FLEET

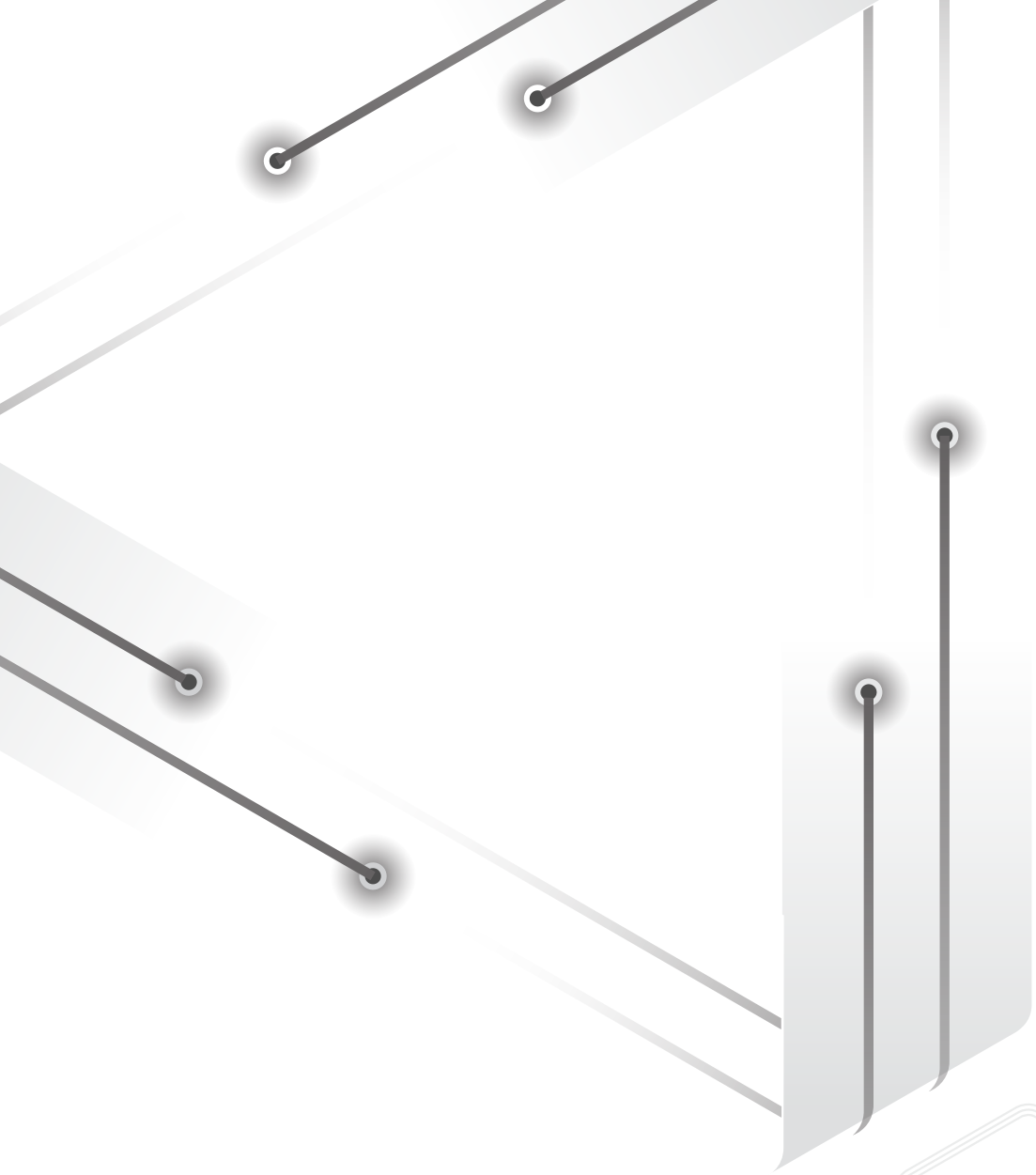
2017

ANNUAL REPORT

FLEET

ARC CENTRE OF EXCELLENCE IN
FUTURE LOW-ENERGY
ELECTRONICS TECHNOLOGIES

Quasi-particle interference pattern on the surface of topological semimetal ZrSiS. Image courtesy of Bent Weber & Michael Fuhrer



The ARC Centre of Excellence in **Future Low-Energy Electronics Technologies (FLEET)** addresses a grand challenge: reducing the energy used in information technology (IT), which now accounts for 5% of the electricity use on Earth, and is doubling every 10 years. The current, silicon-based technology is 40 years old, and reaching the limits of its efficiency. To allow computing to continue to grow, we need a new generation of ultra-low energy electronics.

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FLEET AT A GLANCE

152
CENTRE MEMBERS AND AFFILIATES

127
INVESTIGATORS AND RESEARCH ASSOCIATES

30
EARLY CAREER RESEARCHERS

19
RESEARCH LEADERS FROM 7 UNIVERSITIES

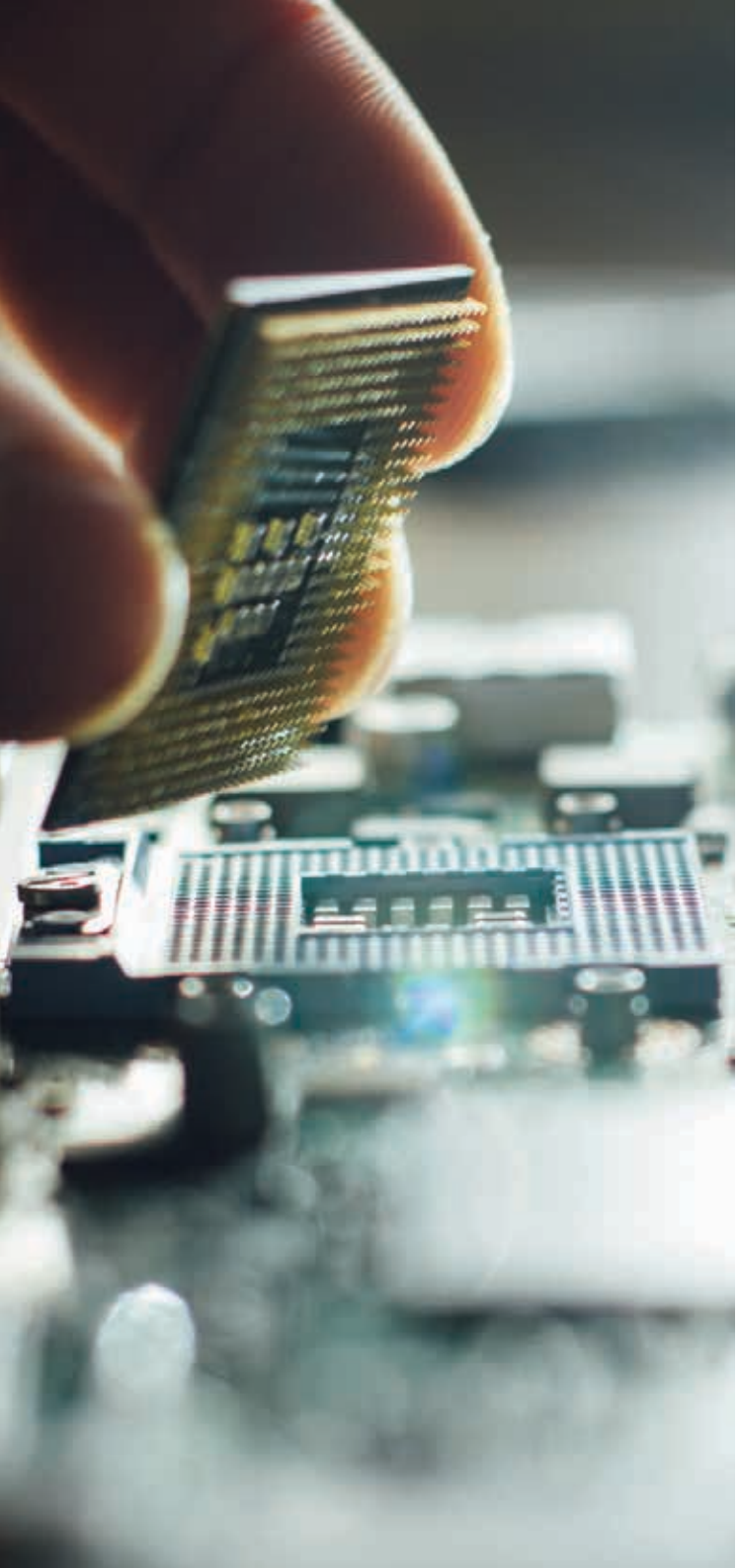
13
INTERNATIONAL PARTNER ORGANISATIONS

CENTRE COMMENCEMENT DATE

29 JUNE 2017

2017–2023 RESEARCH FUNDING

IN-KIND COMMITMENT BY COLLABORATING ORGANISATIONS



2017: FLEET'S FIRST YEAR UNDERSCORES CENTRE'S MISSION

It's been an exciting first year for FLEET as the Centre moves off the drawing board to become a real, vital entity, with over a hundred participants working towards a common goal.

Recent events reinforced the urgency of FLEET's mission, with the dramatic rise of Bitcoin introducing the public to the notion that computing is a limited resource, and that the energy used in computation has become a significant factor limiting its growth.

Bitcoin's reliance on the computationally-intensive process of 'bitmining' sparked a new industry with ever-more energy-hungry computers running non-stop to generate wealth. The resulting energy demands are a central feature of the cryptocurrency, designed to limit wealth creation.

But few expected those energy demands to mount up quite so quickly. In fact, as increasingly strident headlines lamented, Bitcoin's energy use had grown to exceed that of over 150 individual countries.

It was a small-scale demonstration of an unavoidable truth: the exponential demand for new computing capacity must be met with corresponding gains in computing efficiency, or the information revolution will grind to a halt.

To date, that need for computing efficiency was largely satisfied by steady progress in conventional, silicon-based computing technology – a phenomenon referred to in the semiconductor industry as 'Moore's law'. However there is increasing global recognition, even

> Low-energy electronics technology under investigation by FLEET is critical for the future of computing and communications, specifically in reducing power consumption and operating costs of large clusters of servers.

Steven Duvall
FLEET Advisory Committee
Chief Technology Officer and General Manager of Technology Development, Silanna

FLEET will develop:

- New systems in which electricity flows with minimal resistance and therefore minimal wasted dissipation of energy
- Devices in which this 'dissipationless' electric current can be switched on and off at will.

These devices will enable revolutionary new electronics and communications technologies with ultra-low energy consumption.

amongst non-experts, that Moore's law is slowly winding down. Computer-chip performance is flat-lining.

FLEET's mission to produce a new energy-efficient computing technology is vital and timely.

At the same time, the science behind FLEET is gaining more recognition:

The 2016 Nobel Prize in Physics was awarded to David Thouless, Duncan Haldane and Michael Kosterlitz for their work on topological phase transitions and topological insulators. Topological insulators form one of FLEET's three approaches *(see p10)* to low-energy electronics.

Atomically-thin materials, which underpin FLEET's efforts, were featured in the 2010 Nobel Prize in Physics for the isolation of graphene, and continue to attract attention as they move from the laboratory into applications.

Other ideas underpinning FLEET, such as the exploration of phases of matter far from equilibrium, have just begun to catch fire in the scientific community. Thus FLEET begins operations at an opportune time scientifically when new concepts and new tools have just become available and are ripe for exploitation, and FLEET will lead the charge.

FLEET'S GRAND CHALLENGE: MINIMISING THE ENERGY USED IN COMPUTATION

FLEET addresses a grand challenge: reducing the energy used in information technology (IT), which already accounts for 5% of the electricity use on Earth, and is doubling every 10 years.

The current, silicon-based technology is 40 years old, and reaching the limits of its efficiency.

However, fundamental physical limits show that computing efficiency could still be several orders of magnitude better, which inspires us to search for a replacement technology.

We have an insatiable demand for computation. Every year, the demand for computation grows by 70%.

And using computers consumes energy. Lots of energy.

Computing is achieved via microscopic switches called transistors – a couple of billion of them packed into each small computer chip.

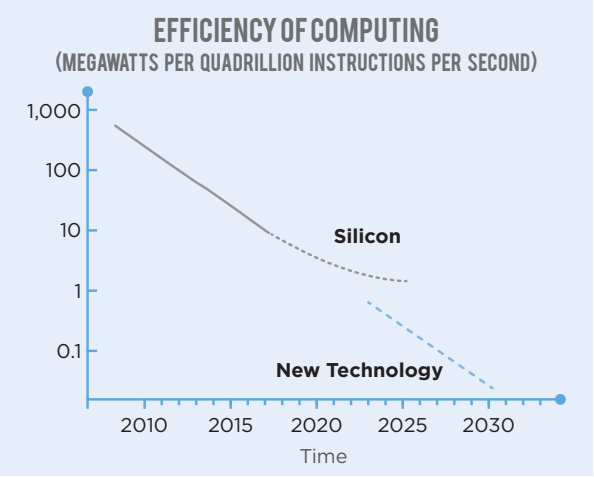
And each time one of those transistors switches, a tiny amount of energy is burnt.

Consider the billions of transistors in each small computer chip, each switching billions of times a second, and multiply that by hundreds of servers in hundreds of thousands of factory-sized data centres...

For many years, the growing energy demands of computations were kept in check by ever-more efficient, and ever more-compact computer chips – a trend related to Moore's Law, which observed that number of transistors in a given area doubled around every 18 months.

But Moore's Law is ending. There are limited future efficiencies to be found in present technology.

> For computation to continue to grow, to keep up with society's ever-increasing demands, we need more-efficient electronics. We need a new type of transistor that burns much less energy when it switches.
>
> **Prof Michael Fuhrer**
> FLEET Director



FLEET will develop electronic devices that operate at ultra-low energy, enabling revolutionary new technologies to drive future electronics and computing, while meeting society's demand for reduced energy consumption.

2017

01 JANUARY

- Chief Operating Officer appointed
- FLEET branding established
- Basic website launched
- Governance structure and budget reviewed

02 FEBRUARY

- Strategic Governance Committee Chairs appointed
- Research video launched
- Guidelines on acknowledgement & using the FLEET brand established

03 MARCH

- Centre Education & Outreach and Communications Coordinators recruited
- KPIs approved by ARC
- Travel policy established

04 APRIL

- Equity & Diversity committee established
- Education & Training committee established
- Outreach committee established
- Recruitment policy established

05 MAY

- Equity & diversity policy established
- Communications committee established
- KPI reporting system established
- Co-hosted SPICE workshop with PI Jairo Sinova, Mainz

06 JUNE

- **Centre commencement: 29 Jun 2017**
- FLEET website launched
- Scholarship policy established
- FLEET – Nanyang Technological University Singapore workshop
- Home Science program launched

07 JULY

- Centre Executive Officer appointed
- FLEET intranet launched
- Research personnel recruitment began
- Visit by PI Victor Gurarie, UC Boulder
- First FLEET lab tour at Swinburne

08 AUGUST

- Centre induction package established
- First FLEET public lecture
- First FLEET research seminar at Monash

09 SEPTEMBER

- Centre quarterly financial reporting process implemented
- First Young Researchers Forum
- AC and ISAC strategically established

10 OCTOBER

- Centre branding installed at headquarters Monash
- Co-hosted Gordon Godfrey workshop at UNSW

11 NOVEMBER

- First FLEET annual workshop
- Visit by Nobel Laureate Wolfgang Ketterle, MIT (ISAC)
- Public lecture by Nobel Laureate Wolfgang Ketterle
- Vist by PI Qi-Kun Xue, Tsinghua University
- Visit by AI Shaffique Adam, National University of Singapore
- Mentoring programs developed (implemented 2018)

12 DECEMBER

- Co-hosted first Victorian ARC centres and hubs staff workshop
- Tender won to host ICON-2DMat 2018 in Australia

MESSAGE FROM THE DIRECTOR

2017 has been a ramp-up phase for FLEET as it builds new research capacity and strength in new scientific areas. FLEET has brought on board 29 HDR students and 30 early-career researchers, with more on the way. This represents an enormous influx of talent now focused on the FLEET mission.

2017 has also been a time of strengthening links with existing research partners as well as building new connections, work that will continue in the coming years.

FLEET is an unprecedented interdisciplinary effort, for example allying atomic-gas researchers with those working on advanced semiconductor materials, and applying new ideas from topology and non-equilibrium physics to real-world engineering problems.

This interdisciplinary opportunity comes with the challenge of combining people of such diverse fields, and learning to speak each other's languages. This process began in February 2017 with a Chief Investigators' workshop, and continued in November with the Centre's first annual workshop, as well as numerous visits among investigators and partners.

The annual workshop brought us together for the first time as a Centre, with detailed tutorial presentations from each theme and well-crafted, informative talks from world-leading experts Prof Wolfgang Ketterle (FLEET ISAC), Prof Qi-Kun Xue (FLEET PI) and A/Prof Shaffique Adam (FLEET AI).

It was a pleasure to see the excitement sparked in the Centre's young researchers attending the workshop as they grasped the big picture of our mission.

FLEET is a seven-year effort, and we have taken a long-term, strategic approach to the management of the Centre.

We are very proud of the scientific advances we have made in 2017, described in this report.

For example in 2017 the Centre has:

> Demonstrated the first thin-film transistor using a topological Dirac semimetal, and

> Devised a powerful new method for making atomically-thin materials from liquid-metal surfaces, which attracted much attention in the popular press.

The Centre has also laid the groundwork for larger advances in the future. FLEET has:

> Developed the first facility in Australia for assembling atom-thick crystals of different materials to form new heterostructures

> Begun construction of optical cavities integrated with atomically-thin semiconductors for exciton–polariton condensation

> Initiated a new, ultrafast scanning tunneling microscope, which will be able to view electronic processes with sub-Ångstrom spatial and sub-picosecond temporal resolution.

The Australian Synchrotron began testing a new endstation for angle-resolved photoemission spectroscopy (overseen by FLEET Partner Investigator Dr Anton Tadich). This facility is essential to FLEET's mission to discover and characterise new atomically-thin materials.

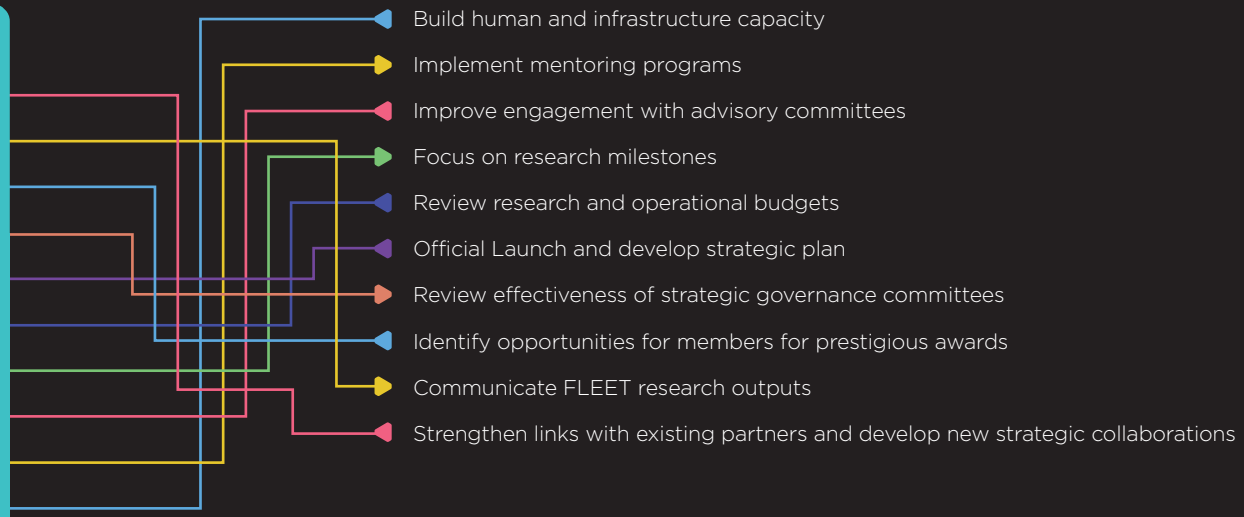
The full potential of these efforts will take years to realise.

Similarly, FLEET's capacity-building mission will not be fulfilled overnight. While FLEET has hired a significant complement of research associates, some positions are still unfilled.

This reflects FLEET's commitment to hiring the highest quality researchers, who will raise the profile of research done in Australia.

FLEET's operations started on 29 June 2017. This, together with our cautious strategy in hiring and developing facilities has resulted in significant underspending for 2017, as outlined in detail in this report. We are confident we are following the best strategy for long-term success in hiring

2018 FOCUS AREAS



the best researchers and taking the necessary time to plan the most-useful scientific infrastructure.

FLEET is dedicated to providing the highest quality training to our students and early-career researchers. During 2017, FLEET initiated training and mentorship programs at all levels aimed at giving researchers the skills to succeed in a broad range of endeavours.

The Centre is also committed to changing the scientific culture – in particular, building a work environment more welcoming for women in science. It has been thrilling to see our efforts in this area enthusiastically adopted, with the result being a more pleasant work environment for everyone. Efforts to make our first annual workshop family-friendly saw many families and partners attend. The result was a more-productive, improved social and networking environment for all participants, with no downside in meeting the scientific goals of the workshop.

FLEET's scope extends far beyond the laboratory. To be successful, FLEET must convey the importance of its mission broadly – to other researchers, policy-makers, teachers, students, and the public at large. During 2017, FLEET has developed the network to enable this both internally and externally, with full-time staff responsible for communication and education, specialist committees, and links with our associate investigators and their organisations.

As new programs are developed, participation in FLEET's outreach programs is ramping up, and we expect to reach our goal of having every FLEET member participate in 20 hours of outreach activities each year.

Thank you for taking the time to read this report and for supporting FLEET's mission to build a more energy-efficient future for computing.

MICHAEL FUHRER
Director, FLEET

Research fellow Feixiang Xiang studies topological matter using quantum transport measurements

INNOVATE

02

FLEET is pursuing the following research themes to develop systems in which electrical current can flow with near-zero resistance:

> Topological materials

> Exciton superfluids

> Light-transformed materials

The above approaches are enabled by the following technologies:

> Atomically-thin materials

> Nano-device fabrication

19
CHIEF INVESTIGATORS

21
RESEARCH FELLOWS

16
PARTNER INVESTIGATORS

29
HIGHER DEGREE RESEARCH (HDR) STUDENTS

13
SCIENTIFIC ASSOCIATE INVESTIGATORS

29
RESEARCH AFFILIATES

103
PRESENTATIONS TO THE SCIENTIFIC COMMUNITY

45
INVITED PRESENTATIONS AT INTERNATIONAL MEETINGS

5
ARTICLES WITH IMPACT FACTOR >10

6
ARTICLES WITH IMPACT FACTOR 1–10

27
PEER REVIEWED PUBLICATIONS

3
RESEARCH THEMES

$1.9M
ADDITIONAL INCOME
SECURED FOR FLEET

$5.2M
VALUE IN RESEARCH GRANTS
AWARDED TO FLEET INVESTIGATORS

2
ENABLING TECHNOLOGIES

CHIEF INVESTIGATORS

MICHAEL FUHRER

Director,
Node leader,
Monash University

A pioneer of the study of electronic properties of 2D materials, Michael synthesises and studies new, ultra-thin topological Dirac semimetals and 2D topological insulators with large bandgaps within Research theme 1.

Michael is an ARC Laureate Fellow, Fellow of the American Physics Society, and Fellow of the American Association for the Advancement of Science.

ELENA OSTROVSKAYA

Node leader, ANU

Leader of Research theme 2, Elena directs theoretical and experimental exciton and exciton-polariton studies, Bose-Einstein condensation, superfluidity, and topologically-protected transport near room temperature.

KRIS HELMERSON

Monash

Heading Research theme 3, Kris uses ultracold atoms in an optical lattice to investigate driven Floquet systems, and topological states in multi-dimensional extensions of the kicked quantum rotor.

XIAOLIN WANG

Node leader, UoW

Directing Enabling technology A, Xiaolin investigates charge and spin effects in magnetic topological insulators and fabrication of FLEET's single-crystal bulk and thin-film samples.

LAN WANG

RMIT

Leading Enabling technology B, Lan also directs study of high-temperature quantum anomalous Hall systems in Research theme 1, and synthesis of novel 2D materials for Enabling technology A.

ALEX HAMILTON

Deputy Director,
Node leader, University of New South Wales

A leading expert on electronic conduction in 2D and nanoscale transistors, and hole behaviour in semiconductor nanostructures, Alex leads Research theme 1 where he directs the program on artificially-engineered topological materials.

Alex has received an Australian Professorial Fellowship, an ARC Outstanding Researcher Award, a UNSW Scientia Professorship and is a Fellow of the American Physical Society.

CHRIS VALE

Node leader, Swinburne

Chris synthesises and characterises topological phenomena in 2D, ultracold fermionic atomic gases, investigating new forms of topological matter within Research theme 3.

KOUROSH KALANTAR-ZADEH

Node leader, RMIT

Kourosh develops novel 2D semiconducting materials and fabrication techniques for advanced devices, using electron and ion beam lithography for Enabling technology B.

MATTHEW DAVIS

Node leader, UQ

Within Research theme 3, Matthew studies transitions between novel non-equilibrium states of matter, focusing on relaxation in non-equilibrium and destructive effects of coupling to the environment.

NAGARAJAN 'NAGY' VALANOOR

UNSW

Nagy explores oxides for low-energy electronic devices founded on topological materials in Enabling technology A, and synthesises ferroelectric and ferromagnetic materials for Research themes 1 and 2.

AGUSTIN SCHIFFRIN

Monash

Agustin investigates optically-driven topological phases using ultrafast photonics, pump-probe spectroscopy and time-resolved scanning probe microscopy within Research themes 1 and 3.

DIMI CULCER

UNSW

Dimi studies theoretical charge and spin transport in topological materials and artificial graphene with strong spin-orbit coupling within Research theme 1.

JAN SEIDEL

UNSW

Jan uses scanning probe microscopy (SPM) to study complex oxide materials systems for Research themes 1 and 2, and nanoscale SPM patterning in topological materials in Enabling technology B.

JEFF DAVIS

Swinburne

Jeff uses femtosecond laser pulses in Swinburne's ultrafast science facility to modify electronic band structure and realise Floquet topological insulators in 2D materials, within Research theme 3.

MEERA PARISH

Monash

Meera investigates the robustness of excitonic superfluidity to an electron-hole density imbalance in bilayers in Research theme 2, searching for exotic forms of superfluidity. She also studies impurities dynamically coupled to fermion-pair superfluids, in Research theme 3.

NIKHIL MEDHEKAR

Monash

Nikhil investigates electronic structure of atomically-thin topological insulators and interfaces in Research theme 1 via quantum mechanical simulations on massively-parallel, high-performance computing systems.

