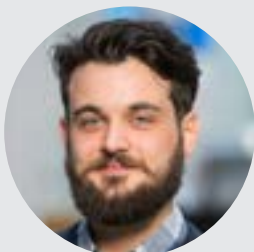
**Jennifer Halpin**

PhD Student, Chemistry

"I did my final year project in Tyndall and continued on with a Masters on developing materials for solar water splitting. One of the things I like most about Tyndall is the close ties to UCC allowing me to be a lab demonstrator for undergraduate chemistry labs and to participate in outreach programmes. I would advise potential students that the city you'll be living in can be just as important as the lab you'll be working in. Luckily Cork has lots to offer in terms of facilities and entertainment."

**PhD research:** Deposition and characterisation of functional metal oxides

**Background:** BSc and MSc Chemistry, UCC. MSc research on "Novel photoanode materials for water splitting applications"



**Gioele Mirabelli**

PhD Student, Electrical and Electronic Engineering

"I got to know Tyndall better while I was an Erasmus student at UCC. Interacting with staff and students and observing the world-class facilities led to my interest in furthering my education at Tyndall. Tyndall's strength is in its variety of state-of-the-art facilities led by world class educators and researchers - these factors ensure immense opportunities for interdisciplinary training and the best mentorships for postgraduates. As a PhD student, you are looking to develop new ideas and build on current ones. Tyndall has given me the necessary resources to collaborate with intelligent and ambitious colleagues and expand on novel research, and has also provided the guidance to express myself independently as a future scientist. I love what I do!"

**PhD research:** Two-dimensional semiconductor materials for future electronics

**Background:** B.Eng and M.Eng in Electronic Engineering from University of Calabria, Cosenza, Italy



**Swatchith Lal**

PhD Student, Engineering Science

"I wanted to work on thermoelectrics. When I saw an exciting position in Tyndall, a little background research convinced me that Tyndall was the best place for my PhD. Tyndall has state-of-the-art facilities and it's an application-focused Institute. I believe that the ultimate success of any research is when it becomes available to the general public. A friendly work environment makes Tyndall a great place to work and the pace at which the research runs is amazing. Tyndall has fantastic resources, offering access to everything you need to do your PhD, and Cork is a great place to study, work and live."

**PhD research:** Micro-thermoelectric cooler for thermal management of photonic devices

**Background:** Mechanical Engineering from Jawaharlal Nehru Technological University-Hyderabad and Masters in Metallurgy and Materials Engineering from National Institute of Technology – Warangal (India)



**Niamh Kavanagh**

PhD Student, Physics

"I did summer projects in Tyndall during my undergraduate degree, I was so impressed with the labs, the people and the work that they were doing here that I went on to apply for a PhD. The people in Tyndall are really friendly and supportive. The high-tech facilities and free tea are pretty nice too! I would advise potential students not to be afraid to ask for help. Also, get involved in outreach opportunities! It's a great way to get to know people in all areas of science and to improve your presentation and communication skills."

**PhD research:** Dense wavelength division multiplexing at 2 microns

**Background:** BSc Physics, UCC



# Student awards and prizes 2016



**Niamh Kavanagh**, Photonics Systems group, was awarded the Rosse Medal by the Institute of Physics for winning the postgraduate student poster and presentation competition. In April, Niamh received first place in the national final of "Famelab" and was also named as one of "6 Rising Stars of Irish Research" and one of "20 incredible women leading the way to scientific advancement" by Silicon Republic. Niamh also received the Institute of Physics Early Career Physics Communicator Award in November. Niamh's research is in the area of dense wavelength division multiplexing at 2 microns.



**Niamh Creedon**, Nanotechnology group, was awarded first place for best presentation for her research on "Soda can templated flexible polymer SERS substrates for multiple sensing applications" at CASi (Conference on Analytical Sciences Ireland) 2016. For her work on the "Development of smart nanosensor systems for on-farm disease diagnostics". Niamh also won a gold medal for most innovative research emerging from 3rd Level, at the 2016 Enterprise Ireland Innovation Arena Awards at the National Ploughing Championships. The award recognises innovative agri-tech capability and new product development in the agriculture sector.



