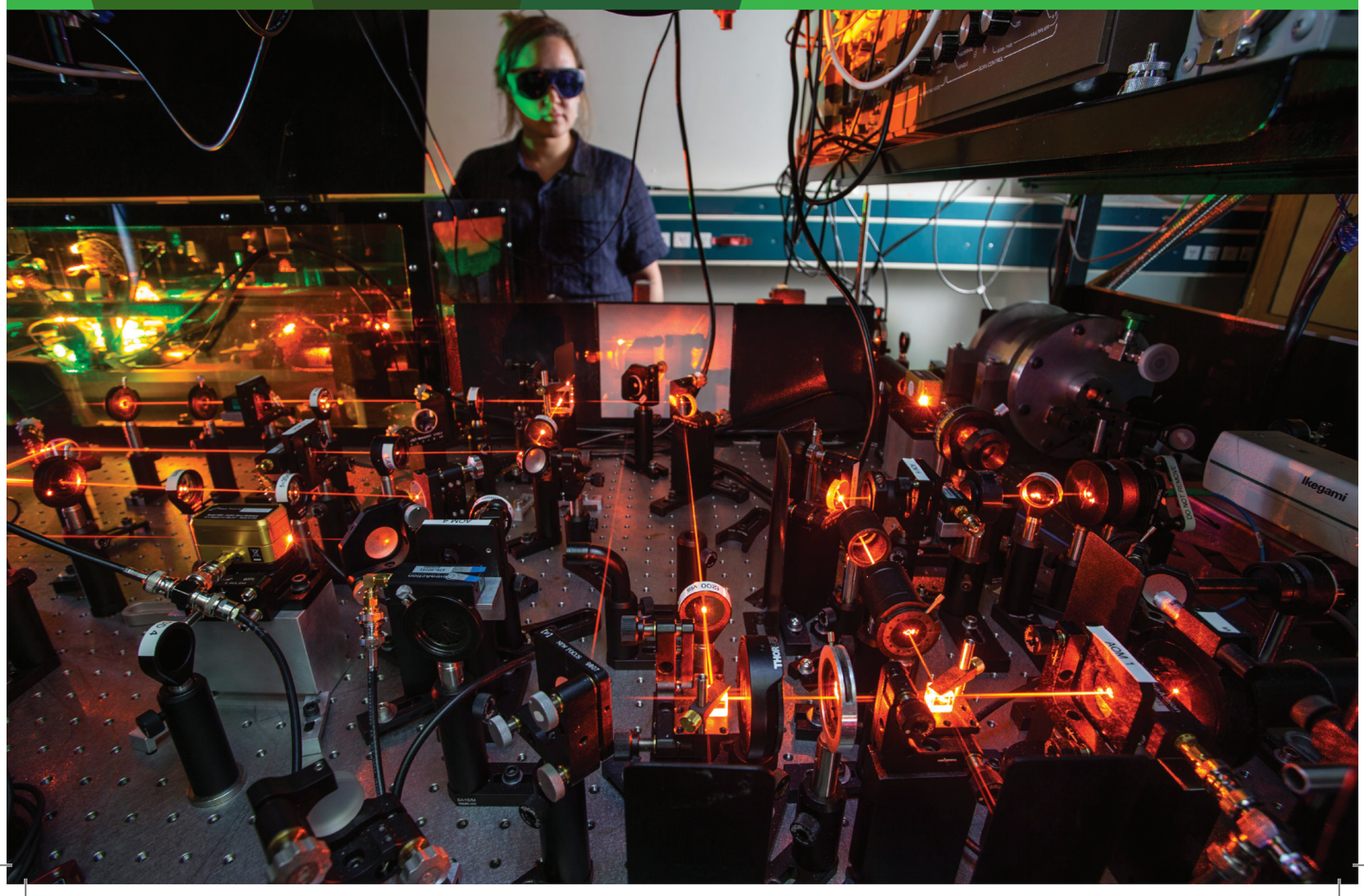
DODD-WALLS CENTRE
FOR PHOTONIC AND QUANTUM TECHNOLOGIES

2017
ANNUAL REPORT



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DODD-WALLS CENTRE
for Photonic and Quantum Technologies

INTRODUCTION

New Zealand's Dodd-Walls Centre is a national Centre of Research Excellence involving five universities and is administratively hosted by the University of Otago. Our research focuses on New Zealand's acknowledged strength in the fields of precision atomic and quantum optical physics, and sensing applications ranging from the size of single atoms to crustal-scale geologic features such as the Alpine Fault.

Our research explores the limits of control and measurement at the atomic scale through the use of laser light, the generation and manipulation of light at its most fundamental, quantum level and the processing and physical nature of information in this quantum realm.

Our name honours two New Zealand pioneers in these fields. Jack Dodd (1922–2005), known for the first experiments of the quantum beat phenomenon and the theoretical explanation, and Dan Walls (1942–1999) who was accomplished across quantum optics, biophotonics, optical bistability, and was active in the field of Bose-Einstein condensation.

Our Mission is

- to create a research centre that is recognised as one of the world's leading organisations in the field of photonic and quantum technologies
- to build upon the acknowledged strength of New Zealand in the areas of non-linear and quantum optics and precision atomic physics
- to train and develop skilled staff and students to the highest international standards
- to help develop the high-tech industry sector, thus ensuring economic growth and continued career pathways in New Zealand.

Collaborating Partners

Tertiary Partners
University of Otago (Host Institution), The University of Auckland, Massey University, University of Canterbury, and Victoria University of Wellington

Non-Tertiary Partners
Callaghan Innovation, Southern Photonics, Otago Museum, Auckland UniServices Limited, and Otago Innovations Limited

International Partners
Centre for Quantum Technologies, Singapore; Fraunhofer Centre for Applied Photonics and the University of Strathclyde, U.K., the Joint Quantum Institute, U.S.A., and the University of Science and Technology, Anhui, China

Host University

University of Otago
Te Whare Wānanga o Otāgo
New Zealand

The University of Auckland
Te Whare Wānanga o Tāmaki Makaurau
New Zealand

Massey University
Te Kunenga ki Pūrehuroa
University of New Zealand

University of Canterbury
Te Whare Wānanga o Waitaha
Christchurch New Zealand

Te Whare Wānanga o te Ūpoko o te Ika a Māui
Victoria University of Wellington

REPORT FROM THE CHAIR

The Dodd-Walls Centre for Photonic and Quantum Technologies is today a well-established National Centre of Research Excellence. It brings together experts from five NZ Universities in the fields of precision atomic and quantum optical physics. Our research explores the limits of control and measurement at the atomic scale through the use of laser light, the generation and manipulation of light at its most fundamental quantum level, and the processing and physical nature of information in this quantum realm. Pioneers Jack Dodd and Dan Walls working in these fields in NZ left a legacy of world class protégés who are now mature leaders in their specialities. They in turn have attracted well over 100 new research students and postdoctoral fellows to these fields, and this entire effort represents a nationally significant platform with critical mass from a global research perspective.

The Centre aims to be recognised as one of the world's leading organisations in these fields.

During the year under review, the Centre hosted meetings of both The Science Advisory Board and The Industrial Advisory Board and presented its achievements to the TEC mid-term review of all ten COREs. These activities provided some insight into the progress we have made towards our goals.

The Science Advisory Board chaired by Professor Allister Ferguson, Department of Physics, University of Strathclyde, UK plus three other eminent physicists, Professor William D Phillips, Joint Quantum Institute, National Institute of Standards and Technology, and University of Maryland, USA, Professor Ian Walmsley, University of Oxford, UK, and Professor Dr Ursula Keller, Department of Physics, ETH, Zurich, Switzerland concluded that the overall level of research quality in the DWC is of a very high standard and in several areas is indeed World-class with several individuals identified as the "go to" authority in their area of expertise. The SAB was impressed by the level of collaboration within the DWC and also with external research institutes and with industry. DWC has built strength and has created synergies that are unique within New Zealand and significant on a World stage.

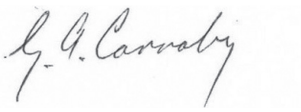
The Industry Advisory Board chaired by Simon Poole, Finisar, Australia plus four other leaders in technology commercialisation, Allister Ferguson, Strathclyde University, UK, Lewis Gradon, Fisher and Paykel Healthcare, NZ, Steve Silvey, Powerhouse Ventures, NZ, and Peter Smith, University of Southampton, UK were generally of the view that the most likely commercial opportunities would arise from the sensor or photonic devices streams, which were seen to be more closely aligned with the short-medium term needs of industry, as evinced by the fact that all the start-ups to date were associated with these two streams. However, the rapidly growing global activity in quantum technologies means that there are also likely to be longer-term commercial opportunities arising from work in this area. Major investments are being made in Europe (particularly UK and by the EC itself) and the US in this area.

The TEC Mid-Term review was carried out by a panel comprising a number of senior Australians and New Zealanders. The panel was chaired by Dr Warren Parker (recently retired Chief Executive of Scion). They concluded that the Dodd-Walls Centre has brought together a set of individually outstanding world class researchers into an area that has high potential to impact on many areas of the New Zealand economy, environment and society. The formation of the Centre has provided an opportunity to foster them working across disciplines to generate new research areas.

During the year the Governance Board carried out its own self review by engaging Dr Ian Watson ONZM to investigate our governance and management practices. His summary was that the Centre is being very well run by people who understand governance and management and seek to apply best practice to all they do. He found what he considered to be an excellent understanding of the philosophy and purpose of CoREs and the tertiary environment in which they operate.

Another highlight of the year was the launch by Hon Paul Goldsmith, Minister of Science and Innovation, of the Interface Challenge as part of NZ Tech Week. This meeting, involving around 200 industry leaders demonstrated how the MacDiarmid Institute and the Dodd-Walls Centre – both Centres of Research Excellence – tackle real world problems faced by NZ industry. Companies highlighted included Fisher and Paykel Healthcare, Defence Technology Agency (DTA), Avertana and Buckley Systems

Independent Director Ray Thomson stood down from the Board at the start of the year. He had played a key role in helping establish our strategies for engagement with industry. In turn we welcomed two new Directors to the Governance Board. Charlotte Walshe and Ian Taylor bring key skills in industry and Maori engagement. May I express my appreciation of the work of all Directors and congratulate our Centre Director Professor David Hutchinson for his inspiring leadership throughout a very successful year.



G.A. CARNABY | FEBRUARY 28, 2018

REPORT FROM THE DIRECTOR

2017 marked a natural point of reflection for the Dodd-Walls Centre, with a mid-term review, meetings of our advisory boards and our own management review, but the foot stayed firmly on the gas and our focus was much more on the road ahead than the rear-view mirror.

Our science excellence remains evident as reflected through our research publications which include articles in flagship journals such as *Nature, Nature Communications* and *Physical Review Letters*. Furthermore, the outlook for our science looks ever brighter with Dodd-Walls Centre researchers securing a staggering five new Marsden contracts totalling over $3M plus a further $14M in funding from MBIE and other sources in 2017 rounds.

Furthermore, our activities translating our research into commercial endeavours and industry continue to grow in strength. As part of Tech Week in May, we ran our inaugural *Interface Event* where NZ industries were asked to present us with a problem. We took on three such challenges from Buckley Systems (one of the world's leading manufacturers of industrial scale magnets based in Auckland), Invisi Shields Technologies (a small company trialling new optical methods for protection of crops against bird predation) and the Defence Technology Agency, delivering on all of them with each leading to ongoing relationships and commercial contracts. We also continued to engage with New Zealand's largest industries in the agricultural space through research contracts and other commercial activities. At the other end of the spectrum through investigator-led development of commercial opportunities, we had at least five new ideas go through a disclosure process with *Return on Science*, which provides advice to individuals and university tech-transfer offices on commercialisation of research. Our primary aim in this commercial space is to provide career opportunities and training for our young staff and students. To this end, we ran our first AgTech Entrepreneurial Workshop, facilitated by Chris Kirk (ex-DVC Research at Lincoln University) in partnership with Otago University's Ag@Otago Research Theme as well as continuing our successful Student Research Commercialisation competition.

From an international perspective, we have welcomed many guests throughout the year, including our Science Advisory Board to our symposium (Nobel Laureate, Bill Phillips amongst them), and the optics and photonics community from across the Tasman to ANZCOP, the Australasian Conference on Optics and Photonics, which the DWC hosted in Queenstown in December.

Education and public outreach remained a high priority of the Centre, with many of our international guests (as well as Centre members) giving public talks or engaging wider audiences through the media. Links are available through our revamped website: doddwalls.ac.nz. The Centre, for example, was a key sponsor in bringing YouTube's *Physics Girl*, Dianna Cowern to Dunedin for the New Zealand Institute of Physics Conference where she ran workshops for teachers, museum educators and physicists and gave a popular

public lecture. Other key outreach activities included a *Curious Minds* funded visit to the Chatham Islands, where DWC staff, students and Otago Museum partners had four days of physics fun with the islands' kids, including science shows at Kopinga, the Moriori Marae, *What is Quantum Physics?* in the pub and science shows at all the islands' schools. We continued to support the successful Science Wānanga programme, which enables Centre staff and students to experience a taste of māoritanga (many of our staff and students originate from overseas) in a marae-based residential setting, while providing hands on, relevant science education. We also increased the number of scholarships we offer for Māori students to attend activities such as *Hands On At Otago* and the *Otago University Advanced Science Schools Academy*.

Other initiatives included increased engagement with the Museum of Transport and Technology in Auckland, especially through the *Science Street Fair*, and hospital school visits in the Auckland area where we bought exciting demonstration based education in to the hospital unit classrooms.

A key element of every thread that runs through the Centre is collaboration and partnership in working towards a common goal. The education teams going to the Science Wānanga at Ōtākou Marae on the Otago Peninsula have members from Auckland, commercial projects funded through Auckland UniServices Ltd are being developed in the Dodd-Walls Development Centre at Otago University, joint Marsden grants are won combining talents from multiple partners, even collaboration within individual universities, down to individual departments, are enhanced. Looking back, we've had a wonderful couple of years establishing a new Centre of Research Excellence. In 2017 we had a wonderful year of collaboration and growth. It's now time to look forward to three more years of ever enhancing activity and success, and to the future beyond.

DAVID HUTCHINSON

ORIENTATING FOR THE FUTURE WITH SUCCESSFUL MID-TERM REVIEWS

The Dodd-Walls Centre is three years old in 2017 and independent reviews of the Centre's governance, management, science and research, and industry relations highlighted the Centre's successes to date (2015–2017) and how well positioned it is for the future.

Science Impact Review

The International Science Advisory Board with senior academic members from top global universities and institutions, including a Nobel Prize winner, are "…impressed by the range, breadth and quality of the work carried out in the DWC." The review recognised that within the Centre there are individuals and groups that are world-leading and are the 'go to' authorities in their area of expertise. Acknowledging the scale and critical mass of talent that CoRE funding creates for the Dodd-Walls Centre, the international reviewers "…particularly noted the range and quality of international talent that the DWC had managed to attract." The ability to attract early career, internationally excellent researchers, is "seen as a mark of excellence for the DWC." Commenting on the Centre's cohort of research students, the reviewers are "…encouraged and impressed by the quality and quantity of students being trained at the DWC." The Centre is committed to impacting the New Zealand economy and the reviewers are "pleased to note that students are being encouraged to look at careers beyond academe."

