
ARC Centre of Excellence in Exciton Science

Annual Report 2017

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A female PhD student with blonde hair, wearing red safety glasses and a white lab coat, is smiling while working in a laboratory. She is using a pipette to transfer liquid into a multi-well plate. The background shows laboratory equipment and shelves.

Our Centre

Our Centre

Vision

At the Australian Research Council Centre of Excellence in Exciton Science, we are committed to building a sustainable energy future where light of all types powers our world.

Mission

We aim to develop the capability to control the position, lifetime and interaction of excitons in a wide range of materials, and use these capabilities to deliver solutions to challenging problems in energy generation, lighting and security.

Who we are

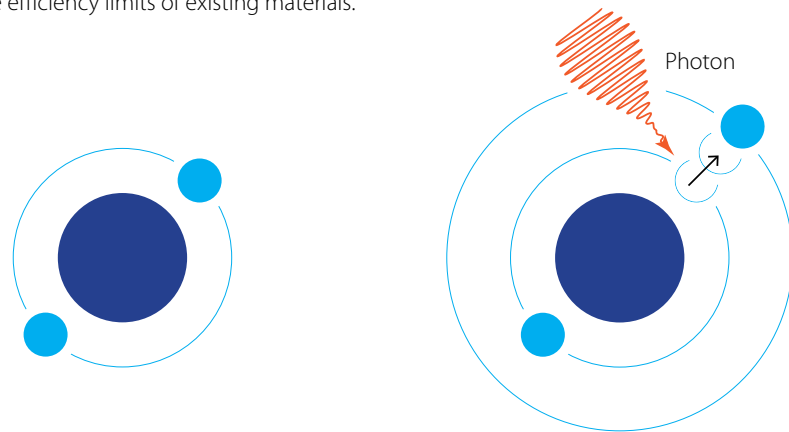
A collaboration between the University of Melbourne, Monash University, RMIT University, UNSW and the University of Sydney, the Centre is working with Partners from across the globe to discover new ways to source and use energy. We also work with our Australian Industry Partners – CSIRO (Commonwealth Scientific and Industrial Research Organisation), the Reserve Bank of Australia (RBA) and the Defence Science and Technology Group (DSTG) – and are proudly an Australian Research Council (ARC) Centre of Excellence.

An international group of Partners contributes expertise and opportunities for student advancement. Our Centre's International Partners are the Universität Ulm, Universität Bayreuth, Shandong University, Chinese Academy of Sciences at Chongqing Institute of Green and Intelligent Technology, Huazhong University of Science and Technology and University of California, Berkeley.

The Centre's primary source of funding is the ARC, through its Centres of Excellence program, which provides \$4.5 million per annum. Our administering institution, the University of Melbourne, and our collaborating institutions – Monash University, University of New South Wales, the University of Sydney, and RMIT University – also contribute \$1.3 million in cash per year.

What is an exciton?

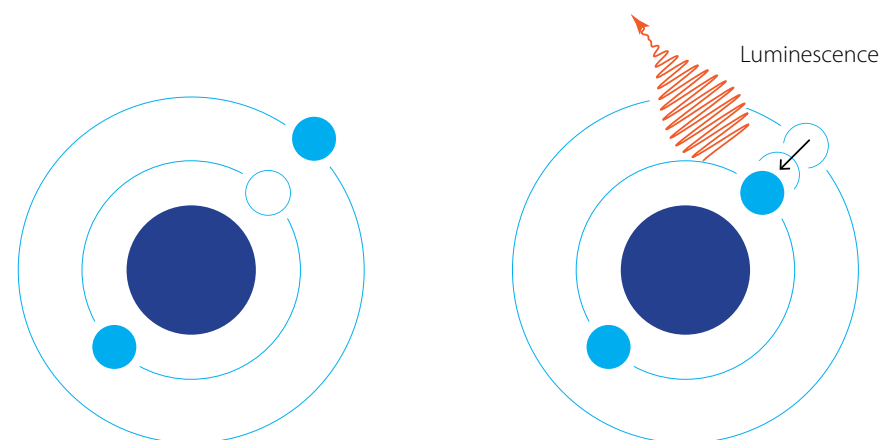
Excitons are bound electron-hole pairs that are central to the conversion of light into energy and energy into light. As such, excitons lie at the heart of many of the most important energy challenges facing society. Excitonic materials are extremely efficient absorbers of light, possess excellent light emission properties and can exhibit a variety of unique phenomena that can enable us to move beyond the efficiency limits of existing materials.



Excitons

All atoms consist of light, fast moving, negatively charged electrons (blue circles) in orbit around a nucleus of positive charge (dark blue circle).

When a photon passes an atom, molecule or crystal, it can be absorbed by an electron, thereby raising the energy of the electron. This corresponds to lifting it from one orbit to another, higher energy one.



The empty orbit that is left behind is called a hole (white circle) – the combination of the electron and the hole is termed an exciton.

Excitons typically only live for a few nanoseconds (10^{-9} sec). The electron usually jumps back down to the orbit it vacated and releases the energy again. This can be as light (luminescence) but in most materials the energy is released as heat – lots of tiny packets of energy. In this way, the energy from the sun is converted every second into the heat we feel all around us. Look at a patch of grass in your garden. On a sunny day, more than 10^{20} excitons are created per square metre every second!

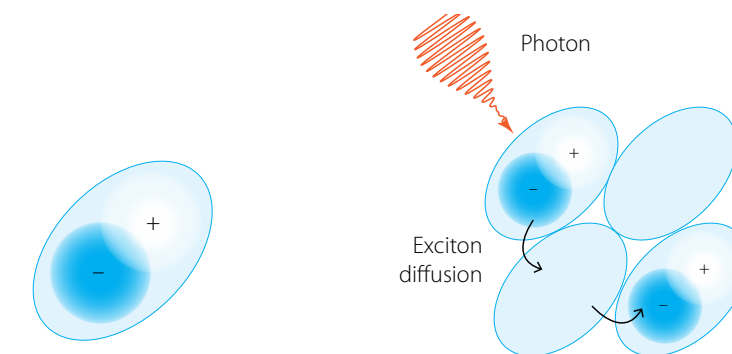
Exciton pathways



Molecules

Molecules are made up of groups of atoms. In a molecule (blue ellipse), the motion of the electrons is much more complex.

Typically, the negatively charged electron moves around the whole molecule so its position is less defined.

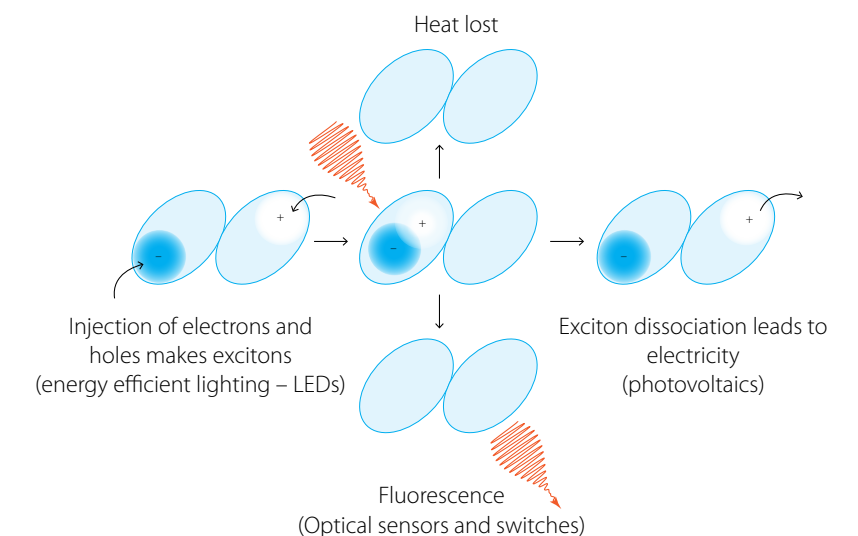


The exciton can be considered as two fuzzy clouds corresponding to the electron and the hole. Since the molecule in its entirety is neutral, the hole behaves as though it has a positive charge. The electron and the hole are attracted to each other and move as a pair.

If we make a crystal from molecules or atoms, then the exciton can move through the crystal before it decays. This fact is crucial for making devices such as solar cells, light emitting diodes (LEDs), photodetectors, sensors and transistors.

Exciton pathways

At the Centre we look at how excitons behave in different sorts of materials ranging from conducting polymers and inorganic perovskites, through to quantum dots, upconverters and dye molecules. Two processes are of special interest: the conversion of excitons into electricity (photovoltaics), and the use of electrical currents to create excitons and, hence, light. This process is at the heart of light-emitting diodes (LEDs), the most energy efficient form of light generation and also forms the basis for lasers.



Director's report

It's been an exciting first year and I am proud to say that our Centre has quickly transitioned from a well-planned idea into a multidisciplinary research organisation. With an exceptional team of 15 Chief Investigators (CIs), along with another three from our Industry Partners, we have developed a collaborative research program based around three Themes:

1. Excitonic Systems for Solar Energy Conversion
2. Control of Excitons
3. Exciton Solutions for Industry.

With 32 postdoctoral researchers and 62 graduate students across our five nodes, we are providing high-quality training and building capacity for a skilled workforce that will help Australia transition to a sustainable and efficient energy future.

In our first year, we were successful in attracting world-class researchers, research scientists and engineers to join our Centre. This team was assembled for the first time at our inaugural Annual Workshop, which brought together 115 staff, students and stakeholders and included research leaders from Massachusetts Institute of Technology (MIT), Cambridge University and National Chiao Tung University in Taiwan.

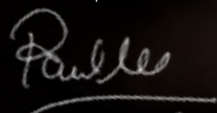
The International Scientific Advisory Committee (ISAC) met for the first time on 12 December 2017. We are privileged to have Professors Neil Greenham, Hiroshi Masuhara and Marc Baldo on our ISAC, and we thank them for their guidance, advice and key recommendations as we begin implementing

our core programs. We were also pleased to have ISAC members attend the launch of our Centre, which took place at the University of Melbourne's Bio21 Institute on 13 December 2017, with 120 people in attendance.

We have been fortunate to have Professor Margaret Sheil, University of Melbourne Provost, as Chair of our Advisory Board. However, with Professor Sheil moving to Queensland University of Technology, we welcome new Provost Professor Mark Considine as Chair in 2018.

With all the start-up activity, planning, recruiting, strategising and collaboration I am pleased to report our researchers and scientists have already published a number of quality papers in prestigious journals (see pp.35–36).

Every researcher, Chief Investigator, Board member, professional staffer and student has greatly contributed to the success of the Centre in its first year of operation. I am proud to be the Director of a world-leading Centre for the study of Exciton Science and I am looking forward to 2018 as we continue to produce innovative research.



Professor Paul Mulvaney
Director, ARC Centre of Excellence in Exciton Science

Chair's report

This year the Australian Research Council Centre of Excellence in Exciton Science took the first steps in an exciting journey that brings together the brightest researchers from around the country to explore innovative ways to source energy. Through their work, the Centre will lead to changes in the way that Australians use solar power.

Our first achievement, and a crucial step in encouraging collaboration, was the negotiation, agreement and execution of the Centre contract across five Australian Academic Partners, six International Partner Organisations and three Industry Partners. There were countless drafts, emails, phone calls and meetings to agree and finally contract with all our Partners. None of this would have been possible without the tireless work of the research administration staff across the Centre, particularly in Research, Innovation and Commercialisation at the University of Melbourne.

Essential to the success of the Centre are the people who comprise it. Our Director, the highly regarded Professor Paul Mulvaney, and his talented interdisciplinary team of Chief Investigators have worked hard over the past six months to recruit world-class postdoctoral researchers and postgraduate students. By the end of 2017 many of them had started on their projects and the rest will soon be in their positions. The Centre now boasts a bright and capable body of researchers from many countries with a healthy gender balance.

In 2018, I will be stepping aside from my role as Chair of this Centre to take on a new role at QUT. It has been an honour to be part of the Centre during this exciting start-up phase, and I thank Director Paul Mulvaney and his team for their energy and hard work. I wish all the best to my successor and will continue to follow with interest the important research the Centre will undertake.



Professor Margaret Sheil
Chair, Centre Advisory Board, ARC Centre of Excellence in Exciton Science

Operations overview 2017



themes, enabling capacities and teams should be structured.

Our Chief Investigators presented their research and roles at the Centre, while our postdoctoral researchers engaged in media training as well as research poster and publication competitions. All participants were able to network and form research connections quickly in an informal setting. As a result, the Workshop proved a valuable way for researchers to get to know and understand the vision of the Centre and how they are contributing to its impact and significance. A special note of thanks goes to MC Salvy Russo, who ran the Chocaholics Quiz.

Our Outreach and Education Manager, Monica Brockmyre, with support from Outreach, Education and Governance Director, Associate Professor Dane McCamey, completed a Centre-wide presentation program outlining the importance of outreach and communications for reaching the Centre's goals. The Outreach program started with two public talks at the

The Centre... advertised internationally, sought out high-performing candidates through our networks and recruited more than 30 outstanding postdoctoral researchers.

On 1 July 2017 the Centre successfully executed all the financial and intellectual property (IP) agreements and started building the foundations of a new Centre. The Executive Committee began to meet monthly and started setting up the research and operational framework. The International Scientific Advisory Committee met to assess our operations and prepared a report that offers guidance and highlights perceived risks that the Centre will need to mitigate through its risk management structure at the Executive Committee meetings.

The research program continued to evolve as Theme Leaders and Platform Champions began to employ project principles to structure our timelines and research dependencies.

The Centre began to attract and recruit world-class researchers. We advertised internationally, sought out high-performing candidates through

our networks and recruited more than 30 outstanding postdoctoral researchers.

The recruitment of professional staff also continued and, by the end of 2017, the Centre had a complete management team in place consisting of a Chief Operating Officer, an Outreach and Education Manager, a Finance Officer, and an Operations staff member at each university (see Our People, pp.42–49, for full list of staff and students). A Business Development Officer will be recruited as the Centre begins to create IP from its research activities.

The Centre has engaged the expertise of international researchers at Shandong University, Huazhong University of Science and Technology and the Chinese Academy of Sciences at Chongqing Institute of Green and Intelligent Technology in China; Universität Bayreuth and the Universität Ulm in Germany; University of

California, Berkeley and Massachusetts Institute of Technology Centre for Excitonics in the United States of America (USA); and Cambridge University in the United Kingdom. We are also pleased to welcome a new International Partner to the Centre, the South China Normal University, Guangzhou, to work with us on next-generation display devices.