**Moises Jezzini**, Integrated Photonics group, was awarded Best Student Presentation on Packaging at SPIE's Silicon Photonics and Photonic Integrated Circuits Conference, part of Photonics Europe International Symposia held in April, for his paper "Design of a high-speed vertical transition in LTCC for interposers suitable for packaging photonic integrated circuits".



**Catherine Ryan**, Advanced Materials and Surfaces group, received the third place poster award at the third International Conference on Bio-based Polymers and Composites in August. Catherine's research is in the area of design, synthesis and characterisation of chitosan-based interpenetrating polymer networks and thin film systems.



**Stephen Rhatigan**, Materials Modelling for Devices group, was joint winner of a three minute thesis competition at the H2FC conference held in Ulster University. Stephen's talk was "Water splitting - an atomistic study."



**Shauna Scanlon**, Life Science Interface group, received the Best Poster award at the Smart Systems Integration conference in Munich in March 2016 for her poster entitled "Development of a multi-parameter sensing system for PAT application in the food and beverage Industry".



**Justin Alexander**, Integrated Photonics group, won Best Presentation for his three minute elevator pitch at the Tyndall Internal Conference. Justin's presentation was entitled "Integrated optical comb source".



**Jennifer Halpin**, Advanced Materials and Surfaces group, received first prize in UCC's Postgraduate Research Showcase in the three minute masters category. Jennifer's PhD research is in the area of deposition and characterisation of ferroelectric metal oxides.



**Joveria Baig**, III-V Materials and Devices group, was part of the winning team at the IPIC SFI/NDRC Entrepreneurship Bootcamp. The team, also including Muhammad Junaid Amin and Philip Marraccini, impressed the judges with their winning pitch on AutoAssist.



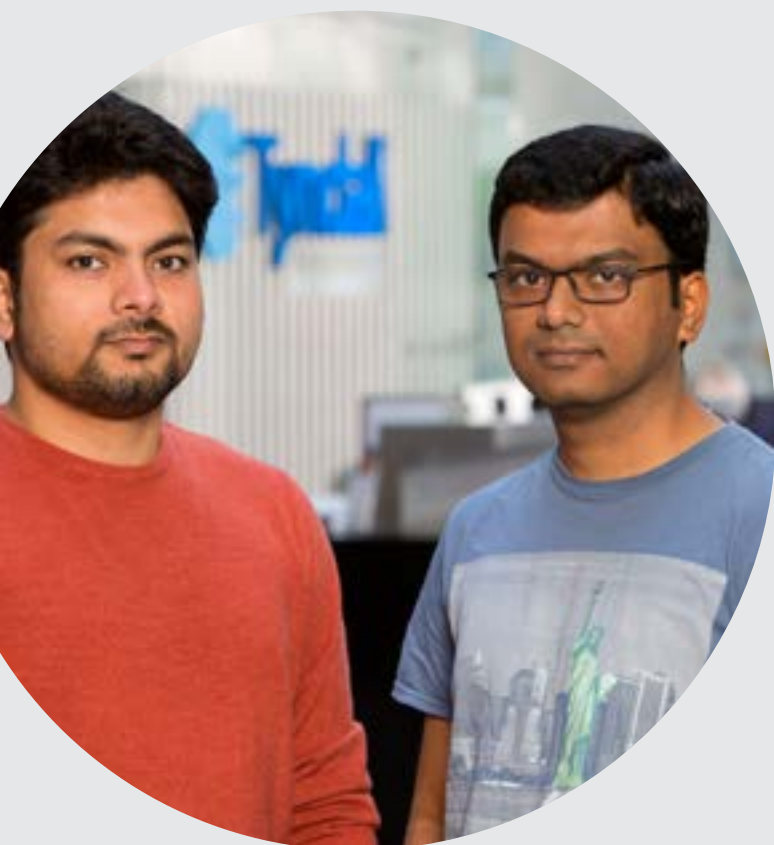
**Amandeep Kaur, Adrian Walsh and Marco Dallasanta** were chosen as finalists in UCC's Entrepreneur of the Year 2016 for their project on Light Solutions. Amandeep and Marco are PhD students with the Photonics Systems group and Adrian's PhD research is with the Nanoelectronic Materials and Devices group.