"[WE ARE] IMPRESSED BY THE LEVEL OF COLLABORATION WITHIN THE DWC AND ALSO WITH EXTERNAL RESEARCH INSTITUTES AND WITH INDUSTRY."

"THE DWC PROVIDES A UNIQUE STUDENT EXPERIENCE"

Industry and Commercialisation Review

The Industry Advisory Board comprises senior industry-facing academics from the U.K. and industry and commercialisation leaders from New Zealand and Australia. The reviewers noted "…the range of outreach programmes and industry engagements that have been implemented and the success of these in both raising industry awareness of the Centre and raising additional research funds." The review concluded that the most likely commercial opportunities in the short-term would arise from the sensor or photonic devices research within the DWC, a view that complements that of the International Science Advisory Board who also recommends that the Centre explore ways to deploy the existing expertise of its researchers to capitalise on international investment in the applications of quantum technology and the benefit these will bring to the New Zealand economy over the coming decade.

"ON THE COMMERCIALISATION FRONT, THERE IS CLEARLY A 'WHOLE OF CENTRE' APPROACH BEING TAKEN."

Governance and Management Review

The organisational structures, flow of information, and quality and levels of decision-making as set up and practiced in the Dodd-Walls Centre was reviewed by Emeritus Professor Ian Watson. Ian was previously the Principal of the Albany, Auckland, campus for Massey University and Assistant Vice-Chancellor (Research), a foundation member of the Foundation for Research, Science and Technology, and was until recently the Chair of the Board for another CoRE. Based on TEC documents, written documents and agreements from the DWC, and in-person interviews, Ian states that within the DWC there is "…a high level of governance practice…[that] indicates a clear understanding of the difference between governance and management." He concludes that "it is clear that whilst the Centre's aim is for science excellence at the international level, it also wishes to put best practice into place wherever it is functioning." This also includes financial management of funds from the TEC and other providers. Ian states that "…the Centre is subject to the same level of financial scrutiny as an academic department at the University of Otago…[and]…this is crucial since Otago is the host institution and is held accountable by TEC for the financial performance of the Centre."

"…THE CENTRE IS BEING VERY WELL RUN BY PEOPLE WHO UNDERSTAND GOVERNANCE AND MANAGEMENT AND SEEK TO APPLY BEST PRACTICE TO ALL THEY DO."

TEC and Royal Society Te Aparangi Mid-term Review

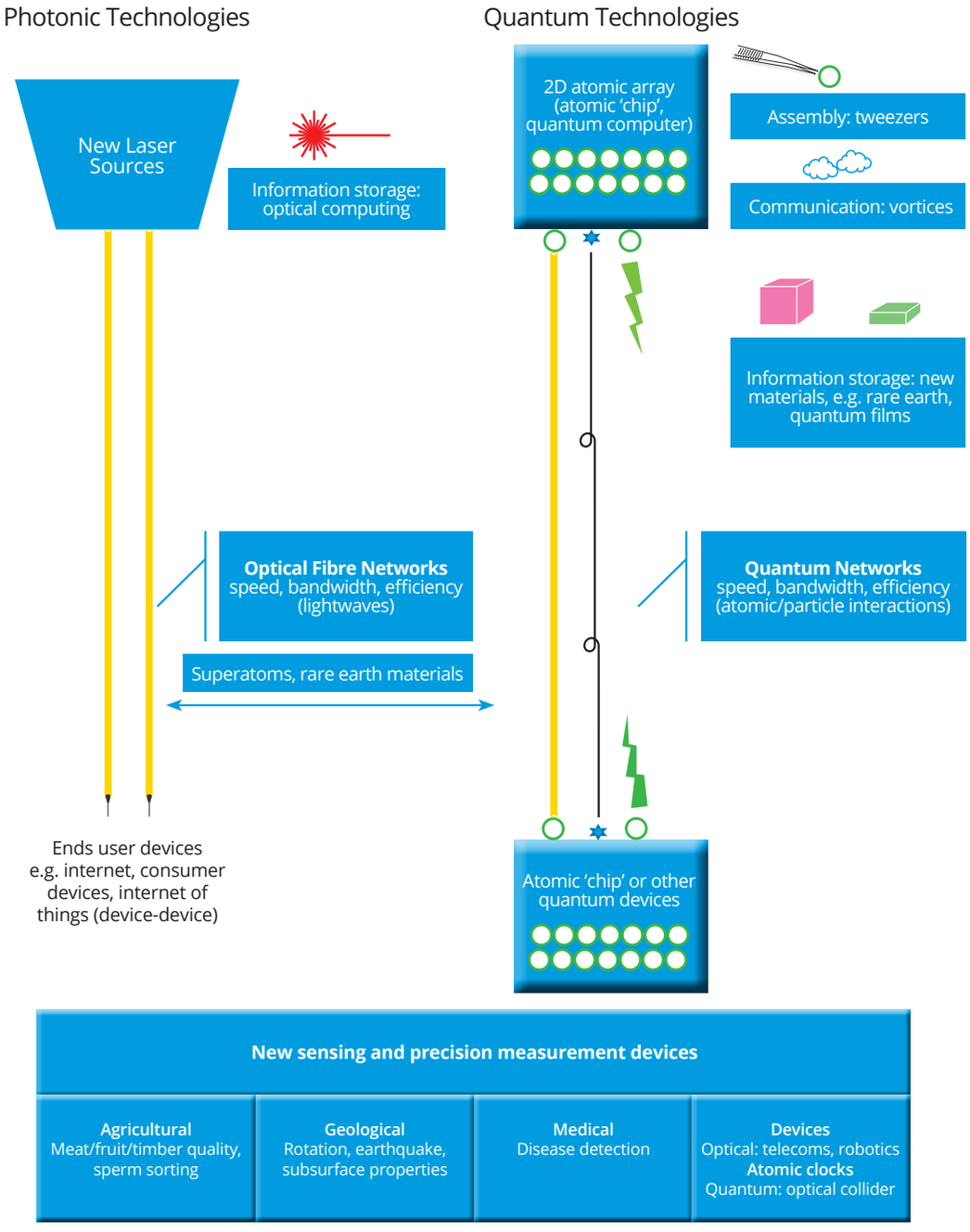
The Dodd-Walls Centre was reviewed during the mid-term review of all ten CoREs that are funded until 2020. The review was done by the Tertiary Education Commission and the Royal Society Te Apārangi. The review panel was chaired by Dr Warren Parker the former CEO of Scion (New Zealand Forest Research Institute Limited). The review acknowledged the unique capabilities of the DWC in New Zealand, the existing linkages with world-leading institutions and research groups, and the potential to continue to engage and measure outcomes into the future.

"THE DODD-WALLS CENTRE BRINGS TOGETHER A SET OF WORLD CLASS RESEARCHERS INTO AN AREA THAT HAS HIGH POTENTIAL TO IMPACT ON MANY AREAS OF THE NEW ZEALAND ECONOMY, ENVIRONMENT AND SOCIETY."

DWC TECHNOLOGIES

Our researchers and students work in two distinct domains as well as the connecting areas between them. The photonics domain utilizes laser light for optical devices, networking and communications. Sensing technologies are a key potential output of much DWC research and there are many dozens, if not hundreds of potential applications right across the economy. Quantum technologies are at present in a theoretical and experimental stage of development, yet the ultimate goal is to develop quantum devices that are faster and more energy efficient than currently available analogues.

An advantage that the CoRE provides to New Zealand and previously independent researchers is that collaboration in the overlap areas between photonic and quantum research, particularly in the area of sensing technologies, is promoted and enabled.



RESEARCH THEMES AND HIGHLIGHTS

THEME 1a:
Photonic Sensors and Imaging

Leaders

Frédérique Vanholsbeeck, The University of Auckland
Jon-Paul Wells, University of Canterbury

Lasers are the power tools in the world of science. In this theme we use their extraordinary light to see, hear, smell and feel far beyond the reach of our senses. When you fire a laser at an object there is a tremendous amount of information in the light that bounces back. We use different colours, pulses and powers of laser light to learn about the structure and function of biological tissue and many other surfaces.

Our expertise in interpreting the way that light interacts with matter has led to many unexpected and fruitful collaborations across New Zealand and abroad. For example, we are developing sensors to sort bull sperm for the dairy industry, detect bacteria on carcasses, grade the quality of meat, and locate blossoms on kiwifruit plants. We are working with engineers and medical researchers to develop a technique for detecting eye disease, a new method for measuring the intensity of skin burns and a force sensor for keyhole surgery. We are also working with geophysicists to measure earthquake vibrations and temperature deep within New Zealand's Alpine Fault.

Our sensing and imaging projects are underpinned by a strong focus on theory and numerical modelling. Our researchers are world renowned for their understanding of nonlinear optics – when light stops behaving according to the normal rules. We are able to exploit these nonlinear effects to create novel sensing and imaging technologies.

THEME 1b:
Photonic Sources and Components

Leader

Neil Broderick, The University of Auckland

They say workers are only as good as their tools. This theme is about developing new and improved lasers, new fibre optic cables, and other optical tools that will open new frontiers for research and medical or industrial applications. We work in collaboration with the other three themes to provide tools that enhance their research and probe further into the quantum world. We are world-renowned for our expertise in fibre lasers that are versatile, lightweight and cheap to produce. We develop these for using as cutters, sorters and sensors for a wide variety of industrial and science applications. We are also well known for our research in nonlinear optics. Our fundamental theories and numerical models are used by top research groups across the world and have led to advances in the development of optical frequency combs, cavity solitons and other nonlinear devices that could in time revolutionise the internet and many other fields.

THEME 2a:
Quantum Fluids and Gases

Leaders

Professor Joachim Brand, Massey University
Neils Kjærgaard, University of Otago

The quantum realm is the 'wild west' of modern science. Although we know some of the basic rules, the vast majority of quantum interactions remain uncharted. In this theme we explore cold atom physics which is like a playground for quantum phenomena. By cooling atoms to just above absolute zero and precisely controlling their state, we have the ability to create and observe almost any quantum effect that we can think of. We run experiments and develop theory to investigate quantum phenomena such as quantum vortices, quantum turbulence, conditions before the Big Bang, and biological processes involved in photosynthesis. We are exploiting newly won understandings of these processes and interactions to develop quantum technologies such as extremely precise gravitometers and clocks. We are world renowned for our legacy in quantum theory and have developed excellent experimental facilities that are enabling world-class results.

THEME 2b:
Quantum Manipulation and Information

Leaders

Jevon Longdell, University of Otago
Harald Schwefel, University of Otago

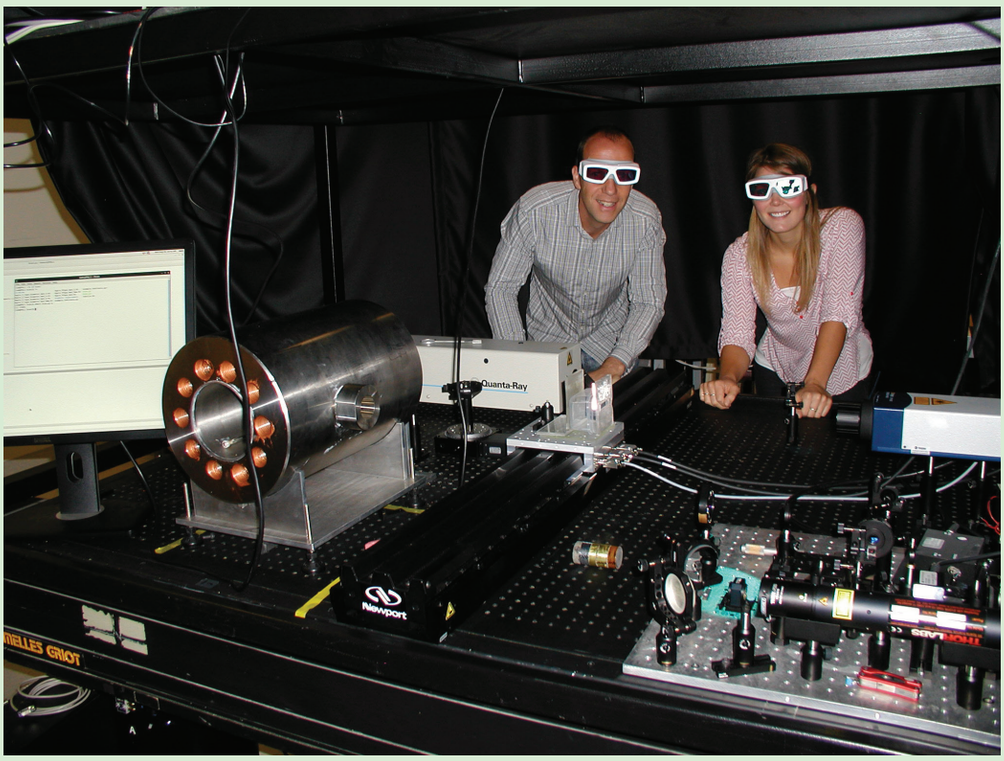
It is one thing to understand how the quantum world works yet it requires another level of precision and control to build reliable devices and systems that exploit quantum phenomena. This kind of 'quantum engineering' is the focus of this theme. Through precise observation and control of the interactions between single photons of light and single atoms we are contributing to the development of a new generation of quantum technologies. Our aim is to exploit the apparently weird aspects of the quantum world such as quantum superposition—the ability of a quantum particle to exist in more than one state at once—and quantum entanglement, when several particles behave as if they were a single entity.

Our researchers have record ability to isolate and control the motion of single atoms. We can move atoms around with laser light and put them together to create completely new molecules, and conduct ultra-precise experiments. Our research is contributing to the development of quantum computers capable of rapidly solving extremely complex problems. We are looking at novel ways of creating qubits, the fundamental processing units for quantum computers, and developing solutions for quantum memory and quantum debugging. Quantum communication is the focus of several projects: we are working on a technique to enable communication between quantum computers over large distances. This involves translating single microwave photons, which quantum computers operate on, to optical photons, which are easily transported down optical fibres. We are also contributing to the fundamental theory behind quantum communication networks and quantum measurement.

2017 RESEARCH HIGHLIGHTS

Earthquake Methods Inspire New Medical Imaging Technique

Inspired by the techniques geophysicists use to reveal structures beneath the Earth's surface, Dodd-Walls Centre PhD student Jami Johnson has developed a non-invasive medical imaging technique which promises a new way to screen for risk of strokes. Using both laser-ultrasound and photoacoustic imaging, the technique works by sending tiny pulses of laser light into the body which cause tiny vibrational 'quakes' in the tissue. These 'quakes' generate sound waves that can be detected to reconstruct an image of the tissue structure. In this way Jami was able to image a human carotid artery to detect signs of calcification, which is a major cause of strokes, the second leading cause of death in the world.



Dodd-Walls Centre PhD student Jami Johnson *(right)* and Dodd-Walls Centre Principal Investigator Kasper van Wijk *(left)* working together in the laboratory.