Our inaugural Annual Workshop, held at Pepper's Moonah from 10 to 13 December 2017, brought together the Centre's Chief Investigators, International Scientific Advisory Board members, postdoctoral researchers, PhD and Masters students, professional staff and industry representatives for four days of scientific presentations, discussions, networking and training. It was the first opportunity to introduce the research program to staff and students, and how our research and research

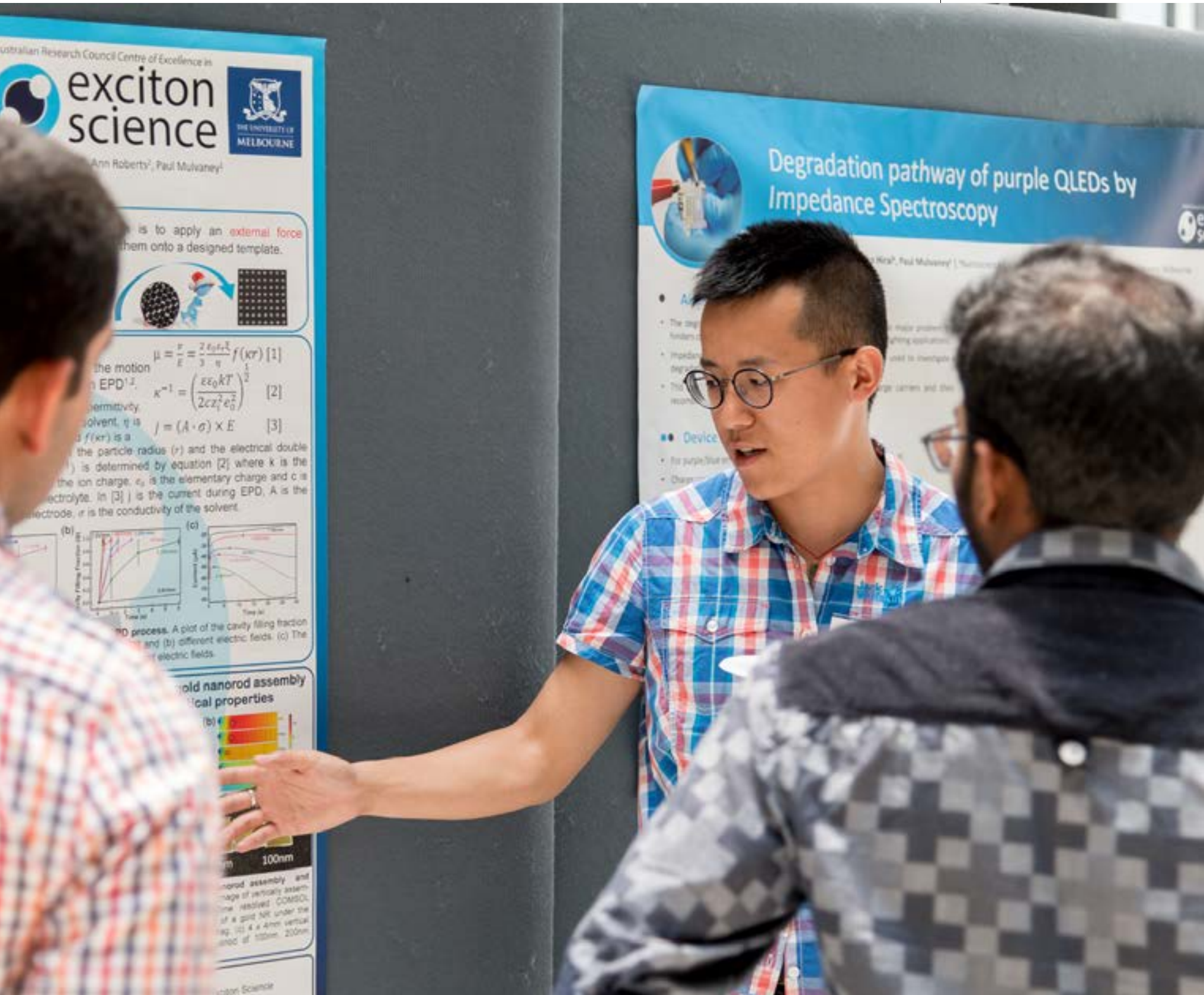
University of Sydney and the University of New South Wales. Tanya Ha, chemist, science communicator and Centre Advisory Board member, gave a third public talk at the University of Melbourne.

The Centre was a co-sponsor of the 'National Science Quiz' and 'Physics in the Pub' held in Melbourne's Camberwell during National Science Week. Charlie Pickering led a panel of scientists, science communicators and celebrities through an 'intellectual obstacle course'.

Despite all the start-up activity, our researchers published 43 scientific papers, undertook a number of industry and government briefings and presentations and presented research nationally and internationally, including plenary lectures at international conferences (see pp. 37–39).

Participants at our inaugural Workshop, 11 December 2017.
Photo by Gavan Mitchell

Launch of the Centre



Opposite page PhD student Heyou Zhang presents his research at the Launch
Above Exciton Launch (L-R): Marc Baldo, Neil Greenham, Tanya Ha, Paul Mulvaney, Margaret Sheil, Hiroshi Masuhara and Scott Watkins
Left Paul Mulvaney and Sue Thomas unveil the Centre's official launch plaque
Photos by Gavan Mitchell

The ARC Centre of Excellence in Exciton Science was officially launched on 13 December 2017 by the Chief Executive Officer of the Australian Research Council, Professor Sue Thomas. It was a splendid celebration with 120 researchers, industry representatives, staff, students and others attending the event at the University of Melbourne's Bio21 Institute.

Guests were welcomed with Exciton goodie bags, while a poster display and tours of the Centre's laboratories gave everyone an opportunity to learn about our work. It was also a chance to showcase the Centre to visitors and collaborators, who were treated to the inaugural viewing of our video 'Towards a Sustainable Future', which introduced our vision of discovering innovative ways to source and use energy.

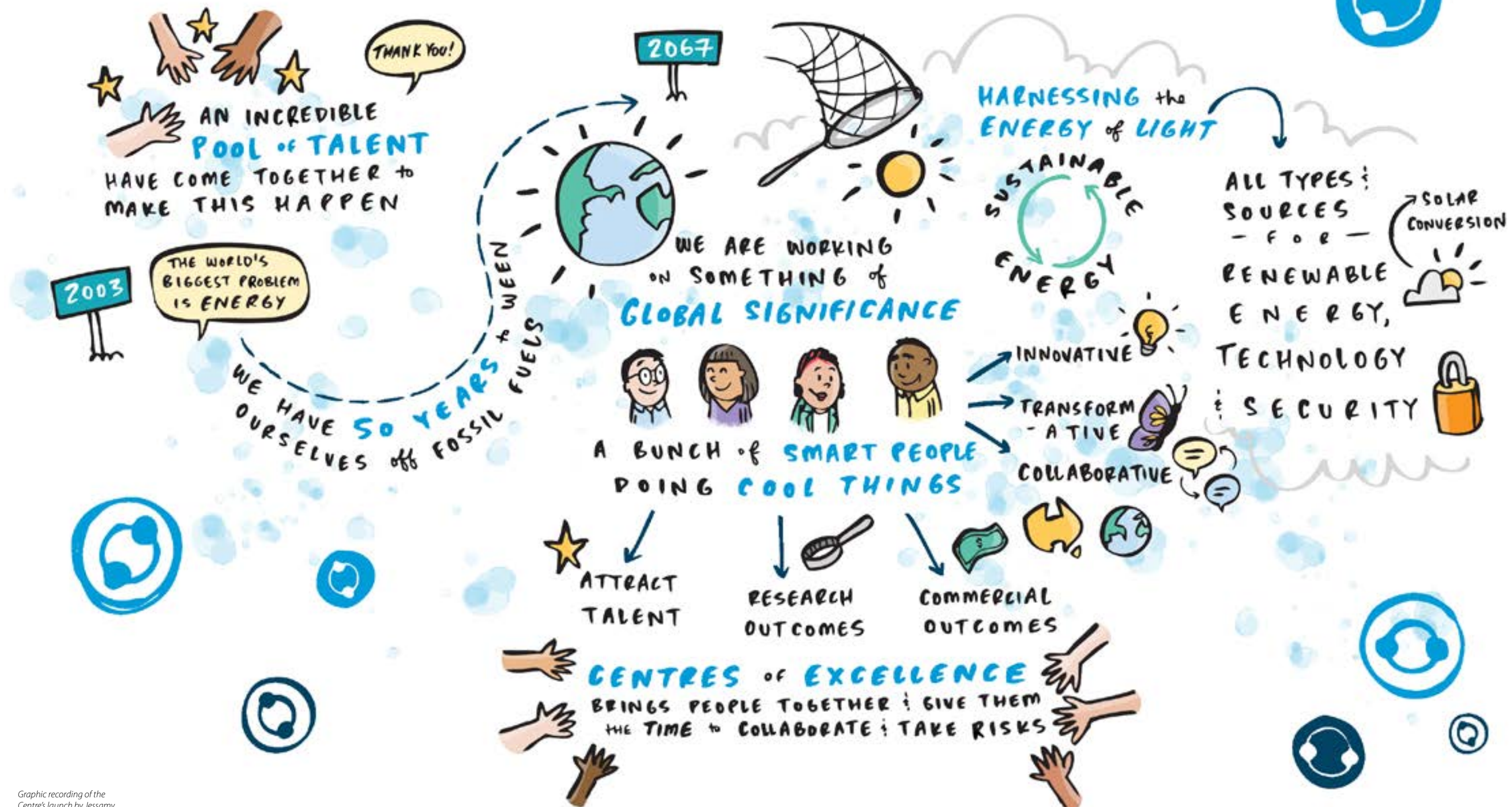
Professor Jim McCluskey, the Deputy Vice-Chancellor (Research) at the University of Melbourne, chaired the launch, which featured presentations by Centre Director Professor Paul Mulvaney, Professor Sue Thomas and the Centre's

Advisory Board Chair, University of Melbourne Provost Professor Margaret Sheil. All looked forward to the significant advances the Centre would be making in addressing our renewable energy challenges.

We were also pleased to welcome VIPs Professor Neil Greenham from the UK's Cambridge University, Professor Hiroshi Masuhara from the National Chiao Tung University in Taiwan, and Professor Marc Baldo from Massachusetts Institute of Technology in the USA. Other dignitaries included Mr Adam Bandt MP, and the University of Melbourne's Dean of Science Professor Karen Day and Head of the School of Chemistry Professor Evan Bieske.

Chief Operating Officer Sarah Mulvey led the Operations team in organising this important event in the Centre's lifecycle. It was a great celebration, both for those who had worked so hard to get the Centre together and for those who will work so hard to produce evidence-based outcomes.

ARC centre of excellence in EXCITON SCIENCE launch



Achievements in research

Research produced by the ARC Centre of Excellence in Exciton Science will help make Australia more economically competitive through improved renewable energy production and better energy use. By creating new ways to harness and manipulate light, we will change the way that Australians think about energy. Improving energy efficiency will have a positive impact on the sustainability of the Australian environment and bolster economic opportunities and job creation.

PhD students Calvin Lee (left) and Riley O'Shea with Dr Anupama Srinivas (centre). Photo by Gavan Mitchell



Two of the research highlights from our first year of operation are showcased here:

- Timothy Schmidt's group's ground-breaking research into increasing light harvesting by reducing waste through the better design of materials.
- Jacek Jasieniak's group's work on how to extend the battery life of mobile phones.

A third case study, from CI Wallace Wong's research group, highlights new methods to master molecular self-assembly and excitonic systems, and can be found on p. 29.

The ARC Centre of Excellence in Exciton Science will help make Australia more economically competitive through better energy use. The Centre will drive innovation and improve Australia's renewable energy production. By creating new ways to harness and manipulate light, we will change the way that Australians think about energy. Improving energy efficiency will have a positive impact on the sustainability of the Australian environment and bolster economic opportunities and job creation.

Case study 1: Important advances in harvesting energy

Led by CI Professor Timothy Schmidt at UNSW, Centre researchers have made an important discovery with significant implications for the future of solar cell material design. It might also mean that 'harvesting energy from the sun without wasting any energy could be within reach' (*Newsweek*).

The team has been looking at ways to capture the energy of visible light that is currently wasted due to the limitations of silicon, which is only able to access approximately 25 per cent of the solar spectrum. To illustrate, silicon on its own is only able to use of about half the energy of green light, which is the peak of the solar spectrum in terms of energy availability.

One of the ways to reduce this waste is through the design of materials that can be coated on top of silicon to capture some of the light that silicon cannot harvest. By incorporating singlet exciton fission, a process that generates two excitons from a single photon, it is hoped that silicon solar cell efficiencies can be boosted beyond 30 per cent.

The work, published in *Nature Chemistry* and also written up in *Newsweek*, examines the role of a short-lived (~8 billionths of a second), excited molecular complex called an excimer in singlet exciton fission and overturns previous thinking by demonstrating that these singlet fission materials must avoid

excimer formation to reach their full potential in enhancing photovoltaic energy conversion.

Professor Schmidt explains, 'As we look to find ways to bring down the cost of solar energy harvesting, we should be designing materials that avoid excimer formation.'

According to Professor Marc A. Baldo, a member of the Centre's International Scientific Advisory Committee and Director of the Center of Excitonics at MIT, 'Singlet exciton fission has enormous promise for improving the efficiency of solar cells, but its dynamics are complex and not well understood. By comparing the fission process when it is run both forwards and in reverse, Schmidt, et al. have performed a remarkably simple test of theories for the mechanism of exciton fission.'

'Their result suggests that what had previously been considered as an intermediate in the fission process may in fact be a source of loss. With this understanding Schmidt et al. propose an important new direction in our search for materials that will enable more efficient solar cells to be developed.'

To view the article – 'Endothermic singlet fission is hindered by excimer formation' – in *Nature Chemistry* go to: <https://www.nature.com/articles/nchem.2926>.

To view the article – 'Backwards physics experiment could help solar panels of the future stop wasting energy from the sun' – in *Newsweek* go to: <http://www.newsweek.com/physics-solar-panels-future-energy-sun-791329>.

Case study 2: How to extend your phone's battery life

The Centre aims to promote awareness of energy efficiency and better energy use. Practical examples of the way in which we can improve energy use, even domestically, abound. This was well illustrated in CI Associate Professor Jacek Jasieniak's article in *The Conversation* (31 July 2017) – 'Explainer: How to extend your phone's battery life' – which has proved to be extremely popular with more than 100,000 hits to date.

In the article, Associate Professor Jasieniak explains how the ability of lithium-ion batteries to store charge depends on the extent of their degradation, and goes through a few simple steps that users can take to minimise this degradation and extend their device's life. By adopting these simple strategies, users can extend their battery life by more than 40 per cent on any given day while maintaining a more consistent battery capacity throughout the lifetime of the device.

According to Associate Professor Jasieniak: 'The amount of battery life our mobiles have on any given day depends on two key factors: how we use them on that particular day, and how we used them in the past.'

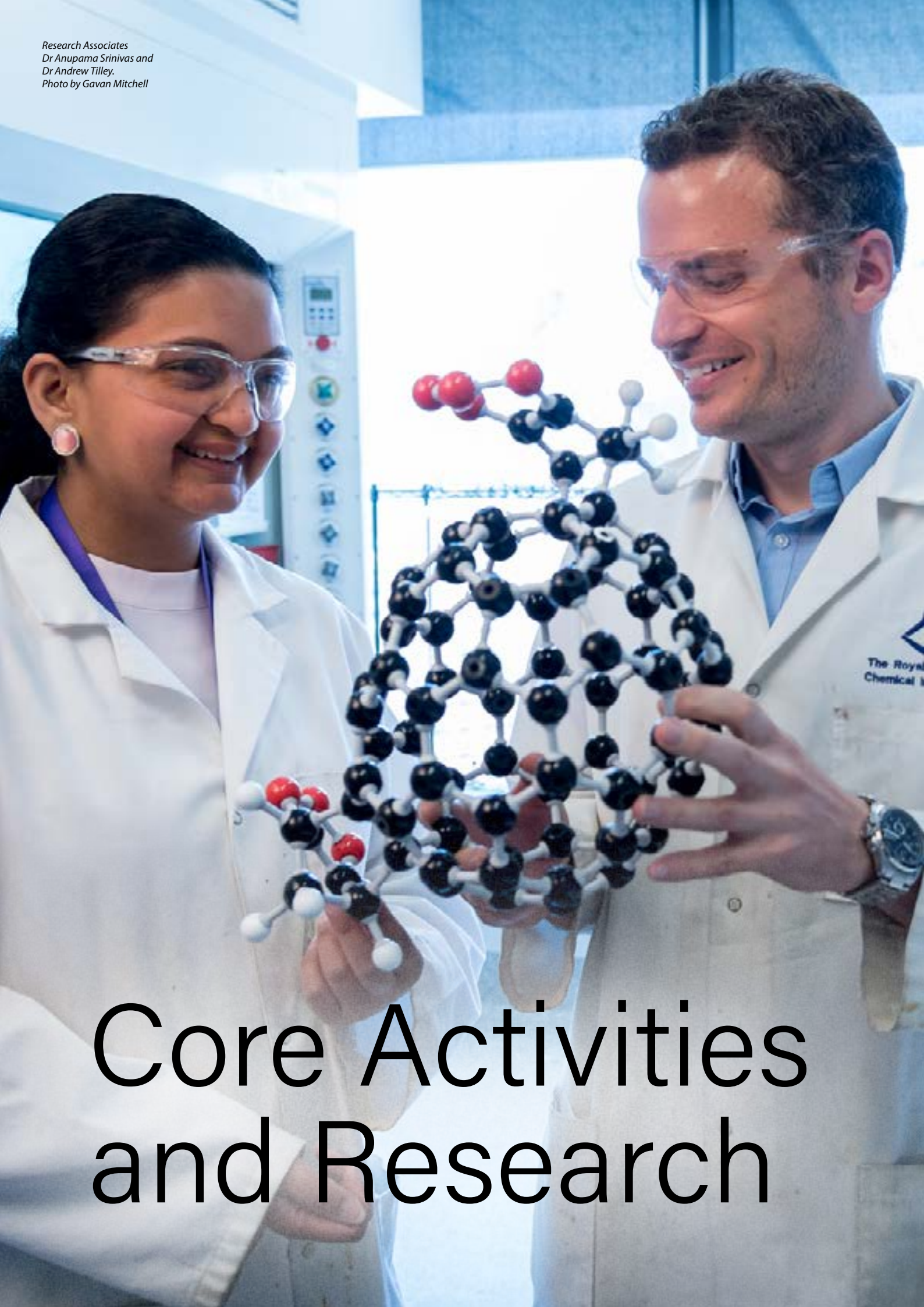
The strategies he suggests for extending the battery life of a mobile phone are:

Control battery discharge
To maximise the battery capacity we should avoid the 0% battery mark altogether, while also keeping those batteries at least partially charged if storing them for a prolonged period of time to avoid deep discharge.