**Natalia Canes Estrada**, Photonics Systems group, was selected as a Student Ambassador by Education in Ireland, an Enterprise Ireland sponsored initiative. Natalia's research is in the area of terabit superchannels using all-optical technology.

## Graduate Student Poster Competition

The Tyndall Graduate Student Poster Competition is an annual event organised by the Student Committee. It aims to provide a common platform for students working in different domains to come together and exchange ideas, thus creating an atmosphere ideal for collaborative outcomes. The competition is judged by a panel which includes Tyndall Board members, giving them an opportunity to see the ground-breaking research being undertaken by our students. There were 39 entries in this year's competition. First prize was awarded to Stefano Facchin, Photonics Systems group, for his poster entitled "A linear optical receiver in 65nm CMOS technology for 56Gb/s PAM-4 signalling". Lisa Helen, Life Sciences Interface group, won second prize for her work on "A 'smart' needle for objective nerve localisation during ultrasound guided peripheral nerve block". Lisa's research was also awarded Best Commercial Pitch at the Tyndall Internal Conference in April 2016. Third prize in the poster competition was awarded to Muhammad Umar Khan, III-V Materials and Devices group, for his poster entitled, "Resonant waveguides: the future in on-chip sensing?" Congratulations also to the other finalists in the poster competition: Natalia Canas Estrad, Ekaterina Filatova, Daniel Lordan, Louise McGrath and Roxane Puicervert.



## BOC Bursary

The BOC Bursary is an annual award presented by BOC Gases to outstanding Tyndall students. In 2016, the award was presented by Eamon Bolton, Ireland Sales Manager for BOC Gases, and Kieran Drain to the joint winners Ricky Anthony and Dhiman Mallick. Ricky, Electrochemical Materials and Energy group, received the award for his research on developing integrated magnetics technology for power conversion applications. Ricky, along with his teammates Mahbub Akhter and Ertugrul Karademir (TCD), was also awarded runner up prize at the IPIC SFI/NDRC Entrepreneurship Bootcamp. Dhiman, Micropower Systems and Nanomagnetism group, received the BOC award for his work on wideband vibration energy harvesting using electromagnetic transduction for powering the Internet of Things.



# PhD theses 2016

## Electronics

### Colm Barrett

"Low-cost fabrication of nanoelectrodes for electrochemical applications"

### Sean Barry

"Development of nanoelectrodes for electrochemical applications"

### John Buckley

"Antenna design for wireless sensor network applications"

### Paul Cahill

"Vibration based health monitoring of civil infrastructure using energy harvesting techniques"

### Ilias Chlis

"Analysis and design of low phase noise CMOS oscillator circuit topologies"

### Mark Hartnett

"Role of sulfur in vibration spectra and bonding and electronic structure of SiGe surfaces and interfaces"

### Anna Hauber

"Carrier momentum relaxation in highly doped polar semiconductors and polar semiconductor heterostructures"

### Jun Lin

"An investigation of border traps in high-k/InGaAs metal-oxide-semiconductor systems"

### Daniel Lordan

"Alternative materials for flexible transparent electrodes"

### Brendan O'Flynn

"Development and deployment of wireless sensor networks"

### Cormac Ryan

"Characterisation and modelling of degradation mechanisms in RF MEMS capacitive switches during hold down operation"

### Niall Savage

"Development of a novel probe integrated with a micro-structured impedance sensor for the detection of breast cancer"

### Jing Tao

"Nanowires for 3D silicon interconnection"

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## Photonics

### Thomas Butler

"Real-time characterisation of dynamic laser fields"