One of the most compelling aspects of this project is the diversity of expertise that came combined to find a solution. In the Physical Acoustics Lab at The University of Auckland where Jami did her research, similar techniques are used to monitor Auckland's volcanoes, measure the ripeness of fruit and probe the Southern Alpine Fault. The group has a unique set of skills and knowledge to understand all these systems. Jami's supervisor, Dodd-Walls Centre Principal Investigator Kasper van Wijk, has a background in geophysics and one of her main collaborators was an expert in computational seismology and imaging Associate Professor Jeffrey Shragge, from the Colorado School of Mines.

"The medical and seismic imaging fields are analogous in many ways," Jami explains.

"Photoacoustic fields can be thought of as mini-earthquakes created inside of an artery, whereas we create laser-ultrasonic fields at the surface of the skin, just like seismologists create man-made explosions at the surface of the earth. The scale is vastly different, but the physics is essentially the same.

Jeff and Jami developed algorithms to reconstruct images of the biological tissue from the sound waves being measured.

To relate this knowledge to the peculiarities of the medical context, Jami worked with Associate Professor Mervyn Merrilees, an expert in medical imaging from The University of Auckland Faculty of Medical and Health Sciences.

"We spoke with Mervyn at the beginning of my PhD," Jami explains, "because we knew that imaging arteries was the end goal for my project. He had the know-how for obtaining samples, ethics approval, and validating our imaging results with methods that are accepted in the medical community."

One of the triumphs of Jami's research was finding a way to overcome a major limitation in photoacoustic imaging known as "reflection artefacts". This is when the sound waves bounce around within the tissue and cause unwanted fuzz or clutter in the images.

Once again, it was a collaboration with geophysicists that helped solve the problem. Jami was struggling with reflection artefacts in her images when Dr Joost van der Neut, an expert in seismic imaging from Delft University of Technology in the Netherlands came to visit their lab. Along with his colleague Kees Wapenaar, Joost worked with Jami to develop a method to predict what the artefacts would be and then remove them from the data. They use ultrasound to identify the bouncing sound waves and then are able to remove the problematic waves from the data. Not only does the method they developed solve a problem in medical imaging, it also suggests a new approach to solve long-standing problems in seismology.

The method Jami and her team have developed fills a gap in current medical imaging technology. Unlike X-rays it is harmless to tissue. It penetrates deeper into the body than other optical techniques and enables higher resolution than ultrasound. It also requires no contact with the skin to operate. During her PhD Jami worked with a US-based expert in non-destructive testing, James Caron, to develop instrumentation that would operate without contact.

Not only could the technique be used to screen for strokes, it could also be used to help guide surgeons and doctors to accurately insert needles or operate. Currently ultrasound is used for such applications, but the need for the ultrasound probe to be in contact with the skin and moved manually restricts its uses.

Throughout her project, the Dodd-Walls Centre supported Jami by providing travel funding to visit her collaborators and attend conferences to present her work. The collaborations she established strengthened research links across the world. Having finished her PhD Jami is now continuing her research in medical imaging at Sorbonne Université in Paris working with her new team to develop ultrasound techniques to see behind bone. She continues to collaborate with Kasper and the medical school in Auckland on advancing biomedical imaging techniques with photoacoustics.

Illuminating Alpine Fault Earthquake Risks and Revealing Geothermal Resources

A collaboration with Victoria University of Wellington geophysicists is revealing information to help us understand and prepare for future earthquakes. The team have also discovered a reservoir of geothermal heat beneath the South Island's West Coast, a result published last year in the world's top scientific journal *Nature*. By sending ultra-short laser pulses down an optical fibre inserted into New Zealand's Alpine Fault, the team are revealing information that informs earthquake models and warning systems. This innovative use of laser technology resulted from a collaboration made possible by CoRE funding.

The project, which received Marsden funding last year, combines the laser and optics expertise of DWC science team leader, Neil Broderick and DWC Principal Investigator Kasper Van Wijk from The University of Auckland with the geological expertise of Victoria University of Wellington Professors John Townend and Rupert Sutherland.

The story began in 2014 when a multi-national team of about 200 scientists, led by John and Rupert, congregated in Whataroa, a small town on the South Island's West Coast. Their mission was to drill hole a kilometre down to the Alpine Fault, to collect samples and measurements and set up a long term observatory inside the fault zone. The project has the attention of the international community because it fills a knowledge gap in understanding the conditions at a fault in the late stages of its cycle when a large earthquake is due. This drilling project provides a unique point of observation as the pressure builds.

"One of the really nice things they left behind in the hole," said Neil, "was an optical fibre cable."

Rupert and John contacted the Dodd Walls Centre to find out how to make the most of this fibre and Neil jumped at the opportunity. Neil is an expert at understanding how laser light travels through optical fibres, in particular when pressure or tension in the fibre forces the laser light to stop following the usual rules of physics and when non-linear effects emerge. In these cases, which are predominant in the intense conditions in the alpine fault, more complex theory is required and Neil and his students are the perfect people to understand what's happening.

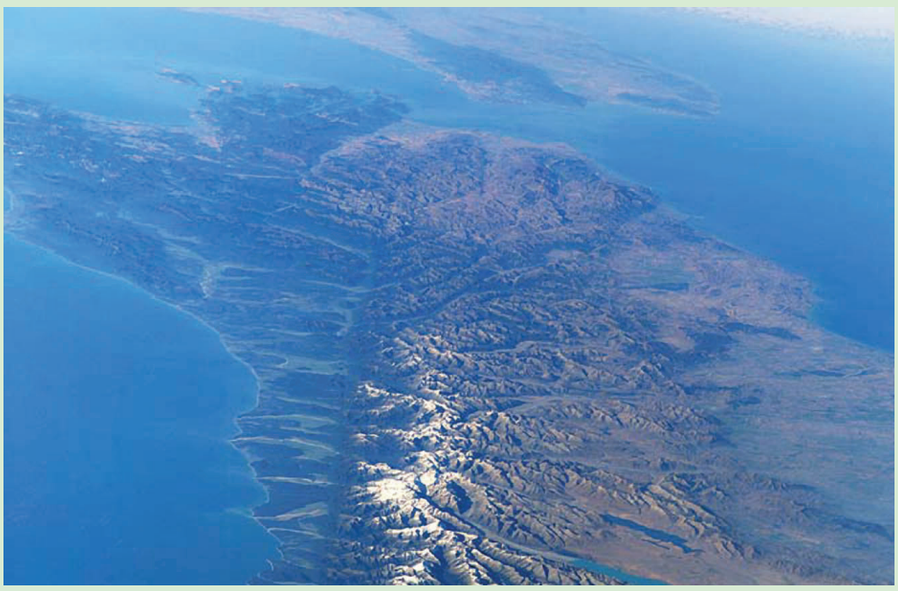


Photo credit: used with permission from NASA-Johnson Space Center, Image Science and Analysis Group, photo taken from the International Space Station.

The Alpine Fault in the South Island of New Zealand seen here as a diagonal line on the land surface from near Franz Josef in the south *(left, front)* to Blenheim in the north *(middle, top)*. Dodd-Walls Centre Deputy Director, Neil Broderick, has been using laser light to measure temperature and fault dynamics at depth inside the fault.

Kasper has a foot in both camps. He understands both optics and geophysics. He is an expert on rocks and vibrational modes of the Earth so he can help analyse the data. Rupert and John are involved in analysing the data and connecting it to the geology.

The team uses fibre laser technology developed in their Auckland labs. These lightweight and portable lasers deliver ultra-short pulses of intense laser light that travel down the fibre and reflect back at points of pressure or tension. By analysing the reflected light the team can deduce pressure, vibrations and temperature all the way down the fibre.

“The results are amazing,” Neil says. “ In most parts of the Earth the temperature gets about five degrees hotter every hundred meters. Our results show around ten times that. We think this is because it is a large, deep and very young fault. As the mountains are being pushed up, they generate heat and they are still cooling down from that.”

Discovering these unexpected resources of geothermal energy under the West Coast could be significant for the local economy and tourism industry as they could be used in thermal pools and attractions.

The project is a win-win for everyone concerned. Neil and Kasper are gaining an incredible insight into a new field. Rupert, John and the international geological community are getting invaluable data to inform their understanding of earthquakes.

The techniques being developed have potential future use for monitoring the structural stability of roads and buildings.

If it wasn’t for the collaborative culture of the Dodd-Walls Centre the project could not have got off the ground.

To begin with, the publicity of having a Centre of Research Excellence helped alert Rupert and John to the expertise available.

“People know that if you want something done with light, you come to the Dodd-Walls Centre,” Neil pointed out. ”So it grew out of that really. It’s a beacon.”

Once the match had been made, the team spent a year doing research and getting preliminary data before they were awarded Marsden Funding. Without the support of the CoRE it would have been impossible to bridge this gap from a good idea to an internationally recognised Marsden funded project.

The team is now delivering compelling results as well as training students with ideal skills for New Zealand’s high tech industry. A PhD student recently began work and a student who recently completed a masters degree on the project has been snapped up by local company Coherent Solutions who specialise in test and measurement equipment for optical communications.

Shining a light on disease: better diagnoses for coeliacs and cancer

Dodd-Walls Centre Postdoctoral Fellow Sara Miller is developing a faster, cheaper and more effective technique for diagnosing coeliac disease with the aim to then apply the same technology to a range of other gastrointestinal illnesses. Working at the University of Otago and alongside Dodd-Walls Centre Principal investigator Keith Gordon, the team plans to incorporate the new techniques into a device that could be used in standard medical procedures. Collaborating with laser specialists and industry advisers in the Dodd-Walls Centre and a gastroenterologist from the Dunedin School of Medicine they have a dream team of experts to realise the idea.

Nowadays, diagnosis of gastrointestinal illness is an uncomfortable, time consuming and expensive process. Firstly the patient undergoes an endoscopy; a camera on a fibre optic cable is passed down their gastrointestinal tract allowing the doctor to visually detect signs of disease. After this, biopsies are often required to confirm a preliminary diagnosis. These small samples of tissue, collected from the affected area, need to be individually prepared and analysed by a pathologist in the lab which takes time and money.

Sara and Keith's idea is to provide an on-the-spot diagnosis by incorporating a range of laser spectroscopy techniques into the endoscope. Laser light will travel down the fibre-optic cable, bounce off the affected tissue, travel up the fibre and be analysed in a portable detection device. By building a database of the characteristic responses of different diseases they hope to provide reliable data for the diagnosis of a range of diseases and disorders including coeliac disease, cancer and irritable bowel diseases. In many cases this will remove the need for biopsies altogether. But if a biopsy is still required, the new instrument will help pinpoint the most at risk areas which will improve the accuracy of the result.

"One of the illnesses this would be really useful for is known as Barrett's oesophagus," Sara explains. "Currently doctors take blind biopsies in four quadrants every two centimetres over the area affected to monitor for cancerous and pre-cancerous changes. That can mean lots and lots of biopsies and it's completely blind as to whether its diseased tissue or not."

The multi-disciplinary team working together to impact the health of thousands of New Zealanders using laser light: Dodd-Walls Centre PhD student Sara Miller *(centre)*, Dodd-Walls Centre Principal Investigator Keith Gordon *(right)* and Michael Schultz, Head of the Department of Medicine at the Dunedin School of Medicine.

To begin with Sara and the team are focusing on coeliac disease. This is partly because of its prevalence. It is currently estimated that 60,000 to 70,000 New Zealanders have coeliac disease (one in seventy), however up to 80% of those are unaware they have the condition. Both Sara and Keith know people with the disease and they wanted to help. The other reason they chose coeliac disease is that it presents a really interesting and complex scientific challenge. Unlike cancer cells which are dramatically different to healthy ones, coeliac disease affects tissue in a more subtle way.

“We reckoned that if we could get the technique to work for coeliac, which is much more subtle, then it would work for any disease,” says Keith.

One of the big advantages of this project has been the group’s close collaboration with medical experts. When Sara first had the idea to study gastrointestinal diseases she had no idea whether it would be practically viable. A search for gastroenterologists at the Dunedin Medical School led them to Associate Professor Michael Schultz.

“I emailed him saying that we had a research idea and asked if he’d be willing to meet with us,” Sara recalls. “He was very receptive so we were very lucky.”

“Michael has been really useful in explaining to us what are good ideas and which ones won’t work,” says Keith. “It’s very important to have someone like him who actually does biopsies and has real expertise in the problem we’re trying to solve.”

The support of the Dodd-Walls Centre has also been essential throughout the project. In the past, Keith and Sara have mainly focused on analysing the quality of products such as milk powder, wool, meat and plastic. They are experts at using laser light to understand complex materials. However this project involves some new and unfamiliar challenges.

“One of the critical issues is getting the light down and then back up the fibre,” Keith explains. “These endoscopes are long and they twist quite a bit so you’ve got to be able to get the light up and down in a reliable way.”

In this area Dodd-Walls Centre Principal Investigator Frédérique Vanholsbeeck from The University of Auckland has been an invaluable support. She understands how laser light behaves in fibre optic cables and has experience building small portable devices like the one Sara and Keith hope to create. The team has also received support and advice from Luke Taylor who works in instrumental prototype development for the Dodd-Walls Development Centre at the University of Otago.

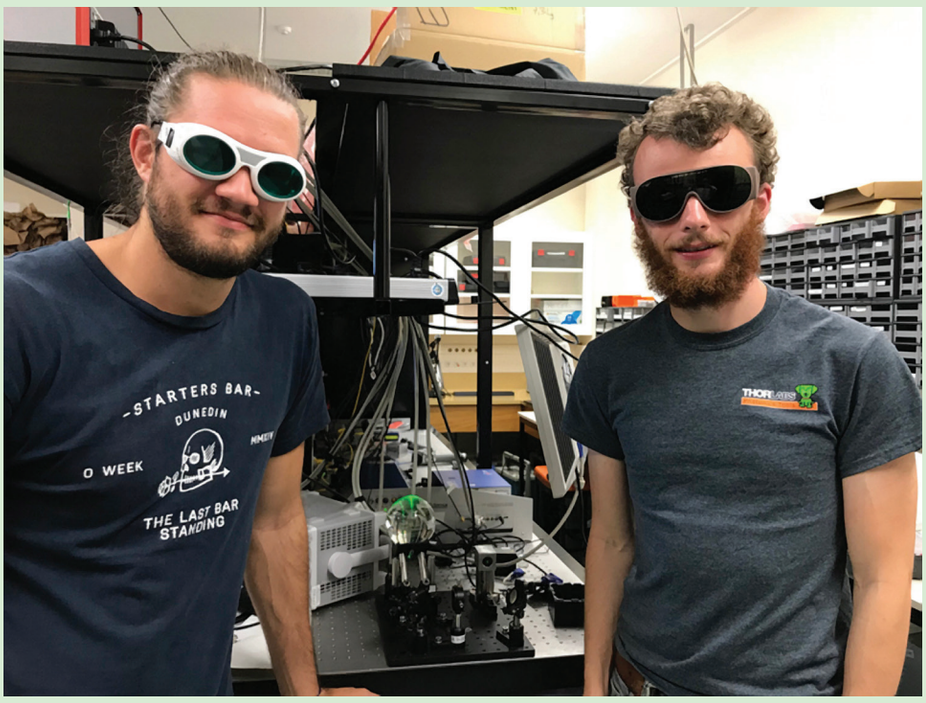
“This means that we can deliberately target techniques and methodologies that can realistically be deployed in a fibre optic cable when someone is having an endoscopy,” says Keith. “…we would have never taken on the project without having this supporting expertise.”