Extend charging times
Charging a phone in five minutes compared with the standard two hours can reduce the battery capacity for that charge cycle by more than 20%.

Keep the temperature just right
Phones should be kept out of direct sunlight for prolonged periods and stored between 0°C and 45°C – the exact range in which lithium-ion batteries can be stored to maintain optimal long-term charge capacity.

Use battery-saving modes
Limit the use of power-hungry hardware and software – reduce screen brightness, turn off the cellular network, use Wi-Fi not 4G, limit video content, and use smart battery modes and Airplane mode.



Core Activities and Research

Research themes

The Centre has three core Research Themes:

- Excitonic Systems for Solar Energy Conversion – research into thin film upconversion devices, next generation luminescent solar concentrators, artificial photosynthesis and solution processed next-generation photovoltaics.
- Control of Excitons – coherent control of excitons, high-throughput materials discovery, exciton dynamics at nanoscale and multiscale studies and models of exciton transport.
- Exciton Solutions for Industry – excitonic materials for security, light emitting devices, photodetectors, sensors and synthesis of novel excitonic materials.

Basic research capabilities underpin the Centre’s ability to achieve its research goals. Our enabling capabilities are:

- Theory and modelling
- Materials and synthesis
- Spectroscopy and measurement
- Device designs and fabrication.

The table below outlines the Themes, Platforms, the Theme Leaders, Deputy Theme Leaders and the Platform Champions for each. The overview sets out the Centre’s research program structure.

Theme #	Theme title	Theme leader	Deputy theme leader	Platform champion
Theme 1	Excitonic Systems for Solar Energy Conversion	Timothy Schmidt	Asaph Widmer-Cooper	
Platform 1.1	Thin film excitonic upconversion devices			Timothy Schmidt
Platform 1.2	Next generation excitonic solar concentrators			Ken Ghiggino
Platform 1.3	Full-spectrum high-efficiency excitonic solar cells			Udo Bach
Theme 2	Control of Excitons	Girish Lakhwani	Jared Cole	
Platform 2.1	Coherent control of excitons			Dane McCamey
Platform 2.2	High-throughput materials discovery			Salvy Russo
Platform 2.3	Excitons at nanoscale interfaces			Girish Lakhwani
Platform 2.4	Multiscale studies and models of exciton transport			Jared Cole
Theme 3	Exciton Solutions for Industry	Wallace Wong	Jacek Jasieniak	
Platform 3.1	Excitonic materials for chemical sensing			Jacek Jasieniak
Platform 3.2	Excitonic security features			Tim James
Platform 3.3	Printed excitonic devices			Paul Mulvaney
Platform 3.4	Organic polariton laser			Wallace Wong
Capabilities and Infrastructure		Salvy Russo (IT) Alison Funston (Spectroscopy)	John Sader (Theory)	Wallace Wong

Theme 1: Excitonic systems for solar energy conversion



- Build a standardised upconversion test platform
- Develop a SNOM apparatus for the determination of triplet diffusion rates
- Develop novel conjugated polymer annihilators
- Develop organic nanocrystal sensitizers

Platform 1.2: Next generation excitonic solar concentrators
Goal: To deliver robust and efficient materials and device geometries for luminescent solar concentrators (LSCs)

Silicon solar cells have demonstrated 25 per cent energy harvesting efficiency in the laboratory, with typical module efficiencies of about 15 per cent. With fixed installation costs, the effective cost of solar energy depends on maximising the amount of sunlight each cell receives. However, while grid price parity can be achieved in many locations, there remain many surfaces in the built environment that are not suitable for the deployment of solar panels (e.g. the sides of buildings or south-facing roofs).

This Theme will deliver new, light-harvesting concepts and novel, full-spectrum materials for next-generation, low-cost, high-efficiency light-harvesting devices.

Grand challenge:
To build the ultimate excitonic light-harvesting system

Theme 1 will involve spectral and spatial manipulation of the solar spectrum, with downshifting and up-conversion to compress broadband sunlight into a narrow band for efficient harvesting by next-generation, solution-processed excitonic solar cells. This Theme will deliver new, light-harvesting concepts and novel, full-spectrum materials for next-generation, low-cost, high-efficiency excitonic light-harvesting devices.

Platform 1.1: Thin film excitonic upconversion devices
Goal: To develop an efficient solid state excitonic upconverter

Upconversion of light involves the sequential capture of two or more low-energy photons and the emission of a higher energy photon. This is performed by exploiting molecular triplet excitons as intermediaries. Successful implementation of high-efficiency upconversion will find diverse applications including solar energy conversion, solar fuels, and laser-induced drug release.

Progress to date has mostly involved bi-molecular compositions in solution. However, for high-fidelity integration into photovoltaic devices, solid-state upconverters should be

*Laser technology is crucial for solar energy conversion.
Photo by Gavan Mitchell*

developed that exhibit high efficiency under solar illumination. The goal of this Platform is to develop an upconverter with 45 per cent efficiency under 10-sun equivalent illumination within four years, and under one-sun illumination during the Centre's lifetime. This will be achieved through the careful optimisation of a number of components. Platform 1.1 is led by the UNSW node with significant input from the University of Melbourne and Monash University.

Key objectives

- Our overall concept is a conjugated polymer annihilation platform with concentrated nanoparticle sensitizers. These will be blended into films of optimised thickness and tested on a standardised breadboard to be developed early in the project.

To reduce the cost of solar energy, one can reduce the installation or materials costs. There are abundant opportunities to integrate photovoltaic elements into buildings, where the installation cost is incorporated into the overall build at little extra cost to building with non-photovoltaic elements. Furthermore, if such building elements, e.g. façade panels, can concentrate diffuse light, then only a small area of photovoltaic material is required.

Luminescent solar concentrators consist of highly luminescent materials embedded in, or coated on, large area planar glass or polymer waveguides. Solar radiation is harvested and the luminescence is concentrated at the edges of the waveguide to improve the performance of solar cells.



This Platform, led by CI Ghiggino, will deliver robust and efficient materials and device geometries for LSCs with superior performance and spectral response to existing devices. The Platform is divided into four work packages across four nodes of the Centre.

Key objectives

- Develop an excitonic LSC with $F > 10$ at $G = 50$
- Produce organic/QD hybrid LSC materials with large Stokes shifts
- Construct and characterise LSC devices
- Provide theoretical analysis and simulations of LSC device geometries and performance
- Explore oriented nanoparticle LSC geometries

Platform 1.3: Full-spectrum high-efficiency excitonic solar cells
Goal: To achieve breakthrough efficiencies in excitonic solar cells beyond the Shockley-Queisser limit

The primary goals of this Platform are to 1) gain control over the quality of solution-deposited semiconductor films; 2) develop a deep understanding of the parameters that determine the efficiency of such solar cells; and 3) achieve record efficiency and excellent stability for solution-processed excitonic solar cells.

After four years, we will produce photo-active thin films with tunable microstructure, controlled grain morphology, preferential crystalline orientation, and no pin-holes by solution

Above PhD student Tamader Alhazani, UNSW
Right Research Associate Dr Randy Sabatini, The University of Sydney



processing. In addition, we will achieve in-depth understanding of charge separation, transport and recombination mechanisms as well as failure mechanisms; and produce large area (up to 20 cm²) solution-processed excitonic solar cells with efficiencies and stabilities that are scalable through modern printing technologies.

The Platform is divided into four work packages spread across all five nodes of the centre and our Industry Partner CSIRO.

Key objectives

- Develop an upconversion perovskite solar cell
- Develop solution-processed CZTS and kesterite-based solar cells and sol-gel processed perovskite cell

Theme 2: Control of excitons

Grand challenge:
To control the four dimensions of an exciton – Energy, Lifetime, Position, and Spin/Polarization – for technological advancement of exciton devices

The realisation of any excitonic device or technology requires control over excitons. In this Theme, we will address control of the four dimensions of an exciton: Energy, Lifetime, Position and Spin/Polarisation. The outcomes of this Theme will include new ways to coherently control excitons, new excitonic materials, nanostructure-controlled excitonic motifs and new theories of exciton transport.

Platform 2.1: Coherent control of excitons

Goal: Develop excitonic logic devices using coherent control of excitons to generate precision states

To exploit excitons fully for advanced applications – in areas such as optical molecular switching, sensitive magnetometry, and spin-based logic – *coherent control* over the *quantum* degrees of freedom (phase, super-position and spin) must be established.

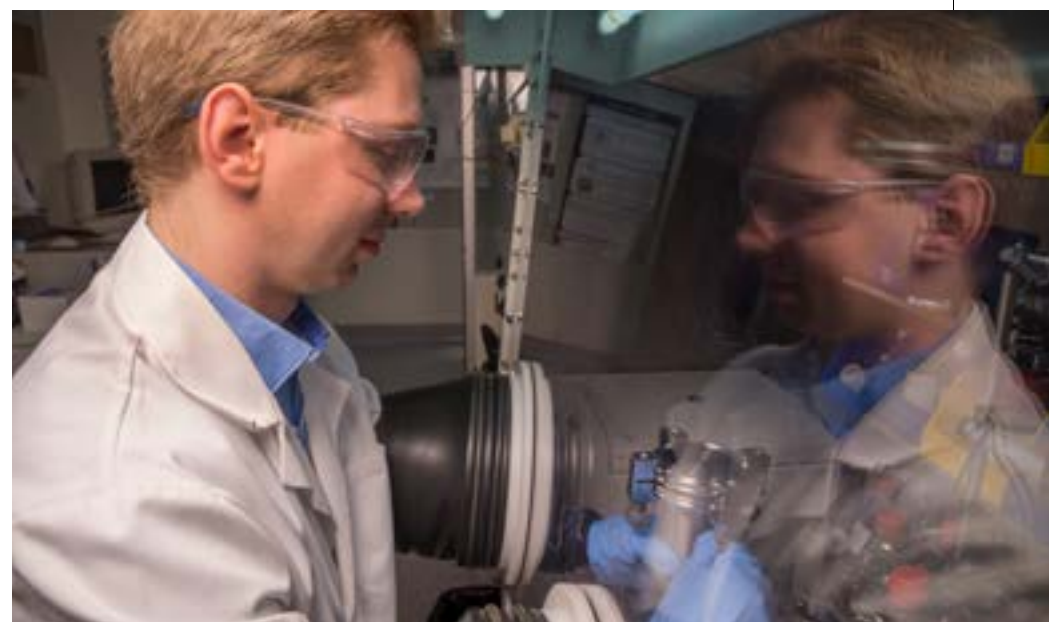
In this Platform, we will *coherently control* quantum excitonic phenomena using a range of approaches including manipulation of spin and optical polarisation with engineered pulse sequences. This will provide coherent control of how far, how quickly and to which location an exciton can migrate within a material, leading to applications such as excitonic logic gates. We aim to advance this field by coupling theory, synthesis and advanced experimental methods to investigate how we can gain control over the behaviour of excitons in molecular and semiconductor systems specifically designed and synthesised for this purpose.

Key objectives

- Establish a strong fundamental experimental and theoretical understanding of the coherence properties of excitons (including spin) in a range of materials
- Demonstrate a proof-of-principle implementation of an exciton logic device, which will exploit coherent effects for operation



Top: Research Fellow Dr Siobhan Bradley, The University of Melbourne
Bottom left: PhD student Cameron Ritchie, The University of Melbourne
Below: Tunable blue LEDs are essential energy efficient light generators.
Photos by Gavan Mitchell



Platform 2.2: High-throughput materials discovery

Goal: To discover a novel photovoltaic material capable of enhancing or outperforming silicon

Various materials have been investigated in recent years for applications such as light-emitting devices, photodetectors and sensors, and photovoltaic devices. Many of these materials have desirable properties such as high optical absorption coefficient, tunable bandgap, high PL quantum yields and long carrier diffusion length. However, synthesis of many of these structures can be constrained by the high cost of base materials and the time-consuming nature of complex synthesis procedures.

In this Platform we are developing a methodology that integrates computational modelling, data mining and advanced chemical techniques to decrease the timeline for synthesis of new materials with tailored excitonic properties,





Exciton dynamics across hybrid interfaces is highly complex and dependent on molecular parameters that directly impact the nanoscale morphology, spin polarisation, exciton manifold and interfacial density of states.

combining computational materials design (CMD) with the latest materials synthesis techniques. We will be applying these methods to initially investigate different types of materials, each of which show promising potential for optoelectronic and photonic applications. These are (i) *Low dimensional hybrid perovskite materials*, (ii) *Antimony chalcogenide photovoltaics*, (iii) *Ferroelectric oxide based materials* and (iv) *Organic-inorganic hybrid materials*.

Key objectives

- Develop a software toolkit for materials design that will be able to combine machine learning and materials modelling techniques on new and existing material property datasets to predict new photovoltaic/excitonic materials with superior properties for the conversion of light into current

Platform 2.3: Excitons at nanoscale interfaces
Goal: To identify key chemical and structural molecular variables that underpin the excitonic behaviour at nanoscale organic-inorganic hybrid interfaces

Constructing a device from a single photoactive molecule is the 'Holy Grail' in the miniaturisation

The realisation of any excitonic device or technology requires control over excitons.

of molecular electronics. So far this has been a distant dream due to difficulties in understanding the fundamental nature of the exciton and controlling its dynamics across organic-inorganic hybrid interfaces. Exciton dynamics across hybrid interfaces is highly complex and dependent on molecular parameters that directly impact the nanoscale morphology, spin polarisation, exciton manifold and interfacial density of states. These parameters are well below the diffraction limit of light and not observable through conventional bulk spectroscopic and imaging techniques.

In this platform, novel sophisticated optical probes will be developed with a focus on determining the key chemical and structural molecular variables that underpin the microscopic function in excitonic materials and at hybrid interfaces, which has been challenging at a bulk level. These studies will inform us about the nature of excitonic behaviour at interfaces and provide us with strategies towards the realisation of single molecule devices.