OLEG SUSHKOV

UNSW

Oleg leads two theoretical investigations within Research theme 1: artificial nanofabricated materials and laterally-modulated oxide interfaces.

OLEH KLOCHAN

UNSW

Oleh leads the fabrication and measurements of artificially-designed topological insulators using conventional semiconductors in Research theme 1.

QIAOLIANG BAO

Monash

Qiaoliang investigates waveguide-coupled 2D semiconductors in Research theme 2 and plasmon-coupled 2D materials and devices in Enabling technology B, focusing on effects of light-matter interactions.

PARTNER INVESTIGATORS

Allan MacDonald
University of Texas

Anton Tadich
Australian Synchrotron

Antonio Castro Neto
National University of Singapore

Barbaros Özyilmaz
National University of Singapore

Ferenc Krausz
Max Planck Institute of Quantum Optics

Frank Klose
Australian Nuclear Science and Technology Organisation

Gil Refael
California Institute of Technology

Ian Spielman
University of Maryland

Jairo Sinova
Mainz University

James Hone
Columbia University

Johnpierre Paglione
University of Maryland

Qi-Kun Xue
Tsinghua University

Sven Höfling
University of Würzburg

Victor Galitski
University of Maryland

Victor Gurarie
University of Colorado

William Phillips
University of Maryland

LEGEND

- Research theme 1, topological materials
- Research theme 2, exciton superfluids
- Research theme 3, light-transformed materials
- Enabling technology A, atomically-thin materials
- Enabling technology B, nano-device fabrication

SCIENTIFIC ASSOCIATE INVESTIGATORS

Bent Weber
Nanyang Technological University Singapore

David Cortie
University of Wollongong

Jared Cole
RMIT University

Jesper Levinsen
Monash University

Jian-zhen Ou
RMIT University

Joanne Etheridge
Monash University

Mark Edmonds
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Martin Schultze
Max Planck Institute of Quantum Optics

Nicholas Karpowicz
Max Planck Institute of Quantum Optics

Paul Dyke
Swinburne University

Shaffique Adam
National University of Singapore

Torben Daeneke
RMIT University

Zhi Li
University of Wollongong

MASTERS STUDENTS

Jackson Wong
University of New South Wales

Lawrence Farrar
RMIT University

HONOURS STUDENTS

James Denier
Swinburne University of Technology

Jessica Alves
Monash University

Oliver Sandberg
University of Queensland

Rebecca Orrell-Trigg
RMIT University

RESEARCH FELLOWS

Aydin Keser
University of New South Wales

Benjamin Carey
RMIT University

Carlos Claiton Noschang Kuhn
Swinburne University

Daisy Qingwen Wang
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Daniel Sando
University of New South Wales

David Colas
University of Queensland

Dmitry Miserev
University of New South Wales

Elizabeth Marcellina
University of New South Wales

Feixiang Xiang
University of New South Wales

Harley Scammell
University of New South Wales

Jonathan Tollurud
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Matt Reeves
University of Queensland

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Pankaj Sharma
University of New South Wales

Peggy Qi Zhang
University of New South Wales

Sascha Hoinka
Swinburne University

Shilpa Sanwlani
Swinburne University

Steven Barrow
RMIT University

Stuart Earl
Swinburne University

Weizhe Liu
Monash University

Yun Suk Eo
University of Maryland

LEGEND

- Research theme 1, topological materials
- Research theme 2, exciton superfluids
- Research theme 3, light-transformed materials
- Enabling technology A, atomically-thin materials
- Enabling technology B, nano-device fabrication

PHD STUDENTS

Ali Zavabeti
RMIT University

Chang Liu
Monash University

Cheng Tan
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Chutian Wang
Monash University

Eliezer Estrecho
Australian National University

Fan Ji
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Fei Hou
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Hanqing Yin
Monash University

Hareem Khan
RMIT University

Hong Liu
University of New South Wales

James Collins
Monash University

Jialu Zheng
Monash University

Maryam Boozarjmehr
Australian National University

Paul Atkin
RMIT University

Pavel Kolesnichenko
Swinburne University

Samuel Bladwell
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Samuel Wilkinson
RMIT University

Sultan Albarakati
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Tatek Lemma
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Tommy Bartolo
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Tyson Peppler
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Vivasha Govinden
University of New South Wales

Wafa Afzal
University of Wollongong

Weiyao Zhao
University of Wollongong

Yonatan Ashlea Alava
University of New South Wales

Zhi-Tao Deng
University of Queensland

Ziyu Wang
Monash University

PROF ALEX HAMILTON

Leader,
Research theme 1
University of New South Wales

"FLEET provides the resources and connections to tackle hard science problems"

Expertise: electronic conduction in 2D and nanoscale transistors, spin-orbit interactions, behaviour of holes in semiconductor nanostructures

Research outputs: 180+ papers, 2500+ citations, h-index 26

Research fellow Daisy Wang studies artificially engineered topological systems

RESEARCH THEME 1: TOPOLOGICAL MATERIALS

The first FLEET approach, to achieve electrical current flow with near-zero resistance, is based on a paradigm shift in the understanding of condensed-matter physics and materials science: the advent of **topological insulators**.

Unlike conventional insulators, which do not conduct electricity at all, topological insulators conduct electricity, but only along their edges.

Along those edge paths, they conduct electrons strictly in one direction, without the 'back-scattering' of electrons that dissipates energy in conventional electronics.

FLEET's challenge is to create topological materials that will operate as insulators in their interior, and have switchable conduction paths along their edges.

For the new technology to form a viable alternative to traditional transistors, the desired properties must be achievable at room temperature – there's no point in saving energy on transistor switching if you have to use even more energy to keep the system supercold.

Topological transistors would 'switch', just as a traditional transistor does.

Applying a controlling voltage would switch the edge paths of the topological material between being a topological insulator ('on') and a conventional insulator ('off').

Approaches used are:

> Magnetic topological insulators and quantum anomalous Hall effect (QAHE)
> Topological Dirac semimetals
> Artificial topological systems.

IN 2018, FLEET WILL:

> Demonstrate transition from classical insulator to topological insulator in ultra-thin Na_3Bi films
> Encapsulate ultra-thin Na_3Bi films for study outside ultra-high vacuum system
> Study electrical transport properties of artificial graphene devices
> Advance fundamental theoretical knowledge of topological materials' electrical properties
> Predict new 2D topological materials from first principle calculations
> Investigate magnetic properties of atomically-thin van der Waals materials.

DEFINITIONS

artificial topological systems Artificial analogues of graphene and 2D topological insulators

dissipationless current Electric current that flows without wasted dissipation of energy

Floquet topological insulator A topological insulator created by applying light to a conventional insulator

quantum spin Hall effect (QSHE) The spin-orbit interaction driven effect that gives a non-magnetic material conducting edges, which can carry current without resistance, as long as no magnetic disorder is present

quantum anomalous Hall effect (QAHE) A magnetic version of the QSHE (above), in which conducting edges carry currents in only one direction, and are completely without resistance

spin-orbit interaction The interaction between electrons' movement and their inherent angular momentum, which drives topological effects

topological materials A relatively new class of material that is electrically insulating in its interior, but conducts along its edges

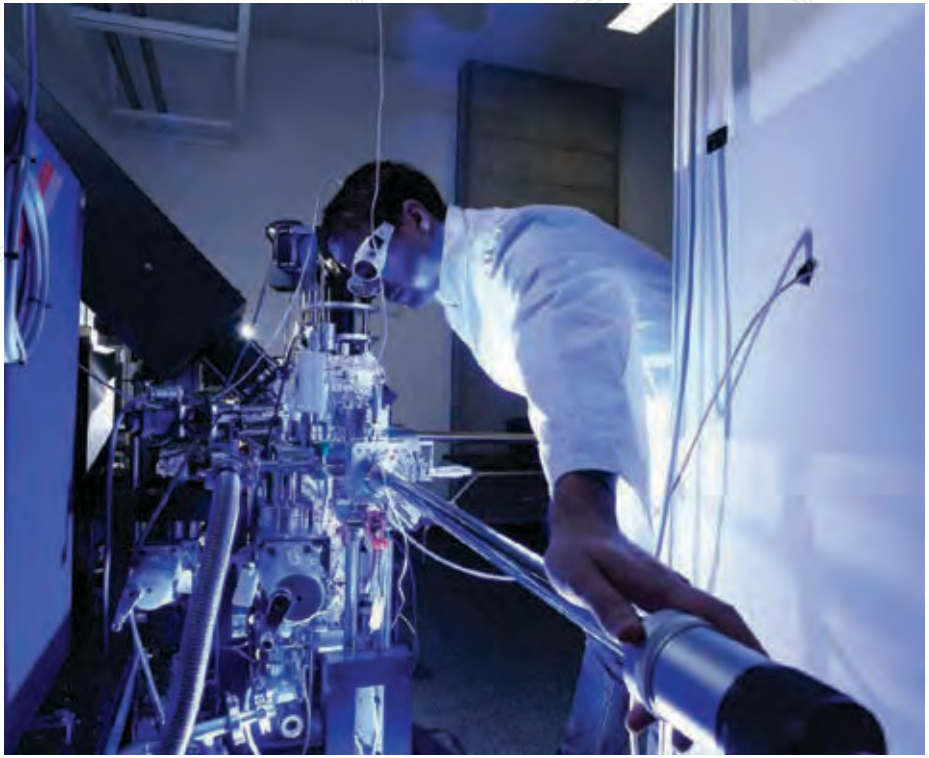
topological Dirac semimetal (TDS) Topological material at the boundary between conventional insulators (which don't conduct) and topological insulators (which conduct along their edges)

van der Waals (vdW) material A material naturally made of 2D layers, held together by weak van der Waals forces

2017 HIGHLIGHTS

The year's first two highlights are particularly important. They provide a possible route to making devices with topologically-protected properties from conventional semiconductors.

> Demonstrating the first transistor made from a topological Dirac semimetal in thin-film form, a pathway to more-complex topological electronic devices *(see case study p20)*
> Fabricating prototype artificial-graphene devices based on conventional semiconductor materials, understanding spin-orbit interactions that could convert artificial graphene into an artificial topological insulator
> Nano-patterning of oxide structures, opening new routes to fabrication of widely applicable nanoscale devices
> Hosting Gordon Godfrey workshop at UNSW *(see p41)*, bringing together experts in spin and strong-electron correlation.



Research fellow Daniel Sando with oxide pulsed laser deposition (PLD) chamber used to fabricate thin-film samples with very high crystalline perfection, preparing interfaces required for FLEET Research theme 1

CASE STUDY

Collaborator Jack Hellerstedt monitors growth of Na_3Bi in scanning tunneling microscope

> I'm excited to see FLEET already leading the way, showing how new breakthroughs in electronics materials can be used to create practical opportunities in ICT.
>
> **Dr Ellen William**
> FLEET Advisory Committee
> University of Maryland

SWITCHING CONDUCTION MODE: A STEP TOWARDS TOPOLOGICAL TRANSISTORS

Applying an electric field switches electronic conduction mode of a topological material

FLEET researchers achieved a significant landmark in the search for a functional topological transistor in 2017, using an applied electric field to switch the conduction mode of a topological material.

A 'gate' electrode was used to switch the conduction mode in the topological material Na_3Bi.

Na_3Bi is a topological Dirac semimetal (TDS), a material that has been referred to as '3D graphene'.

"Electrons travelling within a TDS behave similarly to graphene, moving relativistically (ie, as if they have no mass)," explains FLEET associate investigator Dr Mark Edmonds, a co-author on the paper.

Conduction mode in the TDS was switched between 'n-type' conduction (in which the current is carried by electrons) and 'p-type' conduction (in which the current is carried by 'holes' – which are effectively 'missing electrons').

The work represented the first successful, simple, thin-film transistor made from a topological semimetal and the first transistor made from Na_3Bi.

As the first transistor made from any topological Dirac semimetal in a solid-state, thin-film form, this shows that the technology is amenable to processing into electronic devices over large areas.

As the first demonstration that electronic properties can be successfully manipulated by an applied electric field, it was also a step on the way to more-complex, switchable topological transistors.

In complex, switchable topological transistors, the key is the ability to switch a material between a conventional insulator, and the topological state. Ideally, such switching would be accomplished via an electric field induced by a voltage applied to the transistor's gate electrode.

Such technology would use a topological Dirac semimetal as the channel material, balanced between a conventional insulator and a topological insulator.

"These results make the topological Dirac semimetal Na_3Bi an incredibly fertile platform for exploring some very exciting new areas of physics," says FLEET PhD student James Collins, a co-author on the study. "It means Na_3Bi is an ideal starting point to realise control over the topological properties of a material."

This work is therefore a significant step towards two key goals for Research theme 1:

> An atomically-thin topological insulator with bandgap greater than 77 degrees Kelvin
> Successful switching from a conventional insulator to a topological insulator.

The project represented a successful interdisciplinary collaboration between experts in thin-film growth and electronic characterisation at Monash University, and theoretical modelling led by FLEET Associate Investigator A/Prof Shaffique Adam at the National University of Singapore.

The study was published in Physical Review Materials in October 2017, Vol. 1, issue 5 *(see publication 8, p84)*.

COLLABORATING FLEET PERSONNEL:

> Associate Investigator Mark Edmonds (Monash University)
> PhD student Chang Liu (Monash University)
> PhD student James Collins (Monash University)
> Associate Investigator Shaffique Adam (Yale-NUS)
> CI Michael Fuhrer (Monash University)

> As such a new field of physics, topological materials are ripe for development within the ARC Centre of Excellence program: This research would not have been feasible five years ago, whereas five years from now, everyone will be doing it. The time is right for Australia to lead the world in this area.
>
> **Prof Michael Fuhrer**
> Director, FLEET

NEW PHYSICS AND THE 2016 NOBEL PRIZE IN PHYSICS

Topological materials represent a paradigm shift in material science, first proposed in 1987 and only demonstrated in the lab in the last decade.

In 2004 the potential for topological materials to carry current with negligible dissipation was realised with the prediction of the quantum spin Hall effect (first demonstrated in the lab in 2007).

The quantum anomalous Hall effect (QAHE) was achieved in the laboratory at Tsinghua University in 2013 by Prof Qi-Kun Xue, now a FLEET Partner Investigator and leading the Centre's collaboration with Tsinghua University.

QAHE showed that current could be carried with no measurable dissipation at all, and it was this 2013 discovery that opened up the field of topological electronics being investigated at FLEET.

The importance of topological materials was recognised by the 2016 Nobel Prize in Physics, awarded to Michael Kosterlitz, Duncan Haldane and David Thouless.

A/PROF ELENA OSTROVSKAYA

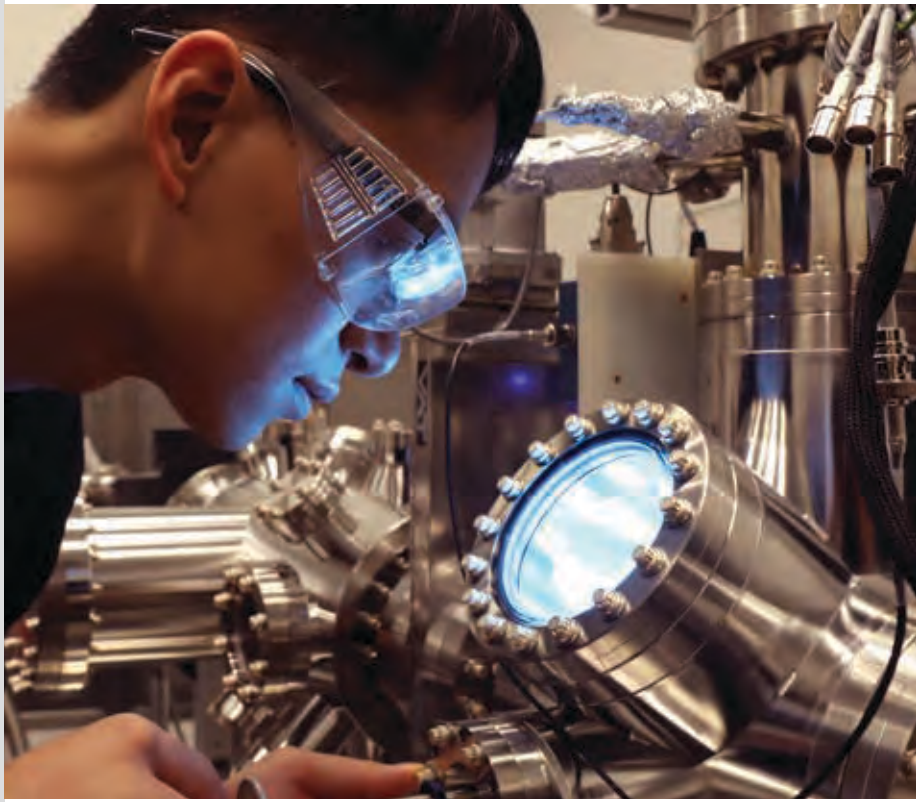
Leader,
Research theme 2

Australian National University

"Exciton–polariton research is entering its most active and exciting phase around the world"

Expertise: nonlinear physics, quantum degenerate gases, Bose-Einstein condensates, microcavity exciton–polaritons

Research outputs:
110+ papers,
3 book chapters,
3100+ citations,
h-index 30



IN 2018, FLEET WILL:

- Achieve strong light-matter coupling in novel microcavities hosting atomically-thin semiconductor monolayers such as the transition metal dichalcogenide $MoSe_2$
- Investigate designs to support twin-layer excitons
- Develop theoretical understanding of nonlinear interactions between exciton–polaritons and control of interactions via exciton-pair resonance
- Build on collaborations between Monash (atomically-thin semiconductor synthesis and microcavity fabrication), UNSW (electrical characterisation of atomically-thin semiconductor devices) and ANU (design and characterisation of microcavities, optical probing of exciton–polaritons).

RESEARCH THEME 2: EXCITON SUPERFLUIDS

FLEET's second research theme will use a quantum state known as a superfluid to achieve electrical current flow with minimal wasted dissipation of energy.

In a superfluid, scattering is prohibited by quantum statistics, which means that charge carriers can flow without resistance.

A superfluid is a quantum state in which all particles flow with the same momentum, and no energy is lost to other motion. Particles and quasi-particles, including both excitons and exciton–polaritons, can form a superfluid.

Researchers are seeking to create superfluid flows following three approaches:

- Exciton–polariton bosonic condensation in atomically-thin materials
- Topologically-protected exciton–polariton flow
- Exciton superfluids in twin-layer materials.

If exciton-superfluid devices are to be a viable, low-energy alternative to conventional electronic devices, they must be able to operate at room temperature, without energy-intensive cooling.

Thus, FLEET seeks to achieve superfluid flow at room temperature, which can be achieved using atomically-thin semiconductors as the medium for the superfluid.

Observing the atomic world – PhD student Fei Hou studying nanoscale properties of functional oxide materials using scanning probe microscopy

DEFINITIONS

dissipationless current Electric current that flows without wasted dissipation of energy

exciton Quasi-particle formed of two strongly-bound charged particles: an electron and a 'hole'

exciton–polariton Part matter and part light quasi-particle: an exciton bound to a photon

microcavities A micrometre-scale structure; an optical medium sandwiched between ultra-reflective mirrors, used to confine light such that it forms exciton–polaritons

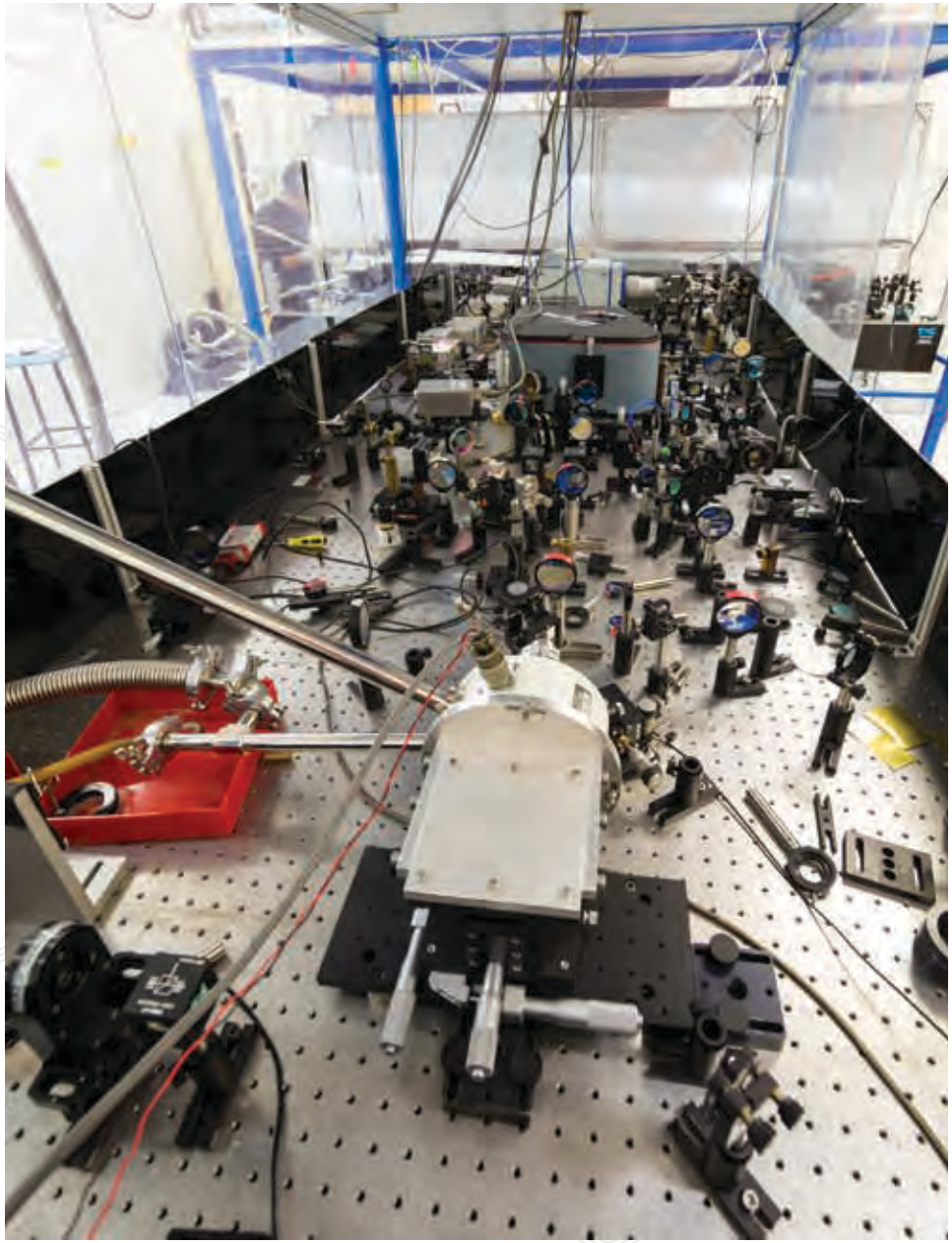
monolayer A single 2D layer of material

superfluid A quantum state in which particles flow without encountering any resistance to their motion. Both excitons and exciton–polaritons can flow in a superfluid.

van der Waals (vdW) material A material naturally made of 2D layers, held together by weak van der Waals forces

2017 HIGHLIGHTS

> Fabricating and characterising microcavities for strong light-matter coupling, in-house *(see case study, p24)*
> In world-first, single-shot imaging an exciton-polariton condensate in inorganic semiconductor microcavities at ANU, providing new insight into polariton condensation, with direct benefits for achieving condensation in microcavities with embedded, atomically-thin semiconductors.



Experimental setup for exciton-polariton condensation at cryogenic temperatures, ANU

CASE STUDY

PhD student Eliezer Estrecho awarded 1st Poster for 'Single-shot imaging of exciton-polariton condensates' at PLMCN18–international conference on physics of light-coupling in nanostructures. Pictured with PI Sven Höfling at University of Würzburg.

TRAPPING LIGHT–MATTER PARTICLES

FLEET collaboration traps light–matter particles

FLEET's Research theme 2 seeks to create near-zero resistance flow of exciton–polaritons, which are hybrid quasi-particles that are part matter and part light.

The resistance-less flow relies on formation of an exciton–polariton condensate – a collective quantum state that behaves as a superfluid.

In superfluids, particles flow without encountering any resistance to their motion. An exciton–polariton condensate is typically created within a semiconductor structure known as an optical microcavity, which enables strong coupling between the photons (light) and excitons (matter).

These microcavities are micrometre-scale heterostructures with two highly-reflective mirrors on either side of an optical medium.

This research took an important step forward in 2017 when FLEET researchers developed sufficiently high-quality microcavities to achieve a strong light–matter coupling regime and to ultimately achieve exciton-polariton condensation at room temperatures.

FLEET's Monash University engineering labs developed the high-quality optical microcavities, which were designed by FLEET researchers at the ANU, led by FLEET PhD student Eliezer Estrecho.

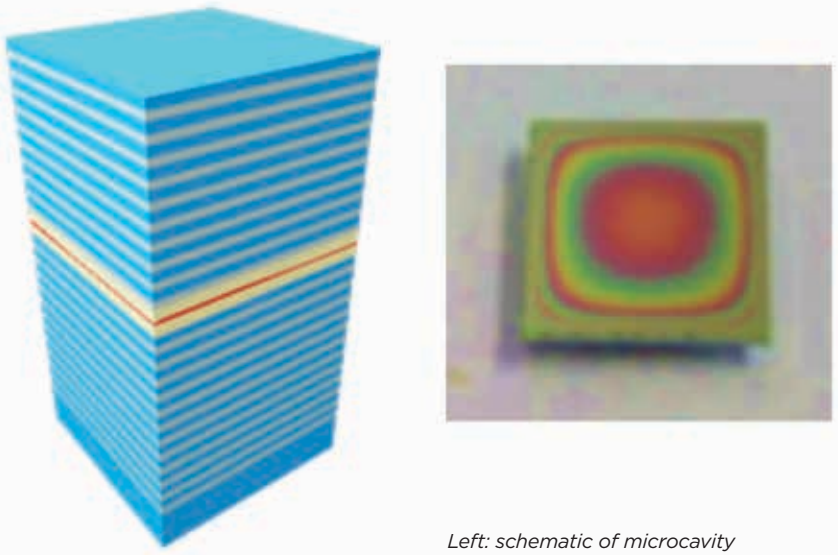
Following fabrication the structures were characterised in the exciton-polariton laboratory at ANU to assess their suitability for embedding the necessary exciton-hosting medium (an atomically-thin semiconductor monolayer) and creating exciton–polaritons.

The main achievement of the experiment was the extended lifetime of the photon trapped in the microcavity, which was at least an order of magnitude larger than that achieved previously in microcavities of similar design. This vastly improves the chances of reaching the strong light-matter coupling regime necessary for observing exciton–polaritons in these structures.

The ability to develop and characterise optical microcavities 'in-house' at FLEET is extremely important for future Centre research as it enables fabrication of highly customised semiconductor devices precisely tailored for studies of exciton–polariton condensation and superfluidity.