World Leading Collaboration on the Hottest Topic in Optics: Combs of Light in Crystal Discs

A team of Dodd-Walls Centre researchers have devised a new way to transform a single colour of laser light into hundreds of different colours using tiny disks of crystal. The resulting new type of 'microresonator optical frequency comb' could improve the energy efficiency of the internet, which currently sucks up vast amounts of energy to encode and transport data. They could also enable ultra-precise new methods of imaging and spectroscopy and could one day be used in portable devices to detect diseases, chemicals or explosives.

Last year the researchers were awarded nearly one million dollars of Marsden Fund money to develop and test this exciting new technology. With the help of the Dodd-Walls Centre and the Royal Society of New Zealand, the collaborative team of researchers from The University of Auckland and the University of Otago have already recruited a postdoctoral fellow and a Masters student in Otago and one PhD student in Auckland to work on the project.

"We're trying to get a lot of hands on board so the knowledge is spread around the student body," said Harald Schwefel, one of the Principal Investigators on the team. "It's cool stuff. I'm confident it will lead to applications and start a new field."



Dodd-Walls Centre PhD students Ian Hendry of The University of Auckland *(left)* and Luke Trainor of the University of Otago *(right)* working together on optical frequency comb experiments.

Optical frequency combs are one of the hottest topics in optics today. The reason is that several applications are in desperate need of different colours (or frequencies) of laser light. For example, the internet. Every email, cell phone call and website visit is encoded into data and sent around the world by laser light. In order to improve bandwidth and fit more data down an optical fibre the signal needs to be split into different frequencies of light that can be read separately. Miro Erkintalo, another Principal Investigator on the project explains the difficulty:

"Lasers only emit one colour at a time. What this means is that, if your application requires many different colours at once, you need many lasers. All of them cost money and consume energy. The idea of these new frequency combs is that you launch one colour into the microresonator (the crystal disc) and out comes a whole range of new colours."

One of the best things about these microresonators is that they operate at very low powers measured in milliwatts. The technology therefore has full potential to dramatically reduce the energy consumption of applications requiring many lasers with different colours – such as the internet.

Another use for the frequency combs is high-precision spectroscopy — using laser light to study and identify the chemical composition, properties and structure of materials including diseases, explosives and chemicals. In order to detect many important molecules, laser light is required in the mid-infrared frequency range. Unfortunately, lasers operating in that region are scarce. The new microresonators show potential to deliver a whole array of laser frequencies within this range.

This project is the first of its kind in the world. Up till now researchers have only explored microresonator optical frequency combs based on so-called 3rd order nonlinear effects. In these devices, the range of frequencies you get out centres around the input frequency. So if you shine near-infrared laser in, you'll get near-infrared light out plus a range of frequencies around the input. But with these new crystal devices (based on 2nd order effects) you can theoretically generate frequency combs in totally different regions of the spectrum. You could shine a green laser in, for example, and generate a frequency comb in the infrared. This would make it possible to reach many previously unobtainable colours.

The idea for the project sprung from a serendipitous meeting of researchers within the Dodd-Walls Centre. Harald who works at the University of Otago is a world expert in crafting crystalline resonators to alter the colour of laser light. He had observed optical frequency combs in his crystals before and wanted to explore them further. Miro is world renowned for his theoretical models explaining 3rd order optical frequency combs. Along with his colleagues at The University of Auckland he has been studying them for a number of years. The idea for the new 2nd order frequency combs emerged from Miro's collaboration with researchers in Italy who had observed 2nd order phenomena in large optical resonators about a metre wide and made with mirrors. Miro had been developing models to explain them. It struck both Miro and Harald that they had two parts to the same puzzle.

"We realised that Harald had a unique ability to create microresonators that are exactly suitable for this kind of experiment," Miro explains. "We had the experience in Auckland to do experiments and I had done the modelling so we thought it would make a good collaboration."

At this stage the team is excited to lay the groundwork and test the stability, spacing and dynamics of the combs. For the future there is potential to develop a niche industry around the research with commercialisable intellectual property and products.

"The technology we're exploring is something entirely new, so there's a lot of basic physics and engineering we need to unravel," said Miro. "But of course, that's how all great things start."

Global Collaboration on Tiny Laser Networks that Promise Big Results

Working in collaboration with experimentalists at The University of Paris-Saclay in France, Dodd-Walls Centre postdoctoral fellow Soizic Terrien is helping to lay the foundations for a completely new approach to computing that operates on light rather than electricity. Working with Dodd-Walls Centre Principal Investigators Neil Broderick and Bernd Krauskopf in the Physics and Mathematics Departments at The University of Auckland, she is developing mathematical models for the building blocks of these new computers. Her results, published last year in *Physical Review A* have attracted international attention and spurred new collaborations with top overseas labs.

Today we are on the verge of a revolution in computing. After decades of rapid development our current electronic transistor-based computing technology is reaching its limit. As demands for information processing continue to rise, the physical limitations of transistor size and the power consumption of standard computers calls for faster, more energy efficient alternatives. The technology Soizic is helping to develop would process information using a network of lasers that would interact in a similar way to the neurons in our brains. Faster and more energy efficient than electronic equivalents, these computers would process information in the form of light and would naturally integrate with telecommunications networks.

At this stage the technology is in very early stages. Soizic's French collaborators have invented a tiny new laser (just a fraction the width of a human hair in size) which they are developing to become the nodes in a new type of computing network. The first challenge is to stabilise the laser's output and to encourage it to produce controlled pulses of light that could be used for information processing. Soizic's role in the collaboration is to develop mathematical models

Photo credit: Qobuz Media. https://vimeo.com/72487156

Soizic Terrien (Dodd-Walls Centre, *middle*) and collaborator Etienne Thoret (LMA, *right*) being interviewed by qobuz, Marseille, France, at a conference organised by the CNRS research unit Laboratoire de Mécanique et d'Acoustique de Marseille (LMA).

that explain and predict how the laser will behave when different parameters are adjusted. It's a real team effort. Sometimes she will discover something interesting in her model and suggest an experiment to explore it. At other times she will work to explain an unexpected result from the lab.

"I find it very exciting to work with experimentalists in this way;" Soizic says, "to actually see what you are working on in the lab for real; helping them make progress in the design of their experiments and working towards an actual device and applications later on."

In their experiments the team have been exploring the effect of feedback. They inject some of the laser's light back into the laser after a short time delay which has the effect of stabilising the output. Soizic's challenge has been to find the simplest model possible that explains the observed behaviour.

"We always try to find the most simple solution, Soizic explains. "To identify the main elements that make that system behave as it does."

In this sense she hit the jackpot. Using a simple model with just two parameters she has been able to explain some confusing aspects of the experiments and to suggest a method for controlling the regularity of light pulses.

This is the first time this theoretical model has been directly compared with experiments. Not only does it explain the behaviour of these tiny lasers, Soizic's theoretical work may also help to understand the behaviour of neurons and several other biological systems. The model she has used has two key ingredients: feedback and excitability. 'Excitability' means that if you give the system a small nudge of energy nothing will happen, but if you give it a slightly larger nudge it will release a large pulse of energy (in the case of the lasers, a pulse of light). Beyond a certain threshold energy, the nudge will always induce the same sized pulse. It turns out that there are many systems in nature that show similar behaviour of feedback and excitability. Soizic's theoretical work could also help to develop new algorithms and computing techniques inspired by neural networks.

The next step, after understanding and controlling the behaviour of one laser, will be to add more lasers and get them 'talking' to each other. Rather than reinjecting light into the same laser, the experimentalists will inject light from one laser into another. In this way they hope to set up a network of lasers that could eventually be made to perform simple tasks such as pattern recognition or discriminating between one type of input and another. If basic 'photonic computers' like this were incorporated into telecommunications networks they would save a lot of energy and increase the efficiency of the internet. These days data are transmitted around the world by lasers in the form of light. But when any information processing is required, the data are converted back into an electrical signal, processed by an ordinary computer then transformed back into light. This is an energy and time consuming process that could be eliminated by using photonic computing devices.

Soizic and her team's success in this project has attracted international attention and spurred further collaborations. Now they are working with another experimental team in Berlin on a similar but more complex system of lasers. They have also started a collaboration with renowned photonics researcher Ursula Keller from ETH Zürich who invented ultra-fast pulsed lasers and several other key photonic innovations. Ursula is on the Dodd-Walls Centre's Scientific Advisory Board and saw Soizic and her colleagues present their research at last year's annual symposium in Dunedin. Ursula was so impressed that she invited the Dodd-Walls Centre researchers to visit her lab in Switzerland and they have started a new project together.

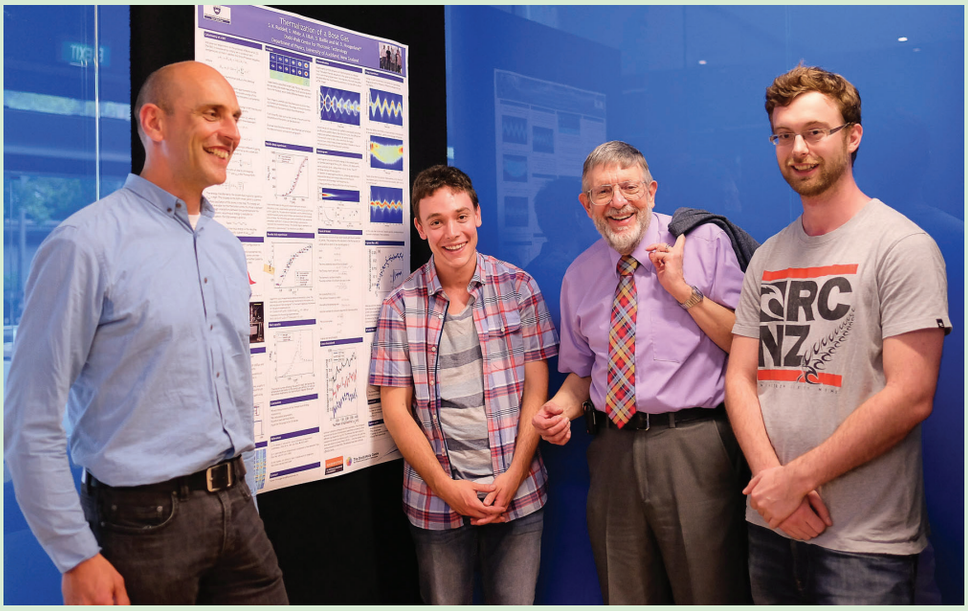
"The Dodd-Walls Centre is providing a very supportive environment for the research we're doing," says Soizic. "The Centre helps with all the travelling, going to conferences and to Paris to work with our collaborators... I find it very motivating working with people of different backgrounds. You come with different ideas and points of view yet somehow when these are put together with others you can do very interesting things."

A World-Leading Quantum Collaboration

At The University of Auckland, a team of Dodd-Walls Centre researchers are developing a unique way solve one of the major barriers facing the global quantum computing effort: how to transport quantum information from one place to another.

One of the major limitations of today's most advanced quantum computers is that they only operate at exceedingly low temperatures (colder than deep space) and in complete isolation from background interactions. As soon as the quantum information leaves this pristine environment it is destroyed, which makes communication virtually impossible. Around the world, researchers have long been searching for a way to convert stored quantum information into light. In this form it could be transported through fibre optic cables, just like ordinary data are today sent through the internet.

The University of Auckland team has succeeded in doing this. Their approach is based on the same fibre optic cables used in the internet. Normally these fibres are about the width of a human hair. But the team stretches them until they are thinner than the wavelength of light. Then, when laser light is sent through them, some of it leaks out the side. In the area surrounding the fibre, ultra-cold atoms are suspended in a vacuum. As light pass by, the atoms on the outside respond, singing in tune. In this way the team have managed to communicate information between individual atoms and individual photons of light.



Discussing quantum information and computing with 1997 Nobel Prize winner Bill Phillips *(centre right)*. Professor Phillips is on the Dodd-Walls Centre's International Science Advisory Board. Also photographed are Principal Investigator Maarten Hoogerland *(far left)* and Dodd-Walls Centre PhD students Sam Ruddell *(centre left)* and Donald White *(far right)*.

Their success is a stepping stone towards a new type of quantum computing network where the individual components (qubits) would be atoms that communicate using light through fibre-optic cables.

Last year the team published their results in *Optica*, a prominent optics publication. Since then Principal Investigator Maarten Hoogerland, has given talks in Austria, Japan, Italy and The Netherlands with enthusiastic responses.

The project is a collaboration between three Principal Investigators within the Dodd-Walls Centre: Maarten Hoogerland, Stuart Murdoch and Scott Parkins. Their unique combination of expertise epitomizes the kind of collaborations made possible by the CoRE. Maarten's speciality is cold atoms. Stuart is an expert in fibre-optics and has the skills to make the tapered fibres. Scott is a quantum theoretical whizz with an interest in how photons and cold atoms interact. Together they are a formidable team.

"None of this would have happened without the Dodd-Walls Centre being there," said Maarten. "They had funding for my PhD student to work on the project and they purchased some of the equipment that was used. In New Zealand it is sometimes difficult to find money to fund a good idea. But because there is funding within the Dodd-Walls Centre it means that when someone has a good idea we can actually make it happen."

New Zealand is a long way from most other countries so it makes sense to specialise in better, faster more secure modes of connecting and communicating. At the University of Otago, Dodd-Walls Centre Principal Investigators are developing two world-leading solutions to the problem of communicating between microwave circuit-based quantum computers.

Harald Schwefel is a world-leading expert in converting light and other electromagnetic radiation from one frequency to another using high quality resonators made of thin discs of crystal. He has developed a way to mix single microwave photons together with photons of visible light to produce visible photons that contain the same quantum information and can be communicated via optical telecommunication fibre. This method has demonstrated greater efficiency than any other fast conversion process.

Jevon Longdell is fine-tuning a method for converting single microwave photons into photons of visible light by using a different type of crystal that has rare earth ions embedded within it. These tiny ions have electronic properties that enable them to absorb photons of microwave energy and emit photons of visible light. Jevon's method, once perfected, will be of high efficiency and be very fast. The technology also has the possibility to act as quantum memory.

DWC RESEARCH EXCELLENCE

Dodd-Walls Centre researchers and their collaborative teams were highly successful at winning funding that adds to TEC CoRE funding and aligns with the Centre's strategic goals. External funding was won to support fundamental science and pre-commercial R&D in the aquaculture, medical, and high-tech manufacturing industries. Our investigators and research students won prizes and awards, evidence of highly effective mentoring and capability building in the next generation of New Zealand's workforce.