Masters student Hanbo Yang

Key objectives

- Determine parameters that control the exciton diffusion in single molecules and multi-chromophoric systems
- Develop optical probes to study energy transfer across organic-inorganic hybrid interfaces and determine the factors that govern energy transfer efficiency
- Measure the impact of spin mixing of singlet and triplet exciton states on energy and charge transfer across hybrid interfaces

Platform 2.4: Multiscale studies and models of exciton transport
Goal: Develop the first general theory for exciton dynamics over multiple length scales

The higher order structures that control the optical and electronic properties of bulk films are notably different from the structures that control the properties of single molecules and quantum dots, with limited information on the crossover in structural and optical properties at intermediate length scales. Given the spatial and energetic disorder (~100 meV) that is often observed at mesoscopic length scales, structure-property relationships become much more complicated in devices and no universal theoretical insight exists between morphology and device physics.

Overcoming this shortfall is critical towards the optimisation of devices in areas ranging from solar energy to sensing, lighting and security.

In this Platform, we will employ a combined theoretical and experimental approach to examine the interplay between electronic coupling, spin and structure on exciton diffusion and delocalisation in disordered organic and hybrid materials on scales ranging from the atomistic to the device level. To this end, this Platform will develop multiscale computational methods that can help interpret and predict exciton behaviour from the nanoscale to the device level. Specially developed experimental techniques with optical resolution down to 50 nm will allow capture of spatial maps of both film topology and excitonic processes, including diffusion length and lifetimes.

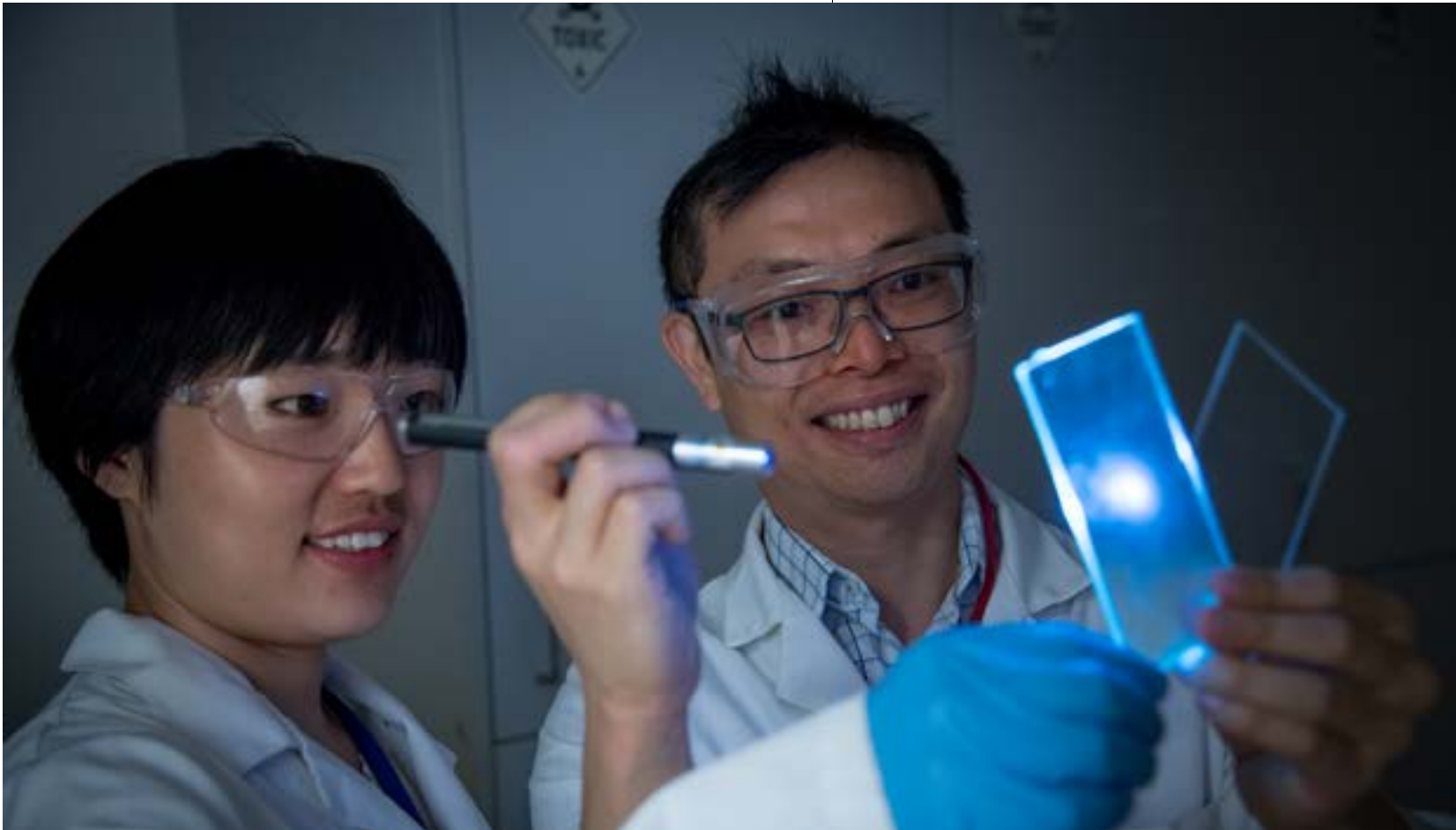
Key objectives

- Develop and extend macro-scale models to incorporate information from high-resolution experiments about meso-scale morphology and 3D exciton dynamics
- Design, fabricate and measure multi-scale 'artificial excitonic transport' as a method of studying naturally occurring excitonic transport (e.g., photosynthesis)

Theme 3: Exciton solutions for industry

Grand Challenge: To develop the first organic polariton laser

Manipulation, detection and use of light through excitonic materials are key concepts that will enable a raft of future technologies. The overarching mission of this Theme is to design and create materials with properties specifically defined for target applications that are relevant to our Industry Partners – DSTG, RBA and CSIRO. Theory and methods developed in Theme 2 will be used to guide and study the progression of materials into device applications. While the initial focus is to build on relationships and progress projects with existing partners, the Centre is seeking to expand into cutting-edge technology areas with new linkages to International and Industry Partners. Our Grand Challenge is to build an electrically pumped organic polariton laser.



Centre PhD student Can Gao with Theme Leader Dr Wallace Wong, The University of Melbourne. Photo by Gavan Mitchell
Top right The Centre is developing unique security features for banknotes with the RBA.

Platform 3.1: Excitonic materials for chemical sensing

Goal: To develop a portable and robust photoluminescence-based chemical sensing device

The fear of terror attacks has led to calls for scientists to invest time and effort in developing smart materials to detect chemical and biological warfare agents. The field of sensors is extremely broad, and encompasses simple paper-based test strips, such as pregnancy test kits, to large high-tech instruments such as PCR-based amplifiers for detecting biological agents. In partnership with the Defence Science and Technology Group, the Centre is in a unique position to develop portable and robust chemical sensors with high sensitivity and specificity. DSTG has already produced a portable colorimetric chemical sensor device. Having spent significant resources on developing a working

device. DSTG is now in the process of upgrading various aspects of the technology with particular focus on a photoluminescence-based response system. This platform brings together expertise in photoluminescent materials, host-guest chemistry, material nanostructuring and gas flow modelling to aid in the development of this next-generation chemical sensor.

Key objectives

- Design and test new photoluminescence-based sensing systems
- Develop gas flow models and optimise sensor device capability through device and substrate structuring
- Integrate new sensing system into DSTG device with improved sensitivity and specificity outcomes

Platform 3.2: Excitonic security features

Goal: To develop excitonic security features for the polymer banknote

Forgery is a major security problem in many industries, with estimated costs in the USA alone exceeding US\$250 billion annually. For example, counterfeit drugs are prevalent in many countries and cause predicted monetary losses of more than US\$75 billion per annum and with significant accompanying health risks to consumers. Counterfeit banknotes are another example of an area of major global forgery.

In this Platform, the Centre will create novel nanostructured exciton materials and develop the science and technology for security applications. It will involve a strong partnership with the RBA to develop unique security features for banknotes, as well as tags that can be used as unique identifiers for food, pharmaceuticals

and other opportunistic markets. A key element of our investigation will be the transduction of one input to another, with some examples being chemical-to-optical and optical-to-electrical transduction. The Platform will evolve from simple transduction mechanisms that probe the sensitising state externally to systems that respond to a change in the sensitising state directly.

Key objectives

- To develop a new optical feature for the RBA that can be detected through an existing bank teller machine
- To create a unique optical identifier suitable for identification of security documents that is non-toxic, photostable and amenable to printing at low temperatures
- To combine top-down and bottom-up nanotechnologies to create unique optical signatures

Platform 3.3: Printed excitonic devices

Goal: To deliver solutions for future lighting and display technologies

Thin film light-emitting devices have come a long way since the first observations of electroluminescence in organic diodes. Various key developments – such as the use of phosphorescent metal complexes, and, more recently, thermally activated delayed fluorescence materials⁵ – have led to the commercialisation of the organic LED technology in the form of ultra-thin light-weight high-resolution displays. However, many fundamental questions regarding materials and device design, particularly for applications that require high efficiency, brightness and stability, remain.

This Platform will deliver solutions for future lighting and display technologies by developing materials and devices beyond current efficiency, brightness and stability limits with spectral coverage from the ultraviolet to visible and IR range. These next-generation light-emitting devices will open up new architectures and applications such as tunable lasers – the focus of Platform 3.4. The key partner in this platform is CSIRO, which is providing facilities and expertise support through its flexible electronics laboratory. CSIRO's printing and device fabrication capability is essential for positive outcomes.

Key objectives

- Develop a blue quantum dot LED
- Demonstrate the use of multi-exciton systems to improve device efficiency and stability

Platform 3.4: Organic polariton laser

Goal: To develop the first organic polariton laser

The invention of lasers has led to a multitude of technological developments including telecommunications, data storage, medicine and many areas of analytical science. Electrically pumped organic lasers remain one of the 'Holy Grails' in optoelectronics, and their development would launch a revolution in low-cost, flexible display devices. To date, however, even optically pumped continuous wave solid state lasers using organic molecules are yet to be realised. As the excitation pulse width or frequency is increased, triplet states are formed, which prevent stimulated emission and thereby increase the lasing threshold often leading to material degradation.

In this Platform, we will employ a combined theoretical and experimental approach towards the realisation of an electrically pumped polariton laser. Polariton lasing does not require population inversion, instead needing only strong coupling between the exciton state and a cavity photon mode. Ultra-low energy thresholds



are, therefore, possible. This pathway both increases the efficiency of the device and limits thermal decomposition.

To this end, we will be investigating a range of organic semiconductors to determine parameters (e.g. lifetimes, Rabi splitting) that are critical to demonstrate lasing, and to develop a theory to identify different polariton modes and characteristic stop-band. We will also be investigating hybrid materials (e.g. Perovskites) to identify strategies towards electrical injection. Finding key industrial partner(s) will lead to technology development, particularly through the fabrication of high-precision optical cavities.

Key objectives

- Investigate photophysical properties of existing light-emitting materials in optical cavities
- Develop theoretical models that can determine different polariton modes and inform the design of new materials
- Identify champion materials for polariton lasing
- Demonstrate electrically injected polariton lasing at low energy thresholds

*PhD student Maria Ritter, The University of Melbourne.
Photo by Gavan Mitchell*



Case study 3: Molecular self-assembly and excitonic systems

The design and synthesis of materials has been a core component of chemical science since scientists learnt to transform substances using chemical reactions. The development of synthetic techniques, as well as methods of isolation and analysis, has meant that a huge range of chemicals and materials can be synthesised. From small organic molecules to nanoparticles to bulk substances, functional materials can now be produced with relative ease and accuracy. Despite these scientific advances, chemists are still only learning to design and build truly complex functional systems; for this, a mastery of molecular self-assembly is critical.

One prominent example of research in progress is artificial photosynthesis. Photosynthesis in organisms is a multi-step, multi-component process that harvests energy from the sun and stores it in the form of chemical bonds in carbohydrate molecules. Although there has been some success in creating synthetic analogues of photosynthetic components, mimicking the entire photosynthetic process has been extremely challenging. Controlled self-assembly is required to build large molecular systems with precision. The 2016 Nobel Prize in Chemistry awarded for 'the design and synthesis of molecular machines' highlighted the importance of this area of research.

The Centre is tackling molecular self-assembly from several angles. CI Dr Wallace Wong and his team are building organic dye assemblies to improve the light harvesting efficiency of solar

cells as well as to increase the sensitivity of chemical sensors.

'We have the knowhow and capability to synthesise organic molecules and polymers with desirable properties. The next challenge is to combine appropriate materials for applications such as photon upconversion', said Dr Wong.

Professor Paul Mulvaney's team has been working with metal and inorganic nanoparticles for decades. While the size and shape of nanoparticles can be controlled during the synthesis, there has been little work done on forming well-defined ensembles of nanoparticles.

'Aggregation of nanoparticles is a common problem in the field. It would be wonderful to control the aggregation and build arrays of nanoparticles. This will form the basis for manufactured excitonic devices', said Professor Mulvaney.

Meanwhile, work is also underway on tuning the crystallisation of inorganic phosphors and perovskite materials. Crystal formation fundamentally relies on the self-assembly of atoms and molecules. Associate Professor Jacek Jasieniak's team is examining the synthesis of nanophosphors and inorganic perovskite nanocrystals, while the teams under Professors Udo Bach and Yibing Cheng are working on hybrid perovskites for solution-processed, thin film solar cells.

'One of the strengths of the Centre is our capability in the synthesis of a variety of materials. Using this background knowledge, we can take our research forward into more complex multi-component systems. Molecular self-assembly will be the key in our endeavours', said Dr Wong.

*Research Associate
Dr Shyamal Prasad, UNSW*

Capabilities



Theory and modelling

This capability supports the Centre's Research Themes by developing a computational materials design methodology that will provide the design rules for next-generation excitonic materials and their devices by modelling their structure and properties.

In 2017 the Centre was awarded two substantial supercomputer grant allocations. The first was 3 million cpu-hrs under the National Computational Infrastructure National Facility (NCINF) Flagship allocation scheme, which awards grants to projects identified by the NCI Board as being of high-impact or national strategic importance. We were also awarded 4 million cpu-hours under the Pawsey Supercomputer Centre Energy and Resources Merit Allocation scheme. These two large supercomputer allocations, along with the supercomputing resources at each of the Centre's node universities, means that we are well resourced to undertake the substantial theory and modelling program required by the Centre's activities.

Spectroscopy and measurement

This capability underpins the measurement of the physical properties of excitons, including energy, lifetime, transport and dissociation. Spectroscopy

and materials characterisation is a major capability of the Centre, with a large portion of our research groups having some spectroscopy expertise and equipment with CIs specialising in spectroscopy. As a result, the Centre can investigate ultrafast exciton generation across the UV, visible and near-infrared spectral regions. We can undertake time-resolved and/or spatially resolved detection of exciton emission (photons), spin-state, transport and exciton dissociation products; and examine single molecule, solution and bulk materials.

Key instrumentation includes:

- laser excitation in the nanosecond to femtosecond regimes across the ultraviolet-visible-near infrared spectrum;
- time-correlated single photon counting (picoseconds-nanoseconds);
- visible/IR femtosecond transient absorption spectroscopy;
- femtosecond fluorescence (upconversion, Kerr gate);
- femtosecond multiple pulse photon echo spectroscopy;
- nanosecond flash photolysis;
- time-resolved fluorescence imaging;

Researcher conducting an experiment, UNSW

Techniques are being developed to engineer materials of high structural order with particular emphasis on material interfaces; both bottom-up (self-assembly) and top-down (nanofabrication) strategies are being deployed. This level of control will not only enable the synthesis of novel excitonic materials with high luminescence (>95 %), strong absorption characteristics (>10⁴ cm⁻¹) and long diffusion lengths (>1 μm) that operate across the visible and IR spectral regions, but will also facilitate their integration into next generation excitonic devices.

The Centre has the capability to produce materials in the three classes – organic conductors, inorganic nanocrystals and perovskite films – at appropriate scale requirements for applications. To facilitate the exchange of information on materials, the Centre is creating a materials register.