### Tung Chun

"Arrays of quantum-light-emitting diodes with site-controlled pyramidal quantum dots"

### Simon Fabbri

"All-optical systems for the terabit network era"

### Patrick Finch

"Ultrashort pulse generation in InAs quantum dot semiconductors"

### Umar Khan

"Design and implementation of micro-structures with refractive index contrast for optical interconnects and sensing applications"

### Katarzyna Komolibus

"Emission properties and carrier dynamics of III-V nanostructures for next generation photonic devices"

### Micki Mitchell

"Development and optimisation of photonic crystal based nanosensors"

### Finbarr O'Callaghan

"Dynamics of coupled modes in two-section semiconductor lasers with saturable absorption"

### David O'Shea

"Optically injected multi-mode semiconductor lasers"

### Silvino Presa

"Characterization of GaN-based light-emitting diodes"

### Muhammad Usman Sadiq

"Design and characterization of InP based Mach-Zehnder modulators"

### Nan Ye

"High speed photodiode and 90° optical hybrid for 2 μm optical communication systems"

# International reach



## Industrial Technologies

Tyndall showcased its integrated ICT capabilities to 1,000 attendees at the Industrial Technologies Conference in Amsterdam. Giorgos Fagas and Tom Healy both spoke at the event and Cian O'Murchu presented a poster. We exhibited an array of Tyndall demonstrators at our booth including smart wearables, electrochemical sensors and energy harvesting.

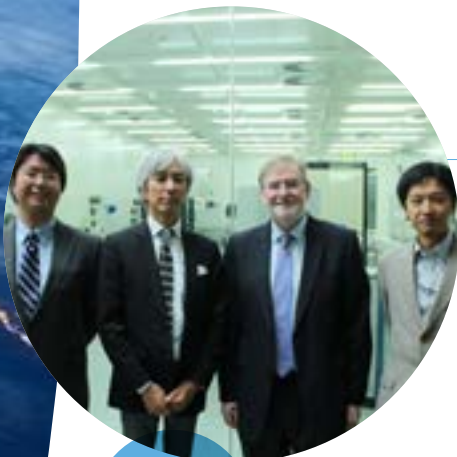


## ALD 2016 Ireland

Dr Simon Elliott co-chaired the 16th International Conference on Atomic Layer Deposition (ALD 2016) in the Convention Centre Dublin. The event is dedicated to the science and technology of atomic layer controlled deposition of thin films and attracted over 800 attendees from across the globe.

## EU Commissioner Phil Hogan

EU Commissioner Phil Hogan received a demonstration of our 'small smart farm', a test bed which uses a variety of wireless sensors to monitor soil conditions. Real time data sets are wirelessly communicated to farmers and 'the cloud', allowing them make better informed decisions on fertilisation and watering requirements on their farms. This technology, enabling 'Precision Agriculture', facilitates optimal resource utilisation and increased production at lower cost.



## Nissan Chemical

Kaoru Yaegashi, iBUC with Makoto Wakabayashi and Yoshikazu Otsuka from Nissan Chemical Japan visited Tyndall to review partnering opportunities in Advanced Materials.

## Samsung, Korea

Dr Simon Elliott gave an invited seminar on simulating Atomic Layer Deposition (ALD) at Samsung Semiconductor R&D Center, Seoul, Korea. Simon was hosted by Master Hanjin Lim, as part of a joint visit with Dr Dennis Hausmann of Lam Research.





## EU Commissioner Carlos Moedas

Carlos Moedas, European Commissioner for Research, Science and Innovation visited Tyndall to discuss the future European Innovation Council (EIC) programme and other aspects of research strategy.



## IPIC – Wuhan MOU

IPIC and the Wuhan East Lake Hi-Tech Development Zone (WHEDZ) signed a Memorandum of Understanding. By developing strong links with China, IPIC is exploring a number of collaborations with industry and academic partners from this area, in particular with the delegation from the Optics Valley of the Wuhan region, China's biggest optoelectronics industry base.