Investigators

Research Funding Awards

ASHTON BRADLEY
DWC Associate Investigator
University of Otago

Marsden Fund Standard Grant, $905,000
Making, probing, and understanding two-dimensional quantum turbulence (3 years)

Grant PI

KAI CHEN
DWC Post-Doctoral Fellow
Victoria University of Wellington

Marsden Fast Start Grant, $300,000
Photoluminescence shines a light on the exemplary optoelectric properties in hybrid organic-inorganic perovskites (3 years)

Grant PI

STÉPHANE COEN
DWC Principal Investigator
The University of Auckland

James Cook Research Fellowship, $200,000
Widely tunable optical fibre frequency comb (2 years)

Grant PI

$18.6 MILLION

NEW COMPETITIVE, EXTERNAL RESEARCH FUNDING AWARDED IN 2017 IN RECOGNITION OF EXISTING RESEARCH EXCELLENCE

AMITA DEB
DWC Research Fellow
University of Otago

Marsden Fast Start Grant, $300,000
Single photon control of optical phase using ultracold Rydberg atoms (3 years)

Grant PI

CATHER SIMPSON AND **NEIL BRODERICK**
DWC Principal Investigators
University of Auckland

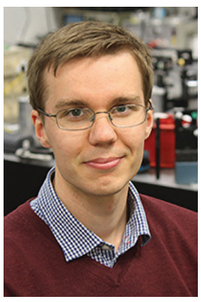
MBIE National Science Challenges: Science for Technological Innovation, $769,732
Precision farming technology for aquaculture (2 years)

Grant Co-AIs, led by Cawthron Institute Ltd

HARALD SCHWEFEL AND **MIRO ERKINTALO**
DWC Associate Investigators
University of Otago and The University of Auckland

Marsden Fund Standard Grant, $910,000
Microresonator frequency combs through second-order nonlinearities (3 years)

Grant Co-PIs



ULRICH ZÜLICKE
DWC Associate Investigator
Victoria University of Wellington

Marsden Standard Grant, $905,000
Supercharging electromagnetism: tuneable magnetoelectricity in unconventional materials (3 years)

Grant PI

R&D and Industry Awards

KEITH GORDON

DWC Principal Investigator
University of Otago

MBIE Endeavour Smart Ideas, $1,000,000
The lake snow toolbox: detecting and qualifying an emerging environmental problem (3 years)

Grant Co-PI, led by Landcare Research New Zealand Ltd

CATHER SIMPSON

DWC Principal Investigator
The University of Auckland

MBIE Endeavour Research Programme, $11,802,990
Fast, efficient and tailored pulsed laser micromachining and additive manufacturing (5 years)

Grant PI

MBIE Endeavour Smart Ideas, $999,804
Portable and handheld device for diagnosis and differentiation of skin cancers

Grant PI

HARALD SCHWEFEL

DWC Associate Investigator
University of Otago

Bright Ideas Competition, 2017 CLEO Laser Science and Electro-Optics, Photonics Applications, $42,000 (equipment)

Grant PI

GEOFFREY WATERHOUSE

DWC Associate Investigator
The University of Auckland

MBIE Catalyst Fund, New Zealand/Australia Research Collaborations, $1,500,000
Disruptive technologies from metal-organic frameworks (3 years)

Grant Co-PI, led by Massey University and CSIRO, Australia

Prizes and Peer Recognition

CATHER SIMPSON
Shimadzu Prize, Applied and Industrial Chemistry, The New Zealand Institute of Chemistry

CATHER SIMPSON
The University of Auckland Vice Chancellor's Sponsored Research and Commercialisation Medal

FRÉDÉRIQUE VANHOLSBEECK
Miriam Dell Award for Excellence in Science Mentoring 2017 from the Association of Women in Science – Highly Commended

GEOFFREY WATERHOUSE
Chinese Academy of Sciences International Partnership Award for Young Scientists

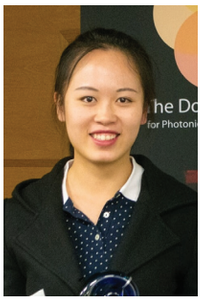
Students

MILENA HORVATH
M.Sc., University of Otago
Supervisors: Amita Deb, Niels Kjærgaard

Best paper by a postgraduate student award, Division of Science, University of Otago

HARPREET KAUR
PhD cand., University of Waikato
Supervisor: Rainer Künnemeyer

The inaugural **Professor John D. McCraw Trophy** for outstanding oratory, winner of the Three Minute Thesis (3MT) competition, winner of the People's Choice Award



FANG (RACHEL)
Ou, PhD cand., The University of Auckland
Supervisor: Frédérique Vanholsbeeck

Te Apārangi Leader Award, The Royal Society of New Zealand

RYAN THOMAS
PhD, University of Otago
Supervisor: Niels Kjærgaard

The Hatherton Award (best scientific paper by a PhD student at any NZ university in the chemical sciences, physical sciences, mathematical, and information sciences), The Royal Society of New Zealand

Dodd-Walls PhD student Harpreet Kaur and the inaugural *Professor John D. McCraw Trophy* for outstanding oratory with traditional carver Wiremu Puke (Ngāti Wairere, Ngāti Porou)

ACTIVITIES IN SUPPORT OF DIVERSITY AND INCLUSIVENESS

Women and girls remain underrepresented in the physical and mathematical sciences, especially physics – an issue of priority to the Dodd-Walls Centre which is directly addressed by our Diversity Committee. The committee's activities are facilitated by a dedicated budget that supported several projects and initiatives throughout the year. These included networking events, retreats, videos and a visit from Australia-based applied sociologist Dr Zuleyka Zevallos who spoke in a Suffrage Day event in Wellington on national approaches to improving the hiring, promotion, retention, recognition and participation of all women in science.

The committee plays an important role in ensuring that diversity considerations are part of all key activities and decisions including the choice of speakers for DWC sponsored conferences and gender balance considerations for new position advertising and recruitment.

Sponsoring More Diverse Events

The Dodd-Walls Centre has made a commitment to ensuring that diversity and equity is considered in all aspects of any event we sponsor. This included ANZCOP (the 3rd Australia–New Zealand Conference on Optics and Photonics) that was held in Queenstown in December. Frédérique Vanholsbeeck was Programme Chair for the conference and describes how the effort to include more women speakers and encourage more female attendees affected the culture of the event: "We ran a very diverse ANZCOP in terms of invited and plenary speakers," she said. "And everyone said that they felt the atmosphere of the conference was different as a result of the improved attendance of women."

Support and Networking Groups for Women in Science

As Dodd-Walls Centre PhD student Maddy Cormack expresses, some of the greatest challenges can come from the inside in the form of doubt and low self-esteem. Along with another female scientist, Maddy established a new group at the University of Otago called *Women in Science 3* providing support for all women working or studying in the mathematical and physical sciences. The Dodd-Walls Centre has provided support to the *Women in Science 3* group as well as The University of Auckland's *Women in Science Network* who have similar goals and facilitate retreats, meetings and events to support women in science.

Making Life Easier for Researchers with Children

Several world-leading women physicists were hosted at the Dodd-Walls Centre's annual symposium in Dunedin. Guest speakers included Ursula Keller from ETH Zürich, Switzerland, leading quantum theorist Ana Maria Rey from JILA Colorado, USA, and biomedical optics expert Monika Ritsch-Marte from Innsbruck, Austria. These women were invited to share their stories in a panel discussion of the challenges they faced on the road to their success and how they overcame the difficulties. The challenge of maintaining a high impact career, while having a family, emerged as a key issue.

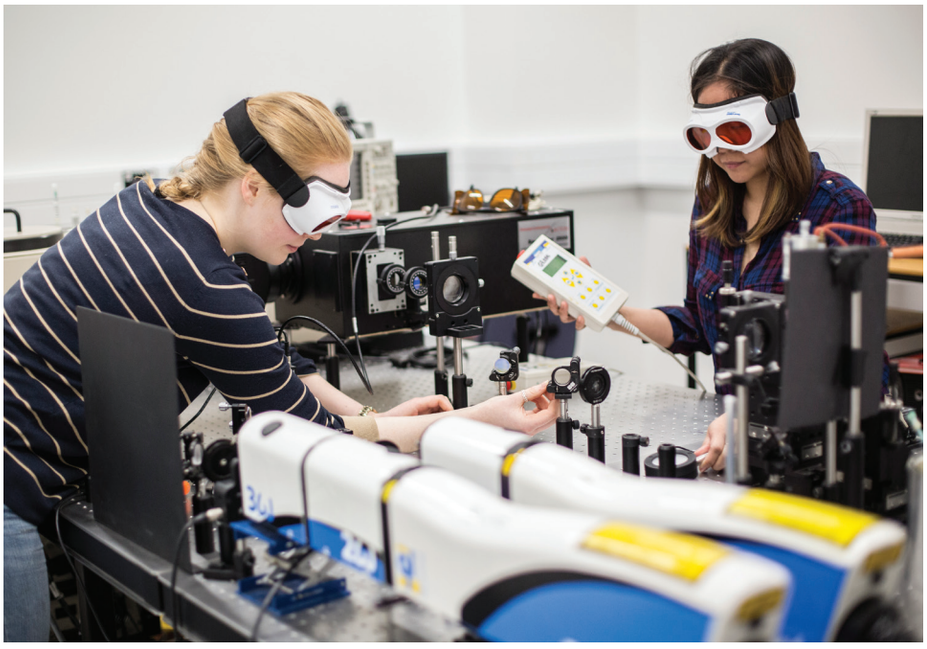
In order to make life easier for women in the Dodd-Walls Centre and to balance childcare needs with research, the Dodd-Walls Centre Carer's Fund has been established. The fund enables caregivers to attend conferences by assisting with babysitting or flights for a supporter to join them at the conference. Efforts have also been made on an individual basis to support women upon their return to work after delivering. Postdoctoral fellow Sara Miller, for example, returned to full-time research at the University of Otago with the support of her group leader and DWC Principal Investigator Keith Gordon.

"Since I returned to work full time in April, I found Keith to be extremely supportive," said Sara. *"I was able to leave the lab to breastfeed my baby during the day whenever she needed it and that was two or three times a day in the early months... For attending conferences I brought my Mum and baby with me; Mum looked after her while I attended the conference."*

Financial support for this was provided through the Dodd-Walls Centre Carer's Fund.

Looking Forward: The International Women in Science Conference 2020

DWC Principal Investigator Cather Simpson together with DWC Director David Hutchinson put together a competitive bid to host The International Union of Pure and Applied Physics (IUPAP) International Women in Physics Conference in 2020. If the bid is successful, this would bring an injection of energy and improve the profile for diversity issues in New Zealand science.



Dodd-Walls Centre PhD students Georgina Shillito *(left)* and Ruth Sales *(right)* working together to solve questions in photochemistry.

INDUSTRY ACTIVITIES

Photonics and quantum technologies underpin products and services in a vast range of industries in the modern economy. The total revenue of core photonics component industries is measured in the hundreds-of-billions of dollars globally while the value of industries enabled by photonics is worth trillions of dollars. Much of the influence of these technologies is hidden, pervasive though it is, and the Dodd-Walls Centre aims to ensure wider recognition of their importance, while leveraging New Zealand's research strengths for the benefit of our economy. The Centre aims to train an appropriately skilled workforce and to attract the world's best talent while supporting the growth of New Zealand's high-tech sector.

Photonics is an ideal focus for New Zealand companies because the capital investment requirements are modest while the products are of high value and are relatively low cost to deploy in the market. The barriers to entry for the photonics marketplace are relatively low and it is presently less complicated than other high-tech sectors to birth new and profitable enterprises. The Dodd-Walls Centre's aim is to establish a domestic ecosystem of photonics-related companies that will attract investment, stimulate R&D activity across a variety of industries and provide viable career options for our world-class and highly-trained graduates.

Research students in the Dodd-Walls Centre are a core focus and one of our greatest strengths. Students and recent graduates are ideally positioned for starting local photonics ventures. They are trained in state-of-the-art technology development and have the time, financial freedom and energy to forge an exciting career path for themselves. An important motivation for student-driven start-ups is provided by the role-modelling of recent graduates who have successfully made the transition into a start-up company. The DWC now has several successful and developing company start-ups that are commercialising IP created through university research and co-creation with industry partners. The start-ups and others closely related to the DWC include Engender Technologies, Photonic Innovations, Coherent Solutions, and Southern Photonics.

OUR AIM IS TO ESTABLISH A DOMESTIC ECOSYSTEM OF PHOTONICS-RELATED COMPANIES THAT WILL ATTRACT INVESTMENT, STIMULATE R&D ACTIVITY AND PROVIDE VIABLE CAREER OPTIONS FOR GRADUATES

DWC Commercialisation Competitions

In 2016 we ran our first student competition to identify potentially commercialisable ideas in photonics and quantum technologies. A second such competition was run in 2017 and new ideas from students were competed with in the competition by student teams interested in commercialisation. Several of the ideas developed in the first competition were presented this year to the Physical Sciences Investment Committee for *Return on Science* and new funding was won to enable further pre-commercialisation development of the technologies.

Incubating New Enterprises

Several groups within the DWC provide opportunities and support for students to network with industry and develop commercial ideas. The Photon Factory at The University of Auckland is led by DWC Principal Investigator Cather Simpson is one such example. Cather won the AgTech section of the Silicon Valley start-up challenge in 2017 which helped to globally promote her new start-up named Engender Technologies Ltd (major shareholders are CRV Ltd, Pacific Channel Nominees Ltd and Auckland UniServices Ltd). Engender Technologies employs a number of DWC graduates in technology-development roles. We are also incubating new enterprises using optical vibrometry with several applications for primary industry productivity improvements and a new laser-machining company that is commercialising IP developed as part of a large MBIE contract.

Elizabeth Reed, Head of Strategy at BBDO Proximity, Singapore *(left)* and Shannon Scown, BioPacific Partners Ltd *(right)*.

Stuart Reed, Finance Manager at Asahi Beverages Group *(far left)*, Carew Hatherley, CEO at Storm Systems Ltd *(middle left)*, Berri Schroder, investor and entrepreneur *(middle right)*, and Marc Karapanovic, Marketing Manager at BrokerWeb Risk Services Ltd *(right)*.

WE ARE PASSIONATE ABOUT COMMERCIALISING OUR IP AND SEEING PHOTONIC AND QUANTUM TECHNOLOGIES YIELD VALUE, AND INCREASED SECURITY AND PRODUCTIVITY TO NEW ZEALAND COMPANIES

Bridging the Worlds of Academic Science and Industry

The Lighthouse Platform is an industry networking group run by the Dodd-Walls Centre and it hosts networking and technology awareness events. Industry participants are encouraged to engage directly with DWC investigators and their teams in order to build functional commercial-focused relationships. In 2017, we developed a new format for the networking events and we invited speakers from local companies ranging from small (Veriphi Ltd, a company with a few staff) to large (Fisher and Paykel Healthcare Corp. Ltd) to speak for five minutes each on the topic of 'How can universities add value to your enterprise'. This was followed by a panel discussion where speakers took questions from the audience. Feedback on the event was very positive and repeat events are requested.