Devices and prototyping

The Centre is working on the development of new energy-efficient devices and energy storage structures such as solar cells, luminescent solar concentrators, and exciton up-conversion systems. The full application potential of emerging excitonic materials will be showcased and explored in prototype devices. We are also working towards novel device designs that are compatible with low-cost fabrication techniques.

The integration of the multitude of excitonic technologies developed by the Centre into integrated third generation photovoltaics, such as tandem solar cells and PV-integrated solar concentrators and upconverters, will be a key focus. In addition, the Centre is developing new technologies with our key industry partners – DSTG on chemical sensing, RBA on security devices, and CSIRO on light emitting devices.

Key infrastructure for device fabrication includes:

- complete solar cell characterisation systems (e.g. simulators, spectral response, a wide range of impedance-based techniques and stability testing);
- a wide range of printing and deposition technologies (e.g. screen, spray, spin coating, dip coating, sputtering and thermal evaporation);
- clean room access (class 100–10000) at the Melbourne Centre for Nanofabrication, CSIRO, RMIT facilities (including electron beam lithography, focused ion beam lithography, reactive ion etching and nanoimprinting);
- a wide range of deposition methods including electron beam evaporation, sputter coating, electroplating and 3D printing; and
- roll-to-roll printing and slot die coating facilities at CSIRO.

Outreach, Engagement and Education



Outreach activity in the laboratory with school children, UNSW

Outreach strategy



Our Outreach strategy is underway with the creation of a diverse set of activities supporting education, engagement and Science, Technology, Engineering and Maths programs.

To date, the Outreach and Education Manager has conducted a series of presentations at each of our five nodes to introduce groups to our principles and processes in this area.

During the year, public engagement talks were organised with:

- CIs Timothy Schmidt and Dane McCamey, and Girish Lakhwani and Asaph Widmer-Cooper introducing the Centre to audiences at the University of Sydney and the University of NSW;
- Director Paul Mulvaney was invited to present the Hans C. Freeman Lecture in Sydney;
- Tanya Ha, Advisory Board Member, *Catalyst* presenter and chemist, gave a public talk, 'Mind over matter: Why chemistry has an image problem and what we can do about it', at the University of Melbourne.

The national and international media took an interest in the Centre with:

- CI Timothy Schmidt's research paper with Dover et al. – 'Endothermic singlet fission is hindered by excimer formation' – featured in *Nature Chemistry* and was followed up by a media article in *Newsweek* ((see Case study 1, p.15, and our Publications list, pp.35–36).
- CI Jacek Jasieniak's article 'How to extend your phone batteries life' published in *The Conversation*, which leveraged the expertise in energy

efficiency within the Centre. *The Conversation* recorded more than 12,000 hits on the article in two days, rating it as high-impact, and it has since recorded more than 100,000 views.

- An article in *Pursuit*, in which Centre Director Professor Paul Mulvaney and CI Professor Ken Ghiggino spoke about the new Centre of Excellence in Exciton Science. They explained how their work to understand the 'quasiparticle' called an exciton could help us to harness solar energy more efficiently, and drastically reduce the energy and environmental cost of lighting.

Education area, our postdoctoral researchers undertook a media pitching session at our Workshop, which concluded with a 30-second pitching competition.

In 2018, we will launch our first Exciton Science Prizes, participate in the Peter Farrell Cup and seek further opportunities for sponsorship.

Outreach and education is also under development with a plan to engage students, high school chemistry and physics teachers, and to initiate a primary schools-based program.

The Centre is expanding its website to include better links to publications, provide more feedback to visitors and post more active news items. Although the current site has increased its audience from zero to 12,300 new visitors over 2017, we are seeking a more integrated platform for the years ahead. The Centre also continues to use other social media – twitter, facebook and instagram – to engage stakeholders, staff and students.

Professor Salvy Russo presents at the Centre's Workshop.
Photo by Gavan Mitchell

Partnerships



A key objective of the Centre is to build both international and local Partner networks that will benefit research, graduate and postdoctoral training, and assist translation of the Centre’s research towards commercial and societal outcomes. International Partner institutions that have made formal commitments to the Centre, or who have Partner or Associate Investigators on their staff now number 11.

International Partners (contributing expertise and opportunities for student advancement)

Chinese Academy of Sciences, Chongqing Institute of Green and Intelligent Technology, China
Huazhong University of Science and Technology, China
Shandong University, China
South China Normal University, Guangzhou, China
Universität Ulm, Germany
Universität Bayreuth, Germany
University of California, Berkeley, USA

International Partners (with Partner or Associate Investigators)

Ludwig-Maximillian Universität München, Germany
University of Kassel, Germany
Princeton University, USA
University of Kerala, India

During its first year of operation, the Centre welcomed a large number of international visitors (see complete list, pp.40–41) to initiate collaborative research and training programs including Professor Köhler (Universität Bayreuth), Professor Hao (Shandong University), Professor Scholes (Princeton University) and Professor Rumbles (NREL and University of Colorado). International Scientific Advisory Committee members

– Professor Baldo (MIT, USA), Professor Greenham (Cambridge University, UK) and Professor Masuhara (National Chiao Tung University, Taiwan) – also attended the Centre’s first Annual Workshop held in December.

An example of early success for the Centre’s international networking strategy was the Chinese Guangzhou Government’s grant to develop new materials for next generation reflective displays. This program will be led and hosted by Professor Guofu Zhou from our newest International Partner, South China Normal University, in collaboration with the ARC Centre of Excellence in Exciton Science, Boston College and the Helmholtz Centre, Berlin. The objective of this international collaboration is to develop new full-colour ‘Kindle’-type displays with improved contrast and fast response to enable video presentations.

Industry Partners

The Australian Partners formally involved with our research programs will assist the Centre with the translation of research outcomes in the following areas of innovation:

- CSIRO Manufacturing Flagship
- Reserve Bank of Australia
- Defence Science and Technology Group of the Department of Defence.

Collaborative research programs are well underway with these Partners in developing new excitonic materials for flexible electronics, security devices and sensors. During November, Centre Chief Investigator Dr Wallace Wong reported on the Centre’s technology vision at the Emerging and Disruptive Technology Assessment Symposium on Advanced Materials and Manufacturing hosted by DSTG in Melbourne, while all translation Partners presented on the opportunities for collaboration at the Centre’s first Annual Workshop.

Publications

In our first months of operation, Centre researchers published 43 peer-reviewed papers, which are listed below.

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Zhu, Y., Nakashima, P. N. H., Funston, A.M., Bourgeois, L. & Etheridge, J. 2017, Topologically enclosed aluminum voids as plasmonic nanostructures, *ACS Nano*, 11(11):11383–11392 (DOI: 10.1021/acsnano.7b05944).

Conference presentations

In our first year, Centre researchers and students gave numerous keynote, plenary and conference presentations, along with public talks and government and industry briefings, all of which are listed below.

Amir Asadpoordarvish, Invited Speaker, 2017 Royal Australian Chemistry Institute (RACI) Centenary Congress, Melbourne, 28 July 2018

Udo Bach, Back-contact perovskite solar cells, Invited Speaker, UQ Conference, Brisbane, 8 January 2017

Udo Bach, Back-contact dye-sensitized and perovskite solar cells, Invited Speaker, Hybrid and Organic Photovoltaics (HOPV), Japan, 3 February 2017

Udo Bach, Back-contact perovskite solar cells, Invited Speaker, CCCF 2017 Conference, Gold Coast, 8 April 2017

Udo Bach, Dipole-field-assisted charge extraction in schottky junction perovskite solar cells, Invited Speaker, HOPV Lausanne, Switzerland, 23 May 2017

Udo Bach, Characterisation of CH₃NH₃PbI₃ perovskite solar cells by TEM, Invited Speaker, Helmholtz Berlin, Germany, 29 May 2017

Udo Bach, Novel redox mediators for dye-sensitized solar cells, Invited Speaker, Asian Conference on Coordination Chemistry (ACCC6), Melbourne, 25 July 2017

Udo Bach, Back-contact perovskite solar cells, Invited Speaker, EMRS Conference, Poland, 20 September 2017

Udo Bach, Back-contact perovskite solar cells, Invited Speaker, ANFF Showcase, Sydney, 22 November 2017

Yibing Cheng, Perovskite solar cells, Invited Speaker, Kyoto University, Japan, 10 June 2017

Yibing Cheng, High efficiency perovskite solar cells – Processing, microstructures and properties, Invited Speaker, 11th Aseanian Conference – Nano-Hybrid Solar Cells, Himeji, Japan, 10 August 2017

Yibing Cheng, Printing of solar cells, National Institute of Clean Energy, China, 21 August 2017

Yibing Cheng, Perovskite solar cells, Kyoto University, Japan, 6 October 2017

Yibing Cheng, High efficiency perovskite solar cells – processing, microstructures and properties, Invited Speaker, 11th Aseanian Conference on Nano-Hybrid Solar cells, Himeiji, Japan, 8 October 2017

Yibing Cheng, Microstructural characterisation of hybrid perovskite solar cells, Asia Communications and Photonics Conference, Invited Speaker, China, 11 October 2017

Yibing Cheng, Provskite solar cells, Invited Speaker, Australia–China Forum on Advanced Materials and Manufacturing, China, 25 October 2017

Yibing Cheng, Microstructural characterisation of hybrid perovskite solar cells, Invited Speaker, Asia Communications and Photonics Conference, Guangzhou China, 10 November 2017

Alison Funston, Tuning of the near-field in coupled metal nanostructures, Invited Speaker, 2017 Royal Australian Chemistry Institute Centenary Congress, Melbourne, 27 July 2017

Alison Funston, Symmetry breaking and silver in gold nanorod growth, Invited Speaker, The University of Melbourne Seminar, Melbourne, 15 August 2017

Alison Funston, Nanoparticle growth assembly and energy transfer, Invited Speaker, Monash University and Helmholtz-Zentrum Dresden-Rossendorf workshop, Germany, 18–26 October 2017

Laszlo Frazer, Reshaping the solar spectrum to capture the sun's power, Inaugural Australasian Community for Advanced Organic Semiconductors (AUAOS), Kingscliff, Queensland, 4 December 2017

Ken Ghiggino, Ultrafast spectroscopy of charge generation in organic photovoltaic materials, Invited Lecture, 2017 Royal Australian Chemistry Institute (RACI) Centenary Congress, Melbourne, 28 July 2017

Ken Ghiggino, Concentration quenching resistant fluorophores for light concentration, 15th Conference on Methods and Applications of Fluorescence, Belgium, 12 September 2017

Ken Ghiggino, Materials for photon harvesting and concentration for photovoltaics, Invited Lecture, Sino–Australia Symposium on Advanced Materials, China, 26 September 2017

Joanna Guse, Electron spin science and technology: Biological and materials science oriented applications, Invited Speaker, 5th Awaji International Workshop, Japan, 21 June 2017

Jacek Jasieniak, Public Seminar, Cooperative Research Centre for Polymers, Manufacturing and Advanced Materials, 21 June 2017

Jacek Jasieniak, Interface engineering of solution process optoelectronic materials and devices, Flinders University, Adelaide, 18 August 2017

Outreach, Engagement and Education

Jacek Jasieniak, p-type layer engineering of hybrid metal halide perovskite photovoltaics, Invited Speaker, Asia Communications and Photonics Conference, Guangzhou, China, 10–13 November 2017

Girish Lakhwani, Exciton polaritons in molecular crystals, Optical Probes Conference, Quebec City, Canada, 17 June 2017

Girish Lakhwani, Exciton polaritons in organic molecular crystals, RACI Congress, 23 July 2017

Girish Lakhwani, Device physics of ZnO nanoparticle memristors, AUCAOS Conference, 3 December 2017

Girish Lakhwani, Exciton polaritons in organic molecular crystals, 21st East Asian Workshop on Chemical Dynamics, Kyoto, Japan, 20 December 2017

Dane McCamey, Electron Paramagnetic Resonance (EPR), Invited Speaker, International Symposium of Magnetic Resonance, Quebec City, Canada, 28 July 2017

Dane McCamey, Seminar, Influence of spin on optoelectronic properties of organic materials and devices, University at Buffalo, Department of Chemical and Biological Engineering, New York, USA, 31 July 2017

Dane McCamey, Spin in organic optoelectronic materials and devices, Seminar, Department of Chemistry, Columbia University, New York, USA, 2 August 2017

Dane McCamey, Spin control and dynamics in engineered molecular systems, Invited Talk, Materials Research Society Fall Meeting, Boston, USA, 28 November 2017

Dane McCamey, Spin control and dynamics in pentacene dimers, Invited Speaker, Australian & New Zealand Society of Magnetic Resonance Conference, Kingscliff, Queensland, 4 December 2017

Dane McCamey, Spin and singlet fission in pentacene dimers with a range of bridges, Inaugural Australasian Community for Advanced Organic Semiconductors (AUCAOS), Kingscliff, Queensland, 4 December 2017

Debora Monego, Ligand-mediated interaction between colloid particles, Centre of Excellence in Exciton Science Annual Meeting

Debora Monego, Ligand-mediated interaction between colloid particles, Centre of Excellence in Exciton Science Annual Meeting, Melbourne, 10 December 2017

Paul Mulvaney, Rapid and directed assembly of nanoparticles into periodic arrays, Invited Speaker, Australasian Colloids and Interface Society (ACIS), Coffs Harbour, NSW, 2 February 2017

Paul Mulvaney, Rapid and directed assembly of nanoparticles into periodic arrays, Invited Speaker, American Chemistry Society (ACS) Nano Symposium, University of California, Berkeley, USA, 2 April 2017

Paul Mulvaney, Large scale nanocrystal arrays, Invited Speaker, American Chemical Society, San Francisco-Nicholas Kotov ACS Award Symposium, 3 April 2017

Paul Mulvaney, Briefing, Australian Research Council Directors Day, Canberra, 27 April 2017

Paul Mulvaney, Large scale nanocrystal arrays, Plenary, United Kingdom Colloids 2017, Manchester, United Kingdom, 10 July 2017

Paul Mulvaney, Large scale nanocrystal arrays, Invited Speaker and Plenary, International Symposium on Energy Conversion and Storage Materials (ISECSM), Brisbane, 31 July–1 August 2017

Paul Mulvaney, Gold nanocrystals: Single particle electrochemistry and hydrostatic pressure experiments, China Nano, Beijing, China, 25 August 2017

Paul Mulvaney, CdTe-ZnO nanocrystal solar cells, Invited Speaker, American Chemical Society Nano Symposium, Peking University, Beijing China, 1 September 2017

Paul Mulvaney, Large scale nanocrystal arrays, Invited Speaker, Hans C Freeman Lecture, The University of Sydney, Sydney, 7 November 2017

Paul Mulvaney, Quantum dot blinking – Some exciton science, Public Lecture, Physical Chemistry Seminar, The University of Sydney, Sydney, 7 November 2017

Paul Mulvaney, Next generation light harvesting molecules for a sustainable energy future, Invited Speaker, Zhaoqing Workshop Exciton Science, Guangzhou, China, 9 November 2017

Paul Mulvaney, Large scale nanocrystal arrays, Asia Communications and Photonics Conference, Guangzhou, China, 10–13 November 2017

John Sader, Dynamics of micron and nanometre scale mechanical devices in fluid with applications to atomic and molecular sensing, Invited Speaker, Department Seminar, The University of Sydney, Sydney, 8 March 2017

John Sader, Why does an inverted-flag flap in a uniform steady flow?, Invited Speaker, Department Seminar, Monash University, Melbourne, 21 March 2017

John Sader, The role of fluid mechanics in nanomechanical sensing, Invited Speaker, 14th International Nanomechanical Sensing Workshop, Hawaii, USA, 5 April 2017

John Sader, Dynamics of micron and nanometre scale mechanical devices in fluid with applications to atomic and molecular sensing, Invited Speaker, Department Seminar, University of Nottingham, Ningbo, China, 20 June 2017