## OVC EXPO, China

Prof. Paul Townsend, Head of Photonics at Tyndall and Director of IPIC, presented an overview of photonics in Ireland and Europe at the opening ceremony of the Optics Valley of China International Optoelectronic Exposition and Forum (OVC EXPO). This event was attended by over 40,000 delegates from 20 countries.



## EC DG CONNECT

Visiting Tyndall to discuss the challenges and opportunities of Digitising European Industry were Ronan Burgess, Deputy Head of Unit Photonics, Willy van Puymbroeck, Head of Unit Competitive Electronics Industry, and subsequently Head of Unit Corporate Financial Procurement and Policy Solutions, and Khalil Rouhana, Deputy Director-General of DG CONNECT, the European Commission Directorate-General for Communications Networks, Content and Technology.







## Eco-India

2016 marked the successful completion of the ECO-India FP7 project, which focused on developing innovative, cost-effective, energy-efficient and sustainable approaches for producing potable water at community level. ECO-India was co-funded by the European Commission and the Government of India, Department of Science & Technology. Aidan Quinn and Mary Manning from Tyndall's Nanotechnology group led the European consortium for this 42 month project. Prof. Asis Mazumdar from Jadavpur University, Kolkata led the Indian consortium.



## PSMA

Power Sources Manufacturers Association (PSMA) executive director Joe Horzempa welcomed Tyndall's Michael Hayes to his role as Vice President of the Association.

## Bluetooth co-inventor

Dr Sven Mattisson, the co-inventor of Bluetooth, presented a mini-workshop on "Low-Power Radio for the Internet of Everything". The event was co-sponsored by the IEEE Solid-State Circuits Society and the SFI research centre CONNECT.



## John Bell and Barend Verachttert

Tyndall showcased its capabilities in smart agriculture and precision farming to Barend Verachttert, Deputy Head and Acting Head of Unit Agri-Food Chain, and John Bell, Head of Directorate – Bioeconomy at the European Commission, DG for Research and Innovation.

# Outreach

50 transition year students completed work experience at Tyndall



850 primary-school students participated in our Secret Spectrum Workshop



Organised Famelab Cork heat and Tyndall PhD student, Niamh Kavanagh, went on to win the national title





1,800 people visited The 'Sum of all Parts' exhibition by artist Angela Gilmour



Engaged 795 secondary school students at workshops and talks

12,000 people participated in Cork Science Festival which was organised by IPIC, APC and MaREI



1,000 attendees enjoyed a Tyndall-developed laser game at the Dublin Maker Festival



315 primary-school students participated in our printmaking STEAM Workshops

160 people attended Tyndall MakerDojo workshops







# Financial



# Income and expenditure summary

Income	2016	2015
	€000s	€000s
Government grant	3,500	3,400
Research	27,301	26,066
UCC contribution	2,142	2,151
	<b>32,943</b>	<b>31,617</b>

Expenditure	2016	2015
	€000s	€000s
Remuneration costs	20,253	20,185
Equipment and infrastructure	2,251	2,509
Consumables and related costs	8,700	8,446
Other operating and deferred costs	1,739	477
	<b>32,943</b>	<b>31,617</b>