The knowledge gained in design, fabrication and optical characterisation of the new microcavities will now be applied in creation of an optimised host structure for exciton–polaritons in atomically-thin semiconductor monolayers.

Design, theory, and characterisation was done at the ANU in collaboration with RIKEN (Japan), while nanofabrication was performed by FLEET researchers at Monash University. Eliezer Estrecho's two-months training with Centre partners at Würzburg University allowed him to take the lead of this project at the ANU.



Left: schematic of microcavity (red represents a TMD monolayer)

Right: actual image of bottom DBR mirror composed of SiO_2/Si_3N_4

COLLABORATING FLEET PERSONNEL:

- PhD student Eliezer Estrecho, ANU
- CI Elena Ostrovskaya, ANU
- PhD student Maryam Boozarjmehr, ANU
- CI Qiaoliang Bao, Monash University

PROF KRIS HELMERSON

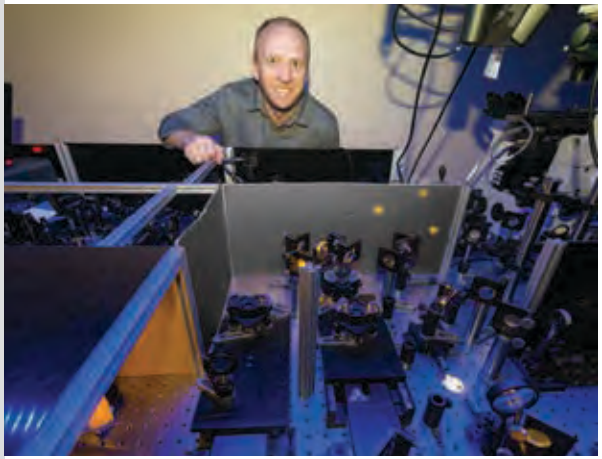
Leader,
Research theme 3

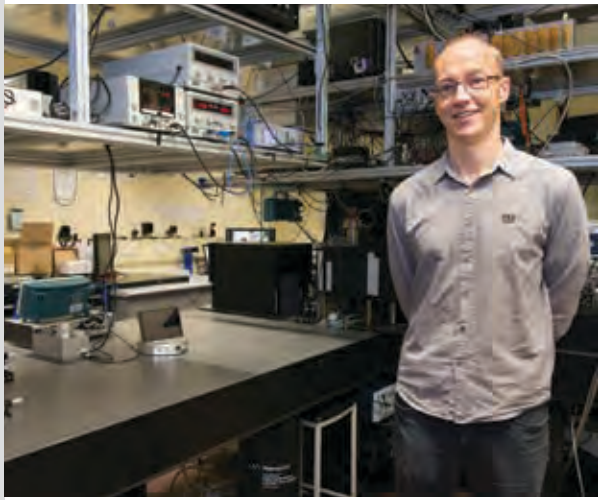
Monash University

"The physics of systems temporarily forced far from equilibrium could open the way to new dissipationless conduction mechanisms, a possible basis of future electronics"

Expertise: ultra-cold collisions of atoms, matter–wave optics, nonlinear atoms dynamics, atomic gas superfluidity, atomtronics, non-linear atom optics

Research outputs: 100+ papers, 5000+ citations, h-index 30





Jeff Davis (top) and Chris Vale (bottom) study dynamic properties of topological materials via cold atoms in synthetic dimensions and ultrafast laser spectroscopy

RESEARCH THEME 3: LIGHT-TRANSFORMED MATERIALS

FLEET's third research theme represents a paradigm shift in material engineering, in which materials are temporarily forced out of equilibrium.

The zero-resistance paths for electrical current sought at FLEET can be created using two non-equilibrium mechanisms:

> Short, intense bursts of light temporarily forcing matter to adopt a new, distinct topological state
> Dynamically engineered dissipationless transport.

Very short, intense pulses of light are used to force materials to become topological insulators *(see Research theme 1, p18)* or to shift into a superfluid state *(see Research theme 2, p22).*

The forced state achieved is only temporary, but researchers learn an enormous amount about the fundamental physics of topological insulators and superfluids as they observe the material shifting between natural and forced states, over a period of several microseconds.

By using ultrashort pulses to switch between the dissipationless-conducting and normal states, we can also create ultra-fast opto-electronic switching of this dissipationless current.

IN 2018, FLEET WILL:

> Develop and characterise 2D materials with spatially uniform optical properties for Floquet band engineering
> Control p-wave Feshbach resonance in 2D Fermi gas, generating a topological superfluid
> Demonstrate spin-orbit coupling in periodically driven atomic system
> Generate and optically characterise air-stable, metal–organic nanomaterials
> Develop theoretical framework incorporating quantum correlations and thermal effects in dynamics of quantum many-body system far from equilibrium
> Acquire and set-up femtosecond laser system for pump-probe spectroscopy of 2D materials
> Design and acquire components for quantum-gas microscope *(see p28)*.

DEFINITIONS

dissipationless current Electric current that flows without wasted dissipation of energy

equilibrium state The state in which a material is in balance, unchanging with time

non-equilibrium state A state temporarily forced by the application of energy, such as light

monolayer A single layer of material

non-linear interactions Interactions in which forces acting on a system cause disproportionate results

superfluid A quantum state in which particles flow without encountering any resistance to their motion. Both excitons and exciton–polaritons can flow in a superfluid.

ULTRA-FAST PULSES OF LIGHT

The pulses of light FLEET uses to transform materials are intensely short. The period is measured in femtoseconds, which are millionths of billionths of a second.

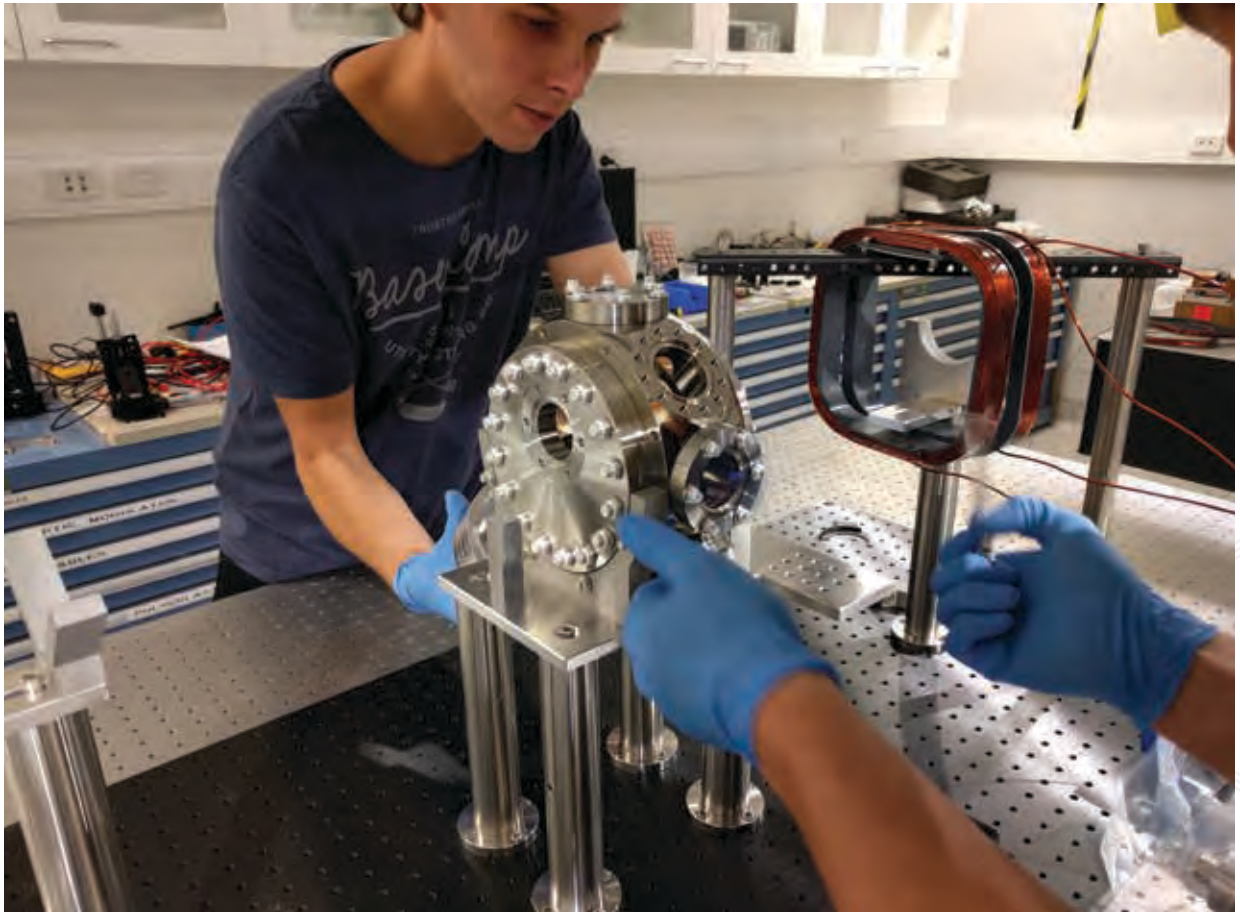
> The networking, brainstorming, and mixing of FLEET members between nodes was my highlight of working in the Centre this year. This motivates each researcher to increase their personal research output.
>
> **Dr Shilpa Sanwali**
> FLEET Research Fellow, Swinburne University of Technology

2017 HIGHLIGHTS

- Establishing new, shared infrastructure at Monash University (low-temperature scanning probe microscopy) and Swinburne University of Technology *(quantum-gas microscope, see case study p28)*
- Determining motion of vortices driven to non-equilibrium temperatures in a 2D superfluid atomic gas
- Hosting visit of Nobel Laureate Prof Wolfgang Ketterle at FLEET's ultra-cold laboratories, and his presentation of public talks *(see p64)*
- Beginning new collaborations between Swinburne University of Technology and Colorado University, and between physics and engineering at Monash University.

> The understanding of atoms in equilibrium was one of the triumphs of 20th century physics, forming the basis of thermodynamics. But the behaviour of systems far from equilibrium is at the frontier of physics.
>
> **Prof Kris Helmerson**
> Research theme 3 leader

CASE STUDY



Research assistant Shaun Johnstone and colleagues building next-generation Bose-Einstein condensate apparatus at Monash University; better optical access will allow precise manipulation of atoms within the condensate

SWINBURNE'S NEW QUANTUM-GAS MICROSCOPE FACILITY

Single-atom manipulation with new shared facility

Clouds of atoms pushed temporarily out of equilibrium provide crucial insights into fundamental physics in FLEET's Research theme 3.

A new quantum-gas microscope facility at Swinburne University of Technology will allow studies of ultra-cold atomic gases, giving researchers the ability to image and manipulate single atoms.

The new microscope will be a critical resource for diverse FLEET experiments, ranging across multiple research institutes including Swinburne, Monash University and ANU.

The facility's ability to image single atoms will greatly facilitate studies of the non-equilibrium, many-body quantum systems that are key to FLEET's Research theme 3.

Fundamental discoveries made from observing the transition of states will inform FLEET's search for electronic conduction without wasted dissipation of energy.

The new apparatus will use clouds of dysprosium (Dy) atoms, the large magnetic moment of which allows for long-range dipolar interactions.

These long-range, dipolar interactions provide an entirely new regime of interactions with which to engineer topological states for dissipationless transport.

The quantum-gas microscope will allow atom-by-atom synthesis of tailored many-body states with novel topological properties.

The new facility represents a paradigm shift for experimental ultra-cold atomic physics in Australia, with complex and expensive experiments performed by multiple researchers from a number of different cooperating institutions.

FLEET researchers have established collaborations with Prof Tilman Pfau (University of Stuttgart) and Prof Wolfgang Ketterle (MIT) to learn the new skills that will be required in working with ultracold dysprosium atomic gases.

Funding was approved under Australian Research Council LIEF grant ARC LE180100142 (November 2017). Also see list of grants on *(see p90)*.

Wolfgang Ketterle (Nobel laureate, MIT) lectures at FLEET annual workshop

PROF XIAOLIN WANG

Leader,
Enabling technology A

University of Wollongong

"FLEET has established an ambitious goal that makes us work together closely"

Expertise: design/fabrication and electronic/spintronic/superconducting properties of novel electronic or spintronic systems such as topological insulators, high spin-polarised materials, superconductors, multi-ferroic materials, single crystals, thin films, nano-size particles/ribbons/rings/wires

Research outputs: 350+ publications, 5500+ citations, h-index 36

ENABLING TECHNOLOGY A: ATOMICALLY-THIN MATERIALS

Each of FLEET's three research themes is heavily enabled by the science of novel, atomically-thin, two-dimensional (2D) materials.

These are materials that can be as thin as just one single layer of atoms in thickness, with resulting unusual and useful electronic properties.

To provide these materials, FLEET will draw on extensive expertise in materials synthesis in Australia and internationally, from bulk crystals to thin films to atomically-thin layers.

The most well-known atomically-thin material is graphene, a 2D sheet of carbon atoms that is an extraordinarily-good electrical conductor.

FLEET uses other atomically-thin materials, with its scientists seeking materials possessing the necessary properties for topological and exciton superfluid states.

> It's exciting to see FLEET addressing the energy challenge of computation through fundamental research on novel materials and unconventional physical mechanisms. This could have profound scientific and industrial impact.
>
> **An Chen**
> FLEET Advisory Committee
> Executive Director, Nanoelectronics Research Initiative (IBM)

IN 2018, FLEET WILL:

- Continue investigation of un-doped and magnetic-doped topological insulator crystal fabrication, such as Fe-Bi_2Te_3 and Fe-Sb_2Se_3
- Search for a new magnetic system for quantum anomalous Hall effect using density-functional theory (DFT)
- Measure quantum transport in very thin Fe-Sb_2Se_3 crystals; a collaboration between FLEET's University of Wollongong and UNSW teams
- Develop magnetic doping to induce anomalous Hall effect or quantum anomalous Hall effect (QAHE)
- Fabricate Weyl semimetals with and without magnetic doping
- Continue scanning tunneling microscope (STM) study of atomically-thin antimony on various substrates at very low temperature and high magnetic field
- Study electronic structures of these novel materials using new ARPES facility at the Australian Synchrotron.

DEFINITIONS

electronic smoothness Free of electronic imperfections

graphene A single 2D layer of carbon atoms

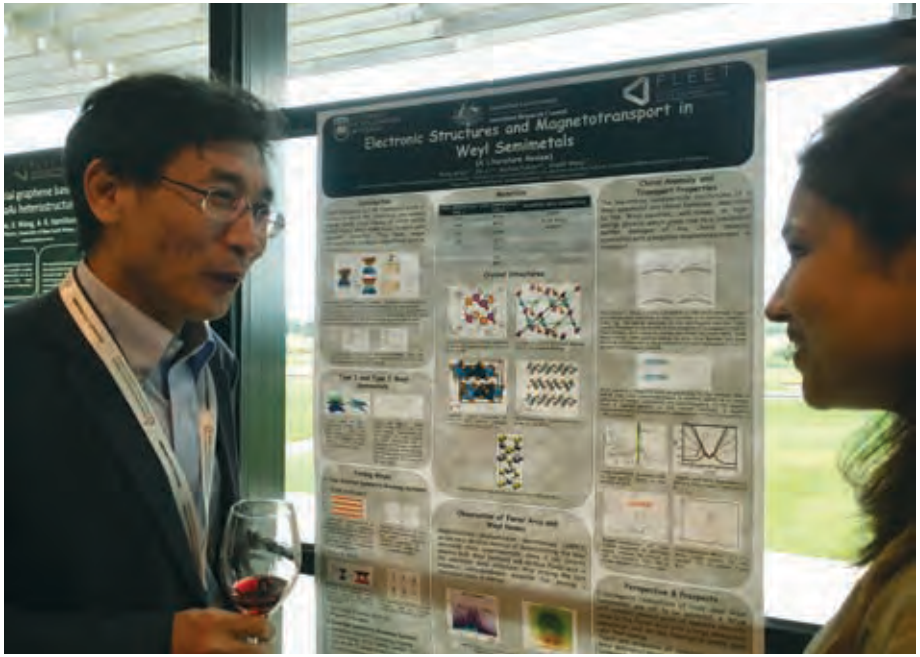
molecular beam epitaxy (MBE) A method used to deposit thin films of single crystals

quantum anomalous Hall effect (QAHE) A magnetic version of the quantum spin Hall effect, in which conducting edges carry currents in only one direction, and are completely without resistance

topological Dirac semimetal (TDS) Topological material at the boundary between conventional insulators (which don't conduct) and topological insulators (which conduct along their edges)

van der Waals (vdW) material A material naturally made of 2D layers, which can be isolated individually or stacked with other materials to form new structures

Weyl semimetals Similar to a topological Dirac semimetal, but with unusual surface states that may lead to dissipationless conduction



PI Qi-Kun Xue discussing Weyl metals with PhD student Wafa Afzal, FLEET annual workshop

2017 HIGHLIGHTS

- Manufacturing the topological material Na_3Bi to be as 'electronically smooth' as the highest-quality graphene-based alternative, while maintaining electron mobility as high as that of graphene *(see p32)*
- Depositing atomically-thin, 2D materials using a new liquid-metal approach: a simple, but ground-breaking innovation described as a 'once-in-a-decade' advance *(see p33)*
- Studying thickness-dependent electronic structure in WTe_2 thin films, and observing transition to 2D behaviour as the samples are made thinner
- Introducing defect-introduced paramagnetism and weak localisation to 2D metal VSe_2 for the first time
- Tuning electronic structure in twin layers of stanine and graphene using strain and gas adsorption, allowing control of the resulting state – whether a fully metallic interface or semimetallic/semiconductor transition
- Discovering a new family of synthetic magnetic structures through atomic-scale engineering of oxide interfaces – a major advance for the custom design of spin structures
- University of Wollongong researchers visiting FLEET Partner Investigator Prof Qi-Kun Xue's group at Tsinghua University, China.

CASE STUDY

ELECTRONICALLY-SMOOTH '3D GRAPHENE'

Topological material matches best graphene alternative for electronic smoothness

A new topological material provides the same remarkable electronic properties as graphene, without that material's major drawback, electronic 'messiness'.

The 2D 'wonder material' graphene has theoretical electron speeds 100 times faster than silicon.

But graphene's 2D nature means it is far too flimsy to use on its own, and must be laid upon a solid substrate. And because graphene is atomically thin, electronic imperfections in the substrate are close enough to cause electronic imperfections in the graphene.

Those imperfections are bad enough to severely restrict graphene's electronic operation. In practice, this means graphene-based devices must be painstakingly constructed with a graphene sheet laid upon a substrate material that minimises such electronic disorder. Hexagonal boron nitride (h-BN) is commonly used for this purpose.

But last year, FLEET researchers at Monash University found that the topological material Na_3Bi can be as 'electronically smooth' as the highest-quality graphene-based alternative, while maintaining graphene's high electron mobility.

"This is the first time a 3D Dirac material has been measured in this way, so it's particularly exciting to have found such a high degree of electronic smoothness," says co-author and FLEET PhD student James Collins.

The discovery will be critical for advancement of the study of this new topological material. It could have wide applications in electronics and potentially open other fields of research.

With electronic smoothness of Na_3Bi now demonstrated, an array of new research possibilities open up. There have been many studies into the relativistic (high mobility) flow of electrons in graphene since it was discovered in 2004. With this latest study, similar studies into Na_3Bi can be expected.

Na_3Bi offers a number of interesting advantages over graphene.

As well as avoiding the difficult construction methods involved in twin-layer graphene/h-BN devices, Na_3Bi can be grown on a millimetre scale or larger. Currently, production of effective graphene/h-BN sheets is limited to only a few micrometres across.

Another significant advantage is the potential to use Na_3Bi as the conducting channel in a new generation of transistors – one built upon the science of topological insulators.

"Electronic devices exploiting topological properties have much less power consumption than regular devices," explains FLEET Associate Investigator A/Prof Shaffique Adam, who led the theoretical component of the study at the National University of Singapore.

The study was published in Science Advances in December 2017, Vol. 3, no. 12 *(see publication 7, p84)*.

> It's exciting to be at the forefront of research into new materials that could change the face of electronics. It's fast-paced and always changing – you have to be able to adapt and come up with new research directions quickly.
>
> **Dr Mark Edmonds, Monash University**
> FLEET Associate Investigator and study co-author

Mark Edmonds closely monitoring Na_3Bi growth, one atomic layer at a time

COLLABORATING FLEET PERSONNEL

- Associate Investigator Mark Edmonds (Monash University)
- PhD student James Collins (Monash University)
- Associate Investigator Shaffique Adam (Yale-NUS)
- CI Michael Fuhrer (Monash University)

LIQUID-METAL SOLUTION TO 2D MATERIAL DEPOSITION

Metal droplets of gallium (photo RMIT University)

Once in a decade advance in 2D materials

FLEET's development of new ultra-low dissipation electronic pathways is enabled by the new science of atomically-thin, two-dimensional (2D) materials.

Large-scale deposition of such 2D materials is a key challenge for FLEET's Enabling technology A.

In 2017, a RMIT-led study found ground-shifting success with a new technique that will open new doors across the range of 2D semiconductors.

The discovery has been described as a 'once in a decade' advance.

The new technique introduces room-temperature liquid metals (gallium-based) as a successful reaction environment for the synthesis of desirable, atomically-thin oxides that were unattainable using prior methods. It can produce large-scale 2D materials across the periodic table.

It's a process so cheap and simple that it could be done on a kitchen stove by a non-scientist.

"I could give these instructions to my mum, and she would be able to do this at home," says new FLEET Associate Investigator Dr Torben Daeneke.

The discovery brings previously-unattainable thin-oxide materials into everyday reach, with profound implications for future technologies.

The simplicity of the method is extremely appealing: it does not require expensive equipment, is fully saleable, does not require vacuum technology and is extremely fast.

This use of room-temperature liquid metals as solvents for creating 2D materials is completely novel, providing a brand-new pathway towards low-dimensional materials.

In 2018, materials produced using the new technique will be further characterised to test their suitability for dissipationless electronics. Theoretical predictions will be used to identify further target materials for the liquid-gallium technique.

The RMIT researchers also collaborated with colleagues at the Queensland University of Technology and University of California, Los Angeles (UCLA).

The study was published in Science in October 2017, Vol. 358, Issue 6361 *(see publication 27, p84)*.

COLLABORATING FLEET PERSONNEL

- PhD student Ali Zavabeti (RMIT University)
- Associate Investigator Jian-zhen Ou (RMIT University)
- Research Fellow Ben Carey (RMIT University)
- Honours student Rebecca Orrell-Trigg (RMIT University)
- CI Kourosh Kalantar-Zadeh (RMIT University)
- Associate Investigator Torben Daeneke (RMIT University)

A/PROF LAN WANG

Leader,
Enabling technology B

RMIT University

"Realising room-temperature quantum anomalous Hall effect could carry really significant benefits for humanity."

Expertise: Low-temperature and high-magnetic field electron and spin transport; topological insulators; magnetic materials; spintronic and magneto-electronic devices; device fabrication; growth of single crystals, thin films and nano-structures.

Research outputs: 90+ papers, 2400+ citations, h-index 26

Kourosh Kalantar-Zadeh in clean room gear, MicroNano Research Facility (RMIT University)

ENABLING TECHNOLOGY B: NANO-DEVICE FABRICATION

FLEET's research sits at the very boundary of what is possible in condensed-matter physics. At the nano scale, nanofabrication of functioning devices will be key to the Centre's success.

Specialised techniques are needed to integrate novel atomically-thin, two-dimensional (2D) materials into high-quality, high-performance nano-devices.

For example, atomically-thin topological insulators will need to be integrated with electrical gates to realise topological transistors. And atomically-thin semiconductors must be integrated with optical cavities to realise exciton–polariton condensate devices.

Nano-device fabrication and characterisation links many of FLEET's groups and nodes. Some groups bring expertise in device fabrication, while other groups are stronger in device characterisation. This teamwork is fundamental to modern science.

FLEET brings together Australian strength in micro- and nanofabrication with world-leading expertise in van der Waals heterostructure fabrication to build the capacity for advanced atomically-thin device fabrication.

DEFINITIONS

ferromagnetic materials Material that can be magnetised

focused ion beam (FIB) A microscope that uses a tight beam of ions to study nanoscale structures, and can also deposit or remove materials to form new structures

glove box Sealed container allowing manipulation within a controlled atmosphere via gloves

heterostructure A structure in which two dissimilar materials are brought together at a controlled interface

paramagnetic materials Materials that are attracted to magnetic fields and ferromagnets, but which are not magnetised

quantum spin Hall effect (QSHE) The spin-orbit interaction driven effect that gives a non-magnetic material conducting edges, which can carry current without resistance, as long as no magnetic disorder is present

quantum anomalous Hall effect (QAHE) A magnetic version of the QSHE (above), in which conducting edges carry currents in only one direction, and are completely without resistance

van der Waals (vdW) materials A material naturally made of 2D layers, held together by weak van der Waals forces

van der Waals (vdW) heterostructure A structure made by stacking layers of different van der Waals materials

IN 2018, FLEET WILL:

> Fabricate vdW heterostructure devices for realising quantum spin Hall effect (QSHE), quantum anomalous Hall effect (QAHE) and twin-layer exciton transistors
> Realise various oxide heterostructure based devices.

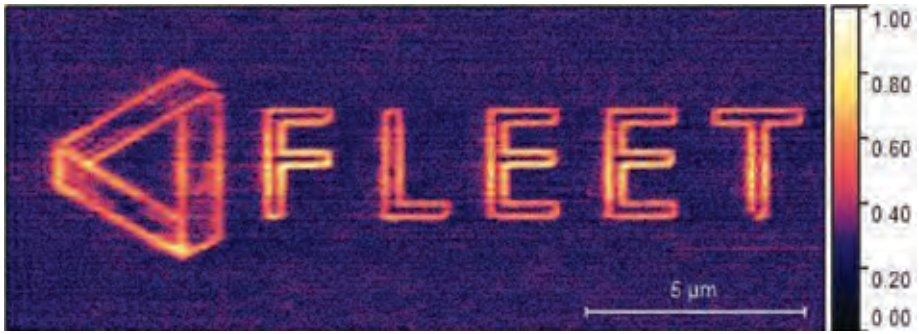
2017 HIGHLIGHTS

> Establishing a dry transfer system for transferring and stacking van der Waals (vdW) heterostructures in a glove box, key to fabricating vdW heterostructures for FLEET's Research themes 1 and 2 *(see p18 and 22)*
> Developing vdW ferromagnetic metal with square-shaped loop, large coercivity and strong perpendicular magnetic anisotropy, paving the way for spintronic devices based on vdW ferromagnetic heterostructures
> Establishing a focused ion beam (FIB) system for device fabrication that allows cutting and etching nanostructures to custom shapes essential for electronic and photonic devices.