Another event with a more ambitious format was run in May as a part of the Auckland Tech Week. At this event we partnered with another CoRE to engage with different industries in a problem-solving role. Three companies were selected to engage with teams from the Dodd-Walls Centre and three additional companies with teams from the partnering CoRE. The teams worked with the companies on a *pro bono* basis for three months prior to the May event to solve problems identified as needing the relevant expertise in which each CoRE specialized. At the event these six problems formed the subject of a video that was made to showcase how the CoREs had assisted domestic companies, and to encourage other industries to engage with the CoREs. This collaborative problem-solving work was fully funded by the Dodd-Walls Centre and the other CoRE, yet after the event several of the companies with whom the teams had worked for free subsequently entered into longer-term paid consultancy relationships. We will run this event again in 2018 as a part of the larger nationwide Tech Week.

Still image from the video made in collaboration with industry partners Buckley Systems and the New Zealand Defence Technology Agency. The video, Dodd-Walls Interface Challenge: solving industry problems with innovative solutions, is available at https://youtu.be/Orzx41OcCco and www.doddwalls.ac.nz

EDUCATIONAL AND PUBLIC OUTREACH

Taking Science To Where Our People Are

The word *extreme* characterises the range and nature of the Dodd-Walls Centre's education and public outreach activities in 2017. We took the 'Hands-on-Science' experience to New Zealand's largest city, Auckland, and to some of the nation's smallest and most remote communities on the Chatham and Pitt Islands. Including events such as creating wonder in young people being treated in hospitals and inspiring a curiosity about science in those using the nation's cycle trails, the Dodd-Walls Centre directly engaged over 6,000 New Zealanders in sixty events across the country.

From a variety of places including universities, marae, local schools, community halls, and even in the middle of a grassy field, the Dodd-Walls Centre Educational Outreach team guided learners of all ages through activities that ranged from measuring pollutants using photometry, to building interferometers, to doing hands-on demonstrations about photonics and astronomy. Some of this year's highlights are detailed below.

Science Wānanga

The Dodd-Walls Centre continued support for the University of Otago's Science Wānanga program. Wānanga were held at the Waipatu Marae in Hastings and at Ōtākou Marae on the Otago Peninsula. Two DWC Principal Investigators, Harald Schwefel and Niels Kjærgaard, entranced the students with demonstrations of interferometry and a range of light-themed demonstrations. The wānanga provided a direct opportunity for students to meet leading researchers in person and learn science first-hand – and the learning went both ways because DWC researchers also learned from the experience having had the opportunity to experience Māori culture and marae customs in an immersive way. The students and researchers learned together as they ate, slept and sang on the maraes.

A particular favourite experience for the students was the water quality testing, where the opportunity to learn about the way we can use photonics to determine the presence of chemical pollutants in water. Using light to inspire young people to experiment and think scientifically is an easy thing to do because light-based phenomena are a part of their everyday experiences. Feedback from the two wānanga showed that the opportunity to meet, work and live alongside scientists was a real hit and we hope to see some of our wānanga alumni in our labs as research students in the years to come.

Girl Guides Visit

A group of postgraduate students and postdoctoral researchers, led by Cushla McGoverin, hosted thirty Girl Guides at The University of Auckland. The girls got to experience and consider a range of physics phenomenon including the benefits of high-efficiency light bulbs compared with incandescent bulbs when they were tasked with powering-up both bulb types with a hand-driven crank generator. The girls had an engaging and busy visit to the Dodd-Walls Centre researchers and shared their experiences in a time-lapse video on Twitter (https://twitter.com/hiitsneelam/status/887572327482892289).

Whirlwind Roadshows

DWC postdoctoral researcher Eyal Schwartz took his passion for astronomy and the Laser Interferometer Gravitational-Wave Observatory (LIGO) experiment on a whirlwind roadshow to fourteen venues across the country. From Invercargill in the south to Whangarei in the north, Eyal entertained end educated learners of all ages at schools, planetaria, and Rotary Club venues about gravitation waves, interferometry and spectrometry.

MOTAT Street Science Fair

Thousands of people turned out on a humid Auckland day in April to experience the fun science demonstrations at the Museum of Transport and Technology's (MOTAT) Street Science Fair. With demonstrations ranging from 'Beamboxes' that demonstrate how light can be used to communicate rapidly and across great distances, to exploring coloured shadows. Over 2,200 visitors were intrigued by the science of light as demonstrated by Dodd-Walls Centre researchers and students.

Extreme Science: Taking Science To The Chatham Islands

The Dodd-Walls Centre has a commitment to engage rural and remote communities in science-based discussions and learning. A team of DWC researchers together with Otago Museum Science Communicators visited all three schools on the Chatham and Pitt Islands and hosted evening community events for a week in July. Demonstrations included Lenz's Law of electromotive force in electrical circuits, the physics of flight, and astronomy. People of all ages were enthralled by their first ever science outreach experience and they made many requests for a return visit from the outreach team. To support their interest in science and star light, some equipment was left behind, including a small telescope, a Rū seismometer and many 'Light Matters Kits'.

Hospital School Visits

To go beyond conventional classrooms, teams of Dodd-Walls Centre students visited hospital-based classes at two locations in Auckland, bringing equipment such as photometric water testing and raspberry pi spectrometers for demonstrations that are usually reserved for university laboratories. The interactions were greatly appreciated by the hospital-bound learners and their parents. The Dodd-Walls Centre intends to expand this type of educational outreach in the future.

Interplanetary Cycle Trail

The Dodd-Walls Centre in partnership with the Otago Central Rail Trail Trust and the Otago Museum, developed and installed the world's largest scale model of our Solar System that is accessible by bicycle (and walking). Located on the iconic Otago Central Rail Trail, the 100-million-to-one scale accurate model has a 14 m diameter Sun at its centre in the Maniototo township of Ranfurly and each planet subsequently is located at its correct orbital distance on the trail going both west towards Clyde and east toward Middlemarch.

The model is designed to communicate the concept of scale to school students and adult visitors alike. Visitors cycle the approximately 1.5 km from the Sun to the Earth (13 cm in diameter), a distance that will take just over 8 minutes at 10 km/h, but they are then amazed as they learn from interpretive signs that they have been travelling at nearly the speed of light at that scale, and that the light from the real Sun above them would have just arrived at Earth the same time they did!

The model has proven hugely popular with the public and the original 7,000 interpretative maps produced in the first printing have already been taken home by visitors.

Model of Jupiter on the Otago Rail Trail bikeway.

Other Educational Outreach Activities and Events Supported By Dodd-Walls Centre Involvement

- Auckland Science Fair, Epsom Girls Grammar School, September
- Aurora Energy Otago Science and Technology Fair, Dunedin, August
- Pua Nga Maara Wānanga:
  Manurewa Marae, Auckland, March
  Umupuia Marae, Auckland, July
  Tiritiri Matangi, Auckland, November
- Advanced Schools Science Academy – two scholarships awarded to Māori students, Dunedin, December

Media Appearances and Commentary

Radio New Zealand National Afternoon programme, Professor Ian Walmsley, University of Oxford and Dodd-Walls Symposium attendee, Quantum technology is changing the world, February 1.

Channel 39 Dunedin, Professor Bill Philips (Nobel Laureate), Joint Quantum Institute, USA, and Dodd-Walls Symposium attendee, February 1.

Television New Zealand, Bianca Sawyer, Dodd-Walls Centre PhD candidate (Otago), Ian Walmsley (Oxford), and Bill Philips (Joint Quantum Institute), New Zealand can play a key role in developing quantum technology, February 2.

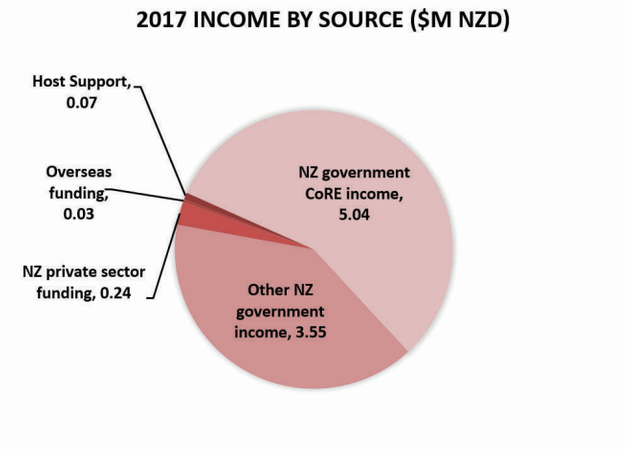
Radio New Zealand, Professor David Hutchinson, What can we learn about quantum physics from bacteria?, February 23.

Australian Broadcasting Corporation, Associate Professor Neils Kjærgaard and Ryan Thomas (PhD candidate, Otago), N.Z. physicists collide ultracold atoms to observe a key quantum principle, March 15.

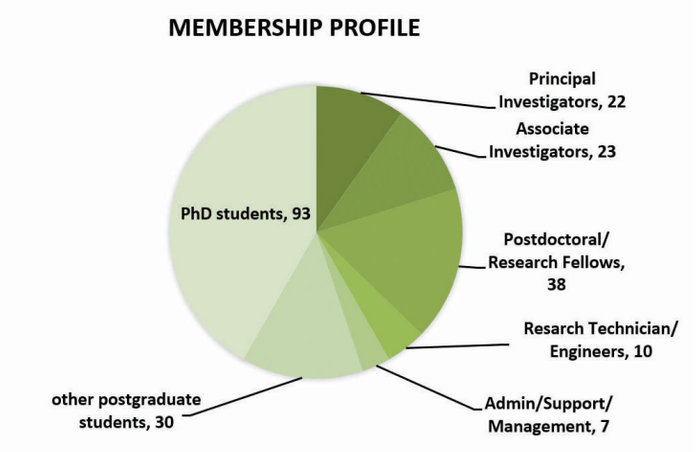
FACTS AND FIGURES

Broad category	Detailed category	Y3 (2017)
Value of CoRE funding from TEC ($M)		5.04
FTEs by category	Principal Investigators	3.13
	Associate Investigators	0.52
	Postdoctoral Fellows	11.67
	Research Technicians	0.78
	Administrative/Support	4.24
	Research Students (9.74 funded by the DWC)	71.79
	Total	**92.13**
Headcounts by category	Principal Investigators	22
	Associate Investigators	23
	Postdoctoral Fellows	38
	Research Technicians	10
	Administrative/Support/ Management	7
	Research Students (14 funded by the DWC)	123
	Total	**223**
Peer reviewed research outputs by type	Journal articles	91
	Books	0
	Book chapters	2
	Conference papers	15
	Other	1
	Total	**109**
Value of external research contracts awarded by source ($M NZD)	Vote Science and Innovation contestable funds	3.51
	Other NZ Government	0.04
	Domestic - private sector funding	0.24
	Overseas	0.03
	Host/Partner Support	0.07
	Total	**3.89**
Commercial activities	Patent applications	2
	Patents granted	0
	Invention disclosures	9
	Total number of spinouts (2015)	2
Students studying at CoRE by level	Doctoral degree	93
	Other	30
	Total	**123**
Number of students completing qualifications by level	Doctoral degree	20
	Other	13
	Total	**33**
Immediate post-study graduate destinations	Further study in NZ	6
	Further study overseas	0
	Employed in NZ	14
	Employed overseas	10
	Other	1
	Unknown	2
	Total	**33**

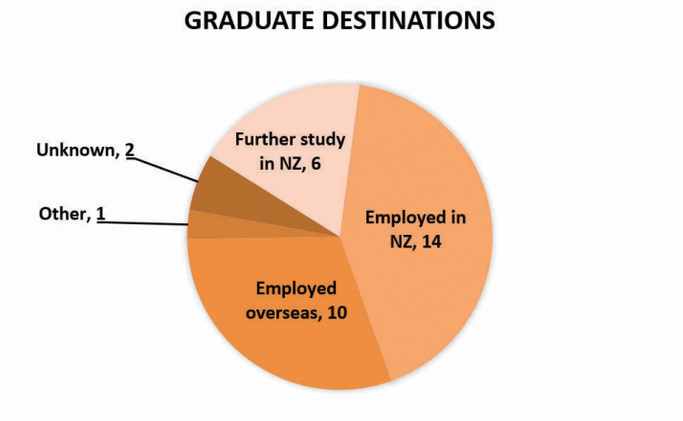
The Dodd-Walls Centre receives funding from sources other than the TEC's CoREs Fund and the additional funding contributes directly to research projects in the four Research Themes. Some DWC staff and student members are supported by these external research funds, whereas others are supported by CoRE funding. The membership profile includes all DWC members, while the financial report indicates only those directly supported by CoRE funds.



The DWC has a total of 45 Investigators (including the Director and Deputy Director) and 48 other research staff. Doctoral students (93) comprise 42% of the total membership of the DWC and in addition to research training, many of our strategic activities involve students including educational outreach activities, Ka Hikitia, and industry interface and R&D. DWC strategic and central activities are led and supported by 4 managers and 3 administrative staff.



All DWC students undertake research and most of them at the highest level in PhD programmes. Those categorised as 'Other' in the Table (Students studying at CoRE by level) include masters, honours, and postgraduate diploma students. Some of these students will go on to PhD programmes while others go on to employment in New Zealand or overseas. Graduate destinations include all PhD and other degree students.



FINANCES

Report by Programme 2017

	Actual	Budget
Income	**5,039,000**	**5,039,000**
Salaries and related costs		
Director, PI and AI	388,311	404,217
Postdoctoral Fellows	754,686	591,358
Others - Managers & Salary-related costs	160,047	214,624
Total salaries and related costs	**1,303,044**	**1,210,199**
Overheads	**1,159,967**	**1,190,361**
Research operating expenditure and depreciation		
Theme 1a Photonic sensing & imaging	280,958	209,500
Theme 1b Photonic sources & components	176,295	206,300
Theme 2a Quantum fluids & gases	263,718	177,000
Theme 2b Quantum manipulation & information	183,435	172,000
Pool opex (New & Emerging Researchers)	151,031	75,000
Total research operating expenditure	**1,055,437**	**839,800**
Scholarships awarded	**630,210**	**524,817**
Scholarships pool	**–**	**–**
Strategic operating expenditure		
Industry Outreach & consultants	244,338	213,000
Educational Outreach	74,923	70,000
Ka Hikitia	23,230	30,000
Total strategic operating expenditure	**342,491**	**313,000**
Centre operating expenditure		
Travel Pool (Research)	128,549	100,000
other centre costs	284,552	290,000
Total centre operating expenditure	**413,101**	**390,000**
Total expenditure	**4,904,251**	**4,468,176**
Net surplus*	134,749	570,824

** The surplus in FY2017 is a planned budgetary surplus that contributes to operational funds in future years; the budgetary surplus for the six years of CoRE funding is $0.*

MEMBERS, GOVERNANCE AND MANAGEMENT

DWC Board members

DR GARTH CARNABY, CHAIR

Dr Garth Carnaby spent the first part of his career applying mathematics and physics to the industrial utilisation of wool. Today he runs his own company providing research, governance, and consultancy, in the science, agriculture, manufacturing, food, and wool fields. He is a past-President of the Royal Society of New Zealand and past chair of the Marsden Fund. He currently chairs the NZ Synchrotron Group Ltd and the BioResource Processing Alliance. He was made a Member of NZ Order of Merit (MNZM) in 2006 for services to the wool industry and a Companion (CNZM) in 2018 for services to Science and Governance.