# Board



**Dr Kieran F. Drain**  
CEO



**Mr Eoin O'Driscoll**  
Chairman



**Prof. Anita Maguire**  
University College Cork



**Mr Marcus Breathnach**  
Department of Jobs, Enterprise  
and Innovation



**Dr Ann Kelleher**  
Intel



**Mr Ian Quinn**



**Mr John Mullins**  
Amarengo



**Mr Kevin Fielding**  
Alta Berkeley



**Dr Lisa Amini**  
IBM TJ Watson Research Centre



**Ms Patricia Reilly**  
Member of Cabinet, Education,  
Culture, Youth and Sport, EC

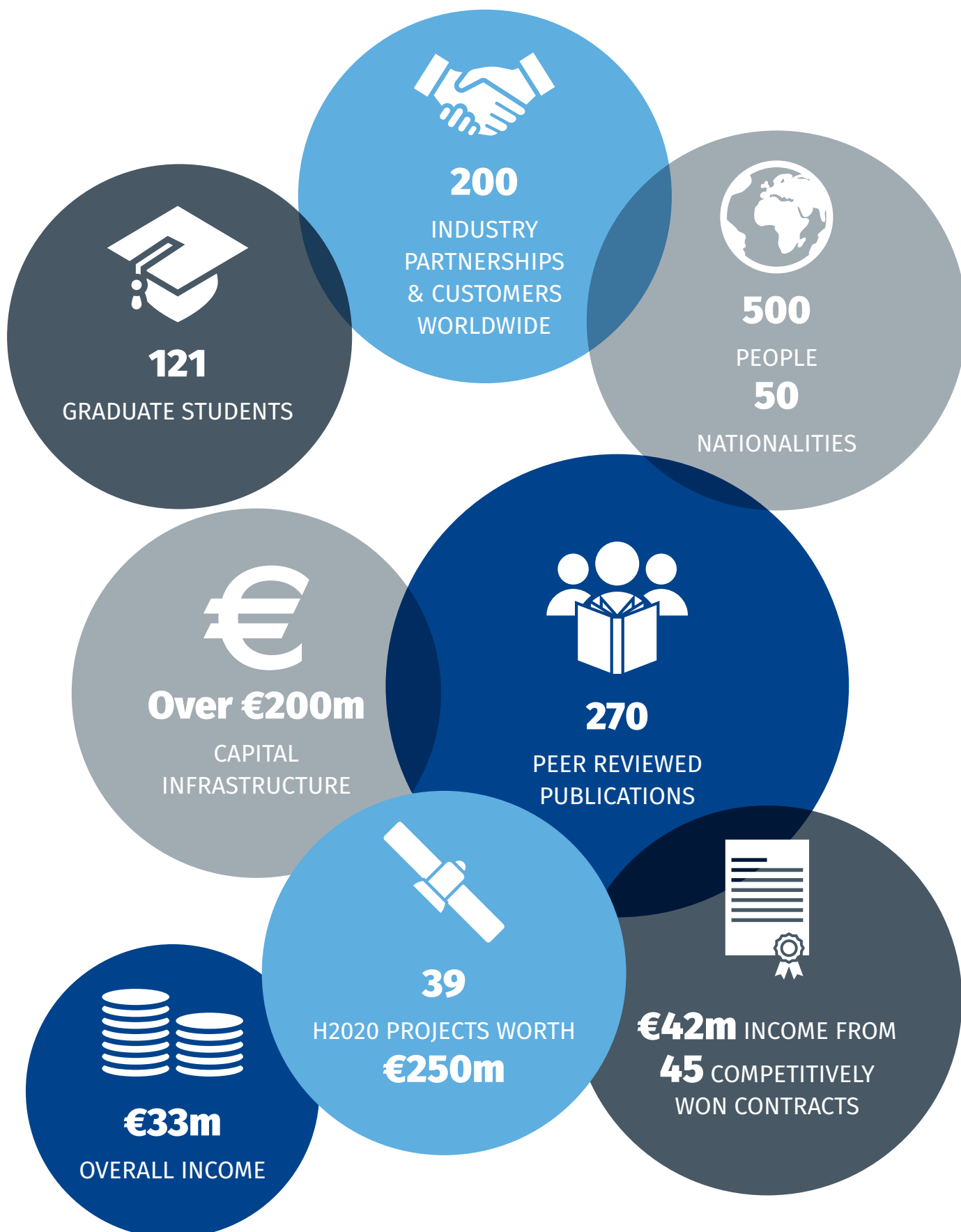


**Prof. Steven Ringel**  
Ohio State University



**Prof. Em. Willy Sansen**  
KU Leuven

# Tyndall in numbers





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[tyndall.ie](http://tyndall.ie)



**European Union**  
European Regional  
Development Fund