> FLEET opens doors to new connections, new capabilities and new ideas that will help drive the quality and impact of my research.
>
> **Dr Jeff Davis,**
> Swinburne University of Technology
> FLEET Chief Investigator

MICRO BRANDING

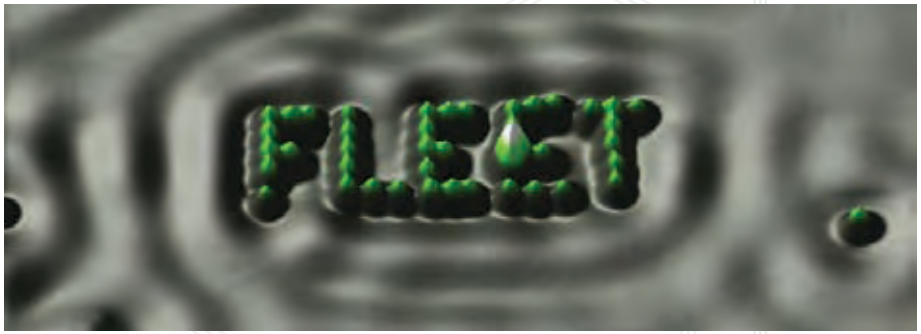
FLEET researchers taking an innovative, even 'playful', approach to their science have created a couple of unique and interesting branding displays for the Centre.



FLEET PhD student Fan Ji developed this micro-sized logo at UNSW. The FLEET logo is etched onto the two-dimensional interface between two materials in letters only a few thousandths of a millimetre high, using bias-assisted atomic force microscopy (AFM) lithography.

Atomic force microscopy (AFM) lithography is used in FLEET's UNSW labs to study and 'mill' materials at microscopic scales. Using the extremely sharp tip of the microscope, surface features can be manipulated: adding and subtracting material as required, at an incredibly precise scale.

The dimensions of the UNSW lithographic brand are approx. 19 micrometres long by 7 micrometres high.



At Monash University, FLEET affiliate Marina Castelli used the tip of a scanning tunneling microscope (STM) to manipulate individual iron atoms, creating a nano-scale logo comprising just 42 atoms.

At Monash University, the sharp tip of a scanning tunneling microscope can be used to manipulate individual iron atoms into place, on a silver substrate. This technique is used to understand the structure of specific nanostructures, and to study their electronic properties. The logo shown is 40 nanometres long by 25 nanometres high, or 42 individual atoms.

The slightly brighter atom in the middle of the 2nd 'E', is actually an accident: a small 'tip crash' of the instrument: "I was trying to push two iron atoms next to each other... luckily it did not destroy the other letters!" says Marina, who works with FLEET's Agustin Schiffrin.

CUSTOM, NANOSCALE STRUCTURES ON DEMAND AT RMIT

Nanostructure fabrication to support FLEET research

FLEET's research to achieve zero-dissipation electrical current depends on the design of key nanoscale structures.

In 2017, Research theme B leader Lan Wang, and PhD student Cheng Tan, developed a method to build such nanoscale structures, required to achieve zero-dissipation electrical current.

These nanostructures, comprising two stacked, 2D semiconductors, are key to FLEET's Research theme 1 (topological materials) and Research theme 2 (exciton superfluids).

Bound together by van der Waals (vdW) forces, and comprising twin, disparate, atomically-thin layers, such structures are known as van der Waals heterostructures.

The new system, developed at RMIT, will enable the fabrication of a range of van de Waal structures, customised to realise room-temperature quantum anomalous Hall effect in Research theme 1 and twin-layer exciton superfluids in Research theme 2.

The 'dry' transfer system allows transfer and stacking of individual layers in an air-free 'glove box', so that air-sensitive materials can be used, and contaminants between the layers, such as water, are eliminated.

The method developed at RMIT allows the construction of numerous heterostructures, such as:

> Ferromagnetic material–topological insulator
> Ferromagnetic material–anti-ferromagnetic material
> Ferromagnetic material–ferroelectric material
> Superconductor–topological insulator.

The possibilities for custom design are endless.

VdW heterostructure fabrication has never previously been performed in Australia.

In 2018, FLEET's RMIT team will collaborate with Centre colleagues at Monash University and UNSW to set up the required systems. Then it will be all systems go: fabricating all kinds of vdW devices for the FLEET team.

Lan Wang and colleague in Class 100 clean room, MicroNano Research Facility (RMIT)

COLLABORATING FLEET PERSONNEL

> PhD student Cheng Tan (RMIT University)
> CI Lan Wang (RMIT University)

COLLABORATE

03

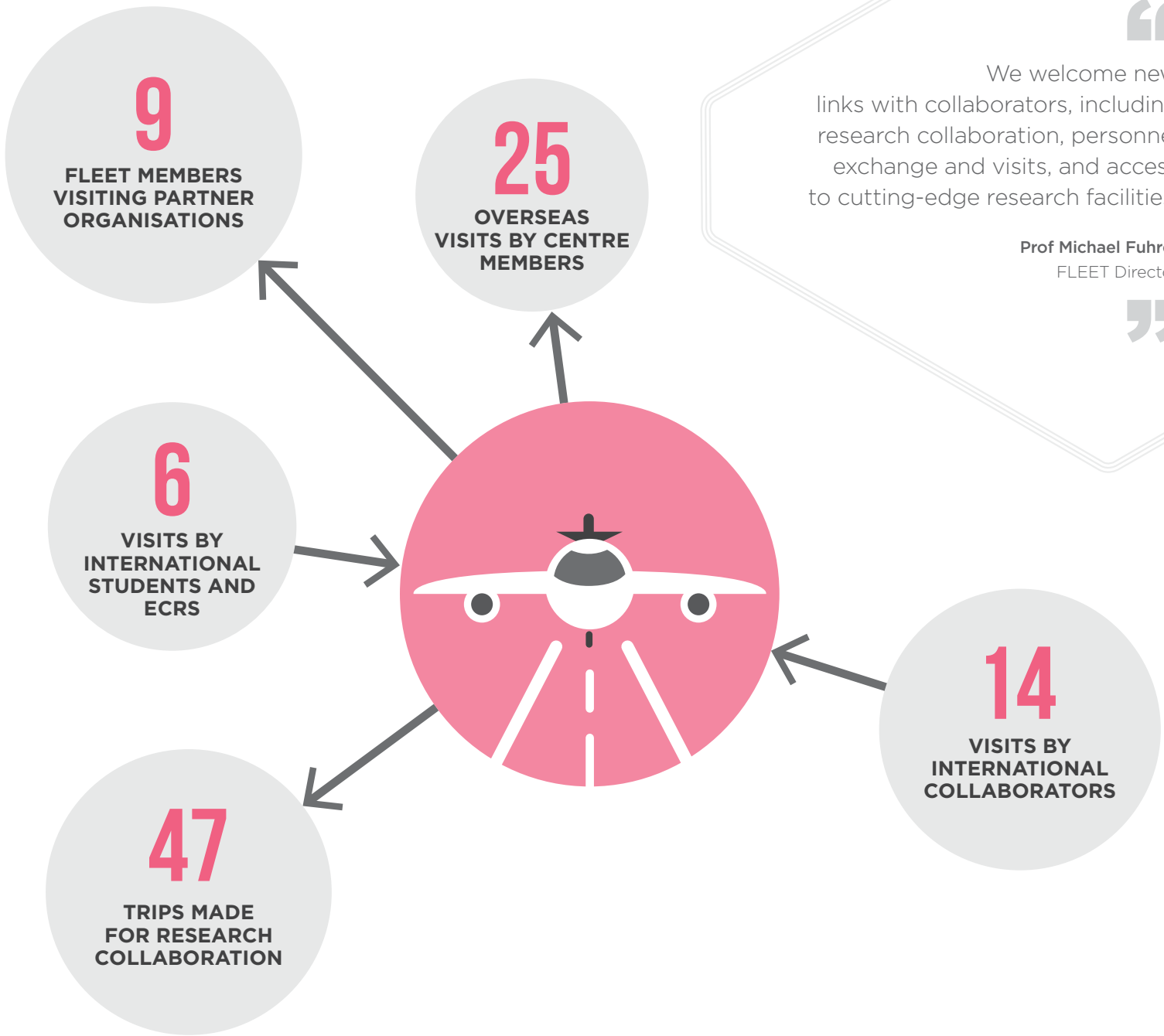
To boost Australian research and help transform the country's electronic technologies, FLEET has forged important national and international partnerships with research institutions, industry and educational organisations.

FLEET collaborator David Nielson (University of Camerino, left) and Al Shaffique Adam (National University of Singapore, right) discussing low-dimensional systems at FLEET annual workshop

8 **NEW ORGANISATION LINKS** FOR TRAINING AND OUTREACH ESTABLISHED

7 **NEW RESEARCH COLLABORATING ORGANISATIONS** ESTABLISHED

3 **END-USER RELATIONSHIPS** ESTABLISHED



> We welcome new links with collaborators, including research collaboration, personnel exchange and visits, and access to cutting-edge research facilities.
>
> **Prof Michael Fuhrer**
> FLEET Director

To enable research collaboration, FLEET has:

- Ensured a strong presence of FLEET personnel at national and international conferences in related areas *(see p85)*
- Sought out potential research partners through collaborative visits *(see p94 and 95)*
- Invited high-profile researchers in the field to give FLEET research seminars *(see p96)*

> FLEET provides great visibility for my research, allows me to link to a large network of renowned collaborators, and provides complementary know-how in fields in which I am not an expert.
>
> **Dr Agustin Schiffrin**
> FLEET Chief Investigator, Monash University

The 2017 Gordon Godfrey Workshop at UNSW was an opportunity for a strong FLEET contingent to engage with leading Australian and international physicists in the field of spin and strong-electron correlations, including Prof David Neilson (University of Camerino, Italy), a pioneer of electron-hole exciton interactions. FLEET researchers from UNSW, RMIT University and Monash University presented findings. Co-sponsorship with the Godfrey Bequest and UNSW School of Physics allowed free registration, maximising the benefit of this gathering.

FLEET research seminars present the latest science to relevant researchers, fostering discussion and collaboration in fields relevant to FLEET research. Topics covered last year include:

> Angular momentum of BCS-BEC fermionic superfluids with multiply quantised vortices, FLEET Partner Investigator Prof Victor Gurarie (University of Colorado, USA), pictured top right
> Magneto-optical polarisation spectroscopy with synchrotron radiation on graphene, Prof Hans-Christoph Mertins (University of Applied Sciences, Muenster, Germany)
> Imaging surface states of a strongly correlated topological insulator, Prof Jenny Hoffman (Harvard University, USA), pictured bottom right
> Quantum Emitters in Flatland, A/Prof Igor Aharonovich (University of Technology, Sydney).

Right: Poster session, Gordon Godfrey workshop on spins and strong electron correlations (UNSW)

FLEET TO HOST INTERNATIONAL 2D CONFERENCE

In 2018, FLEET will bring the International Conference on Two-Dimensional Materials & Technologies (ICON-2DMat) to Australia for the first time.

Attendance at the international conferences on 2D materials is growing, reflecting rising interest in the useful electronic, opto-electronic and material properties of atomically-thin materials.

Previous conferences have been in Hangzhou, China (2014), Hong Kong (2016) and Singapore (2017).

The 4th conference will be held in Melbourne on 10–13 December 2018.

ICON-2DMat 2018 will connect leading Australian scientists in the field with international experts to discuss the latest two-dimensional materials research and emerging applications.

It will be an opportunity for FLEET to showcase the strength of atomically-thin materials research in Australia.

More information FLEET.org.au/ICON2DMAT

RESEARCH TRANSLATION

FLEET will present the electronics industry with viable solutions to the problem of power consumption at data centres; without efficiency improvements these facilities will become alarmingly large consumers of energy within the next two to three decades.

The technology developed at FLEET will allow industries to produce more-efficient electronic circuits and memory devices for data centres.

FLEET will:

> Produce electronic materials intellectual property that can form the basis of spin-off companies
> Build links to intermediary research institutes and provide an avenue to deliver intellectual property to development laboratories with a commercialisation focus
> Leverage strong ties with research centres focused on novel materials research and translation; for example, the Monash Centre for Atomically Thin Materials
> Liaise with potential stakeholders in novel electronic devices and systems through a network of industry liaisons.

INDUSTRY LIAISONS

Dr Andrew Hind

General Manager of Molecular Spectroscopy , Agilent Technologies

Chris Gilbey

CEO , Imagine Intelligent Materials Pty Ltd

Dr Jim Patrick

Chief Scientist and Senior Vice President Research and Applications, Cochlear Limited

Mark Muzzin

Entrepreneur

Dr Steven Duvall

Chief Technology Officer and General Manager of Technology Development, Silanna

> FLEET is an outstanding role model for other institutions which seek practical solutions to problems by pursuing fundamental and basic research.
>
> **Sir Michael Pepper**
> University College London
> FLEET International Scientific Advisory Committee

> One of my highlights of 2017 was explaining my research to a school student of 15/16 years old, whose fascination by the physics I work with every day was inspirational.
>
> **Pavel Kolesnichenko**
> FLEET PhD student,
> Swinburne University of Technology

EDUCATIONAL AND OUTREACH COLLABORATION

FLEET is collaborating with leading educational and engagement experts to have a positive impact on the wider community's engagement with science.

The Centre builds on successful educational and partnership models to increase the community's understanding of what scientists do and how a STEM-proficient workforce adds value, communicate FLEET-relevant science and develop the scientific literacy of Australians.

FLEET works with specialised educational and outreach liaisons:

Dr Eroia Barone-Nugent

Growing Tall Poppies Science Partnership Program

Dr Toby Bell

Monash University's Global Challenges program, whose students have developed innovative FLEET outreach tools *(see p61)*.

Camille Thomson

Australian Institute of Policy and Science, assisted with delivery of specialised science communication training *(see p53)*.

Prof Pankaj Sah

Science of Learning Centre, University of Queensland, collaborates to bring FLEET outreach programs to the wider community

Also see 'Building future science leaders' *(see p51)* and the Education and Training Committee *(see p77)*.

> With the peak of the mineral resources boom having passed, and a decrease in traditional domestic manufacturing sectors, Australia needs to focus on innovation in science and technology. It is critical to develop advanced, flexible skillsets within our future science leaders.
>
> **Anton Tadich**
> FLEET Partner Investigator,
> Australian Synchrotron
> YouRforum panelist

Left: Global Challenges students Daniel Schultz (left) and Joshua Zail presented their project outcomes (see p61) at FLEET Annual workshop.

Below: Lyndal Byford (Australian Science Media Centre) demonstrating how to promote research using videos at FLEET YouRforum in October 2017 (see p53).

CENTRES OF AWESOME

Sharing best practice within ARC-funded research centres, finding efficiencies, setting up future networks – and swapping a few war stories

While the training needs of researchers are key, skilling-up professional staff is also extremely valuable.

FLEET worked with the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) to bring operations staff from 18 ARC-funded centres together, sharing best practice and learnings, and developing future networks among people in similar roles.

How do centres become 'greater than the sum of the parts'? What strategies have professional staff found to enhance centre cohesiveness? What works with respect to managing KPIs? What *doesn't* work? How can we go from Centres of Excellence to Centres of Awesome?

The first Victorian ARC Centres and Hubs Staff (VACHS) Workshop brought together representatives from ten ARC Centres of Excellence, five ARC Industry Transformation Research Hubs, and three ARC Training Centres.

Delegates included staff from operations, finance, communication, outreach, education and training, centre administration and node management.

The workshop was designed to leverage the skills and expertise of those in the room to maximise success in ARC centre reviews, re-bids, centre cohesiveness, financial management, outreach, social media, internal communications, education and training, mentoring, diversity and equity.

Sessions on what we do well shared successful, innovative programs from mentoring to internal communication to outreach, sharing best-practise across the centres.

An opening poster presentation outlining organisational structure proved an effective ice-breaker, with the building of future networks amongst common roles a primary aim.

Sharing knowledge and common challenges faced by ARC centres and hubs

Although each centre's operations team works as a unit, the individual focus of each role can make people feel as though they are working in isolation. Brainstorming sessions combining common roles to identify shared challenges, and possible solutions, brought relief as people discovered their challenges were shared.

Participants also shared tools and programs for KPI management, finance, internal communications and social media.

FLEET was one of several centres to take advantage of the workshop to bring together operations staff from multiple nodes (ANU, UNSW and Swinburne University of Technology) to the host at Monash University, contributing to Centre cohesion.

As the first such event in Victoria, there was agreement that this was just the beginning. Future events are planned – both bringing all centres and hubs together again, and informal arrangements maintaining contact between individuals in similar roles.

The workshop has also inspired similar networking efforts within host Monash University.

> I returned to work, grateful to have witnessed such positive energy and enthusiasm to do our best as the ARC's 'treasured investments'. Hearing first-hand tips and examples from other Centres of Excellence was invaluable, and I benefited from the brainstorming of common challenges and solutions with other node administrators. I'm excited to share my newly-gained knowledge with colleagues and students.
>
> **Ruby Chan**
> Node Administrator, OzGrav

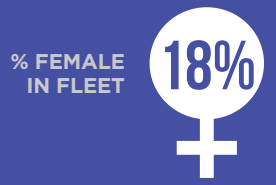
> The success of the Victorian ARC Centres and Hubs Staff Workshop has inspired Monash Research to create a similar peer-support group within the university, which will connect and create opportunities for administration managers of complex externally-funded research projects to share best-practice, enable professional development and create a 'voice' for action on common issues to permit faster problem-solving.
>
> **Helen Partridge**
> Manager, ARC Grants and Contract Team,
> Monash Research Office.

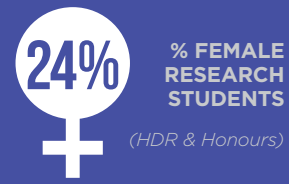
Oleh Klochan and research fellow Daisy Wang performing low temperature transport measurements of mesoscopic systems

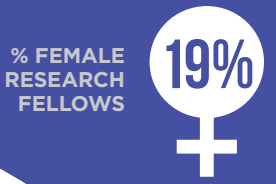
EQUITY

04

FLEET aims to achieve 30% of women researchers across the Centre by 2021.







EQUITY AND FAIRNESS AT FLEET

Women are under-represented at higher levels in science, and in this regard FLEET is no exception. We must do better.

Diverse teams do better science. By improving our performance with respect to equity and diversity, we are not only doing what's right and fair, we will also be creating a more effective research team.

FLEET aims to achieve 30% of women researchers across the Centre by 2021. In its first year, FLEET has reached well over the 2017 target of 10% women HDRs and ECRs (with 21% and 17%, respectively). This brings the current proportion of women across the Centre to 18%.

But this is just a starting point. In particular the Centre must increase the representation of women in senior roles.

Regarding ethnic diversity, FLEET has people of 20 nationalities, from more than 20 cultural backgrounds, across all levels of the Centre.

Improving the situation regarding women in physics is a complex task that cuts across all the ways we work together.

FLEET is:

> **Targeting outreach** to girls in schools to improve future participation in science

> **Balancing recruitment** panels and shortlists: 'If not 50/50, then why not?'

> **Supporting careers** via mentoring, Women in FLEET Fellowships and scholarships, and travel support

> **Attracting the best** female researchers to physics with a $5000 scholarship to high-performing Honours students and up to $15,000 research support to female research fellows

> **Creating an inclusive workplace** with that goal cutting across all Centre policies, including support for part-time work, flexible hours and family-friendly meeting times.

CENTRE ROLE	FEMALE	TOTAL	%
Chief and partner investigators	2	35	6%
Research Fellows	4	21	19%
Students and research assistants	12	58	21%
Advisors and Associate Investigators	5	33	15%
Business Team	4	5	80%

> FLEET challenges me all the time, and has deepened my understanding of a field essential to the progress of technology. I thought I would never be able to work within an environment full of such brilliant minds.
>
> **Jessica Alves,**
> Women in FLEET
> Honours scholarship recipient

Top: Research fellow Shilpa Sanwlani joined by daughter at FLEET annual workshop

Above: Family participation at annual workshop poster session

Left: FLEET's Dr Dianne Ruka entertains kids with an in-workshop science show

FLEET's inaugural annual workshop *(see p56)* was a remarkable family- and partner-friendly event. It involved 35 partners and family, including 17 children, paid childcare, family involvement in workshop social events, and a science show to entertain the kids during the research poster presentations.

IN 2018, FLEET WILL:

- Run a comprehensive culture survey to determine beliefs and environment regarding equity
- Set strategies for wider diversity issues, including ethnicity, the LGBTI+ community, religion and Indigenous peoples
- Offer equity and access training and mentoring opportunities to all FLEET members
- Take advantage of the significant Centre recruitment in 2018 to progress toward our goal of 30% women across all nodes.

EDUCATION

04

FLEET helps develop Australia's future science leaders, ensuring they are prepared for future success wherever their career takes them.

PhD student Fan Ji setting up her atomic force microscope

BUILDING FUTURE SCIENCE LEADERS: EDUCATION AT FLEET

FLEET ensures our young researchers are prepared for future success whereever their career takes them.

The Centre currently supports 29 higher degree by research (HDR) students and 30 early-career researchers (ECRs), with another 21 affiliate students and early-career researchers working on FLEET projects and invited to Centre training, workshops and events.

All FLEET's students and young researchers receive excellent supervision, are exposed to opportunities for professional development and networking, and are supported in navigating diverse career pathways.

FLEET connects its researchers with internal and international networks, for example, offering research internship programs at partner organisations.

In 2017, FLEET's focus was recruitment and induction, planning and training. Young members benefitted from skills workshops and had opportunities to present at the annual workshop. A future mentoring program will be fully implemented in 2018, allowing the Centre to meet its mentoring targets.

Members' induction includes:

> FLEET's research mission and operational structure
> Members' roles and responsibilities
> FLEET's resources and operational processes.

IN 2018, FLEET WILL:

> Have a significant presence at the 2018 Canberra International Physics Summer School on Topological Matter at ANU, providing both financial and in-kind support for the school
> Partner with other ARC Centres of Excellence to deliver training for FLEET members across Australia, such as working with the ARC Centre of Excellence for Engineered Quantum Systems on the 2018 Ideas Factory, developing collaboration and research communication skills
> Investigate online communications training, building on the skills delivered in 2017
> Increase opportunities for ECRs and HDRs to participate in Centre operations via committees and workshops
> Implement FLEET mentoring programs supporting research and professional development
> Create opportunities for FLEET HDRs and ECRs to present their work at international meetings.

LEARNING TO TELL THEIR SCIENCE STORY: EARLY-CAREER RESEARCH TRAINING

Communications workshop for early-career researchers and PhD students

Success in science requires the ability to describe one's research in a coherent and compelling manner.

FLEET has made an early start in building these skills in ECRs, with a half-day training session targeting science communications skills.

Top: From left, Fan Ji, Hong Liu, Emma Laird and Elizabeth Marcellina practise their elevator pitch

Above: Yun Suk Eo (left) and Eliezer Estrecho developing Why, What, How and What If

CASE STUDY

SKILLING-UP EARLY-CAREER RESEARCHERS AND PHD GRADUATES

> FLEET is helping me to establish myself within the research community, building new networks and finding opportunities for high-impact work.
>
> **Dr Torben Daeneke**
> FLEET Associate Investigator
> RMIT University

So you've got a PhD, now what's next?

Smartphone video skills to take science communications to the next level

The vast majority of PhD graduates will not end up in academia – FLEET's HDR students must develop a diverse skills base to maximise future career opportunities in a competitive environment.

FLEET helps young researchers build a broad range of skills with programs such as **YouRforum** (Young Researchers Forum), which in 2017 provided training on post-PhD careers and video communication.

The 'Got PhD, what next?' forum exposed PhD students and recent graduates to a panel of science PhD graduates whose paths had led them to a range of diverse careers, including academia, research management, entrepreneurship and industry. Panellists shared their career pathways and discussed tips on transferring into different fields following a PhD.

YouRforum's smartphone video training introduced delegates to the skills required to put their science into a professional and effective video format, using only a smartphone and a professional editing app (provided). The training was presented in collaboration with the Australian Institute of Policy and Science (AIPS), and included all the necessary elements for preparing video for online and broadcast media.

While **YouRforum** training is specifically targeted at FLEET members, sessions are open to researchers from other centres and universities, building links with these other organisations and providing a valuable networking element for the participants.

YouRforum was an original initiative of the Monash Centre for Atomically Thin Materials.

A professional external facilitator from consultancy Mind Your Way coached young researchers on the particular skills needed for writing, presenting and discussing science.

Around 70 FLEET and affiliated ECRs learned to effectively structure their communications, and to customise their language for different audiences, different forums and different lengths.

A 'Why, What, How, What if' structure was applied to a whole range of communications, from the classic 'elevator pitch' to talking to politicians or potential investors, giving an in-depth presentation to research collaborators or writing a scientific paper:

> Why are we doing this, and why should you care?
> What did we do? (briefly)
> How we did it, in logical steps
> What if, what's next, questions and bonus material.

Too often, scientists assume their audience already knows why a piece of research is important. By learning to start with 'Why', FLEET's up-and-coming researchers will deliver more compelling and more effective communications.

Communicating well is crucial to FLEET's success, as well as the future career success of our ECRs; it will maximise their chances of success in published articles, presentations, grants and applications.

By having ECRs explain their research to each other, across nodes and research themes, FLEET also used the exercise to improve Centre cohesion, with ECRs making connections and discovering how other teams' research projects were related to their own.

Careers in industry panel discussion; from left, Dr Alexe Bojovschi (Academy of Innovative Business), Dr Monika Fekete (Australian Coffee Science Lab), Dr Richard Huysmans (Raven Consulting Group), facilitated by FLEET's Dr Tich-Lam Nguyen (YouRforum founder)

FLEET PhD student Chutian Wang demonstrating 2D materials using scotch tape and microscope, Monash University Open Day

ENGAGE

06

To engage the public and encourage more interest in science for future generations of Australians

862
AVERAGE MONTHLY **NEW USER VISITS TO FLEET.COM.AU**

3877
AVERAGE MONTHLY **UNIQUE PAGE VIEWS**

286
FOLLOWERS **ON TWITTER**

48
MENTIONS **IN ONLINE MEDIA**

217
FOLLOWERS **ON FACEBOOK**

550
VIEWS OF **FLEET RESEARCH VIDEO**

5
Research workshops organised, *2 international*

5
Research seminars held

339
Total number of **Centre members attending training workshops**

557
Hours spent on outreach

3068
School students reached through outreach activities

62
School teachers engaged

30
Home science activities demonstrated

839
Total number of **Non-Centre members attending training workshops**

3150
Public audience reached through outreach activities

2
PRESS RELEASES

1
PRINT ARTICLE IN AUSTRALIAN MANUFACTURING TECHNOLOGY MAGAZINE

2
RADIO INTERVIEWS

> FLEET's 2017 annual workshop really solidified the various branches of the centre and created a common narrative for the research efforts.
>
> **Dr Harley Scammell**
> FLEET Research Fellow UNSW

FLEET'S FIRST ANNUAL WORKSHOP: A CASE STUDY ON MEMBER ENGAGEMENT

Forging a Centre that is greater than the sum of its parts

FLEET's inaugural annual workshop in Torquay, Victoria, represented the Centre's first chance to cement relationships between geographically-isolated research nodes and diverse physics disciplines.