PROFESSOR RICHARD BLAIKIE

Professor Richard Blaikie is Deputy Vice-Chancellor (Research and Enterprise) at the University of Otago and Professor in Physics. He is a former Director of the MacDiarmid Institute (2008-11), former member of the Marsden Fund Council and served for one year on the New Zealand Science Board (2011). He was awarded the Hector Medal in 2013 for his fundamental and wide-ranging contributions to the field of nano-optics and a Thomson Medal in 2015 in recognition of his science leadership.

PROFESSOR JIM METSON

Professor Metson is the Deputy Vice-Chancellor (Research) at The University of Auckland. He is a physical chemist, co-founder of the University's Research Centre for Surface and Materials Science and of the Light Metals Research Centre, a founding member of the MacDiarmid Institute, and he has worked extensively with international industry. He was Chief Science Advisor to NZ's MBIE and the NZ Government's representative on the science group that developed the Australian Synchrotron.

PROFESSOR RICHARD BARKER

Professor Barker was appointed Pro-Vice-Chancellor of the Division of Sciences at the University of Otago in 2017 and is proud to head the Division at New Zealand's most science intensive university. Richard joined the Department of Mathematics and Statistics at the University of Otago in 1998, was appointed Professor of Statistics in 2007, and was Head of the Department of Mathematics and Statistics from 2008 to 2016. His research speciality is Bayesian hierarchical modelling and statistical ecology.

DWC Board members continued

DR DIANNE MCCARTHY

Dr Dianne McCarthy has extensive experience in a number of senior management and governance roles in the tertiary education, science and health sectors. She was made an Officer of the New Zealand Order of Merit for her services to education in 2008, a Companion of the Royal Society of New Zealand for her services to science in 2015, and a Companion of the New Zealand Order of Merit for her services to science, business and women in 2016.

MS CHARLOTTE WALSHE

Charlotte Walshe is the Chief Executive Officer of Christchurch-based Jade Software Corporation. Charlotte, with degrees from the University of Canterbury in mathematics and physics as well as in Entrepreneurial Development from the MIT Sloan School of Management, has a background in the technology sector and was CEO of Dynamic Controls for more than a decade prior to joining Jade Software.

MR IAN TAYLOR

Ian Taylor is an innovator and business leader whose companies include Taylormade Media and Animation Research Limited, the latter renowned for its sports graphics and decision review systems. Ian is of Ngāti Kahungunu and Nga Puhi descent, has a law degree from the University of Otago and a background in broadcasting. He was named the 2010 *New Zealander of the Year* and the 2013 *Outstanding Māori Business Leader of the Year*. In 2012, Ian was appointed a Companion of the New Zealand Order of Merit for services to television and business.

Investigators, Management and Administration

Last Name	First Name	Title	Institution	Role in the DWC
Hutchinson	David	Professor	University of Otago	Director
Broderick	Neil	Professor	The University of Auckland	Deputy Director
Albert	Michael	Professor	University of Otago	Principal Investigator
Andersen	Mikkel	Dr	University of Otago	Principal Investigator
Auguié	Baptiste	Dr	Victoria Uni. of Wellington	Associate Investigator
Baillie	Danny	Dr	University of Otago	Associate Investigator
Ballagh	Rob	Professor	University of Otago	Principal Investigator
Blaikie	Richard	Professor	University of Otago	Associate Investigator
Blakie	Blair	Professor	University of Otago	Principal Investigator
Bodyfelt	Joshua	Dr	Massey University	Associate Investigator
Bradley	Ashton	Dr	University of Otago	Associate Investigator
Brand	Joachim	Professor	Massey University	Principal Investigator
Bubanja	Vladimir	Dr	Callaghan Innovation	Associate Investigator
Carmichael	Howard	Professor	The University of Auckland	Principal Investigator
Coen	Stephane	A/Professor	The University of Auckland	Principal Investigator
Craigie	Cameron	Dr	AgResearch NZ Ltd	Associate Investigator
Deb	Amita	Dr	University of Otago	Associate Investigator
Erkintalo	Miro	Dr	The University of Auckland	Associate Investigator
Golovko	Vladimir	Dr	University of Canterbury	Associate Investigator
Gordon	Keith	Professor	University of Otago	Principal Investigator
Grant	Craig	Dr	Otago Museum	Ed. Outreach Manager
Griffin	Ian	Dr	Otago Museum	Honorary Fellow
Harvey	John	Professor	The University of Auckland	Industry Team Leader
Hodgkiss	Justin	Dr	Victoria Uni. of Wellington	Associate Investigator
Hoogerland	Maarten	Dr	The University of Auckland	Principal Investigator
Jin	Jianyong	Dr	The University of Auckland	Associate Investigator
Kaipio	Jari	Professor	The University of Auckland	Associate Investigator
Kjærgaard	Niels	A/Professor	University of Otago	Principal Investigator
Krauskopf	Bernd	Professor	The University of Auckland	Principal Investigator
Künnemeyer	Rainer	A/Professor	University of Waikato	Associate Investigator
Le Ru	Eric	Professor	Victoria Uni. of Wellington	Associate Investigator
Leonhardt	Rainer	A/Professor	The University of Auckland	Principal Investigator
Longdell	Jevon	A/Professor	University of Otago	Principal Investigator
McCane	Brendan	A/Professor	University of Otago	Associate Investigator
McGoverin	Cushla	Dr	The University of Auckland	Associate Investigator
Murdoch	Stuart	Dr	The University of Auckland	Principal Investigator
Parkins	Scott	A/Professor	The University of Auckland	Principal Investigator
Reeves	Roger	Professor	University of Canterbury	Associate Investigator
Reid	Michael	Professor	University of Canterbury	Associate Investigator
Reis	Marlon	Dr	AgResearch NZ Ltd	Associate Investigator
Schwefel	Harald	Dr	University of Otago	Associate Investigator
Simpson	Cather	Professor	The University of Auckland	Principal Investigator
Taylor	Luke	Dr	University of Otago	Prototype Manager
Van Wijk	Kasper	A/Professor	The University of Auckland	Principal Investigator
Vanholsbeeck	Frédérique	Dr	The University of Auckland	Principal Investigator
Waterhouse	Geoff	A/Professor	The University of Auckland	Associate Investigator
Wells	Jon Paul	Professor	University of Canterbury	Principal Investigator
Xu	Peter	Professor	The University of Auckland	Associate Investigator
Zülicke	Ulrich	Professor	Victoria Uni. of Wellington	Associate Investigator
Tompkins	Peggy	Dr	University of Otago	Programme Manager
Evans	Diana	Ms	University of Otago	PA/Administrator
Foster	Anita	Ms	University of Otago	Administrator
Sirisena	Premika	Ms	The University of Auckland	Administrator

Postdoctoral and Research Fellows

Last Name	First Name	Title	Institution	Position
Aguergaray	Claude	Dr	The University of Auckland	Postdoctoral Fellow
Al-Imarah	Emad	Dr	The University of Auckland	Postdoctoral Fellow
Canela	Victor	Dr	The University of Auckland	Postdoctoral Fellow
Anthony	Jessienta	Dr	The University of Auckland	Postdoctoral Fellow
Au	Maggie	Dr	Engender Technologies Ltd	Postdoctoral Fellow
Brodie	Graham	Dr	The University of Auckland	Postdoctoral Fellow
Chen	Kai	Dr	Victoria Uni. of Wellington	Postdoctoral Fellow
Chen	Stephen	Dr	University of Otago	Postdoctoral Fellow
Delgado	Adrian	Dr	University of Otago	Postdoctoral Fellow
Ding	Boyang	Dr	University of Otago	Postdoctoral Fellow
Engl	Thomas	Dr	Massey University	Postdoctoral Fellow
Fialko	Oleksandr	Dr	Massey University	Postdoctoral Fellow
Filippov	Igor	Dr	The University of Auckland	Research Fellow
Freeman	Paul	Dr	The University of Auckland	Postdoctoral Fellow
Garbin	Bruno	Dr	The University of Auckland	Postdoctoral Fellow
Giraldo	Andrus	Dr	The University of Auckland	Postdoctoral Fellow
Horvath	Sebastian	Dr	The University of Auckland	Postdoctoral Fellow
Jonmohamadi	Yaqub	Dr	The University of Auckland	Research Fellow
Kho	Julie	Dr	The University of Auckland	Postdoctoral Fellow
Kolenderska	Sylwia	Dr	The University of Auckland	Postdoctoral Fellow
Mallett	Ben	Dr	The University of Auckland	Postdoctoral Fellow
Miller	Sara	Dr	University of Otago	Postdoctoral Fellow
Muthiah	Maran	Dr	The University of Auckland	Postdoctoral Fellow
Nieuwoudt	Michel	Dr	The University of Auckland	Postdoctoral Fellow
Schwartz	Eyal	Dr	University of Otago	Postdoctoral Fellow
Sompet	Pimonpan	Dr	University of Otago	Postdoctoral Fellow
Terrien	Soizic	Dr	The University of Auckland	Postdoctoral Fellow
Thomas	Ryan	Dr	University of Otago	Postdoctoral Fellow
Toikka	Lauri	Dr	Massey University	Postdoctoral Fellow
Yu	Xiaoquan	Dr	University of Otago	Research Fellow
Herrera	Ivan	Dr	The University of Auckland	Postdoctoral Fellow
Ruddell	Sam	Dr	The University of Auckland	Postdoctoral Fellow
Bauer	Bastian	Dr	The University of Auckland	Postdoctoral Fellow
Ebling	Ulrich	Dr	Massey University	Postdoctoral Fellow
Helm	John	Dr	University of Otago	Postdoctoral Fellow

PhD Students

Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Alizadeh	Yashar	University of Canterbury	S
Anyi	Caroline	University of Canterbury	
Ardekani	Iman	The University of Auckland	
Ashforth	Simon	The University of Auckland	
Baber	Logan	The University of Auckland	
Barnsley	Jonathan	University of Otago	
Bogunovic	Dijana	The University of Auckland	C
Bourke	Levi	University of Otago	C
Brown	Dylan	The University of Auckland	S
Canela	Victor	The University of Auckland	C
Chai	Shijie	University of Otago	
Chakraborti	Taparabata	University of Otago	

Chan	Andrew	The University of Auckland	
Chen	Wan-Ting	The University of Auckland	C
Chen	Hao	The University of Auckland	
Cink	Ruth	Auckland University of Technology	
Clarke	James	The University of Auckland	
Cormack	Maddy	University of Otago	S
Cosme	Jayson	Massey University	C, S
Dillon	Owen	The University of Auckland	
Dosado	Aubrey Gabasa	The University of Auckland	S
Fernandez-Gonzalvo	Xavier	University of Otago	C, S
Fersterer	Petra	University of Otago	
Fisher	Ewan	The University of Auckland	
Goh	Hwan	The University of Auckland	S
Gulley	Anton	The University of Auckland	
Guo	Rachel	The University of Auckland	
Gutiérrez-Jáuregui	Ricardo	The University of Auckland	C
Haase	Thomas	The University of Auckland	
Hensley	Noah	University of Otago	
Hitchman	Sam	The University of Auckland	
Hong	Fan	University of Otago	
Honney	Claire	The University of Auckland	
Hope	James	The University of Auckland	
Hosking	Peter	The University of Auckland	
Hsieh	Pei-Huan (Sally)	The University of Auckland	
Hyndman	Adam	The University of Auckland	
Jeszenszki	Peter	Massey University	S
Johnson	Jami	The University of Auckland	C
Jull	Harrisson	University of Waikato	S
Kang	Hong	The University of Auckland	C
Kaur	Harpreet	University of Waikato	
King	Gavin	University of Otago	
Kumari	Madhuri	University of Otago	C
Lee	Lia	The University of Auckland	
Loveday	James	The University of Auckland	S
Martines-Gasoni	Rodrigo	University of Canterbury	C
Masson	Stuart	The University of Auckland	
Mautner	Ira	The University of Auckland	
McDonald	Rob	University of Otago	
McPhail	Vivian	The University of Auckland	S
Mesbah	Rassoul	University of Otago	
Mikhisor	Maria	University of Otago	C
Mo	Zonglai	The University of Auckland	
Neiman	Alex	University of Canterbury	
Nemet	Nikolett	The University of Auckland	
Nielsen	Alexander	The University of Auckland	S
Novikova	Nina	The University of Auckland	
Oh	Sue-Ann	University of Otago	
Onyema	Chikezie	University of Canterbury	
Otupiri	Robert	The University of Auckland	S
Ou	Rachel (Fang)	The University of Auckland	
Reynolds	Luke	University of Otago	S
Rooney	Jeremy	University of Otago	
Ruddell	Samuel	The University of Auckland	C
Sales	Ruth	University of Otago	S
Savoie	Maxime	University of Canterbury	
Sawyer	Bianca	University of Otago	S
Sayson	Noel	The University of Auckland	
Scott	Jonty	University of Canterbury	
Shamailov	Sophie	Massey University	C
Solis	Daniel	University of Otago	