Outreach, Engagement and Education

John Sader, Dynamics of micron and nanometre scale mechanical devices in fluid with applications to atomic and molecular sensing, Plenary, Platinum Seminar, Monash University, Melbourne, 10 August 2017

John Sader, Ultrafast dynamics of nanoparticles and their acoustic propulsion, Thin Films and Photonics and Organic Electronics Interdisciplinary Workshop, University of Shandong, China, 27 September 2017

John Sader, The role of fluid mechanics in nanomechanical sensing and atomic force microscopy, Invited Speaker, Bio-mechanical Research Symposium, Stanford University, USA, 9 October 2017

John Sader, Time dependent fluid mechanics at nanometer length scale, Invited Speaker, Department seminar, California Institute of Technology, USA, 12 October 2017

John Sader, Interatomic force laws that corrupt their own measurement, Invited Speaker, Company seminar, Nanoworld, Switzerland, 30 November 2017

John Sader, Ultrafast dynamics of nanoparticles and their acoustic propulsion, Invited Speaker, Department seminar, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, 1 December 2017

Ashish Sharma, Fluorescence decay pathways sensitive to circularly polarised excitation, RACI Congress, 23 July 2017

Tim Schmidt, Endothermic singlet fission does not proceed via an excimer intermediate, Inaugural Australasian Community for Advanced Organic Semiconductors (AUCAOS), Kingscliff, Queensland, 5 December 2017

Trevor Smith, Time-resolved emission microscopy – Methods and extended applications, Invited Lecture, 1st National Fluorescence Lifetime Microscopy (FLIM) Workshop, UNSW Sydney, 20 February 2017

Trevor Smith, Mapping time-resolved and emission depolarization behaviour of evanescent wave-induced emission, International Conference on Photochemistry, France, 18 July 2017

Trevor Smith, Time-resolved and fluorescence anisotropy imaging of alignment and energy migration in conjugated polymer films, 15th Conference on Methods and Applications of Fluorescence, Belgium, 12 September 2017

Trevor Smith, Photophysical processes in thin films studied by time-resolved and polarised microspectroscopy, Invited Lecture, Sino–Australia Symposium on Advanced Materials, China, 26 September 2017

Trevor Smith, Time-resolved spectroscopy and fluorescence microscopy of organic photovoltaic materials, Departmental Seminar, Department of Chemistry, School of Science and Technology, Kwansei Gakuin University, Japan, 9 November 2017

Trevor Smith, Ultrafast and micro-spectroscopy of organic photovoltaic materials, Tohoku–Melbourne Workshop: Advanced Materials – Scientific & Engineering Challenges, Japan, 5 November 2017

Trevor Smith, Fluorescence anisotropy imaging of polymeric and bio-materials, National Workshop on Fluorescence and Raman Spectroscopy (FCS 2017), India, 18 December 2017

Asaph Widmer-Cooper, Self-assembly of matchstick nanoparticles at a solid–liquid interface, ACIS 2017 Conference, 29 January 2017

Asaph Widmer-Cooper, Ligand-mediated interactions between nanoparticles, AMN8 Conference, New Zealand, 12 February 2017

Asaph Widmer-Cooper, Tuning nanoparticle interactions and assembly, Soft Nanomaterials Symposium, 2 June 2017

Asaph Widmer-Cooper, NANAX8 ligand-mediated interactions between nanoparticles, Conference, Portugal, 2 July 2017

Asaph Widmer-Cooper, Self-assembly of matchstick nanoparticles at a solid-liquid interface, ACS Colloids Meeting, USA, 9 July 2017

Asaph Widmer-Cooper, Self-assembly of patchy nanorods at an interface, Statistical Mechanics of Soft Matter, Sydney, 28 November 2017

Wallace Wong, Light harvesting using emissive aggregates, DAAD Bayreuth–Melbourne Symposium, Melbourne, 10 March 2017

Wallace Wong, Light harvesting using emissive aggregates, Distinguished Visitor Lecture, Institute for Future Environments (IFE), Queensland University of Technology Conference, Brisbane, 11 May 2017

Wallace Wong, A green route to conjugated polyelectrolyte interlayers for high performance solar cells, Invited Speaker, International Symposium on Functional Pi Systems (FPI), Hong Kong, 6 June 2017

Wallace Wong, Light harvesting using emissive aggregates, Invited Speaker, International Conference on Materials Science and Advanced Technology (ICMAT), Singapore, 20 June 2017

Wallace Wong, Controlled synthesis of conjugated polymers, Polymer Vic – RACI Meeting, Melbourne, 25 September 2017

Wallace Wong, Future energy technologies, Emerging and Disruptive Technology Assessment Symposium (DST Group), Melbourne, 29 November 2017

Jared Wood, Self-assembly of nanorods in polymer solution, 2 SM^2 Meeting, 7 November 2017

Gangcheng Yuan, Quantum dot blinking, China Nano, Beijing, China, 31 August 2017

Visitors

Name of visitor	Visitor institution	Country of visitor institution
Dr Heping Shi	Shanxi University	China
Professor Henry Snaith	Oxford University	UK
Dr Arnim Heinemann	Universität Bayreuth	Germany
Professor Masanori Ando	AIST, Kyoto University	Japan
Ms Kanako Watanabe	Tohoku University	Japan
Professor Helmuth Moehwald	Max-Planck Institute	Germany
Professor Anna Koehler	Universität Bayreuth	Germany
Professor Thomas Scheibel	Universität Bayreuth	Germany
Dr Andrew Telford	Imperial College London	UK
Jie Zhang	Institute of Printed Electronic Industry	China
Yanping Zhu	Institute of Printed Electronic Industry	China
Professor Fengyan Zhang	Xiamen University	China
Dr Mingli Sun	Northeast Forestry University	China
Tawfique Hasan	University of Cambridge	UK
Alex Martucci	Padua University	Italy
Professor Wolfgang Parak	Marburg University	Germany
Gregory Burgess	University of Birmingham	UK
Professor Rangan Banerjee	Indian Institute of Technology	India
Dr Scott Watkins	Kyung-in Synthetic Corporation	South Korea
Professor Paul Weiss	University of California, Los Angeles	USA
Liming Dai	Case Western Reserve University	USA
Shouhua Feng	Jilin University	China
Dr Murad Tayebjee	University of Cambridge	UK
Professor Neil Greenham	University of Cambridge	UK
Samuel Sanders	Columbia University	USA
Dr Klaus Boldt	University of Konstanz	Germany
Sven Hüttner	Universität Bayreuth	Germany
Dr Arnim Heinemann	Universität Bayreuth	Germany
Dr Zhengrong Shi	Entrepreneur	China
Dr Klaus Boldt	University of Konstanz	Germany
Delegates	German Chamber of Commerce	Germany
Professor Greg Scholes	Princeton University	USA
Professor Garry Rumbles	University of Colorado	USA

Name of visitor	Visitor institution	Country of visitor institution
Dr Nathaniel Davis	University of Cambridge	UK
Professor Kevin Webb	Purdue University	USA
Professor Ron Steer	University of Saskatchewan	Canada
Professor Seth Marder	Georgia Institute of Technology	USA
Jae-Joon Lee	Dongguk University	Korea
Taiho Park	Pohang University of Science and Technology	Korea
Tae-Hyuk Kwon	Ulsan National Institute of Science and Technology	Korea
Professor Harry Atwater	California Institute of Technology	USA
Marc Schächtele	University of Tuebingen	Germany
Robin Dolleman	Delft University	Netherlands
Professor Hiroshi Masuhara	National Chiao Tung	Taiwan
Professor Marc Baldo	MIT	USA
Professor Anil Kumar	Department of Chemistry, Indian Institute of Technology Bombay	India
Dr Lawrence Jones	Eddison Electric Institute	USA
Dr Andrew Telford	Imperial College	UK

Our People



Research Associate
Dr Xia Zhang, The University
of Sydney

Chief investigators



Our Chief Investigators: Alison Funston, Timothy Schmidt, Jared Cole, Wallace Wong, Dane McCamey, Girish Lakhwani, Jacek Jasieniak, Paul Mulvaney, Udo Bach, Asaph Widmer-Cooper, Salvy Russo, Ken Ghiggino, Trevor Smith, John Sader and Yibing Cheng. Photo by Gavan Mitchell

The Centre currently has 15 Chief Investigators over its five nodes.

Name	Title
Professor Udo Bach	Centre Deputy Director
Professor Yibing Cheng	Deputy Leader of Device Design and Fabrication Capability
Professor Jared Cole	Deputy Theme Leader of Control of Excitons, Theme 2
Dr Alison Funston	Capability Leader of Spectroscopy and Measurement
Professor Ken Ghiggino	Deputy Capability Leader of Materials and Synthesis, Manager International Links
Associate Professor Jacek Jasieniak	Director and Capability Leader of Device Design and Fabrication
Dr Girish Lakhwani	Theme Leader of Control of Excitons, Theme 2
Associate Professor Dane McCamey	Outreach, Education and Governance Director, UNSW Node Manager
Professor Paul Mulvaney	Centre Director
Professor Salvy Russo	Centre Deputy Director, Capability Leader of Theory and Modelling
Professor John Sader	Deputy Capability Leader of Theory and Modelling Platform
Professor Timothy Schmidt	Theme Leader of Excitonic Systems for Solar Energy Conversion, Theme 1
Associate Professor Trevor Smith	Deputy Capability Leader of Spectroscopy
Dr Asaph Widmer-Cooper	Deputy Theme Leader of Excitonic Systems for Solar Energy Conversion
Dr Wallace Wong	Theme Leader of Exciton Solutions for Industry, Theme 3

Partner investigators

Associate investigators



The Centre currently has 10 Partner Investigators over its Industry and International Partner organisations.

Name	Organisation
Dr Anthony Chesman	CSIRO
Dr Fiona Scholes	CSIRO
Professor Greg Dicoski	Reserve Bank of Australia
Dr Rebecca McCallum	Defence, Science and Technology Group
Professor ChunLei Du	Chinese Academy of Sciences
Doctor Jiang Tang	Huazhong University of Science and Technology, Chongqing Institute of Green and Intelligent Technology
Professor Xiao Tao Hao	Shandong University
Professor Jeffrey B. Neaton	University of California, Berkeley
Professor Martin B. Plenio	Universität Ulm
Professor Markus Lippitz	Universität Bayreuth

The Centre currently has 10 Associate Investigators over its five nodes and International Partner organisations.

Name	Organisation
Professor Rebekah Brown	Monash University
Professor Jochen Fledmann	Ludwig-Maximillian Universität München
Professor Susan Huelga	Universität Ulm
Professor Heike Klussman	University of Kassel
Professor Anna Köhler	Universität Bayreuth
Professor Gary Rosengarten	RMIT University
Professor Greg Scholes	Princeton University
Dr Ken Silburn	Head Teacher Science, Casula High School
Professor K. G. Thomas	University of Kerala
Associate Professor Daniel Gomez	RMIT University

Postdoctoral researchers

The Centre currently has 32 postdoctoral researchers over its five nodes.

Name	Title
Dr Andre Anda	Research Fellow, Quantum Physics, Atomic, Molecular and Optical Physics and Theoretical Chemistry
Dr Amir Asadpoor Darvish	Research Associate, Solid State Physics, Experimental Physics, Materials Science
Dr Stefano Bernardi	Postdoctoral Researcher
Dr Jamie Booth	Postdoctoral Researcher
Dr Siobhan Bradley	Research Fellow in Spectroscopy of Excitonic Materials
Dr Debadi Chakraborty	Research Fellow, Computational Physics, Materials Physics and Materials Science
Dr Laszlo Frazer	Research Associate
Dr Sebastian Furer	Postdoctoral Researcher
Dr Rugang Geng	Research Associate
Dr Anu Gulur Srinivas	Research Fellow in the Synthesis of Sensor Materials
Dr Akhil Gupta	Research Fellow in Light Harvesting Materials
Dr Christopher Hall	Research Fellow in Ultrafast Laser Spectroscopy
Dr Thilini Ishwara	Research Associate, Fabrication of Solid State Upconverter system
Dr Calum Kinnear	Research Fellow in Single Nanocrystal Arrays
Dr Mike Klymenko	Postdoctoral Researcher
Dr Daniel Ladiges	Postdoctoral Researcher
Dr Dongchen Lan	Research Fellow in Mesoscopic Transport
Dr Laurent Lermusiaux	Postdoctoral Researcher
DrWei Li	Postdoctoral Researcher
Dr Yawei Liu	Postdoctoral Researcher
Dr Jian Feng Lu	Postdoctoral Researcher
Dr Igor Lyskov	Postdoctoral Researcher
Dr Pegah Maasoumi	Research Fellow in Device Fabrication
Dr Shyamal Prasad	Research Associate
Dr Carolina Rendón Barraza	Research Fellow in Spectroscopy of Excitonic Materials
Dr Kevin Rietwyk	Postdoctoral Researcher
Dr Sonia Ruiz Raga	Research Fellow, Chemical Engineering
Dr Randy Sabatini	Postdoctoral Research Associate in Semiconductor Devices
Dr Jiangjian Shi	Postdoctoral Researcher
Dr Andrew Tilley	Research Fellow in Light Harvesting Materials
Dr Tian Zhang	Postdoctoral Researcher
Dr Xia Zhang	Research Fellow in Single Molecule Spectroscopy

Professional staff



Our professional staff: Sandra Pedersen, Johanna Monk, Kathy Palmer, Sarah Mulvey, Brooke Bacon and Diana Londish
Absent: Monica Brockmyre, Piumika Perera, Spencer Wong. Photo by Gavan Mitchell

The Centre currently has nine professional staff members working across our five nodes.

Name	Title
Sarah Mulvey	Chief Operating Officer (UoM)
Kathy Palmer	Finance Manager (UoM)
Johanna Monk	Administration (UoM)
Spencer Wong	IT Developer (UoM)
Diana Londish	Operations (USyd)
Sandra Pedersen	Operations (Monash)
Brooke Bacon	Operations (RMIT)
Piumika Perera	Operations (UNSW)
Monica Brockmyre	Outreach and Education (UNSW)

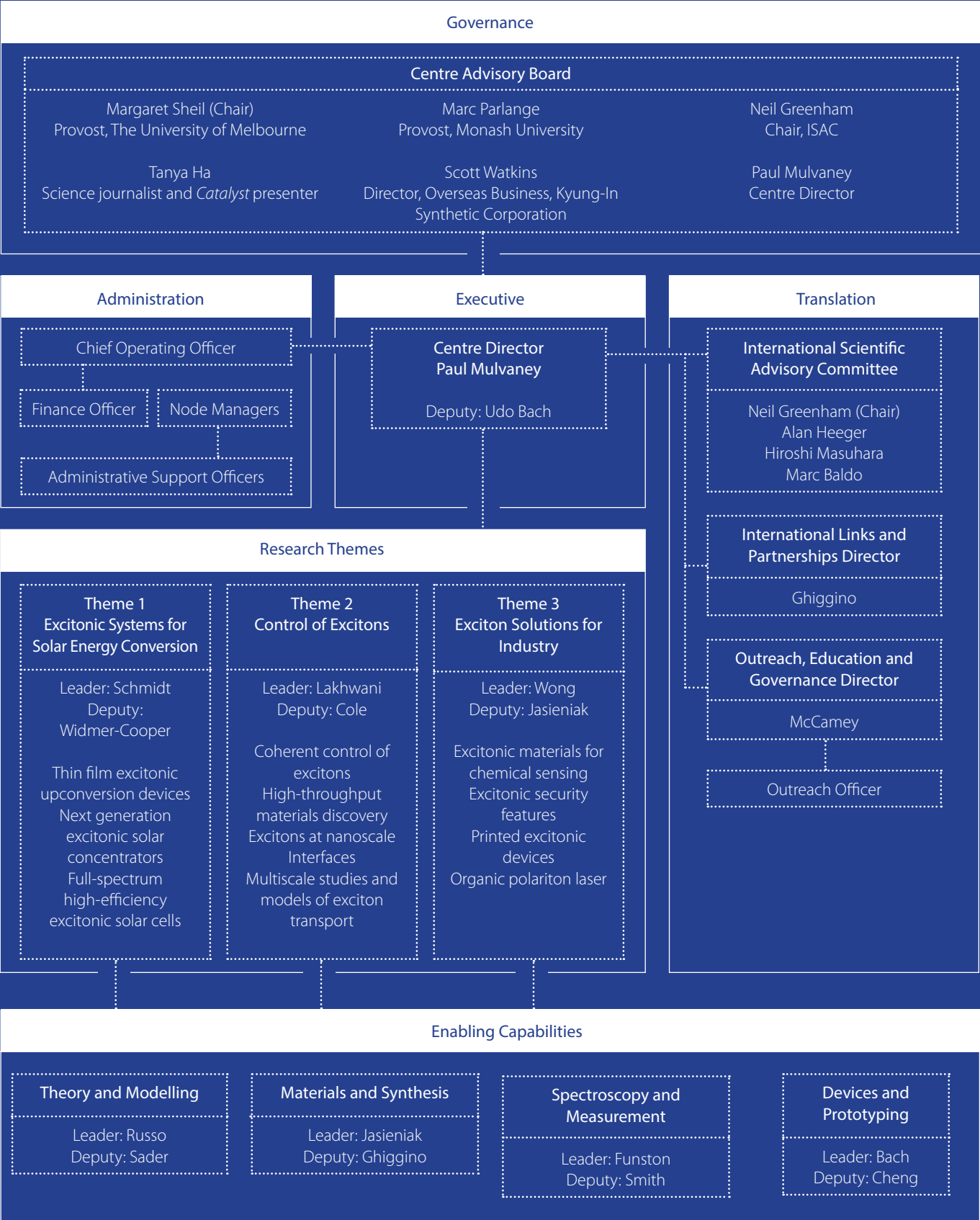
Research students

The Centre currently has 62 research students over its five nodes..