With a focus on education, each day began with a tutorial laying out the fundamentals for one of three research themes. This introduction maximised the value of the more-detailed project updates that followed. Presenters were also carefully briefed to ensure that project updates would be pitched at the right level for a non-expert audience.

As this was our first chance to forge collaborative links, time was left for discussions that cut across geographic and research lines and work.

The workshop was also remarkably successful in incorporating kids and families *(see p50)*, with over 30 partners and family involved, including 17 children.

The annual workshop built on other functions that are building and maintaining Centre cohesion, including inductions, an internal monthly newsletter, outreach collaborations and FLEET-branded clothing.

Delegates at FLEET inaugural annual workshop, November 2017

> The inaugural FLEET workshop in Torquay was a highlight of 2017. I learned how my work fits into the grand scheme of FLEET and how the different themes all lead toward the same goal. It was great to put faces to names, and to start to feel part of something much bigger than just my work.
>
> **Dr Daniel Sando**
> FLEET Research Fellow UNSW

FLEET Education and Training Coordinator Dr Dianne Ruka demonstrates angular momentum to kindergarten teachers and students

SPREADING A PASSION FOR SCIENCE: ENGAGEMENT AND OUTREACH AT FLEET

FLEET has focused significant efforts on science outreach in its first year, with the aim of

> Increasing the participation of students in science and physics

> Increasing understanding of and passion for science in the general public

> Improving the outreach skills of FLEET members

> Supporting the public discussion of FLEET-specific research

Up to 75% of future jobs will require skills in science, technology, engineering and maths (STEM). Yet school participation in science has been declining for several years.

FLEET shares the responsibility to support students and teachers to increase this participation rate, linking the science teaching curriculum to cutting-edge research. In addition to increasing the numbers studying and working in science, FLEET works towards increasing the number of girls and women participating in physics, chemistry and engineering.

In addition to FLEET's standalone efforts, such as Home Science *(see p60)*, FLEET Geeks *(see p62)* and research seminars *(see p96)*, some of FLEET's most successful outreach activities in its first year were collaborations with other centres and groups.

> My 12-year-old son was entranced by Dianne's onstage science demonstrations at the National Science Quiz in Adelaide. He shows a leaning towards science and is a questioner by nature. I was delighted he might head in a STEM direction that would bring him exposure to such excellent science role models."
>
> **Maura McInerney**
> Parent

Working closely with university communications teams, FLEET gave relevant physics demonstrations and lab tours at university open days, to show prospective students where a physics or electrical engineering career could take them.

FLEET worked with the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) to support the National Science Quiz, a panel of scientists and comedians answering questions about common scientific phenomena. FLEET Director Prof Michael Fuhrer was a panellist and FLEET Education and Training Coordinator Dr Dianne Ruka and Communications Coordinator Errol Hunt performed science demonstrations, pictured right.

SCIENCE SAYS!

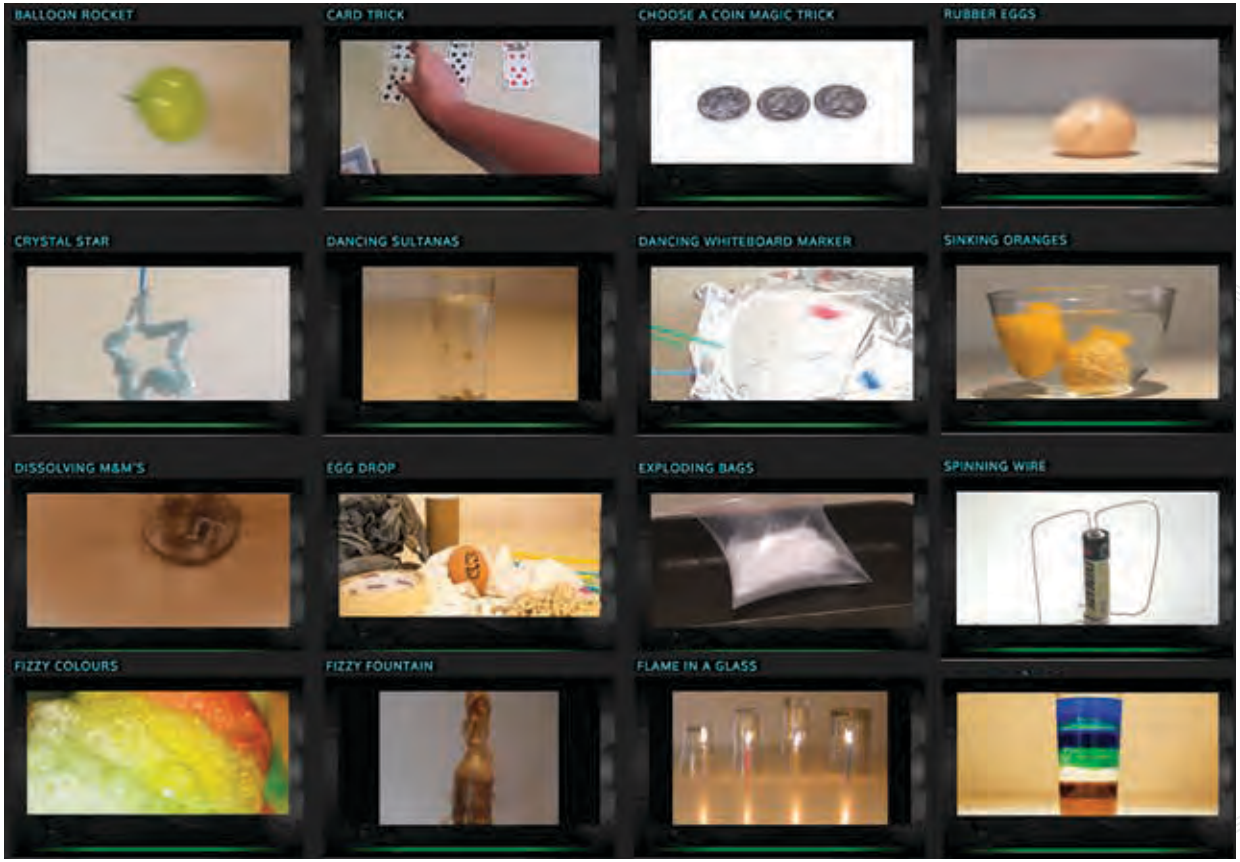
FLEET supported the first Melbourne show of Science Says!, a science entertainment event run by The Science Nation, with FLEET's A/Prof Meera Parish and Prof Chris Vale appearing on the panel.

FLEET collaborated with Swinburne University of Technology, Monash University School of Physics and Astronomy, and the Australian Institute of Physics to capitalise on Prof Wolfgang Ketterle's presence in Melbourne. This included presenting both a public talk to a physics-oriented audience at Swinburne University of Technology *(see p64)*, and an event for secondary school students at Monash University *(see p65)*.

In 2018, FLEET will create a bank of activities and experiments for students to complete when visiting a FLEET node. These activities will be designed in accordance with AI Educational Liaison Dr Eroia Barone-Nugent's framework for the Growing Tall Poppies program, designed to increase girls' participation in physics.

Above: Facilitator and panelists of Science Says!

Below: Director Michael Fuhrer explains tying electrons into knots



MAGIC JUMPING BEANS

Transform a marble, aluminium foil and a square container to apparently give the 'bean' a life of its own. In reality, it's gravity. It's not magic – it's science!

RUBBER EGGS

Use an egg and vinegar to dissolve the shell, creating an egg with an expanded, rubbery texture.

FLOATING WATER

A deceptively simple experiment using hot and cold water dyed different colours to illustrate the effect of density and mixing.

HOME SCIENCE EXPERIMENTS: IT'S NOT MAGIC – IT'S SCIENCE!

Simple, accessible science for school-age kids and their parents

FLEET's Home Science and FLEET Geeks *(see p62)* programs provide science opportunities for young children and adults alike, making science easy, accessible and relevant.

FLEET's Home Science activities introduce younger students to easy, fun science experiments using accessible, everyday items. They are ground-tested and simple instructions are written for a non-science audience, including a description of the underlying scientific concepts. A new experiment is released every week on the website, and promoted through social media. Extension activities and links to the Australian teaching curriculum are provided where possible.

CASE STUDY

MACRO-CHIPS AND ELECTRONIC CARD GAMES: CHALLENGING STUDENTS

Fresh minds develop hands-on learning methods for schools

FLEET is developing innovative ways to communicate some key physics to school students.

A collaboration with Monash University Science allowed the Centre to enlist fresh brains to this communications challenge.

A team of maths and physics students from Monash Bachelor of Science–Global Challenges took on the task of developing hands-on games and resources to demonstrate FLEET-relevant science themes in the classroom.

The student team designed a range of innovative games and physical demonstrations, including:

> **Electron tiggy**, a physical ice-breaker activity to demonstrate electron scattering in conventional semiconductors

> **Wired**, a card game to introduce electrical circuit components, including transistors

> **The Macrochip**, a physical, water-based demonstration of binary computing via transistor switches.

Global Challenges team with FLEET outreach kits. From left: Joshua Zail, Daniel Schultz, Clarissa Frizziero, Elle Phillips.

ELECTRON TIGGY is a fun, physical demonstration of electron scattering in semiconductors – a key concept in discussing topological transistors that do not allow scattering. Based on British bullrush, Electron tiggy uses stationary players as 'impurities' who slow running players ('electrons') as they cross the field.

WIRED is a card game that introduces students to electrical components and circuit diagrams. Cards display circuit components (matched to the school curriculum) and players 'build' a circuit by playing the right cards in order.

THE MACROCHIP builds on a common 'water analogy' used in teaching circuits, in which the pressure pushing water through pipes represents voltage, and the amount of water that flows represents current. In the 'macrochip' (that is, a 'macro'-scale microchip) the flow of water shows how transistor switching is used in computing. Vinyl tubing joins tap valves that represent switchable transistors, with four end points representing the binary (0/1, or on/off) digits in a four-digit number. Students open and close taps to build any binary number from 0000 to 1111.

All exercises involve a hands-on element, which has been shown to be very effective in learning and recall. This helps address a particular challenge of teaching FLEET's areas of science, which is that atomic-scale phenomena aren't very physically accessible.

The team developed instructions for manufacture and play that can be used by classroom teachers or by scientists visiting the class. Feedback from teachers has been extremely positive.

The project represented a successful collaboration with FLEET educational liaison Dr Toby Bell at Monash University Science.

FLEET GEEKS: TAKING SCIENCE TO SCHOOLS

Reaching schoolkids, and setting scientists up for outreach success

Bringing practising scientists to schools brings enormous benefits.

The FLEET Geeks program sees FLEET members performing science shows at primary schools and kindergartens, demonstrating physics with equipment not typically available to students.

It's not magic, it's science. Dr Dianne Ruka demonstrates induction by dropping a magnet through a pipe

The program brings scientists to the students, allowing them to ask questions about scientific phenomena seen in the show, everyday science, a career in science or whatever burning questions they have.

Hands-on learning is extremely effective in getting students to recall science lessons, so FLEET Geek programs involve the students in fun, easy exercises such as investigating static electricity (using a van de Graaff machine), thermal conductivity (the heat of coins) and induction (a magnet dropped down a copper tube).

Students also engaged with gravity and forces using a Newton's cradle and weights, and angular momentum using a spinning stool.

Students are pushed to ask 'why', and to offer possible explanations for the phenomena observed.

As well as asking about physics in the show or in their lives, students are also encouraged to talk about scientists, and about studying or working in science.

The experiments inspire even young students with a sense of joy and magic, as well as the knowledge that they too can be scientists, and right now – all they have to do is look around them and ask 'why?'

FLEET Geeks exposes students to science role models, and helps challenges preconceived notions about scientists.

Before one primary school visit, students were asked what a scientist does, and what a scientist looks like.

Many students didn't know what a scientist does, or responded that scientists 'make potions'. Drawings of a scientist were almost exclusively male, in particular men with crazy, white hair.

Challenged with the question "Why aren't you wearing a lab coat?", FLEET outreach coordinator Dr Dianne Ruka responded by describing different types of scientist. Her message was: "We don't all wear lab coats, we don't all work in a lab and not all scientists are men with crazy white hair!"

In 2017, FLEET Geeks was trialled at primary schools and kindergarten, reaching students up to year 6. In 2018 FLEET will train more Centre members to deliver these activities, and expand the program to public places such as shopping centres.

Home Science *(see p60)* and FLEET Geeks are designed to make science more accessible for students, and to spark interest and curiosity in STEM for Australians at a young age.

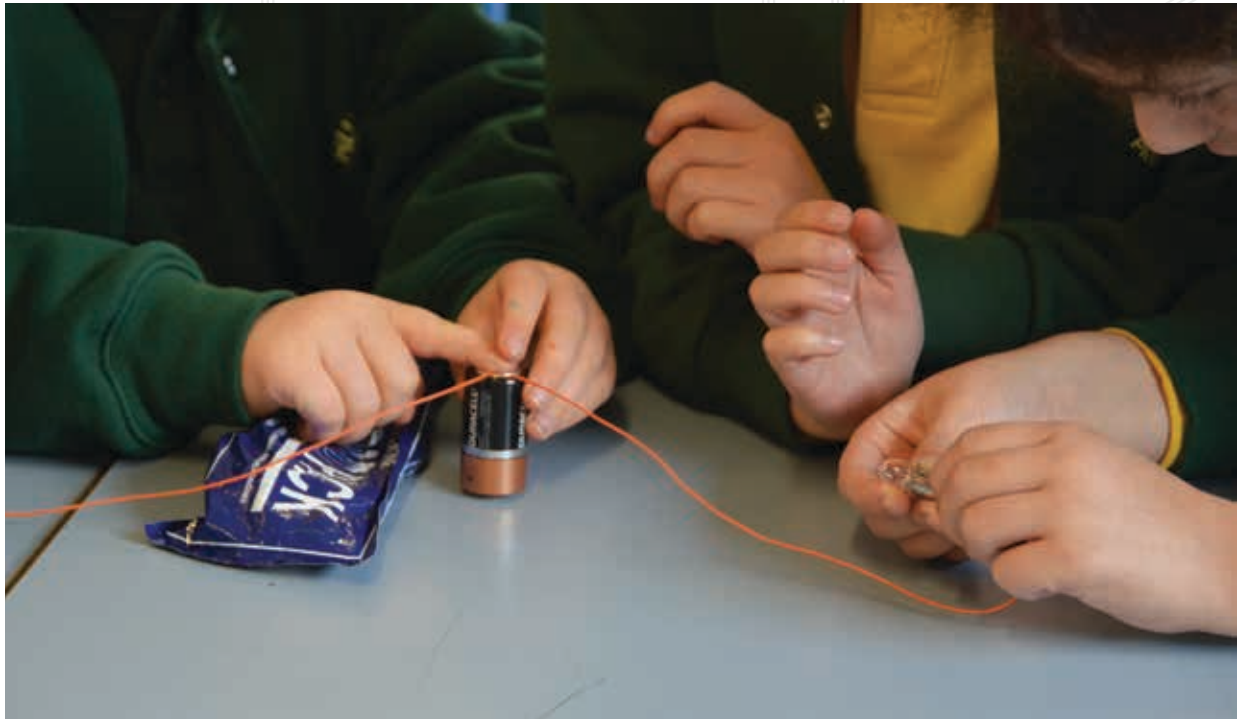
FLEET Geeks is a key component of FLEET's developing 'toolkit' of science outreach that Centre members can dip into, ensuring that their science outreach is achievable and effective. All our experiments are trialled before being taken into schools, to ensure student engagement and successful delivery.

The FLEET Geeks program connects practising scientists to schools, and sets Centre members up for success in delivering science outreach.

FLEET members are expected to perform at least 20 hours of science outreach per year.

> FLEET Geeks had lots of surprises and I learned a lot of things I didn't know.
>
> **Xavier S**
> Year 2, Hughesdale Primary School

Primary school students learning about electrical conductivity using simple props



CASE STUDY

TEMPERATURES A MILLIONTH OF OUTER SPACE: NOBEL PHYSICS PUBLIC TALK

Why do physicists use temperatures a million times colder than outer space?

Taking 'strange states' and ultra-cold atomic physics to the public

At ultra-cold temperatures, only millionths of a degree above absolute zero, the quantum nature of individual atoms materialises in a phase known as a Bose-Einstein condensate.

Such states are used by FLEET researchers in Research theme 2 (exciton superfluids) and Research theme 3 (light-transformed materials).

Nobel physics laureate Prof Wolfgang Ketterle (pictured left) told a crowd of around 250 at Swinburne University of Technology about Bose-Einstein condensates (BECs), and other strange states of matter that exist at nano-Kelvin temperatures. These temperatures open a new door to the quantum world where particles behave as waves and 'march in lockstep'.

Ketterle expressed excitement at the discoveries that could remain to be made "if we can reach the pico-Kelvin scale".

The talk was co-presented by Swinburne, FLEET and the Victorian branch of the Australian Institute of Physics.

Prof Wolfgang Ketterle, who was co-awarded the 2001 Nobel Prize in Physics for realising BECs in the lab, is a key FLEET adviser.

Ketterle was in Australia for the inaugural annual FLEET workshop in Torquay, at which he gave one of the workshop's most popular talks. He described the BECs that form an integral part of research in FLEET's Research theme 2 (in A/Prof Elena Ostrovskaya's labs at ANU) and Research theme 3 (Prof Kris Helmerson's Monash labs and Prof Chris Vale's Swinburne labs).

Prof Ketterle advises FLEET as a member of the Centre's International Scientific Advisory Committee.

> "I have a new nerd crush! I was very impressed with Prof Ketterle's communication skills and the way he talked to the kids. I am no physicist, but he made complex physics intelligible."
>
> **Dr Linda McIver**
> Teacher, John Monash Science School

CASE STUDY

LUNCH WITH A LAUREATE: INSPIRING FUTURE PHYSICISTS

A rare opportunity for schoolkids to meet a Nobel laureate

Secondary-school physics students sometimes worry they need to map out a career in detail from the outset.

But taking a slightly flexible approach to a career in physics can work out pretty well.

FLEET advisor Prof Wolfgang Ketterle (Massachusetts Institute of Technology) spoke to 90 students and teachers about his own sometimes circuitous physics career, while describing his research into ultra-cold physics (pictured right).

For any students (or researchers!) who were nervous about their future career path, Ketterle offered reassurance that changing research fields midstream had only increased his confidence and creativity.

Describing his move into ultra-cold atomic research, Ketterle said “although the field was new and I didn’t know anything about it, I knew how to learn new information”.

In retrospect, considering that the research won Ketterle a Nobel Prize in 2001, it worked out okay – and not only in “making better refrigerators,” at which Ketterle modestly claims some ability.

> My students had a fantastic time meeting the academics and discovering their fields of physics. Prof Ketterle’s presentation was inspirational, with humour and a capacity to touch on deep science with young maturing scientific minds.
>
> **Michele Linossier**
> Teacher, Scotch College

Exposing young students to a scientist who has won the Nobel Prize in Physics was a rare chance to inspire their own aspirations for physics achievement.

The talk at Monash University was followed by a casual 'Lunch with a Laureate,' with teachers and students sharing personal, round-table chats with Ketterle and other physicists, including Monash and FLEET researchers and Monash University's Dean of Science Prof Jordon Nash.

A 'speed-dating' forum exposed students in small groups to six minutes with each academic, and the chance to quiz them with difficult questions about their fields of physics, chemistry and materials science.

The talk was co-presented by Monash University School of Physics and Astronomy, FLEET and the Victorian branch of the Australian Institute of Physics.

Ketterle was awarded the Nobel Prize in Physics in 2001 for his work in the creation of Bose-Einstein condensates in the laboratories at MIT.

12 FLEET members from Monash and Swinburne meeting local students in "Speed-dating a scientist" session

SHARING FLEET NEWS AND SCIENCE: COMMUNICATION

FLEET's communications functions include:

- Internal communication to forge a cohesive and effective Centre
- Informing the public of the benefits to Australia of FLEET's ARC-funded research
- Supporting FLEET's outreach functions of building a more science-aware public
- Effectively communicating FLEET's research outputs to audiences that range in knowledge all the way from completely non-scientific up to the research community and potential collaborators.

In our first year FLEET has focused significant efforts on internal communications, working to build Centre cohesion via member induction, an internal newsletter to share news and tips, and an annual workshop *(see p56)* that was designed to forge inter-node links and build members' knowledge of other research themes.

Communication with external stakeholders is also underway, including involving affiliated researchers through the annual workshop and newsletter, engaging and building a social media audience to extend the reach of research and Centre communications, and sharing research achievements with journalists, online media and node communications teams.

FACEBOOK @FLEETCENTRE

217 **Followers** FLEET Facebook page

507 Number of **posts**

883 Number of times **FLEET videos were watched** at 95%

22,604 Number of people who **saw our posts**.

108 **Users engaged:** 28 day average

241 **Number of people reached:** 28 day average

2,365 Number of people who **engaged with our posts**.

TWITTER @FLEETCENTRE

286 Number of **Followers**

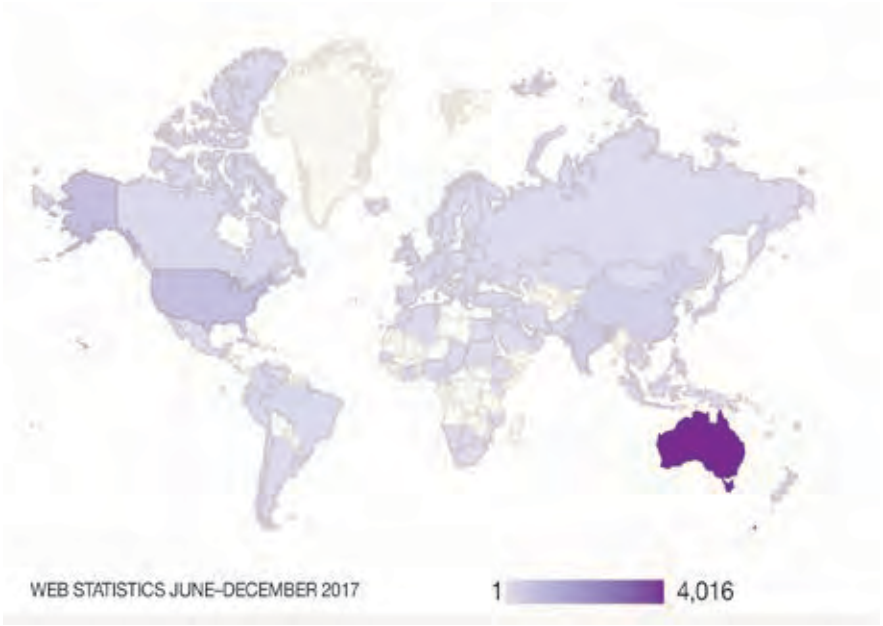
156 Number of **Mentions**

2,777,222 Number of **Tweet Impressions**

445 Number of **Tweets**

4,407 Number of **Profile visits**

FLEET.ORG.AU

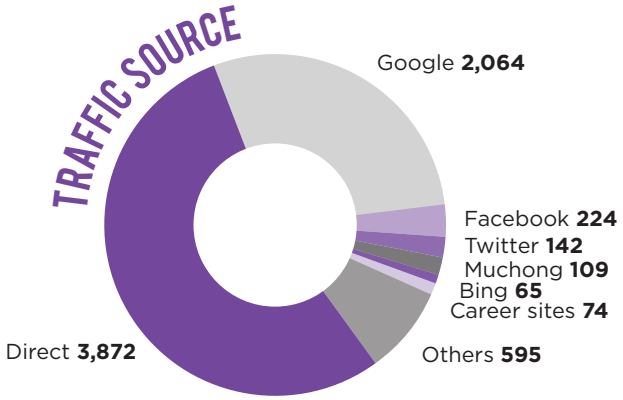


35,327 Number of **unique page views**

7,145 Number of **of new users**

14,868 Number of **sessions**

3.36 Number of **pages per session**



> There is a real buzz about FLEET. Team members are excited about each other's work, and people from different universities, in different states, are brain-storming together.
>
> **Prof Alex Hamilton**
> Deputy Director, FLEET

> Within FLEET, I feel I am a part of something much bigger and not just a Brownian particle wandering around.
>
> **Pavel Kolesnichenko**
> PhD student, Swinburne University

IN 2018, FLEET WILL:

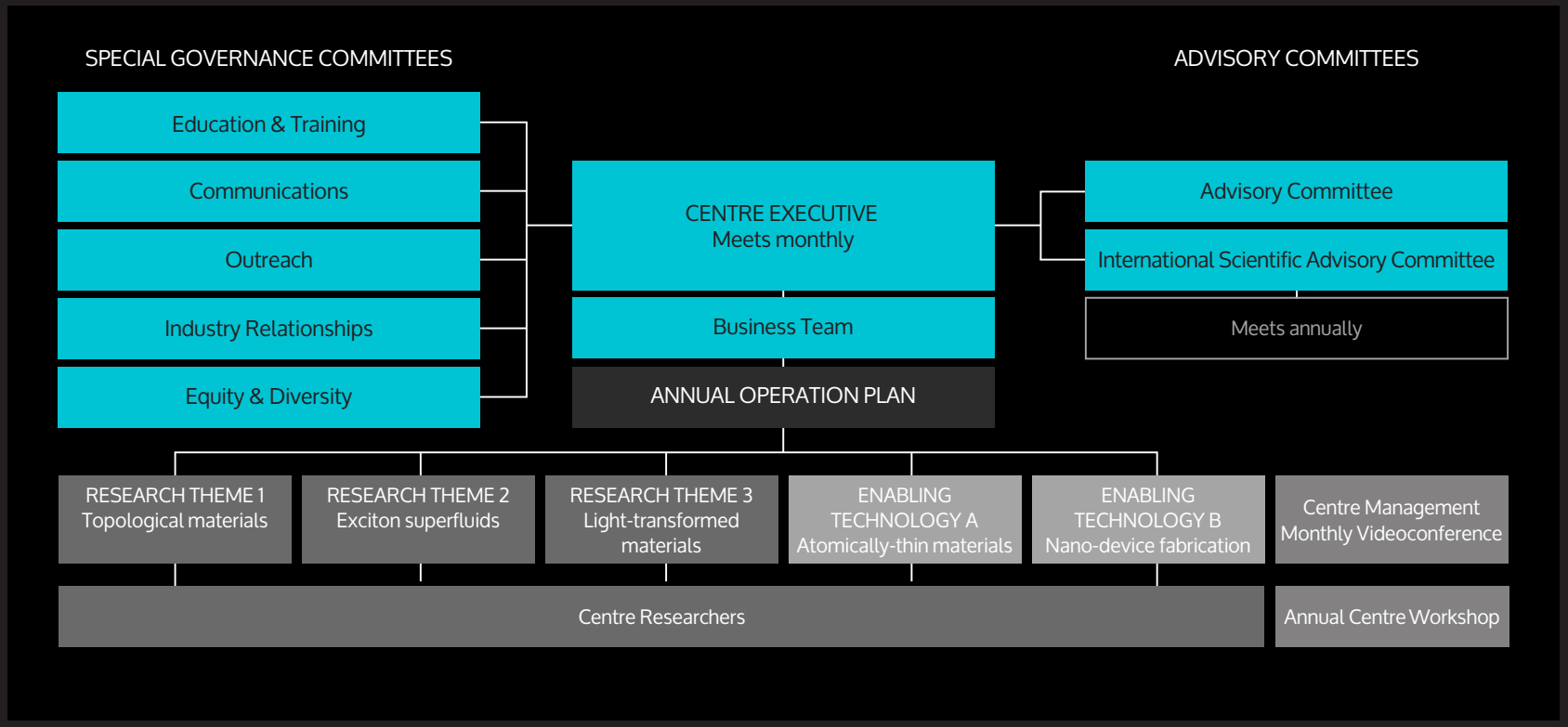
- Continue to build an audience for our messages – both scientific and in leadership functions, including expanding our newsletter to relevant stakeholders and other markets, starting with China.
- Further improve Centre cohesion via our second annual workshop, building on learnings from the first workshop.