Research students	Supervisor	Organisation
Arun Ashokan	Paul Mulvaney	UoM
Yue Dong	Paul Mulvaney	UoM
Weijie Nie (with Shandong)	Paul Mulvaney	UoM
Gangcheng Yuan	Paul Mulvaney	UoM
Heyou Zhang	Paul Mulvaney	UoM
Christian Blauth	Paul Mulvaney Tadahiko Hirai	UoM CSIRO
Cameron Ritchie	Paul Mulvaney Jacek Jasieniak	UoM Monash
Maria Ritter (with Universität Bayreuth)	Paul Mulvaney Stephan Förster	UoM Bayreuth
Susanne Seibt (with Universität Bayreuth)	Paul Mulvaney Stephan Förster	UoM Bayreuth
Joseph Johnson	John Sader	UoM
Jesse Collis	John Sader	UoM
Eric Shen	John Sader	UoM
Mohammed Jameel	Trevor Smith	UoM
Peng Zeng	Trevor Smith	UoM
Hamid Soleimanejad	Trevor Smith Ken Ghiggino	UoM
Bolong Zhang	Wallace Wong	UoM
Can Gao	Wallace Wong Trevor Smith	UoM
Wu Na	Wallace Wong Paul Mulvaney	UoM
Riley O'Shea	Wallace Wong Paul Mulvaney	UoM
Carl Belle	Salvy Russo	RMIT
David Ing	Jared Cole	RMIT
Hugh Sullivan	Jared Cole	RMIT
Dorota Bacal	Udo Bach	Monash
Giovanni DeLuca	Udo Bach	Monash
Abbas Eghlimi	Udo Bach	Monash
Qicheng Hou	Udo Bach	Monash
Linton Lin	Udo Bach	Monash
Wenxin Mao	Udo Bach	Monash

PhD students	Supervisor	Organisation
Adam Surmiak	Udo Bach	Monash
Boer Tan	Udo Bach	Monash
Yen Yee Choo	Yibing Cheng	Monash
Liangcong Jiang	Yibing Cheng	Monash
Mathias Rothmann	Yibing Cheng	Monash
Shuai Ruan	Yibing Cheng	Monash
Wen Liang Tan	Yibing Cheng	Monash
Ali Ali	Alison Funston	Monash
Bala Maddala	Alison Funston	Monash
Ari Mayevsky	Alison Funston	Monash
Anum Nisar	Alison Funston	Monash
Anchal Yadav	Alison Funston	Monash
Chun Kiu Ng	Jacek Jasieniak	Monash
Bin Li	Jacek Jasieniak	Monash
Hanchen Li	Jacek Jasieniak	Monash
Jize Lin	Jacek Jasieniak	Monash
Jason Sun	Jacek Jasieniak	Monash
Chujie Wang	Jacek Jasieniak	Monash
Samira Aden	Udo Bach	Monash
Dorota Bacal	Udo Bach	Monash
Rebecca Milhuisen	Udo Bach	Monash
Tamader Alhazani	Dane McCamey	UNSW
Joanna Guse	Dane McCamey	UNSW
Minh Triet Nguyen	Dane McCamey	UNSW
Cameron Dover	Timothy Schmidt	UNSW
Nastaran Faraji Ouch Hesar	Timothy Schmidt	UNSW
Elham Gholizadeh	Timothy Schmidt	UNSW
Dylan Dowling	Timothy Schmidt	UNSW
Lara Gillan	Timothy Schmidt	UNSW
Billy Pappas	Timothy Schmidt	UNSW
Ashish Sharma	Girish Lakhwani	USyd
Madhuranga Rathnayake	Asaph Widmer-Cooper	USyd
Debora Monego	Asaph Widmer-Cooper	USyd
Jared Wood	Asaph Widmer-Cooper	USyd

Structure, Governance and Performance



Our boards and committees



The Centre is led by the Director supported by an Executive Committee, and receives advice from both a Centre Advisory Board and an International Scientific Advisory Committee. In addition, Chief Investigators are assigned individual areas of responsibility to ensure appropriate oversight of critical Centre activities.

Executive Committee

The Centre is led by an Executive Committee that supports the Director to maintain operational oversight of the Centre's activities. The Executive Committee has responsibility for all areas of the Centre's operation – including research, administration, outreach, education and engagement activities – and is composed of the following membership:

- Professor Paul Mulvaney, FAA – Centre Director (The University of Melbourne)
- Professor Salvy Russo – Deputy Director & Capability Leader (RMIT University)
- Professor Udo Bach – Deputy Director (Monash University)
- Professor Timothy Schmidt – Theme Leader, Excitonic Systems for Solar Energy Conversion (UNSW)
- Dr Girish Lakhwani – Theme Leader, Control of Excitons (The University of Sydney)
- Dr Wallace Wong – Theme Leader, Exciton Solutions for Industry (The University of Melbourne)
- Professor Ken Ghiggino – International Partnerships (The University of Melbourne)

- Associate Professor Dane McCamey – Director of Outreach, Education and Governance (UNSW)
- Ms Sarah Mulvey – Chief Operating Officer.

The Centre Executive Committee's formal meetings are held monthly (either in person or via video conference), with ongoing informal communication between meetings. Six meetings were held during 2017.

Centre Advisory Board

Providing the Centre Director with high-level advice related to the management, operation and strategy of the Centre, the Centre Advisory Board comprises senior members of the management, business, media and academic communities. Membership in 2017 comprised:

- Professor Margaret Sheil, Chair (1 July 2017–12 December 2017)
Provost, The University of Melbourne
Former CEO of Australian Research Council
- Professor Marc Parlange
Provost and Senior Vice-President, Monash University
- Dr Scott Watkins
Director, Overseas Business, Kyung-in Synthetic Corporation, South Korea
- Tanya Ha
Science Journalist and *Catalyst* Presenter

Our Executive Committee (L–R): Wallace Wong, Timothy Schmidt, Girish Lakhwani, Dane McCamey, Paul Mulvaney, Udo Bach, Salvy Russo and Ken Ghiggino (Absent: Sarah Mulvey). Photo by Gavan Mitchell



- Professor Neil Greenham (ex officio, Chair, International Scientific Advisory Committee) Deputy Head of Physics, University of Cambridge, UK
- Professor Paul Mulvaney (ex officio, Centre Director)

The Centre Advisory Board did not meet in 2017.

International Scientific Advisory Committee
Advising the Centre Director on the scientific merit of the Centre’s research programs, the International Scientific Advisory Committee reviews the Centre’s progress for the previous year, benchmarks this against internationally leading research organisations, and provides advice related to the Centres future research direction and research operations.

- The Committee consists of four eminent members from the USA, UK and Taiwan:
- Professor Neil Greenham – Chair Deputy Head of Physics, University of Cambridge, UK
 - Professor Alan Heeger 2000 Nobel Laureate in Chemistry Professor of Physics University of California Santa Barbara, USA
 - Professor Marc Baldo Director, Center of Excitonics Professor of Electrical Engineering and Computer Science MIT, USA
 - Professor Hiroshi Masuhara Chair Professor of Applied Chemistry National Chiao Tung University, Taiwan

The Committee’s first meeting was held on 12 December 2017 during the Centre’s inaugural Annual Workshop.
Professor Alan Heeger resigned from the Board due to personal reasons.
Professor Sheil resigned from the Board following her appointment in late 2017 as Vice-Chancellor of the Queensland University of Technology.

Diversity
The Centre is committed to equal employment opportunity, and to providing a safe, respectful and rewarding work environment, free from all forms of unlawful discrimination, harassment, vilification or victimisation.

- The Executive Committee has endorsed the formation of a Diversity Working Group to research, consult and develop a Centre-wide Diversity Plan. The Group will be investigating Node leaders in equity, diversity and inclusion policy, including:
- UNSW’s strategy, Equity, Diversity and Inclusion: Providing an equitable and inclusive environment for all.
 - The University of Melbourne’s Diversity and Inclusion Strategy, which identifies the need for representation of priority groups, such as women; Lesbian, Gay, Bisexual, Transgender and/or Intersex; Indigenous people; and people with disability.

The Diversity Working Group is headed by Director Paul Mulvaney, and is joined by CIs Dr Alison Funston and Dr Asaph Widmer-Cooper and professional staff member Ms Johanna Monk.

PhD students Riley O’Shea and Can Gao, The University of Melbourne. Photo by Gavan Mitchell

Risk

Our risk strategy is led by CI Girish Lakhwani, who has started the process of consultation with the CIs, the Operations team and the Executive Committee to establish the Centre’s risks, impact and mitigation. The current risk profile overview will form part of the risk-reporting framework for the Executive Committee and the Centre Advisory Board and is outlined in the following matrix.

Potential Risk	Potential risk	Impact	Mitigation
Research	Research Platforms fail to deliver	Medium	Monitoring through Executive Committee meetings
	Links between CIs doing experiments synthesis and theory fail to develop	Medium	Managed by Platform-based monthly meetings between CIs
Translation and Outreach	Rival business models become available reducing the significance of the work	Medium	CIs and research staff have good knowledge and understanding of rival technologies and existing competition and will monitor advances throughout the project
	Insufficient outreach and education-focused activities	Medium	Outreach, Education and Governance Director ensures all outreach channels are explored, and that all available and appropriate opportunities are utilised
Management	A CI resigns or retires mid-way through the Centre’s period of operation	High	Centre Director discusses developing plans and possible scenarios in consultation with the Executive Committee
	Labs of CIs are disrupted due to unforeseen circumstances	High	All CIs are involved in multiple projects so, where possible, reallocation of resources and research staff will be made, along with a plan (in consultation with Capability Leaders and Executive Committee) to ensure minimum disruption
	A CI moves to a different university to maximise career prospects	High	Mitigated by advanced planning through constant interactions with CIs, relevant Node leader and Executive Committee; if the move results in a one person Node, an action plan for affected and potential new node will be formulated
Financial	Centre exceeds line item expense	Low	Mitigated through Finance Officer’s continuous interaction with administration staff at all Nodes and at weekly Operations meeting, with a reallocation or use of contingent funds, where necessary and appropriate, by the Executive Committee

Financial summary

The Centre’s main source of funding is the Australian Research Council through the Centres of Excellence program. The ARC provides ~\$4.5 million per annum, and the administering institution, the University of Melbourne, and the collaborating institutions Monash University, UNSW, The University of Sydney and RMIT University contribute ~\$1.3 million in cash contributions per year.

Financial support

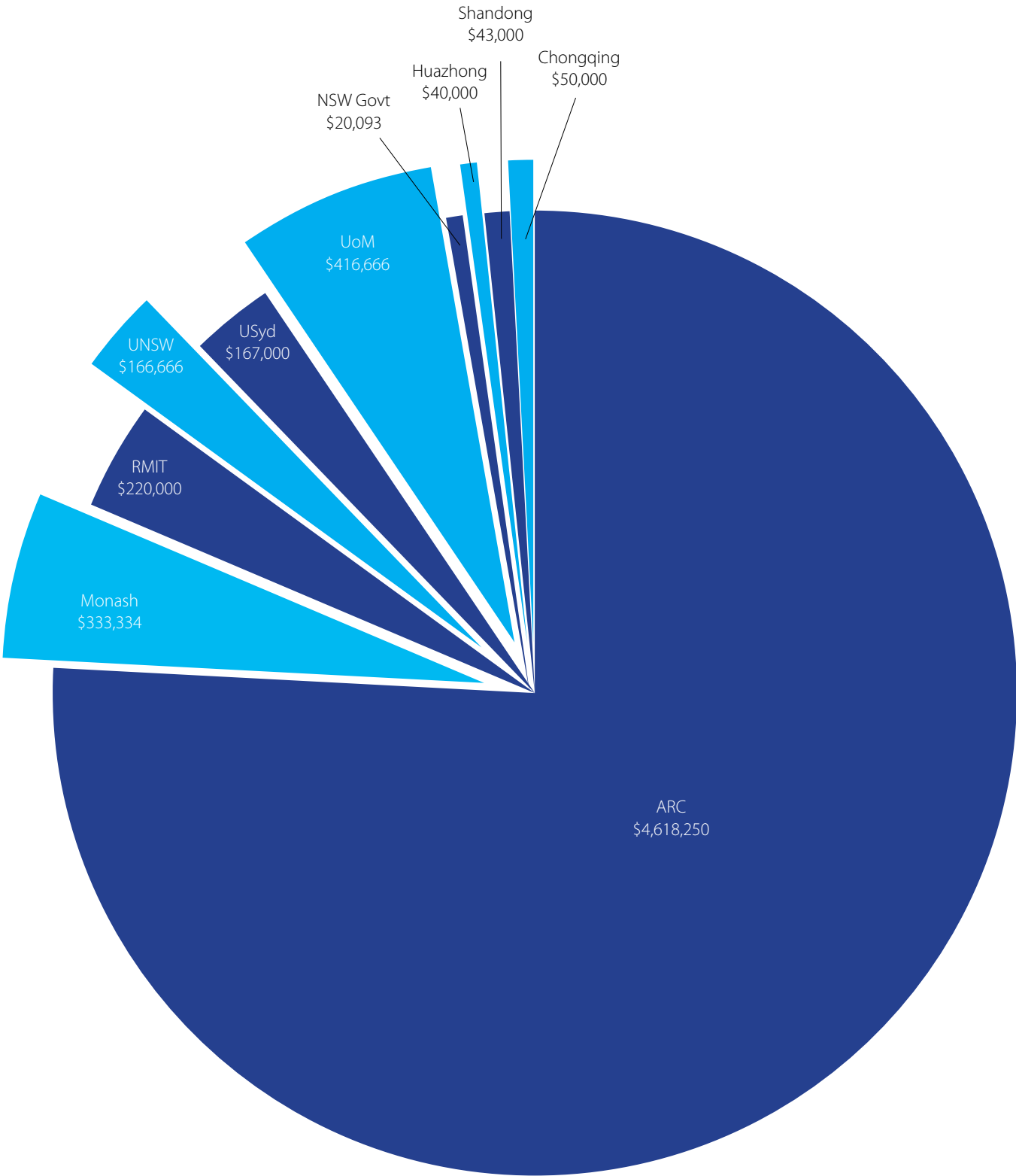
Financial statement		2017	Forecast 2018
Income	ARC grant	\$4,618,250	\$4,546,438
	Collaborating organisations	\$1,303,666	\$1,303,328
	International Partners	\$133,000	\$123,000
	Other – State Government	\$20,093	\$40,000
Total income		\$6,075,010	\$6,012,766
Expenditure	Salaries	\$827,899	\$3,812,888
	Scholarships	\$64,790	\$623,569
	Equipment	\$23,235	\$0
	Maintenance	\$232,718	\$870,120
	Travel	\$169,098	\$452,391
	Other	\$86,552	\$253,797
Total expenditure		\$1,449,291	\$6,012,766
Carry forward		\$4,625,719	\$0

Notes: Expenditure is low compared to income due to the late start of the Centre. Funding began on 1 January 2017 while the official operating start date of the Centre was 1 July 2017; ARC Grant funds include annual indexation.