INSIDE FLEET

07

The global FLEET network brings together top-quality staff, students and collaborating partners to deliver on the Centre's mission.

From left, Dimi Culcer, Feixiang Xiang and Harley Scammell, UNSW


SPECIAL GOVERNANCE COMMITTEES
Education & Training
Communications
Outreach
Industry Relationships
Equity & Diversity
CENTRE EXECUTIVE
Meets monthly
Business Team
ANNUAL OPERATION PLAN
ADVISORY COMMITTEES
Advisory Committee
International Scientific Advisory Committee
Meets annually
RESEARCH THEME 1
Topological materials
RESEARCH THEME 2
Exciton superfluids
RESEARCH THEME 3
Light-transformed materials
ENABLING TECHNOLOGY A
Atomically-thin materials
ENABLING TECHNOLOGY B
Nano-device fabrication
Centre Management
Monthly Videoconference
Centre Researchers
Annual Centre Workshop

BUSINESS TEAM

DR CATHERINE BUCHANAN

Executive Officer

Catherine coordinates KPI and budget reporting across FLEET's seven nodes and provides administrative support to the Executive and governance committees.

CECILIA BLOISE

Node Coordinator UNSW

Cecilia supports FLEET operations at UNSW and provides support to node leader Alex Hamilton.

DR DIANNE RUKA

Senior Education and Training Coordinator

Dianne leads FLEET's education and training missions, student recruitment, career development programs, internship placement and outreach programs.

ERROL HUNT

Senior Communications Coordinator

Errol coordinates FLEET's communications strategies, communicates Centre mission and outcomes within FLEET, to the scientific community, to potential end-users and to the public via media.

DR TICH-LAM NGUYEN

Chief Operating Officer

Tich-Lam oversees FLEET's financial and operational effectiveness, aimed at delivery of the Centre's strategic goals.

> FLEET's business team supports its outstanding researchers to achieve their scientific, engagement and equity goals. I'm proud to be part of a Centre that is transforming STEM culture in Australia and creating the sustainable technology we need in the 21st century.

Dr Catherine Buchanan
FLEET Executive Officer

ADVISORY COMMITTEE (AC)

FLEET's Advisory Committee helps the Executive Committee develop FLEET's strategic plan, which sets out how the Centre will meet its goals, in particular in creating linkages with industry, academia, and government. The Advisory Committee:

> Reviews FLEET's Annual Operating Plan
> Provides recommendations on financial management
> Provides recommendations on general management and operation, to ensure the Centre achieves its objectives
> Produces an annual report of strengths, weaknesses and opportunities.

PROF ANDREW PEELE
Director

Australian Synchrotron, Australia

DR AN CHEN
Executive Director

Semiconductor Research Corporation, IBM Nanoelectronics Research Initiative, USA

DR CATHY FOLEY
Science Director

CSIRO Manufacturing Flagship, Australia

PROF ELLEN WILLIAMS
Distinguished Professor

University of Maryland, USA

PROF IAN SMITH
Vice-Provost of Research and Research Infrastructure

Monash University, Australia

PROF LUIGI COLOMBO
Fellow

Texas Instruments, USA

DR STEVE DUVALL
Chief Technology Officer and General Manager

Silanna, Australia

> FLEET will spectacularly translate our fundamental knowledge of solid-state systems, which is crucial for a world that must become more efficient in its use of electronics.
>
> **Prof Andrew Peele**
> Director, Australian Synchrotron
> President, Australian Institute of Physics
>
> FLEET Advisory Committee

INTERNATIONAL SCIENTIFIC ADVISORY COMMITTEE (ISAC):

> Provides independent scientific advice to FLEET investigators, both directly and through the Centre Director.
> Advises on the scientific directions of FLEET
> Benchmarks the quality of FLEET research against international standards
> Produces an annual report placing FLEET's progress in an international context and making recommendations for future directions.

> It is an exciting time for the study of topological phases of matter, and it is great to see FLEET's focus on using this new science for more efficient electronics.
>
> **Prof Ali Yazdani**
>
> Princeton Center for Complex Materials
> International Scientific Advisory Committee

INTERNATIONAL SCIENTIFIC ADVISORY COMMITTEE MEMBERS (TWO-YEAR APPOINTMENT):

PROF ALI YAZDANI
Professor of Physics

Princeton University, USA

PROF HIDENORI TAKAGI
Director

Max Planck Institute for Solid State Research, Germany

SIR KOSTYA NOVOSELOV
Professor of Physics

University Manchester, UK

SIR MICHAEL PEPPER
Professor of Physics

University College London, UK

PROF WOLFGANG KETTERLE
Professor of Physics

Massachusetts Institute of Technology, USA

> FLEET is investing not only in research, but also in the people who will form the future Australian electronics industry. For example, by providing our members opportunities to take part in the Centre's operation, we help train better-rounded future leaders with a diverse set of skills and capabilities.
>
> **Dr Tich-Lam Nguyen**
> FLEET Chief Operating Officer

FLEET'S EXECUTIVE COMMITTEE

FLEET's Executive Committee oversees strategic plans for the Centre, in accordance with the Australian Research Council Funding Agreement and agreements with the Centre's collaborating organisations. The committee's responsibilities include:

- Overseeing general management and operation of the Centre
- Proper allocation of funding
- Approval of Centre activities
- Approval of Centre intellectual property ownership
- Approval of any amendments to Centre budget and research program
- Promoting interactions between participants and partners across nodes and institutions
- Solving problems in the successful execution of the Centre's mission.

FLEET's Executive team comprises leaders of research themes and nodes, and committee chairs.

PROF MICHAEL FUHRER

Director

Michael is a pioneer of the study of electronic properties of 2D materials, with extensive experience establishing and managing large, inter-disciplinary research teams in Australia and the USA.

He directs implementation of FLEET's vision and mission and coordinates the three Research themes and two Enabling technologies. With FLEET's Executive team, Michael implements the Centre's strategic plan regarding research, technology transfer, training and mentorship, and outreach.

An accomplished communicator, Michael represents FLEET's work to the research community, government, students, media and the public.

Michael is an ARC Laureate Fellow and former Director of the Monash Centre for Atomically Thin Materials and the Center for Nanophysics and Advanced Materials (University of Maryland).

DR TICH-LAM NGUYEN

Chief Operating Officer

Tich-Lam manages FLEET's operations and its business team. She's responsible for the Centre's financial and operational effectiveness and the oversight of activities contributing to the development and delivery of its strategic goals.

Tich-Lam holds a PhD in Chemistry from RMIT University and a Master of Management from the Melbourne Business School.

COMMITTEE MEMBERS:

PROF ALEX HAMILTON

Deputy Director

Leader, Research theme 1

Node leader, University of New South Wales

PROF CHRIS VALE

Node leader, Swinburne

Chair, Outreach Committee

A/PROF ELENA OSTROVSKAYA

Leader, Research theme 2

Node leader, Australian National University

Chair, Equity & Diversity Committee

PROF KRIS HELMERSON

Leader, Research theme 3

Monash University

PROF KOUROSH KALANTAR-ZADEH

Node leader, RMIT

Chair, Industry Relationship Committee

A/PROF LAN WANG

Leader, Enabling technology B

RMIT University

PROF MATTHEW DAVIS

Node leader, University of Queensland

Chair, Education & Training Committee

PROF NAGARAJAN 'NAGY' VALANOOR

Chair, Communications Committee

University of New South Wales

PROF XIAOLIN WANG

Leader, Enabling technology A

Node leader, University of Wollongong

> I hope FLEET can make a lasting contribution to Australian Science – increasing interactions between universities, promoting women in science and engaging the public in science.
>
> **Prof Alex Hamilton**
> FLEET Deputy Director

EQUITY AND DIVERSITY COMMITTEE

FLEET fosters a culture of inclusiveness and works to promote diversity across the Centre. FLEET's Equity and Diversity Committee sets the Centre's equity priorities, monitors our progress via staff surveys, and learns from equity best practice across the science sector *(see p48)*.

> FLEET's efforts to foster inclusiveness, eliminate discrimination and support diversity benefit everyone. Diverse research groups do better research, and workplaces that are 'minority friendly' are better places to work for all staff!
>
> **A/Prof Elena Ostrovskaya**
> Chair, Equity and Diversity Committee

COMMITTEE MEMBERS:

A/PROF ELENA OSTROVSKAYA
Committee Chair, ANU

DR DIMI CULCER
UNSW

DR JEFF DAVIS
Swinburne

PROF KRIS HELMERSON
Monash

A/PROF LAN WANG
RMIT

PROF MATTHEW DAVIS
UQ

A/PROF MEERA PARISH
Monash

DR TICH-LAM NGUYEN
FLEET Chief Operating Officer

PROF XIAOLIN WANG
UoW

YONATAN ASHLEA ALAVA
PhD student, UNSW

BUILDING FUTURE SCIENCE LEADERS: EDUCATION AND TRAINING COMMITTEE

FLEET is building future Australian science leaders amongst the Centre's ECRs and HDRs. FLEET's Education and Training Committee sets the Centre's strategies and sponsorship priorities, checking progress and development requirements *(see p51)*.

FLEET also has a team of educational and outreach associate investigators *(see p44)*.

> FLEET will ensure that our members understand that their amazing technical skills and knowledge can be applied much more broadly than just in specialist physics research, and we will give them the tools to do so.
>
> **Prof Matthew Davis**
> Chair, Education and Training Committee

COMMITTEE MEMBERS:

PROF MATTHEW DAVIS
Committee Chair, UQ

DR DIANNE RUKA
Education and Training Coordinator

A/PROF ELENA OSTROVSKAYA
ANU

PROF JAN SEIDEL
UNSW

PROF JARED COLE
Scientific Associate Investigator, RMIT

DR JEFF DAVIS
Swinburne

PROF KRIS HELMERSON
Monash

PROF XIAOLIN WANG
UoW

SPREADING A PASSION FOR SCIENCE: OUTREACH COMMITTEE

FLEET will increase science literacy in the Australian community, and inspire more participation in science. FLEET's Outreach Committee sets outreach strategy and determines appropriate outreach activities and public events to support *(see p58)*.

FLEET also has a team of educational and outreach associate investigators *(see p44)*.

> "FLEET's outreach program has shown that there's a real passion among people of all ages to learn about and connect with cutting-edge science."
>
> **Prof Chris Vale**
> Chair, Outreach Committee

COMMITTEE MEMBERS:

PROF CHRIS VALE
Committee Chair, Swinburne

DR DIANNE RUKA
Education and Training Coordinator

DR DIMI CULCER
Deputy Chair, UNSW

A/PROF ELENA OSTROVSKAYA
ANU

ERROL HUNT
Communications Coordinator

A/PROF NIKHIL MEDHEKAR
Monash

PROF MATTHEW DAVIS
UQ

RESEARCH TRANSLATION: INDUSTRY RELATIONSHIPS COMMITTEE

FLEET's Industry Relationships Committee's task is to:

> Ensure FLEET research outcomes are fed into affiliated and broader industries
> Engage with current industrial partners and attract future industry partners
> Establish the ground for translation and eventual commercialisation of research outputs, with maximum benefit to the consumers *(see p43)*.

COMMITTEE MEMBERS:

PROF KOUROSH KALANTAR-ZADEH
Committee Chair, RMIT

DR JIAN-ZHEN OU
Scientific Associate Investigator, RMIT

A/PROF QIAOLIANG BAO
Monash

PROF XIAOLIN WANG
UoW

> The Industry Relationships Committee will lead engagement with industrial partners and establish groundwork for ultimate translation and commercialisation of FLEET's science into affiliated industries.
>
> **Prof Kourosh Kalantar-Zadeh**
> Chair, Industry Relationships Committee

SHARING FLEET NEWS AND SCIENCE: COMMUNICATIONS COMMITTEE

FLEET's Communications Committee gathers information and leads on newsworthy stories from diverse nodes, feeding them through to the communications coordinator, channels feedback from the nodes, and develops strategies to communicate FLEET research to the wider research community, partners, stakeholders, potential end-users and the public *(see p67)*.

In 2018 the Communication Committee will expand its membership to include more student representation.

> The highlight for internal communication in 2017 was the annual workshop that brought all FLEET members together, forging friendships and collaborative links.
>
> **Prof Nagarajan Valanoor**
> Chair, Communication Committee

COMMITTEE MEMBERS:

PROF NAGARAJAN 'NAGY' VALANOOR
Committee Chair, UNSW

DR DAVID COLAS
Research Fellow, UQ

DR DAVID CORTIE
Scientific Associate Investigator, UoW

ERROL HUNT
Communications Coordinator

PROF JARED COLE
Scientific Associate Investigator, RMIT

DR JEFF DAVIS
Swinburne

MARYAM BOOZARJMEHR
PhD student, ANU

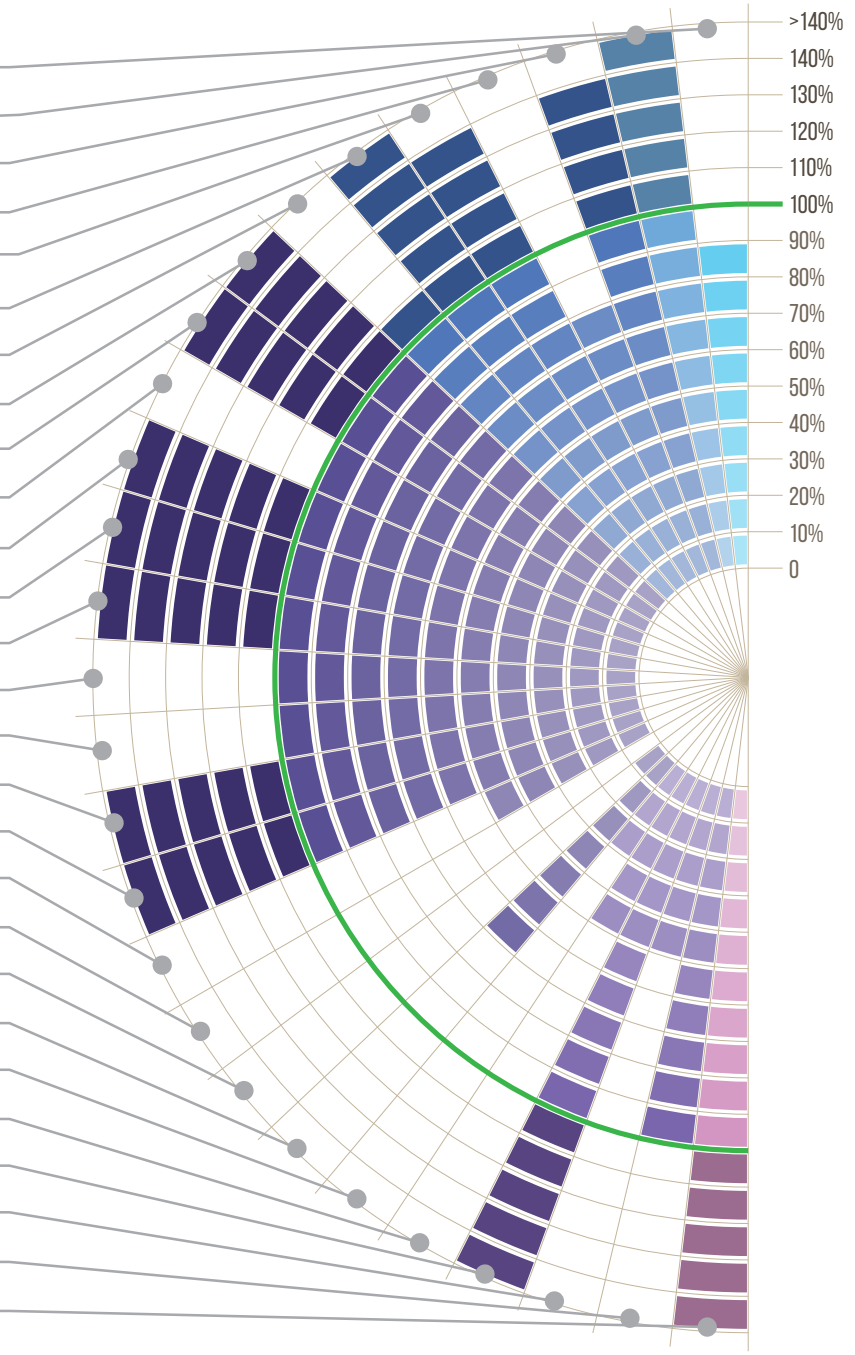
08 PERFORMANCE

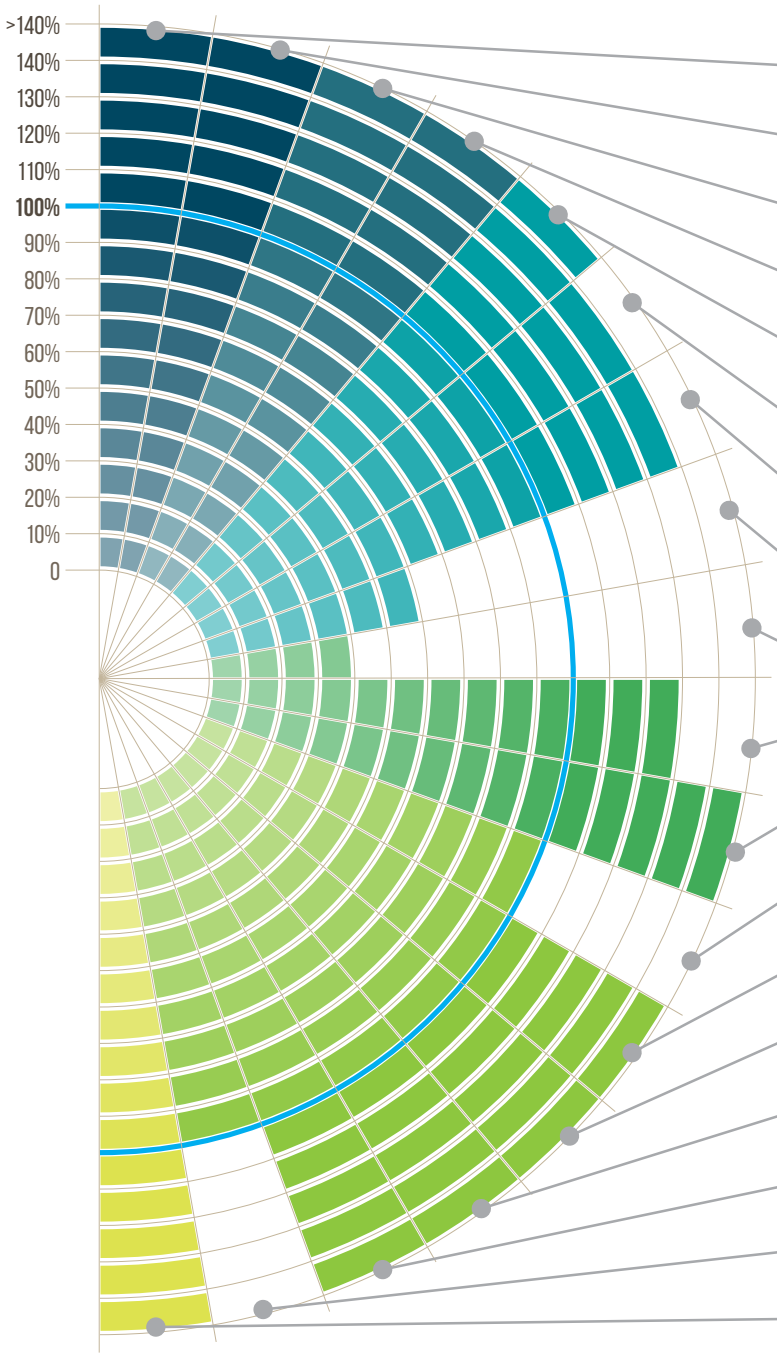
FLEET has set ambitious goals and made a great start in 2017 towards achieving them.

PERFORMANCE MEASURES

- Research outputs
- Quality of research outputs
- Personnel
- Education & training
- Presentations & briefings
- Partnership development

STANDARD KPI	Target	Actual
Journal articles	30	27
Publications in journals with IF >7	6	11
Postdoctoral researchers	15	21
Honours students	5	4
PhD students	20	27
Masters by research students	0	2
Associate Investigators	21	22
Research development courses	1	2
Professional development courses	1	3
Training workshops held on diversity and gender equity	1	1
Centre attendees at training workshops	50	339
Non-Centre attendees at training workshops	50	893
Workshops held within Australia	1	3
Workshops held outside Australia	1	1
National symposium & conferences facilitated	1	1
International symposium & conferences facilitated	0	2
Mentoring programs	2	4
Mentors within the Centre	30	14
Mentors external to the Centre	5	0
FLEET mentees	40	3
Organisational links in training and mentorship programs	3	2
Presentations to the public	10	3
Presentations to government	2	1
Presentations to industry/business/end-users	2	3
Presentations to non-government organisations	2	1
Presentations to professional organisations and bodies	2	2
New collaborating organisations	2	7





Actual	Target	CENTRE SPECIFIC KPI
21%	10%	**Percentage of women HDRs in FLEET**
17%	10%	**Percentage of women ECRs in FLEET**
45	12	**Invited talks at international conferences**
2	0	**New fellowships awarded to CIs, ECRs and AIs**
6	2	**International students and ECRs visiting FLEET**
14	10	**International senior investigators visiting FLEET**
7	5	**Chief Investigators visiting partners**
3	5	**ECRs & HDRs students visiting partners**
2	5	**Non-peer reviewed works by FLEET members**
51	40	**Mentions of FLEET research in the media**
862	300	**New users to Centre website, monthly average**
562	600	**Hours spent in outreach activities**
3,068	200	**Primary/secondary students reached**
62	20	**Primary/secondary teachers reached**
3,150	1,000	**Public reached**
6	3	**Organisational links in education and outreach programs**
3	3	**End-user relationships established**
5,257	500	**Additional research income secured by Centre staff ('000)**

PERFORMANCE MEASURES

- Gender equity
- Recognition
- Partnership development
- Media
- Outreach
- New funding

PEER-REVIEWED JOURNAL PUBLICATIONS

1. Q. Cao; F.F. Yun; L. Sang; F. Xiang; G. Liu; X.L. Wang, *Defect introduced paramagnetism and weak localization in two-dimensional metal VSe_2*, Nanotechnology, **2017**, 28 (47) 475703, DOI: 10.1088/1361-6528/aa8f6c. IF < 4
2. M. Capsoni; A. Schiffrin; K.A. Cochrane; C.G. Wang; T. Roussy; A.Q. Shaw; W. Ji; S.A. Burke, *Selective Hybridization of a Terpyridine-Based Molecule with a Noble Metal*, The Journal of Physical Chemistry C, **2017**, 121 (42), 23574-23581, DOI: 10.1021/acs.jpcc.7b08576, IF 4-7
3. K. Cedergren; R. Ackroyd; S. Kafanov; N. Vogt; A. Shnirman; T. Duty, *Insulating Josephson Junction Chains as Pinned Luttinger Liquids*, Physical Review Letters, **2017**, 119 (16), DOI: 10.1103/PhysRevLett.119.167701, IF 4-7
4. D. Culcer; A. Sekine; A.H. MacDonald, *Interband coherence response to electric fields in crystals: Berry-phase contributions and disorder effects*, Physical Review B, **2017**, 96 (3), DOI: 10.1103/PhysRevB.96.035106, IF < 4, #
5. T. Daeneke; P. Atkin; R. Orrell-Trigg; A. Zavabeti; T. Ahmed; S. Walia; M. Liu; Y. Tachibana; M. Javaid; A.D. Greentree; S.P. Russo; R.B. Kaner; K. Kalantar-Zadeh, *Wafer-Scale Synthesis of Semiconducting SnO Monolayers from Interfacial Oxide Layers of Metallic Liquid Tin*, ACS Nano, 2017, DOI: 10.1021/acsnano.7b04856, IF >10, *
6. S.C. Dhanabalan; B. Dhanabalan; J.S. Ponraj; Q. Bao; H. Zhang, *2D-Materials-Based Quantum Dots: Gateway Towards Next-Generation Optical Devices*, Advanced Optical Materials, **2017**, 1700257, DOI: 10.1002/adom.201700257, IF 4-7
7. M.T. Edmonds; J. Collins; J. Hellerstedt; I. Yudhistira; L.C. Gomes; J.N.B. Rodrigues; S. Adam; M. Fuhrer, *Spatial charge inhomogeneity and defect states in topological Dirac semimetal thin films of Na_3 Bi*, Science Advances, **2017**, 3 (12), eaao6661, DOI: 10.1126/sciadv.aao6661, IF 4-7, *
8. J. Hellerstedt; I. Yudhistira; M.T. Edmonds; C. Liu; J. Collins; S. Adam; M. Fuhrer, *Electrostatic modulation of the electronic properties of Dirac semimetal*, Physical Review Materials, **2017**, 1 (5), ROI: 10.1103 PhysRevMaterials.1.054203, IF 4-7, *
9. H. Khan; A. Zavabeti; Y. Wang; C.J. Harrison; B.J. Carey; M. Mohiuddin; A.F. Chrimes; I. Alves de Castro; B.Yue Zhang; Y.M. Sabri; S.K. Bhargava; J. Zhen Ou; T. Daeneke; S.P. Russo; Y. Li; K. Kalantar-Zadeh, *Quasi physisorptive two dimensional tungsten oxide nanosheets with extraordinary sensitivity and selectivity to NO_2*, Nanoscale, **2017**, 9 (48), 19162-19175, DOI: 10.1039/C7NR05403C, IF 7-10, *
10. Z. Li; J. Zheng; Y. Zhang; C. Zheng; W.Y. Woon; M.C. Chuang; H.C. Tsai; C.H. Chen; A. Davis; Z.Q. Xu; J. Lin; H. Zhang; Q. Bao, *Synthesis of Ultrathin Composition Graded Doped Lateral WSe_2 /WS_2 Heterostructures*, ACS Applied Materials & Interfaces, **2017**, 9 (39), 34204-34212, DOI: 10.1021/acsami.7b08668, IF 7-10
11. X. Lin; A.N. Jumabekov; N.N. Lal; A.R. Pascoe; D.E. Gómez; N.W. Duffy; A.S.R. Chesman; K. Sears; M. Fournier; Y. Zhang; Q. Bao; Y.B. Cheng; L. Spiccia; U. Bach, *Dipole-field-assisted charge extraction in metal-perovskite-metal back-contact solar cells*, Nature Communications, **2017**, 8 (1), DOI: 10.1038/s41467-017-00588-3, IF >10
12. C. Liu; J. Hellerstedt; M.T. Edmonds; M.S. Fuhrer, *Temperature-dependent n— p transition in a three-dimensional Dirac semimetal Na_3 Bi thin film*, Physical Review B, **2017**, 96 (23), DOI: 10.1103/PhysRevB.96.235412, IF 4-7, *
13. H. Liu; D. Culcer, *Coulomb drag in topological materials*, Journal of Physics and Chemistry of Solids, **2017**, DOI: 10.1016/j.jpcs.2017.06.015, IF < 4
14. W. E. Liu; E.M. Hankiewicz; D. Culcer, *Weak Localization and Antilocalization in Topological Materials with Impurity Spin-Orbit Interactions*, Materials, **2017**, 10 (7), 807, DOI: 10.3390/ma10070807, IF < 4
15. W. E. Liu; E.M. Hankiewicz; D. Culcer, *Quantum transport in Weyl semimetal thin films in the presence of spin-orbit coupled impurities*, Physical Review B, **2017**, 96 (4), DOI: 10.1103 PhysRevB.96.045307, IF < 4
16. Y. Liu; B.Nanjunda Shivananju; Y. Wang; Y. Zhang; W. Yu; S. Xiao; T. Sun; W. Ma; H. Mu; S. Lin; H. Zhang; Y. Lu; C.W. Qiu; S. Li; Q. Bao, *Highly Efficient and Air-Stable Infrared Photodetector Based on 2D Layered Graphene–Black Phosphorus Heterostructure*, ACS Applied Materials & Interfaces, **2017**, 9 (41), 36137-36145, DOI: 10.1021/acsami.7b09889, IF 7-10
17. W. Mao; J. Zheng; Y. Zhang; A.S.R. Chesman; Q. Ou; J. Hicks; F. Li; Z. Wang; B. Graystone; T.D.M. Bell; M.Uller Rothmann; N.W. Duffy; L. Spiccia; Y.B. Cheng; Q. Bao; U. Bach, *Controlled Growth of Monocrystalline Organo-Lead Halide Perovskite and Its Application in Photonic Devices*, Angewandte Chemie International Edition, **2017**, DOI: 10.1002/anie.201703786, IF >10 *
18. D.S. Miserev; A. Srinivasan; O.A. Tkachenko; V.A. Tkachenko; I. Farrer; D.A. Ritchie; A.R. Hamilton; O.P. Sushkov, *Mechanisms for Strong Anisotropy of In-Plane*, Physical Review Letters, **2017**, 119 (11), DOI: 10.1103/PhysRevLett.119.116803, IF 7-10
19. N. Ramakrishnan; Y.Tong Lai; S. Lara; M.M. Parish; S. Adam, *Equivalence of effective medium and random resistor network models for disorder-induced unsaturating linear magnetoresistance*, Physical Review B, **2017**, 96 (22), DOI: 10.1103/PhysRevB.96.224203, IF < 4, *
20. M.T. Reeves; T.P. Billam; X. Yu; A.S. Bradley, *Enstrophy Cascade in Decaying Two-Dimensional Quantum Turbulence*, Physical Review Letters, **2017**, 119 (18), DOI: 10.1103/PhysRevLett.119.184502, IF 7-10
21. T. Sun; Y. Wang; W. Yu; Y. Wang; Z. Dai; Z. Liu; B.Nanjunda Shivananju; Y. Zhang; K. Fu; B. Shabbir; W. Ma; S. Li; Q. Bao, *Flexible Broadband Graphene Photodetectors Enhanced by Plasmonic Cu_{3x} P Colloidal Nanocrystals*, Small, **2017**, 13 (42), 1701881, DOI: 10.1002/smll.201701881, IF 7-10
22. J. Tollerud; J.A. Davis, *Coherent multi-dimensional spectroscopy: Experimental considerations, direct comparisons and new capabilities*, Progress in Quantum Electronics, **2017**, 55, 1 -34, DOI: 10.1016/j.pquantelec.2017.07.001, IF >10
23. X.B. Wang; L. Cheng; Y. Wu; D.P. Zhu; L. Wang; J.X. Zhu; H. Yang; E.E.M. Chia, *Topological-insulator-based terahertz modulator*, Scientific Reports, **2017**, 7 (1), DOI: 10.1038/s41598-017-13701-9, IF 4-7
24. S.A. Wilkinson; N. Vogt; J.H. Cole, *Coulomb drag and depinning in bilinear Josephson junction arrays*, New Journal of Physics, **2017**, 19 (9), 93023, DOI: 10.1088/1367-2630/aa8661, IF < 4
25. J. Yuan; W. Ma; L. Zhang; Y. Lu; M. Zhao; H. Guo; J. Zhao; W. Yu; Y. Zhang; K. Zhang; H.Ying Hoh; X. Li; K.Ping Loh; S. Li; C.W. Qiu; Q. Bao, *Infrared Nanoimaging Reveals the Surface Metallic Plasmons in Topological Insulator*, ACS Photonics, **2017**, 4 (12), 3055-3062, DOI: 10.1021/acsphotonics.7b00568, IF 4-7
26. F.F. Yun; D.L. Cortie; X.L. Wang, *Tuning the electronic structure in stanene/graphene bilayers using strain and gas adsorption*, Phys. Chem. Chem. Phys., **2017**, 19 (37), 25574-25581, DOI: 10.1039/C7CP03678G, IF 4-7, *
27. A. Zavabeti; J.Zhen Ou; B.J. Carey; N. Syed; R. Orrell-Trigg; E.L.H. Mayes; C. Xu; O. Kavehei; A.P. O'Mullane; R.B. Kaner; K. Kalantar-Zadeh; T. Daeneke, *A liquid metal reaction environment for the room-temperature synthesis of atomically thin metal oxides*, Science, **2017**, 358 (6361), 332-335, DOI: 10.1126/science.aao4249, IF >10, *

DOI *Article Digital object identifier*
IF *Impact Factor at time of publication*
* *Publications involving associate investigators*
\# *Publications involving partner investigators*

PRESENTATIONS

TALK TITLE	SPEAKER	EVENT NAME	COUNTRY	DATE	PRESENTATION TYPE	NOTES
Electronic Control at the Nanoscale: Towards Solid Interfaces with Enhanced Electronic and Optoelectronic Functionalities	Agustin Schiffrin	NanoS-E3 Conference	Australia	28/09/2017	Conference Presentation	
Long Range P-wave Proximity Effect into a Disordered Metal	Aydin Keser	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	02/11/2017	Conference Presentation	
Resolving spin dynamics at the nanometer-scale with radioactive ion-beams	David Cortie	Wagga Wagga The Annual Condensed Matter and Materials Meeting	Australia	01/02/2017	Conference Presentation	
Beyond the Silicon Age: Ion Beam Implantation and Modification for Magnetic Nanolayers	David Cortie	ANSTO User Meeting	Australia	03/10/2017	Seminar	
A Charge-insensitive Single-atom Spin-orbit Qubit In Si: Fully Tunable Coherence And Control	Dimi Culcer	Australian Institute of Physics Summer Meeting	Australia	05/12/2017	Conference Presentation	
Mechanisms of the in-plane g-factor anisotropy in p-type quantum point contacts	Dmitry Miserev	Wagga Wagga The Annual Condensed Matter and Materials Meeting	Australia	03/02/2017	Conference Presentation	
In-plane g-factor anisotropy in p-type quantum point contacts	Dmitry Miserev	Australian Institute of Physics Summer Meeting	Australia	06/12/2017	Conference Presentation	
In-plane g-factor anisotropy in p-type quantum point contacts	Dmitry Miserev	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	31/10/2017	Poster	
Non-equilibrium condensation and optical control of exciton polaritons.	Elena Ostrovskaya	Physics Colloquium	Australia	22/08/2017	Seminar	
3D to 2D crossover in WTe_2 crystals	Feixiang Xiang	University of New South Wales	Australia	27/11/2017	Workshop / Symposium	
Multiple universalities in order-disorder magnetic phase transitions	Harley Scammell	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	31/10/2017	Poster	
Strong influence of spin-orbit coupling on magnetotransport in two-dimensional hole systems	Hong Liu	Australian Institute of Physics Summer Meeting 2017	Australia	06/12/2017	Conference Presentation	
Domain Walls and Phase Boundaries in Multiferroic Oxides	Jan Seidel	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	01/11/2017	Conference Presentation	
Domain walls and phase boundaries in multiferroic oxides	Jan Seidel	University of New South Wales	Australia	05/09/2017	Workshop / Symposium	
Charge transport in Josephson junction arrays: the interplay of disorder, decoherence and dissipation	Jared Cole	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	26/08/2017	Conference Presentation	
Using qubits as a tool in materials science: unravelling the mystery of two-level defects in amorphous solids	Jared Cole	School of Mathematics and Physics Colloquium	Australia	24/07/2017	Seminar	
Identifying a Superfluid Reynolds Number via Dynamical Similarity	Matt Reeves	Quantum Science Seminar	Australia	21/03/2017	Seminar	
How to get your students to prepare for class: Introducing Semant and other ideas	Matthew Davis	University of Queensland School of Mathematics & Physics Teaching Seminar	Australia	03/05/2017	Seminar	
Impurities coupled to a bosonic medium	Meera Parish	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	30/10/2017	Conference Presentation	
Dynamics of impurities in quantum gases	Meera Parish	Australian Institute of Physics summer meeting	Australia	05/12/2017	Conference Presentation	
Electronic Properties of High-Quality Epitaxial Topological Dirac Semimetal Thin Films	Michael Fuhrer	Wagga Wagga The Annual Condensed Matter and Materials Meeting	Australia	01/02/2017	Conference Presentation	

TALK TITLE	SPEAKER	EVENT NAME	COUNTRY	DATE	PRESENTATION TYPE	NOTES
Epitaxial Thin Films of Topological Dirac Semimetal Na_3Bi	Michael Fuhrer	Gordon Godfrey Workshop on Spins and Strong Electron Correlations	Australia	31/10/2017	Conference Presentation	
Metals, insulators, and something new: The discovery of "topological insulators" and how they might change the world	Michael Fuhrer	National Science Week - Monash STEM Talk	Australia	15/05/2017	Public Lecture	
Tying Electrons into Knots	Michael Fuhrer	Monash University Open Day Science Presentations	Australia	06/08/2017	Public Lecture	
Overview of FLEET and research in Fuhrer Lab	Michael Fuhrer, Lan Wang	Meeting with Lockheed Martin representatives Anthony Jacomb-Hood and Jim Beffa to discuss research projects	Australia	02/11/2017	Technical Briefing	
Floquet states of superfluids	Oliver Sandberg	Honours final talks	Australia	17/10/2017	Academia Lecture	
Photoluminescence and Differential Maps of Monolayers of WS_2 Reveal Branched Pattern	Pavel Kolesnichenko, Jeff Davis	MCATM 2-Dimensional Materials Characterization Workshop	Australia	30/05/2017	Poster	
Structural and electrical properties of PLD grown PbZrxTi1-xO3/$SrRuO_3$/$SrTiO_3$ heterostructures	Vivasha Govinden	University of New South Wales	Australia	16/08/2017	Group meeting	
Journal Club: Domain wall motion in Pb(Zr0.20Ti0.80)O3 epitaxial thin films	Vivasha Govinden	University of New South Wales	Australia	24/10/2017	Seminar	
When freezing cold is not cold enough - New forms of matter near absolute zero temperature	Wolfgang Ketterle	Swinburne University of Technology	Australia	30/11/2017	Public Lecture	
Electronic Properties of Epitaxial Topological Dirac Semimetal Thin Films	Mark Edmonds	31st International Winterschool on the Electronic Properties of Novel Materials, IWEPNM 2017	Austria	07/03/2017	Conference Presentation	*
Universality and dynamics of impurities in quantum gases	Meera Parish	Controllable Quantum Impurities in Physics and Chemistry	Austria	18/08/2017	Conference Presentation	*
Quantum kinetic theory of magneto-transport in topological materials	Dimi Culcer	The World of Topological Matters	China	14/07/2017	Conference Presentation	*
A single-atom spin-orbit qubit in Si	Dimi Culcer	Peking University Condensed Matter Seminar	China	21/11/2017	Seminar	*
A single-atom spin-orbit qubit in Si	Dimi Culcer	Beijing Computational Science Research Center Seminar	China	22/11/2017	Seminar	*
A single-atom spin-orbit qubit in Si	Dimi Culcer	Chinese Academy of Sciences Institute of Physics Solid State Seminar	China	23/11/2017	Seminar	*
A single-atom spin-orbit qubit in Si	Dimi Culcer	Tsinghua University Condensed Matter Seminar	China	24/11/2017	Seminar	*
Domain walls and phase boundaries - new nanoscale functional elements in complex oxides	Jan Seidel	Wuhan University of Geosciences	China	08/12/2017	Conference Presentation	*
Nanoscale bubble domains in ferroelectric thin films	Peggy Qi Zhang	Atomic force microscopy for advanced functional materials	China	10/12/2017	Conference Presentation	*
Topological Defects in Ferroelectric Thin Films	Peggy Qi Zhang	Tsinghua University	China	27/11/2017	Seminar	*
Topological Defects in Ferroelectric Thin Film	Peggy Qi Zhang	Hubei University	China	01/12/2017	Seminar	*
Topological Defects in Ferroelectric Thin Films	Peggy Qi Zhang	Huazhong University of Science and Technology	China	07/12/2017	Seminar	*

* *indicates invited presentations to international research community*

TALK TITLE	SPEAKER	EVENT NAME	COUNTRY	DATE	PRESENTATION TYPE	NOTES
Optoelectronics of 2D Materials	Qiaoliang Bao	ChinaNano2017	China	29/08/2017	Conference Presentation	*
Grand design of materials and properties	Xiaolin Wang	University of Macau	China	08/09/2017	Conference Presentation	*
Grand design of novel materials and physical properties	Xiaolin Wang	Hubei University	China	15/10/2017	Conference Presentation	*
Quantum transport and electronic structures of WTe2 bulk and thin crystals	Xiaolin Wang	The 2nd "International Workshop on Spintronics Memory and Logic"	China	12/06/2017	Conference Presentation	*
Materials Design	Xiaolin Wang	Beijing Institute of Technology	China	19/10/2017	Seminar	*
Spin gapless semiconductors	Xiaolin Wang	Beihang University	China	20/10/2017	Workshop / Symposium	*
Observation of charge density wave on monoelemental Sb(110)	Zhi Li	2017 BUAA-UOW Joint Workshop Program	China	20/10/2017	Workshop / Symposium	*
Observation of charge density wave on monoelemental Sb(110)	Zhi Li	2017 Beihang University - University of Wollongong Joint Workshop Program	China	20/10/2017	Workshop / Symposium	*
Atomic-Scale Engineering of Solid Interfaces: Towards Enhanced Electronic and Optoelectronic Functionalities	Agustin Schiffrin	Physics Seminar in Prof. P. Jelinek's research group	Czech Republic	18/05/2017	Seminar	*
Sub-cycle optical control of electronic properties of materials	Agustin Schiffrin	SPICE Workshop "Non-Equilibrium Quantum Matter" - Spin Phenomena Interdisciplinary Center	Germany	01/06/2017	Poster	
Electronic Control at the Nanoscale: Towards Solid Interfaces with Enhanced Electronic and Optoelectronic Functionalities	Agustin Schiffrin	University of Regensburg	Germany	23/03/2017	Seminar	*
Atomic-Scale Engineering of Solid Interfaces: Towards Enhanced Electronic and Optoelectronic Functionalities	Agustin Schiffrin	Physics Seminar in Prof. S. Loths's group at the Max Planck Institute for the Structure and Dynamics of Matter	Germany	29/05/2017	Seminar	*
Novel soliton dynamics in one dimensional open-dissipative polariton systems	David Colas	PLMCN18 - 18th International Conference on Physics of Light-Matter Coupling in Nanostructures	Germany	10/07/2017	Poster	
Quantum computing with rough multi-valley Si systems: electrically-driven spin and valley resonances and overcoming roughness	Dimi Culcer	16th International Conference on the Formation of Semiconductor Interfaces	Germany	05/07/2017	Plenary lecture	*
Single-shot Bose-Einstein condensation of exciton polaritons: from fragmented to Thomas-Fermi regime	Elena Ostrovskaya	18th International Conference on Physics of Light-Matter Coupling in Nanostructures	Germany	10/07/2017	Conference Presentation	*
Non-equilibrium Bose-Einstein condensation of exciton polaritons	Elena Ostrovskaya	SPICE Workshop "Non-Equilibrium Quantum Matter" - Spin Phenomena Interdisciplinary Center	Germany	30/05/2017	Conference Presentation	*
Dynamics of impurities in quantum gases	Meera Parish	Non-equilibrium Quantum Matter	Germany	02/06/2017	Conference Presentation	*
Fully tuneable coherence and control of acceptor qubits	Dimi Culcer	BME Physics Seminar	Hungary	11/07/2017	Seminar	*
Strain tuning the remarkable functionalities of BiFeO3 films	Daniel Sando	International Symposium on Integrated Functionalities	India	09/12/2017	Conference Presentation	*
Fully tunable coherence and control of acceptor qubits via magnetic field orientation	Dimi Culcer	IWPSD 2017 - XIX International Workshop on The Physics of Semiconductor Devices	India	12/12/2017	Conference Presentation	*
Quantum kinetic theory of magneto-transport in topological materials	Dimi Culcer	Bose Colloquium	India	15/12/2017	Seminar	*
Nonvolatile Ferroelectric Domain Wall Memory	Pankaj Sharma	6th International Symposium of Integrated Functionalities 2017	India	13/12/2017	Conference Presentation	*

* *indicates invited presentations to international research community*

TALK TITLE	SPEAKER	EVENT NAME	COUNTRY	DATE	PRESENTATION TYPE	NOTES
Domain walls and phase boundaries for memory applications	Jan Seidel	Tel Aviv University	Israel	14/11/2017	Conference Presentation	*
Topological structures as nanoscale functional elements: Electrical and mechanical properties of phase boundaries in $BiFeO_3$	Jan Seidel	Tel Aviv University	Israel	13/11/2017	Seminar	*
Electronic Properties of Epitaxial Topological Dirac Semimetal Thin Films	Michael Fuhrer	International Centre for Theoretical Physics Conference on Weyl Fermions in Materials	Italy	26/10/2017	Conference Presentation	*
Chemical solution deposition derived bismuth ferrite thin films	Peggy Qi Zhang	Tokyo Institute of Technology	Japan	13/11/2017	Seminar	*
Topological Defects in Ferroelectric Thin Films	Peggy Qi Zhang	Tohoku University	Japan	14/11/2017	Seminar	*
Chemical solution deposition derived bismuth ferrite thin films	Peggy Qi Zhang	Kyoto University-Uji campus	Japan	16/11/2017	Seminar	*
Domain Walls as Nanoscale Functional Elements	Jan Seidel	SIPS - Sustainable Industrial Processing Summit & Exhibition, Cancun	Mexico	23/10/2017	Conference Presentation	*
A single-atom spin-orbit system for computing applications	Dimi Culcer	University of Canterbury School of Physical and Chemical Sciences Seminar Series	New Zealand	26/10/2017	Seminar	*
Using qubits as a tool in materials science: unravelling the mystery of two-level defects in amorphous solids	Jared Cole	School of Chemistry and Physics Seminar	New Zealand	19/11/2017	Seminar	*
Quantum kinetic theory of magneto-transport in topological materials	Dimi Culcer	Advanced many-body and statistical methods in mesoscopic systems III	Romania	06/09/2017	Conference Presentation	*
From liquid metal core to two dimensional semiconducting skin	Kourosh Kalantar-Zadeh	2017 Recent Progress in Graphene & 2D Materials Research, Sep 2017, Singapore	Singapore	20/09/2017	Conference Presentation	*
Topological Electronics	Michael Fuhrer	Institute of Physics Singapore Meeting 2017	Singapore	22/02/2017	Conference Presentation	*
Synthesis and optical applications of two-dimensional metal-halide perovskites	Qiaoliang Bao	CLEO-PR, OECC&PGC 2017 at Singapore	Singapore	01/08/2017	Conference Presentation	*
Photonics and Optoelectronics of 2D Materials	Qiaoliang Bao	The International Conference on 2D Materials and Technology	Singapore	13/12/2017	Conference Presentation	*
The codes of matter: A simple model for design of new class of functional materials	Xiaolin Wang	ICMAT 2017 - International Conference on Materials for Advanced Technologies	Singapore	20/06/2017	Conference Presentation	*
Excitation spectra of near-homogeneous Fermi gases	Chris Vale	Bose-Einstein condensation 2017 - Frontiers in quantum gases	Spain	07/09/2017	Conference Presentation	*
Exciton-polariton condensation in non-Hermitian potentials	Elena Ostrovskaya	Bose-Einstein Condensation 2017: Frontiers in Quantum Gases	Spain	05/09/2017	Conference Presentation	*
Observation of dynamical emergence of negative temperature vortex states in a 2D superfluid	Matthew Davis, Matt Reeves	Bose-Einstein Condensation 2017	Spain	06/09/2017	Poster	
Universality and dynamics of impurities in quantum gases	Meera Parish	BEC 2017 Bose-Einstein Condensates – Frontiers in Quantum Gases	Spain	04/09/2017	Conference Presentation	*
Atomic-Scale Engineering of Solid Interfaces: Towards Enhanced Electronic and Optoelectronic Functionalities	Agustin Schiffrin	Physics Seminar at the University of Basel	Switzerland	06/09/2017	Seminar	*
A multiferroic on the brink: modulation of functional properties using strain- and electric field-induced transitions in $BiFeO_3$ films	Daniel Sando	1st MRS Thailand International Conference	Thailand	02/11/2017	Conference Presentation	*

* *indicates invited presentations to international research community*

TALK TITLE	SPEAKER	EVENT NAME	COUNTRY	DATE	PRESENTATION TYPE	NOTES
Asymptotic Freedom and Multiple Universalities in Quantum Critical Magnets	Harley Scammell	University College London	United Kingdom	22/09/2017	Technical Briefing	
Nonvolatile Ferroelectric Domain Wall Memory	Pankaj Sharma	International Workshop on Topological Structures in Ferroic Materials	United Kingdom	10/08/2017	Conference Presentation	
Ultrafast control of electrons in materials with the electric field of light	Agustin Schiffrin	IEEE Photonics Conference	United States	04/10/2017	Conference Presentation	*
Bragg spectroscopy of near-homogeneous Fermi gases	Chris Vale	48th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics	United States	07/06/2017	Conference Presentation	*
Spin-orbit interactions in in inversionasymmetric two-dimensional (2D) hole systems: A variational analysis	Elizabeth Marcellina	EP2DS - International Conference on Electronic Properties of Two-Dimensional Systems	United States	01/08/2017	Poster	
Domain walls and phase boundaries - new nanoscale functional elements in complex oxides	Jan Seidel	Materials Science & Technology conference	United States	19/10/2017	Conference Presentation	*
Topological structures as nanoscale functional elements	Jan Seidel	Brookhaven National Lab	United States	16/09/2017	Seminar	*
Pathway selective CMDS for revealing weak interactions in complex systems	Jeff Davis	SciX - Federation of Analytical Chemistry and Spectroscopy Societies	United States	11/10/2017	Conference Presentation	*
Revealing Interactions in Complex Systems with Coherent Multi-Dimensional Spectroscopy	Jeff Davis	R. G. Herb Condensed Matter Seminar	United States	13/10/2017	Seminar	*
Impurities in quantum gases	Jesper Levinsen	Correlations and Entanglement in and out of Equilibrium: from Cold Atoms to Electrons	United States	11/07/2017	Conference Presentation	*
Plasmon Resonances of Highly Doped Two-Dimensional MoO_3 and MoS_2	Kourosh Kalantar-Zadeh	Materials Research Society (MRS) Meeting, Boston, 2017	United States	13/10/2017	Conference Presentation	*
Spatial Charge Inhomogeneity and Defect States in Topological Dirac Semimetal Thin Films	Mark Edmonds	Australian Physcis Society March Meeting	United States	13/03/2017	Conference Presentation	
Growth and Electronic Properties of Topological Dirac Semimetal Na_3Bi Thin Films	Mark Edmonds	21st American Conference on Crystal Growth and Epitaxy (ACCGE-21) and 3rd Symposium on 2D Electronic Materials	United States	24/07/2017	Conference Presentation	*
Non-equibrium phase transition and bistability in a driven-dissipative superfluid	Matthew Davis	University of Colorado Boulder	United States	08/08/2017	Seminar	
Non-equibrium phase transition and bistability in a driven-dissipative superfluid	Matthew Davis	University of Arizona	United States	17/08/2017	Seminar	
Unravelling Elastic Anomalies during Morphotropic Phase Transitions	Pankaj Sharma	Materials Research Society (MRS) spring meeting 2017	United States	18/04/2017	Conference Presentation	
Collective oscillations of an interacting 2D Fermi gas	Paul Dyke	48th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics	United States	05/06/2017	Conference Presentation	
Ultrafast Control of Electrons in Materials with the Electric Field of Light	Agustin Schiffrin	IEEE Photonics Conference	United States	4/10/2017	Conference Presentation	*