In-kind contributions 2017

Collaborating organisations	The University of Melbourne	\$1,558,335
	Monash University	\$855,682
	University of NSW	\$222,577
	RMIT University	\$502,326
	The University of Sydney	\$354,749
Industry Partners	CSIRO	\$303,317
	DSTO	\$26,500
	RBA	\$69,875
International Partners	Chongqing Institute of Green and Intelligent Technology – Chinese Academy of Sciences	\$60,000
	Universität Ulm	\$15,000
	Huazhong University of Science and Technology	\$45,000
	University of California, Berkeley	\$50,000
	Universität Bayreuth	\$120,000
	Shandong University, China	\$20,000

Income 2017



Key performance indicators

Performance Measure	Target 2017	Actual 2017
Number of research outputs		
Refereed (peer-reviewed) journal articles	30	42
Book chapters	1	0
Contributed conference presentations	30	62
Patents and IP disclosures	2	0
Quality of research outputs		
High-impact publications	15%	19%
New citations to Centres of Excellence (CoE) outputs p.a.	50	145
Cumulative citation to CoE outputs	50	145
Invited or keynote international conference presentations	10	35
Plenary international conference presentations	0	1
Highly cited papers (top 1% in International Scientific Indexing)	0	1
Number of training courses held by the Centre		
Summer course in solar cell technologies	1	0
Training course in excitonics (or new postgraduate course)	1	0
Media training programs / dealing with the public and science communication skills	0	1
Number of workshops / conferences held / offered by the Centre		
CoE annual Exciton Science Conference	1	1
Workshops / conferences fully funded	1	1
Co-sponsored / co-funded conferences / symposia / workshops / seminars	2	2
Number of additional researchers working on Centre research		
Postdoctoral Researchers	15	33
Honours students (at any one time)	10	13
PhD students (at any one time)	25	51
Masters by Research students	6	6
Masters by Coursework students	2	3
Associate Investigators	11	12
Undergraduate students (Capstone subjects or Summer vacation scholars)	10	12

Number of postgraduate completions	Target 2017	Actual 2017
PhD	0	2
Master of Science	3	3
Honours	6	5
Number of mentoring programs supported by the Centre		
Sponsorship program – Exciton Science Prize	1	0
Outreach Program presentations	5	6
Co-sponsorship of events with Quantum Victoria, National Science Week etc.	2	2
Early Career Researcher mentoring / training programs	2	1
CI Science leadership programs	2	0
Number of presentations/briefings		
Public talks	5	9
Government or industry briefings	4	4
Website hits	200/month	1,025/month
Twitter mentions	10/month	7.6/month
News articles about the Centre	10	11
School visits	5	15
Exciton Science Prize entries	20	22
Number of new organisations collaborating with, or involved in, the Centre		
New international linkages	2	1
International visitors	20	41
Visits to international laboratories	20	9
New industry links	0	1
Number of commercial-related outputs		
New grants from non-ARC sources (\$25k p.a.)	1	2
Sponsorship/participation in entrepreneurial training schemes (e.g. Start-up boot camps)	1	0
Joint publications (between nodes)	4	5
Graduates entering renewable energy-related industries or employment	5%	0%
Gender equity targets		
Maximum male:female PhD student ratio	4:1	4:1
Maximum male:female Postdoctoral Researcher ratio	5:1	4:1

Activity plan 2018

2018 will be the first full year of funding for the Centre of Excellence in Exciton Science after our commencement on 1 July 2017. The Centre’s initial work has been focused on recruiting talented postdoctoral research fellows, and the subsequent revision and expansion of our research programs based on their input.

Theme 1: Excitonic systems for solar energy conversion
Theme 1 consists of three Platforms or approaches for improving solar energy conversion, with a focus on the synthesis of new materials that harvest more of the near-infra-red part of the spectrum. Typical classes of materials that we are investigating include kesterite-based inorganic materials, polyaromatic hydrocarbons such as pentacene, and chelated rare earths such as Er³⁺ ions. In 2018, the first systematic synthesis of new chromophores will commence. A key step is validating whether so-called triplet-triplet annihilation is a viable pathway to high-efficiency upconversion.

A key scientific challenge is to understand why current upconverting rare-earth ions exhibit low efficiencies. With the best ions exhibiting less than 1 per cent efficiency, it is difficult to exploit the near-IR spectrum. Thus, the main goal of Platform 1.1 in 2018 will focus on improving the upconversion efficiency of both organic chromophores and rare-earth materials.

A second approach to improving solar energy usage is through luminescent solar concentrators, which is being explored in Platform 1.2. This involves collecting solar energy in thin films and then wave-guiding it to the edges, thereby concentrating the light emitted along the edges. The light is harvested by thin strips of solar cells, which involves large cost reductions as the polymer film collects and concentrates the light. Key challenges in 2018 involve theoretical modelling of LSCs to find the optimal design and materials. We will also be building links with local polymer company Martogg to examine how the scale-up of LSCs can be achieved.

Platform 1.3 focuses on low temperature, printed solar cells. In 2018, Platform 1.3 will work on optimising printing technologies for its ‘solar inks’ with CSIRO and Greatcell Solar P/L, an Australian company leading the push to manufacture printed solar cells.

Theme 2: Control of excitons
Our solar energy research relies on breakthroughs in materials science, spectroscopy and theory. In 2018, Theme 2 will launch four Platforms into the basic science of excitons. The vision is to understand exciton, spin, lifetime, energy and polarisation. The main goal of Platform 2.1 is to *coherently control* quantum excitonic phenomena using a range of approaches including manipulation of spin and optical polarisation with engineered pulse sequences. In 2018, this Platform will begin its activities by constructing instruments for systematic study of excitons in magnetic fields, under hydrostatic pressure, and at cryotemperatures. These experiments will push our understanding of exciton spin, energy, and lifetime.

In Platform 2.2, we will begin our ambitious computational and theoretical efforts to create software that can undertake high-throughput screening of material optical properties. The goal is simply to be able to predict in a matter of hours, the properties of any material. This Platform has a four-year timeframe to reach its initial goal of screening 100 materials per week. Initial focus areas include: (i) Low dimensional hybrid perovskite materials, (ii) Antimony chalcogenide photovoltaics, (iii) Ferroelectric oxide-based materials, and (iv) Organic-inorganic hybrid materials.

Platform 2.3 pushes research to the single molecule level. Can we build devices from single excitons? Can we push excitons around inside nanostructures? What happens at interfaces? The goal here is to study single excitons in 1D and 2D nanostructures and to push for ultimate control of exciton position – the target of Platform 2.4.

In Platform 2.4, we will employ a combined theoretical/experimental approach to examine the interplay between electronic coupling, spin and structure on exciton diffusion and delocalisation in disordered organic and hybrid materials on scales ranging from the atomistic to the device level. The Platform will develop multiscale computational methods that can help interpret and predict exciton behaviour from the nanoscale to the device level.

Theme 3: Exciton solutions for industry
The Centre aims not only to do basic science but to help with translation through new ways of partnering with industry. Theme 3 involves teaming up with CSIRO, the Reserve Bank of Australia and Defence Science Technology Group on applications in which exciton science can provide new ideas and solutions. In 2018 we will expand our industry links through a pilot research program with Buglass, an Australian semiconductor company making blue lasers.

In Platform 3.1 we are focusing on novel ways to detect small concentrations of molecules in the environment, in industrial settings and in combat situations. In 2018, we will synthesise new molecules that will be trialled as detectors both for methyl bromide (a common fungicide) and for a range of difficult targets including nerve gases. We will also look at understanding how the gas flow to the sensor affects its performance.

In Platform 3.2 we will continue developing quantum dot LEDs as a pathway to energy efficient lighting. Unfortunately, LEDs are expensive to produce and difficult to scale up. Hence they are ideal for displays, laptops, TVs etc. but struggle to perform at a large scale such as street-lighting. Thus, we are working with CSIRO on a range of materials that will improve the energy efficiency of lighting across Australia.

Another of our core industry partners is the RBA. Australia’s polymer bank note technology is the envy of the rest of the world because of their durability and anti-counterfeiting qualities. In 2018, Platform 3.3 will start a new series of experiments to create next-generation anti-counterfeiting structures for Australian banknotes. The end goal is to have new features available for print trials in late 2020.

In 2018, we begin a new program in Platform 3.4 to create electrically pumped organic lasers. Such lasers can, in principle, be produced on computer chips (i.e. be miniaturised) and will consume orders of magnitude less power. Our work will involve simultaneous optical modelling of materials, complex nanofabrication and sophisticated picosecond spectroscopy, and will draw together the Centre’s multiple nodes.

Capabilities
While we are keen to get our Platforms underway, the Centre is also trying to build world-class infrastructure for Australian science. Key to this is a new LIEF (Linkage Infrastructure, Equipment and Facilities) project targeting 2019 for high-throughput materials characterisation. In Theme 2, we will conduct screening through computation, and this new projected capability will be used to create Australia’s largest facility for testing materials for optical, electronic and potentially mechanical properties. This new facility will cost in excess of \$4million in its first phase, and will draw on expertise across several Centres of Excellence.

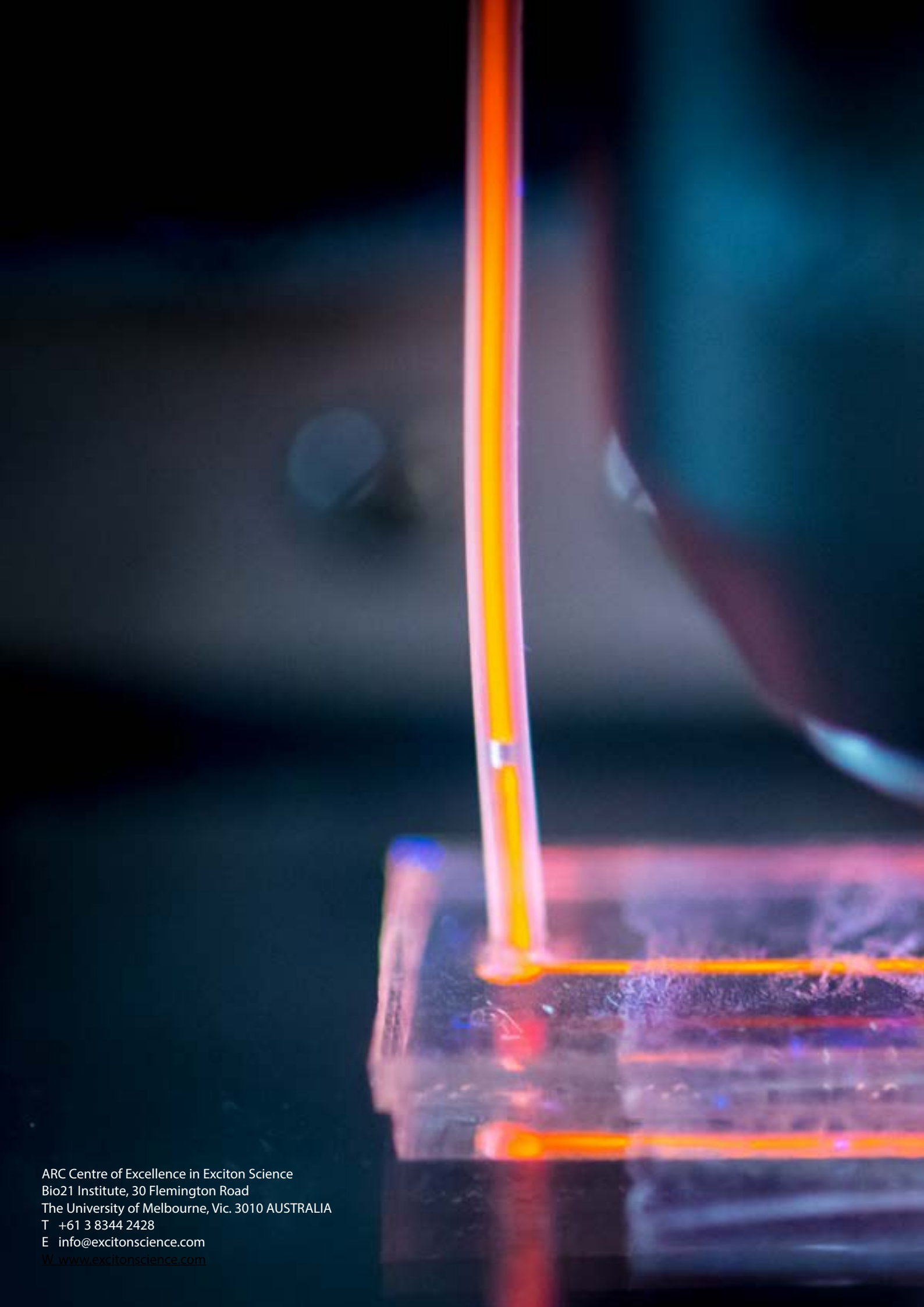
Management and governance
With more than 30 postdoctoral researchers and in excess of 110 graduate students already placed within the Centre, the management of careers, maximising staff potential and creating productive workplaces is a major challenge for our Operations team. In 2018, we will continue to ensure that the Centre has a global profile through extensive social media conduits and through high-quality visitor programs. In addition, the Centre Advisory Board and International Scientific Advisory Committee act as sentinels over our performance. Importantly, we are setting up business entrepreneurship, mentoring and leadership courses for all our staff and students to help them broaden their education and to hone their transferable skills. Many of these courses and programs will be set up in collaboration with other Centres of Excellence as a way to raise the bar in terms of student attributes.

Outreach
In 2017, the Centre focused primarily on the setting up of a high-profile web presence, which received more than 22,000 hits. Social media is a powerful way to reach younger audiences, but in 2018 we aim to get more personal. We will be developing materials for university outreach programs and will continue to feed into existing education programs such as CSIRO’s Learning by Doing, National Science Week.

Acronyms

AIST	Advanced Industrial Science and Technology
ARC	Australian Research Council
CI	Chief Investigator
CoE	Centres of Excellence
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSTG	Defence Science and Technology Group
IP	intellectual property
IR	infra-red
IT	information technology
LED	light-emitting diode
LSCs	luminescent solar concentrators
MIT	Massachusetts Institute of Technology
Monash	Monash University
NSW Govt	New South Wales State Government
PAH	polycyclic aromatic hydrocarbon
PI	Partner Investigator
PL	photoluminescence
PV	photovoltaics
QD	quantum dot
RBA	Reserve Bank of Australia
RMIT	RMIT University
SNOM	scanning near-field optical microscopy
STEM	Science, Technology, Engineering and Mathematics
UK	United Kingdom
UoM	The University of Melbourne
USyd	The University of Sydney
UNSW	University of New South Wales
USA	United States of America





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