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AWARDS, HONOURS AND GRANTS

FLEET MEMBER INVOLVED	TITLE OF FUNDING SCHEME OR AWARD	PROJECT ID	TOTAL VALUE (AUD)	SOURCE	NOTES
Agustin Schiffrin	MCATM Travel Grant		4,000	Monash University	
Qiaoliang Bao	MCATM Travel Grant		4,000	Monash University	
Jian-zhen Ou	VESKI Victoria Fellowship		18,000	State Government	
Xiaolin Wang, David Cortie, Zhi Li	URC Major Equipment Grants		246,000	University of Wollongong	
Xiaolin Wang	University of Wollongong Vice Chancellor's research award – Researcher of the Year			University of Wollongong	
Jan Seidel	Arc Postgraduate Council Supervisor Award			University of New South Wales	
Elizer Estrecho	Best poster award (1st place)			International Conference on Physics of Light-Matter Coupling in Nanostructues (PLMCN18)	
David Colas	Best poster award (3rd place)			International Conference on Physics of Light-Matter Coupling in Nanostructues (PLMCN18)	
Torben Daeneke	Discovery Projects 2018 round 1	DP180102752	307,239	Australian Research Council (ARC)	
David Cortie	Discovery Early Career Researcher Award 2018 round 1	DE180100314	353,773	Australian Research Council (ARC)	
Kristian Helmerson	Discovery Projects 2018 round 1	DP180100872	402,993	Australian Research Council (ARC)	
Jian-zhen Ou, Qiaoliang Bao	Linkage Infrastructure, Equipment and Facilities 2018 round 1	LE180100030	541,705	Australian Research Council (ARC)	
Lan Wang	Linkage Infrastructure, Equipment and Facilities 2018 round 1	LE180100150	595,280	Australian Research Council (ARC)	
Jan Seidel, Nagarajan Valanoor, Oleg Sushkov	Linkage Infrastructure, Equipment and Facilities 2018 round 1	LE180100109	832,648	Australian Research Council (ARC)	
Mark Edmonds	Monash University Faculty of Science Early Career Researcher Award		5,000	Monash University	*
Mark Edmonds	Internation Synchrotron Access Program		6,400	Australian Synchrotron	*
David Cortie, Xiaolin Wang	ANSTO-UOW Seed funding		17,000	University of Wollongong	*
David Cortie, Xiaolin Wang	UOW ANSTO Seed Funding	377201065	17,000	Australian Nuclear Science and Technology Organisation	*
David Cortie	Discovery early career research award	DE180100314	353,773	Australian Research Council (ARC)	*
Michael Fuhrer, Kourosh Kalantar-Zadeh, Jan Seidel, Jian-zhen Ou, Mark Edmonds, Lan Wang	Linkage Infrastructure, Equipment and Facilities 2018 round 1	LE180100054	824,080	Australian Research Council (ARC)	*
Chris Vale, Matthew Davis, Kristian Helmerson, Meera Parish	Linkage Infrastructure, Equipment and Facilities 2018 round 1	LE180100142	727,900	Australian Research Council (ARC)	*

** indicates additional funding to FLEET*

MEMBER INVOLVEMENT IN INTERNATIONAL BOARDS AND COMMITTEES

FLEET MEMBER INVOLVED	NAME OF BOARD OR COMMITTEE
Jan Seidel	International Workshop on Topological Structures in Ferroic Materials, Scientific Advisory Committee
Meera Parish	Scientific committee of the BEC Conference series

MEMBERS ON EDITORIAL BOARDS

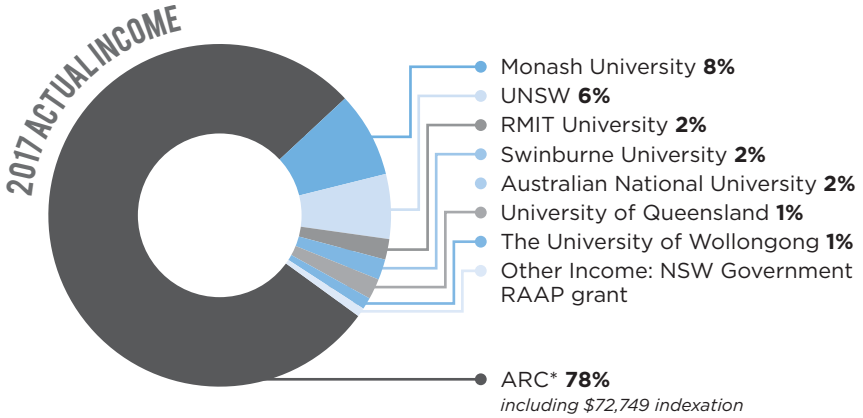
FLEET MEMBER INVOLVED	NAME OF PEER REVIEWED JOURNAL
Elena Ostrovskaya	Scientific Reports
Jan Seidel	Advanced Electronic Materials (Wiley)
Matthew Davis	SciPost Physics
Matthew Davis	European Physical Journal D
Xiaolin Wang	Scientific Report
Xiaolin Wang	Science Bulletin
Qiaoliang Bao	Nature Publishing Journal: 2D Materials and Applications
Qiaoliang Bao	Chinese Optical Letters

> FLEET's cohesion is already making a difference as my team pools resources and shares ideas with theoretical physicists at RMIT University and quantum modellers at Monash University, developing deep, basic ideas about the physics of quantum transport. These collaborations would never have happened without us being linked by the Centre.
>
> **Dr Dimi Culcer,**
> UNSW, FLEET Chief Investigator

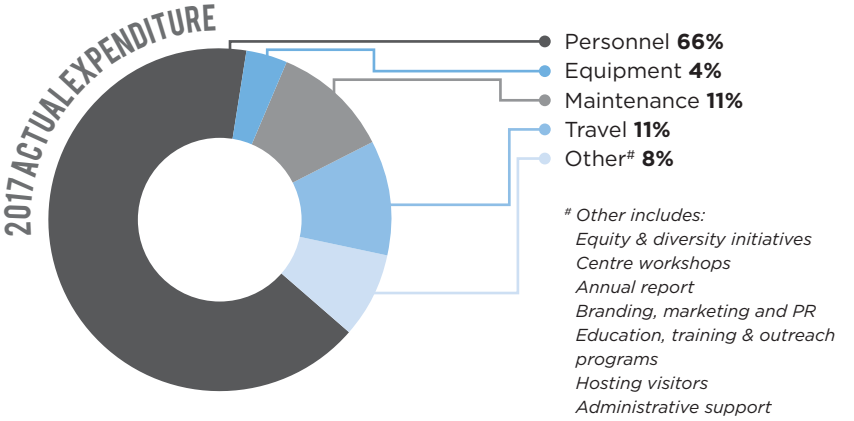
> FLEET brings together condensed-matter physics in Australia in a way that hasn't happened since the 1970s.
>
> For my entire career, condensed-matter physics has either been "old science" or has played second fiddle to quantum (optics/computing). There were so many amazing things happening in the rest of the world, but it was almost ignored here.
>
> FLEET has brought both a critical mass and a sense of purpose to this field in Australia.
>
> **Prof Jared Cole**
> RMIT University, FLEET Associate Investigator

INCOME SOURCES, EXPENDITURE CATEGORIES AND CARRY FORWARD

REPORTING PERIOD	2017	2018
INCOME	Actual ($)	Forecast ($)
ARC *	4,922,749	4,700,000
Monash University	496,000	496,000
The University of New South Wales	348,068	348,000
RMIT University	154,571	154,667
Swinburne University of Technology	116,000	116,000
The Australian National University	113,000	58,000
The University of Queensland	58,000	57,999
The University of Wollongong	58,000	58,000
Other Income: NSW government - RAAP grant	30,000	
TOTAL INCOME	6,296,388	5,988,666



REPORTING PERIOD	2017	2018
EXPENDITURE	Actual ($)	Commitment ($)
Personnel	1,596,155	4,119,552
Equipment	113,390	273,224
Maintenance	260,614	426,182
Travel	258,880	588,961
Centre Strategic Fund	-	137,682
Other #	201,097	457,082
TOTAL EXPENDITURE	2,430,137	6,002,683
CARRY FORWARD TO 2018	3,866,251	



COLLABORATING ORGANISATION IN-KIND CONTRIBUTIONS

$IN-KIND	2017 ACTUAL ($)	2018 COMMITMENT ($)
Monash University	475,055	680,640
The University of New South Wales	608,302	577,290
RMIT University	365,329	378,288
Swinburne University of Technology	596,961	309,007
The Australian National University	122,699	65,417
The University of Queensland	94,496	155,028
The University of Wollongong	42,126	120,889
National University of Singapore, Singapore	71,776	99,000
Max Planck Institute of Quantum Optics, Germany	25,880	34,425
California Institute of Technology, USA	29,619	26,800
University of Maryland, USA	67,898	62,700
Johannes Gutenberg-Universitat Mainz, Germany	10,200	30,200
Columbia University, USA	12,200	36,200
University of Colorado Boulder, USA	17,000	17,000
Tsinghua University, China	14,500	118,500
Australian Synchrotron	243,256	240,465
Universitat Würzburg, Germany	27,512	19,512
Australian Nuclear Science and Technology Organisation	132,000	436,000
University of Texas, USA	18,000	31,000
Joint Quantum Insitute, USA	118,476	30,000
TOTAL IN-KIND CONTRIBUTIONS	3,093,285	3,468,361

> This research area allows me to push the frontiers of human knowledge, while at the same time working towards an aim that has the potential to make a major impact for the whole world.
>
> FLEET opens doors to new connections, new capabilities and new ideas that will help drive the quality and impact of my research.

Dr Jeff Davis
Swinburne University of Technology FLEET Chief Investigator

FLEET VISITS TO PARTNER ORGANISATIONS

FLEET TRAVELLER(S)	INSTITUTION	COUNTRY	TRAVEL TYPE	DATES
Michael Fuhrer	National University of Singapore	Singapore	FLEET members visiting partner organisation	18 February 2017 – 25 February 2017
Agustin Schiffrin	MPQ	Germany	FLEET members visiting partner organisation	15 May 2017 – 17 May 2017
Michael Fuhrer, Agustin Schiffrin, Meera Parish, Jeff Davis, Elena Ostrovskaya	Mainz University	Germany	FLEET members visiting partner organisation	28 May 2017 – 3 June 2017
Xiaolin Wang, Zhi Li	Tsinghua University	China	FLEET members visiting partner organisation	19 October 2017 – 22 October 2017
Elena Ostrovskaya, Eliezer Estrecho, David Colas	University of Würzburg	Germany	FLEET members visiting partner organisation	9 July 2017 – 14 July 2017

“A highlight of FLEET in 2017 has been the coming together of researchers from disparate fields to create something far greater than our separate efforts.

While we have an end-goal, we’re free to work out how to get there. I love the idea that we’re trying to probe new physics.

I’m inspired to be developing new levels of understanding of physics, which could lead to revolutionary devices and energy efficiencies.”

Dr Stuart Earl
FLEET Research Fellow, Swinburne University

VISITORS TO FLEET NODES

NAME OF VISITOR	INSTITUTION	COUNTRY	POSITION	VISIT DATES	NODES VISITED
Prof Hans-Christoph Mertins	University of Applied Sciences Muenster	Germany	Professor of Physics	21 April 2017 – 24 August 2017	Monash University, Australian Synchrotron
A/Prof Elbert Chia	Nanyang Technological University	Singapore	Research Professor	12 June 2017 – 13 June 2017	Monash University
Dr Bent Weber	Nanyang Technological University	Singapore	FLEET Scientific Associate Investigator	12 June 2017 – 13 June 2017	Monash University
Dr Justin Song	Nanyang Technological University	Singapore	Research Professor	12 June 2017 – 13 June 2017	Monash University
Prof Christos Panagopoulos	Nanyang Technological University	Singapore	Research Professor	12 June 2017 – 13 June 2017	Monash University
Prof Qihua Xiong	Nanyang Technological University	Singapore	Research Professor	12 June 2017 – 13 June 2017	Monash University
Dr Ashton Bradley	University of Otago	New Zealand	Senior Lecturer	26 June 2017 – 30 June 2017	University of Queensland
Prof Victor Gurarie	University of Colorado Boulder	United States	FLEET Partner Investigator	10 July 2017 – 7 August 2017	Monash University, Swinburne University
Dr Jayanta Kumar Mishra	Nanyang Technological University	Singapore	Research Fellow	29 June 2017 – 16 September 2017	Monash University
Prof Jennifer Hoffman	Harvard University	United States	Professor of Physics	21 August 2017 – 24 August 2017	Monash University, University of New South Wales
Prof Qi-Kun Xue	Tsinghua University	China	FLEET Partner Investigator	8 September 2017 – 7 December 2017	Monash University
Dr Maciej Pieczarka	Wroclaw University	Poland	PhD Student	7 October 2017 – 5 January 2018	Australian National University
A/Prof Shaffique Adam	National University of Singapore	Singapore	FLEET Scientific Associate Investigator	25 November 2017 – 2 December 2017	Monash University
A/Prof Thomas Jespersen	Niels Bohr Institute	Denmark	Scientific Associate Investigator	29 October 2017 – 6 November 2017	University of New South Wales
Prof David Neilson	University of Camerino	Italy	Scientific Associate Investigator	30 October 2017 – 5 November 2017	University of New South Wales
Prof Marco Polini	NEST; Istituto Nanoscienze-CNR	Italy	Scientific Associate Investigator	30 October 2017 – 3 November 2017	University of New South Wales
Dr Xiaoquan Yu	University of Otago	New Zealand	Research Fellow	13 November 2017 – 17 November 2017	University of Queensland
Dr Yun Suk Eo	University of Maryland	United States	Research Fellow	25 November 2017 – 2 December 2017	Monash University
Prof Wolfgang Ketterle	Massachusetts Institute of Technology	United States	FLEET International Scientific Advisory Committee	28 November 2017 – 5 December 2017	Monash University, Swinburne University
Dr Michael Fraser	RIKEN Brain Science Institute	Japan	Collaborator	4 December 2017 – 15 December 2017	Monash University, Australian National University

FLEET SEMINARS / WORKSHOPS

WORKSHOP / SEMINAR TITLE	EVENT TYPE	WORKSHOP / SEMINAR DATES	LOCATION
FLEET Introduction Workshop	Centre Conference / Workshop	6 February 2017 – 8 February 2017	Gold Coast, QLD
Jennifer Hoffman - Imaging the Surface States of a Strongly Correlated Topological Insulator	FLEET Research Seminar	23 August 2017	Clayton, VIC
SPICE workshop on Non-Equilibrium Quantum Matter	International Workshop	30 May 2017 – 2 June 2017	Mainz, Spain
FLEET - Nanyang Technological University Singapore Partnership Development Workshop	Centre Conference / Workshop	12 June 2017 – 13 June 2017	Clayton, VIC
Victor Gurarie - Angular momentum of BCS-BEC fermionic superfluids with multiply quantized vortices	FLEET Research Seminar	10 August 2017	Clayton, VIC
Hans-Christoph Mertins - Magneto-Optical Polarisation Spectroscopy with Synchrotron Radiation on Graphene	FLEET Research Seminar	22 August 2017	Clayton, VIC
YouR Forum: Got PhD, What Next?	Professional Development Workshop	08 September 2017	Clayton, VIC
YouR Forum: When a picture is worth 1000-words	Professional Development Workshop	19 October 2017	Clayton, VIC
Gordon Godfrey Workshop on Spins and Strong Electron Correlations	International Workshop	30 October 2017 – 3 November 2017	Sydney, NSW
FLEET 2017 Annual Workshop	Centre Conference / Workshop	26 November 2017 – 29 November 2017	Torquay, VIC
FLEET Early Career Researcher Workshop - Science Communications	Research Development Workshop	26 November 2017	Torquay, VIC
Fairness and Diversity at FLEET	Equity & Diversity Workshop	28 November 2017	Torquay, VIC
Angeline Bartholomeusz: Intellectual Property Management	Research Development Workshop	28 November 2017	Torquay, VIC
Igor Aharonovich - Quantum Emitters in Flatland	FLEET Research Seminar	04 December 2017	Clayton, VIC
Victorian ARC Centres and Hubs Staff Workshop	Professional Development Workshop	14 December 2017	Clayton, VIC

FLEET MEMBERS IN THE MEDIA

PRESS RELEASE

Date
19 October 2017

Press release title
Liquid metal discovery ushers in new wave of chemistry and electronics

FLEET members mentioned
Kourosh Kalantar-Zadeh, Torben Daeneke

Link
https://www.eurekalert.org/pub_releases/2017-10/ru-lmd101517.php

Outcomes
Re-published by 31 online media outlets

PRESS RELEASE

Date
22 December 2017

Press release title
Electronically-smooth '3d graphene': a bright future for trisodium bismuthide

FLEET members mentioned
Mark Edmonds, Michael Fuhrer

Link
https://www.eurekalert.org/pub_releases/2017-12/acoe-eg121717.php

Outcomes
Re-published by 12 online media outlets

MONASH UNIVERSITY STAFF NEWSLETTER (APPROX 15,000)

Date
17 April 2017

Article title
Two-dimensional materials key to solving 'invisible' computing energy challenge

Centre members mentioned/Involved
Qiaoliang Bao, Michael Fuhrer, Meera Parish

Link
http://www.fleet.org.au/blog/insider-2d-materials-energy-challenge/

Publisher
Monash University Strategic Marketing and Communications

Details Article on FLEET, ICT energy use, Monash contribution

RADIO

Date
4 June 2017

Article title
Radio interview 3RRR interviewed Michael Fuhrer

Centre members mentioned/Involved
Michael Fuhrer

Link
http://ondemand.rrr.org.au/grid/20170903110001

Publisher 3RRR

PRINT, MAGAZINE

Date
1 August 2017

Article title
Materials on atom thick and nano-transistors – Australian solutions to future electronics

Centre members mentioned/Involved
Michael Fuhrer, Alex Hamilton, Mark Edmonds, Lan Wang, Xiaolin Wang, Qiaoliang Bao, Nagarajan Valanoor, Jan Seidel, Oleg Sushkov, Oleh Klochan, Errol Hunt

Link
http://amtil.com.au/uploads/AMT_AUGSEPT_2017/index.html#68

Publisher Australian Manufacturing Technology

ONLINE

Date
15 August 2017

Article title
Topological insulators and how they might change the world – STEM Talk – National Science Week

Centre members mentioned/Involved
Michael Fuhrer

Link
https://www.youtube.com/watch?v=jQ_ihxXcqpg

Publisher
Monash Education

RADIO

Date
30 November 2017

Article title
ABC Melbourne Radio AM774 interviewed Wolfgang Ketterle

Centre members mentioned/Involved
Wolfgang Ketterle

Link
http://www.fleet.org.au/blog/ketterle-abc-radio-melbourne/

Publisher
ABC Radio Melbourne

Outcomes
Radio interview on ABC Melbourne with Red Symonds

OUTREACH ACTIVITIES

NAME OF EVENT	DATES	AUDIENCE TYPE	LOCATION	APPROX. AUDIENCE REACHED
St Spyridon high school visit to UNSW	13 March 2017	School students	Sydney, NSW	30
Matrix Tutoring Practical Day	23 April 2017	School students	Sydney, NSW	60
Hughesdale, VIC Primary School Grade 2 visit	14 June 2017	School students	Melbourne, VIC	80
National Science Quiz - Melbourne, VIC	17 June 2017	Public	Camberwell, VIC	200
National Science Quiz - Adelaide, SA	25 June 2017	Public	Adelaide, SA	400
Work experience - Monash	26 June 2017	School students	Clayton, VIC	10
National Youth Science Forum - lab tours	07 July 2017	School students	Clayton, VIC	20
Girls in Physics Breakfast - Hawthorn, VIC	21 July 2017	School students	Hawthorn, VIC	10
Teaching Quantum Hall Effect to undergraduate students	24 July 2017	Undergraduate students	Sydney, NSW	6
Indigenous Experience Day - lab tour	27 July 2017	School students	Clayton, VIC	15
Girls in STEM breakfast	27 July 2017	School students	Canberra, ACT	70
Scienceworks collaboration	28 July 2017	Other professional organisations and bodies	Melbourne, VIC	3
Swinburne Open Day	30 July 2017	Public	Hawthorn, VIC	40
Monash Open Day FLEET Lab Tours	06 August 2017	Public	Clayton, VIC	75
Monash Open Day demos	06 August 2017	Public	Clayton, VIC	300
Monash Open Day Public lecture: tying electrons into knots	06 August 2017	Public	Clayton, VIC	80
JMSS student interviews	09 August 2017	School students	Clayton, VIC	70
Science week physics booth at the Australian Museum	10 August 2017	School students	Sydney, NSW	1400
Science Teachers Association of Queensland Senior Science Day	12 August 2017	School teachers	Brisbane, QLD	11
RMIT open day	13 August 2017	Public	Melbourne, VIC	200
Girls in Physics Breakfast - La Trobe	15 August 2017	School students	Melbourne, VIC	80
FLEET Geeks Physics Show	17 August 2017	School students	Hughesdale, VIC	550
Prof. Jenny Hofmann (Harvard) visit & lab tour	21 August 2017	Research community	Clayton, VIC	1
School science Collingwood College	24 August 2017	School students	Melbourne, VIC	100
Science Industry Night - Maths, Physics & Astronomy	24 August 2017	Undergraduate students	Clayton, VIC	100
Australian National University Open Day	26 August 2017	School students	Canberra, ACT	300
STEM Blitz presentation	30 August 2017	Research community	Melbourne, VIC	50
UNSW open day – physics booth, liquid nitrogen show and student panel	02 September 2017	Public	Sydney, NSW	500
RMIT School of Science Spring Lecture Series	04 September 2017	Public	Melbourne, VIC	50

NAME OF EVENT	DATES	AUDIENCE TYPE	LOCATION	APPROX. AUDIENCE REACHED
Phoenix College student lab tour	12 September 2017	School students	Ballarat, VIC	4
Prof. Yasuo Cho (Tohoku Uni) visit & lab tour	15 September 2017	Research community	Sydney, NSW	1
Student visit by Republic Polytechnic of Singapore	19 September 2017	Undergraduate students	Sydney, NSW	30
Matrix tutoring practical day	07 October 2017	School students	Sydney, NSW	60
Australian Synchrotron Open Day	08 October 2017	Public	Clayton, VIC	200
Ferrofluid activity developed for Wollongong Science Centre	12 October 2017	School students	Wollongong, NSW	50
Talk to Kenmore South State School	19 October 2017	School students	Brisbane, QLD	90
Laboratory Visit Year 10	24 October 2017	School students	Sydney, NSW	4
John Monash Science School Science Fair	31 October 2017	School students	Clayton, VIC	16
Monash Energy Materials and Systems Institute (MEMSI) Energy Showcase	01 November 2017	Industry / Business / End-Users	Clayton, VIC	45
Dr Rama Vasudevan (ORNL, USA) lab tour	02 November 2017	Research community	Sydney, NSW	1
St Margaret's School Berwick, VIC Science Fair	02 November 2017	School students	Berwick, VIC	60
Dr. Manuel Hinterstein (KIT) visit & lab tour	09 November 2017	Research community	Sydney, NSW	1
Lab visit of international undergraduate students at Swinburne University	12 November 2017	Research community	Melbourne, VIC	25
AIP FLEET Lab Tours	13 November 2017	Research community	Clayton, VIC	21
Work Experience	13 November 2017	School students	Hawthorn, VIC	1
Lab Tour	14 November 2017	School students	Hawthorn, VIC	1
The 10th Research Symposium for Chinese PhD Students and Scholars in Australia	18 November 2017	NGOs	Clayton, VIC	200
Antarctic flight with high school students/general public	25 November 2017	Public	Sydney, NSW	50
The Sun Rises For Free	27 November 2017	Public	Clayton, VIC	170
Wolfgang Ketterle Public Lecture	30 November 2017	Public	Hawthorn, VIC	250 (Public Lecture)
Laboratory tour for high school students	30 November 2017	School students	Sydney, NSW	42
Lunch with Physics Nobel Laureate Wolfgang Ketterle	01 December 2017	School students	Clayton, VIC	75
STAVCon	01 December 2017	School teachers	Melbourne, VIC	14
Lunch with a Laureate - teacher numbers	01 December 2017	School teachers	Clayton, VIC	12
Science Says!	2 December 2017	Public	Melbourne, VIC	50
Deeper Darker Brighter - acts of light in deep space	07 December 2017	Public	Hawthorn, VIC	
STEM Professionals in Schools	08 December 2017	School teachers	Lilydale, VIC	
FLEET Geeks	12 December 2017	School students	Wodonga, VIC	150
Regional STEM Conference	13 December 2017	School teachers	Wodonga, VIC	25
UNSW Information Day	16 December 2017	Public	Sydney, NSW	100

PHOTOGRAPHY CREDITS

PAGE	IMAGE	CREDIT
Cover		Bent Weber
7	Michael Fuhrer	Mark Chew
10	Feixiang Xiang	Grant Turner
18	Daisy Wang	Grant Turner
19	Daniel Sando	Grant Turner
20	Jack Hellerstedt	Steven Morton
22	Fei Hou	Grant Turner
23	Lab	ANU
24	Eliezer Estrecho & Sven Höfling	University of Würzburg
26	Jeff Davis & Chris Vale	Steven Morton
28	Shaun Johnstone	Steven Morton
29	Wolfgang Ketterle	Steven Morton
30	Qi-Kun Xue & Wafa Afzal	Tich-Lam Nguyen
32	Mark Edmonds	Steven Morton
34	Kourosh Kalantar-Zadeh	Steven Morton
37	Lan Wang & person in clean room	Steven Morton
38	David Nielson & Shaffique Adam	Steven Morton
41	Gordon Godfrey workshop	Alex Hamilton
41	Victor Gurarie & Jenny Hoffman seminars	Tich-Lam Nguyen
46	Centres of awesome	Steven Morton
48	Oleh Klochan & Daisy Wang	Grant Turner
50	Shilpa Sanwlani	Steven Morton
50	Dianne & poster session	Tich-Lam Nguyen
51	Fan Ji	Grant Turner
52	Fan Ji, Hong Liu, Emma Laird	Alex Hamilton
52	Yun Suk Eo & Eliezer Estrecho	Tich-Lam Nguyen
53	YouR Forum	Dianne Ruka
54	Chutian Wang	Tich-Lam Nguyen
56	Workshop delegates	Steven Morton
57	Workshop images	Steven Morton, Alex Hamilton and Tich-Lam Nguyen
58	Dianne Ruka	Tich-Lam Nguyen

PAGE	IMAGE	CREDIT
59	National science quiz	ACEMS
59	Science says	Dianne Ruka
59	Michael Fuhrer	Tich-Lam Nguyen
61	Global challenges	Dianne Ruka
62	Dianne Ruka	Tich-Lam Nguyen
63	Kids with battery	Dianne Ruka
64	Wolfgang Ketterle	Steven Morton
65	Lunch with laureate	Steven Morton
66	Science speed dating	Steven Morton
69	3 Theorists	Grant Turner

FLEET

ARC CENTRE OF EXCELLENCE IN
FUTURE LOW-ENERGY
ELECTRONICS TECHNOLOGIES

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Design Idaho Design & Communication

OUR PARTNERS

FLEET is an Australian Research Council Centre of Excellence linking a highly interdisciplinary team of high-profile Australian and international researchers.