PhD Students continued

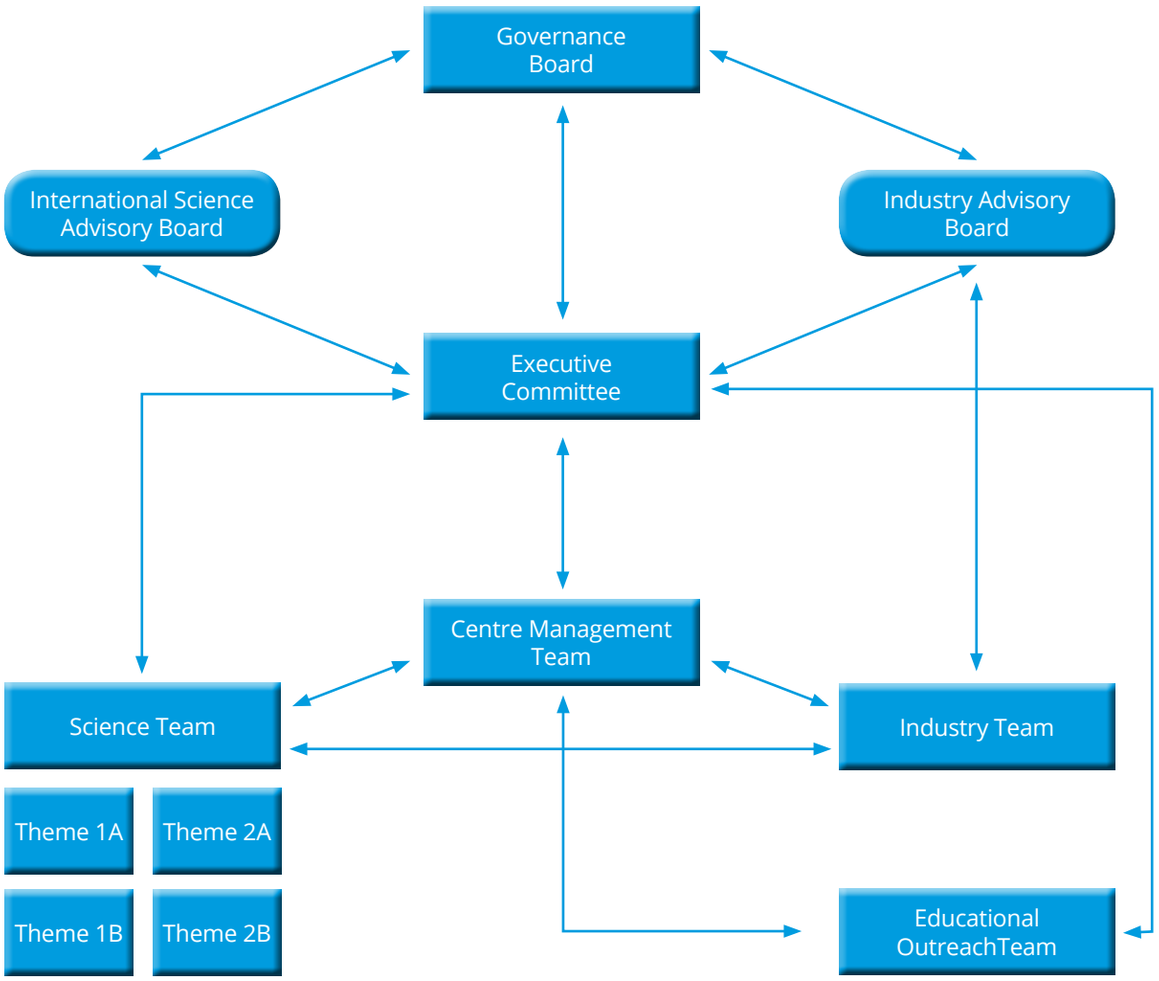
Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Sun	Jason	University of Waikato	
Sutton	Joshua	University of Otago	
Symes	Luke	University of Otago	
Tesana	Siriluck	University of Canterbury	
Thomas	Ryan	University of Otago	C
Thompson	Sarah	The University of Auckland	C
Thorn	Karen	Victoria University of Wellington	
Trainor	Luke	University of Otago	
Urbanska	Magdalena	The University of Auckland	S
Vargas	Matheus	The University of Auckland	
Vogt	Dominik	The University of Auckland	
Wang	Yadong	The University of Auckland	S
Wang	Qing	The University of Auckland	
Wang	Xindi (Andy)	The University of Auckland	
Webb	Karen	The University of Auckland	C
Whitby	Reece	The University of Auckland	C
White	Donald	The University of Auckland	C
Williamson	Lewis	University of Otago	C
Ye	Piao (Tracy)	The University of Auckland	
Zhou	Huihua	The University of Auckland	S

Other Research Degree Students

Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Agineray	Heiana	The University of Auckland	C
Airey	Margaux	The University of Auckland	C
Arul	Rakesh	The University of Auckland	C
Bi	Toby	The University of Auckland	C
Cawte	Michael	University of Otago	S
Chilcott	Matthew	University of Otago	
Chisholm	Craig	University of Otago	
Cowdell	Carolyn	University of Otago	C
Cullen	Sarah	The University of Auckland	C
Djorovic	Aleksa	Victoria Uni. of Wellington	
Elliott	Alex	The University of Auckland	S
Everts	Jonathan	University of Otago	C
Fernandes	Kevin	The University of Auckland	S
Gendler	Naomi	The University of Auckland	C
Hari	Neelam	The University of Auckland	C
Hendry	Ian	The University of Auckland	C
Hoang	Chong	The University of Auckland	
Hobbs	Rhys	University of Otago	S
Jain	Chetna	The University of Auckland	C
Lee-Hand	Jeremy	University of Otago	
McLeod	Tarentaise	University of Otago	
Mitchell	Nikolas	University of Otago	C
Pamplin	Adam	University of Canterbury	C
Pham	Hoan	The University of Auckland	
Rakonjac	Jelena	University of Otago	
Shi	Scarlett	The University of Auckland	
Steele	Rock	The University of Auckland	
Tang	Stanley	The University of Auckland	
Wiseman	Henry	The University of Auckland	
Wofgramm-Russell	Vincent	The University of Auckland	

ORGANIZATIONAL AND COMMITTEE STRUCTURE OF THE DODD-WALLS CENTRE

The DWC is organized into four research themes, two engagement teams (Educational and Industry) and a Centre management team. Three boards (governance, science advisory and industry advisory) support the DWC in achieving its strategic goals.



Committee and Theme Membership

Governance Board

Independent Chair	Garth Carnaby	G.A. Carnaby Associates Ltd
DVC Research Host Institution	Richard Blaikie	University of Otago
DVC Research Partner Institution	Jim Metson	The University of Auckland
PVC Sciences (Director's line manager)	Richard Barker	University of Otago
Independent Director	Di McCarthy	DCM Solutions Ltd
Independent Director	Charlotte Walshe	Jade Software Ltd
Independent Director	Ian Taylor	Animation Research Ltd
Director *(ex officio)*	David Hutchinson	University of Otago
Deputy Director *(ex officio)*	Neil Broderick	The University of Auckland
Programme Manager *(ex officio)*	Peggy Tompkins	University of Otago
Secretary	Diana Evans	University of Otago

Executive Committee

Director	David Hutchinson (Chair)	Otago
Deputy-Director	Neil Broderick	Auckland
Principal Investigator	Michael Albert	Otago
Principal Investigator	Blair Blakie	Otago
Principal Investigator	Maarten Hoogerland	Auckland
Principal Investigator	Harald Schwefel	Otago
Principal Investigator	Frédérique Vanholsbeeck	Auckland
Principal Investigator	Cather Simpson	Auckland
Principal Investigator	Stéphane Coen	Auckland
Principal Investigator	Jon-Paul Wells	Canterbury
Industry Team Leader *(ex officio)*	John Harvey	Auckland
Programme Manager *(ex officio)*	Peggy Tompkins	Otago
Secretary	Diana Evans	Otago

Industry Advisory Board

Dr Simon Poole	Finisar Australia Pty Ltd	Chair

Education Outreach Team

Principal Investigator	Bernd Krauskopf	Auckland
Principal Investigator	Kasper van Wijk	Auckland
Director	David Hutchinson	Otago
Education Manager	Craig Grant (Chair)	Otago Museum
Director of Otago Museum	Ian Griffin	Otago Museum
Outreach Co-ordinator	Andy Wang	Auckland
Secretary	Anita Foster	Otago

Dodd-Walls Centre Management Team

Programme Manager	Peggy Tompkins	Otago
Director	David Hutchinson	Otago
Deputy Director	Neil Broderick	Auckland
Administrator and PA to Director	Diana Evans	Otago
Administrator	Premika Sirisena	Auckland
Administrator	Anita Foster	Otago

International Science Advisory Board

Professor Allister Ferguson	University of Strathclyde, Scotland
Professor Bill Phillips	Joint Quantum Institute, U.S.A.
Professor Artur Ekert	Centre for Quantum Technologies, Singapore
Professor Ian Walmsley	University of Oxford, England
Professor Ursula Keller	Institute of Quantum Electronics, Switzerland

Industry Team

Industry Team Leader	John Harvey	Auckland
Director	David Hutchinson	Otago
Deputy Director	Neil Broderick	Auckland
Principal Investigator	Mikkel Andersen	Otago
Associate Investigator	Justin Hodgkiss	Victoria
Principal Investigator	Frédérique Vanholsbeeck	Auckland
Industry Manager	Luke Taylor	Otago
Programme Manager	Peggy Tompkins	Otago
Secretary	Premika Sirisena	Auckland

Science Team

Deputy Director	Neil Broderick	Auckland
Director	Nominee: Blair Blakie	Otago
Theme Leader (1a)	Jon-Paul Wells	Canterbury
Theme Leader (1b)	Neil Broderick	Auckland
Theme Leader (2a)	Niels Kjærgaard	Otago
Theme Leader (2b)	Jevon Longdell	Otago
Industry Team Leader *(ex officio)*	John Harvey	Auckland
Programme Manager	Peggy Tompkins	Otago
Secretary	Diana Evans	Otago

Theme 1a – Photonic Sensors and Imaging (PSI)

Professor Jon-Paul Wells	THEME LEADER, Canterbury, Physics and Astronomy
Dr Baptiste Auguié	Victoria, Physics
Professor Richard Blaikie	Otago, Physics
Dr Cameron Craigie	AgResearch Ltd
Dr Marlon dos Reis	AgResearch Ltd
Dr Vladimir Golovko	Canterbury, Chemistry
Professor Keith Gordon	Otago, Chemistry
Dr Cushla McGoverin	Auckland, Physics
Professor John Harvey	Auckland, Physics
Associate Professor Justin Hodgkiss	Victoria, Chemical and Physical Sciences
Professor Jari Kaipio	Auckland, Maths
Associate Professor Rainer Leonhardt	Auckland, Physics
Professor Eric Le Ru	Victoria, Physics
Associate Professor Jevon Longdell	Otago, Physics
Associate Professor Rainer Künnemeyer	Waikato, Engineering
Associate Professor Brendan McCane	Otago, Computer Science
Professor Roger Reeves	Canterbury, Physics & Astronomy
Professor Mike Reid	Canterbury, Physics & Astronomy
Dr Harald Schwefel	Otago, Physics
Associate Professor Kasper Van Wijk	Auckland, Physics
Dr Frédérique Vanholsbeeck	Auckland, Physics
Professor Peter Xu	Auckland, Mechanical Engineering

Theme 1b – Photonic Sources and Components (PSC)

Professor Neil Broderick	THEME LEADER, Auckland, Physics
Associate Professor Stéphane Coen	Auckland, Physics
Dr Miro Erkintalo	Auckland, Physics
Professor Justin Hodgkiss	Victoria, Chemical and Physical Sciences
Dr Jianyong Jin	Auckland, Chemistry
Professor Bernd Krauskopf	Auckland, Mathematics
Associate Professor Rainer Leonhardt	Auckland, Physics
Associate Professor Stuart Murdoch	Auckland, Physics
Dr Harald Schwefel	Otago, Physics
Associate Professor Geoff Waterhouse	Auckland, Chemistry

Theme 2a – Quantum Fluids and Gases (QFG)

Associate Professor Niels Kjærgaard	THEME LEADER, Otago, Physics
Dr Danny Baillie	Otago, Physics
Emeritus Professor Rob Ballagh	Otago, Physics
Professor Blair Blakie	Otago, Physics
Dr Ashton Bradley	Otago, Physics
Professor Joachim Brand	Massey, N.Z. Institute for Advanced Study
Professor Howard Carmichael	Auckland, Physics
Dr Amita Deb	Otago, Physics
Dr Maarten Hoogerland	Auckland, Physics
Professor David Hutchinson	Otago, Physics
Associate Professor Scott Parkins	Auckland, Physics
Professor Ulrich Zülicke	Victoria, Chemical and Physical Sciences

Theme 2b – Quantum Manipulation and Information (QMI)

Dr Harald Schwefel	THEME LEADER, Otago, Physics
Professor Michael Albert	Otago, Computer Science
Dr Mikkel Andersen	Otago, Physics
Professor Joachim Brand	Massey, NZ Institute for Advanced Study
Dr Vladimir Bubanja	Callaghan Innovation
Professor Howard Carmichael	Auckland, Physics
Dr Maarten Hoogerland	Auckland, Physics
Professor David Hutchinson	Otago, Physics
Associate Professor Jevon Longdell	Otago, Physics
Associate Professor Scott Parkins	Auckland, Physics
Professor Mike Reid	Canterbury, Physics and Astronomy
Professor Jon-Paul Wells	Canterbury, Physics and Astronomy

STRATEGIC OUTCOMES

The research plan of the Dodd-Walls Centre and our strategic initiatives will deliver results in six key outcome areas as follows:

INCREASED SCIENTIFIC IMPACT

- Foster cutting-edge translational research by collaboration across different areas of research
- Establish a pipeline of new research to scientific and industrial communities
- Establish New Zealand as a hub of international conferences and events
- Raise the international profile of the Dodd-Walls Centre as a world-class research centre

ENHANCED ECONOMIC OUTPUT

- New start-up businesses with support from external capital
- Foster initiatives with established New Zealand enterprises
- Attract investment from overseas multi-national corporations

STRONGER WORKFORCE

- Build expertise in research translation to commercialisation
- Build a pool of highly trained individuals with interest in high-tech and other skilled jobs
- Link the pool of highly trained individuals to companies in need of these skills

BETTER CAREERS

- Foster skills that enable a variety of career options for students and staff
- Enhance career development through opportunities for leadership within the Dodd-Walls Centre
- Address barriers to participation or advancement related to gender and diversity

IMPROVED DECISION MAKING

- Offer advice on matters of scientific or technological importance to government
- Use and share best practice governance and management for research centres
- Engage with government agencies about performance and impact
- Use performance reports to demonstrate how outcomes will be achieved

IMPROVED SCIENTIFIC LITERACY

- Educational outreach programmes established or augmented through museums and in rural areas
- Programmes enhance the experience of learning about science, encouraging further participation by students, teachers, whanau and the general public
- Scientific educational materials generated as part of the programmes is available to teachers

VALUE CREATION IN THE DODD-WALLS CENTRE

The Dodd-Walls Centre's research themes and management teams are linked and resourced such that the capital resources effectively support activities and produce outputs that over time are delivering impact and achieving strategic outcomes. The Dodd-Walls Centre's value chain is illustrated here:

2017 PEER-REVIEWED JOURNAL PUBLICATIONS

AUTHORS*	TITLE	JOURNAL
Al Qahtani, H. S.; Metha, G. F.; Walsh, R. B.; **Golovko, V. B.**; Andersson, G. G.; Nakayama, T.	Aggregation behavior of ligand-protected Au_9 clusters Au_9 clusters on sputtered atomic layer deposition TiO_2	*The Journal of Physical Chemistry* C **121**, 10781–10789 (2017)
Alvino, J. F.; Bennett, T.; Kler, R.; Hudson, R. J.; Aupoil, J.; Nann, T.; G**olovko, V. B.**; Andersson, G. G.; Metha, G. F.	Apparatus for the investigation of high-temperature, high-pressure gas-phase heterogeneous catalytic and photo-catalytic materials	*Review of Scientific Instruments* **88**, 54101 (2017)
Anderson, M.; **Wang, Y.; Leo, F.; Coen, S.; Erkintalo, M.; Murdoch, S. G.**	Coexistence of multiple nonlinear states in a tristable passive Kerr Resonator	*Physical Review X* **7**, 31031 (2017)
Ayet, A.; **Brand, J.**	The single-particle density matrix of a quantum bright soliton from the coordinate Bethe ansatz	*Journal of Statistical Mechanics: Theory and Experiment* **2017**, 23103 (2017)
Baillie, D.; Wilson, R.M.; **Blakie, P.B.**	Collective excitations of self-bound droplets of a dipolar quantum fluid	*Physical Review Letters* **119**, 255302 (2017)
Bourges, A.; **Blakie, P. B.**	Different growth rates for spin and superfluid order in a quenched spinor condensate	*Physical Review A* **95**, 23616 (2017)
Barland, S.; **Coen, S.; Erkintalo, M.**; Giudici, M.; Javaloyes, J.; **Murdoch, S.**	Temporal localized structures in optical resonators	*Advances in Physics: X* **2**, 496–517 (2017)
Calleja, R.; Humphries, A.; **Krauskopf, B.**	Resonance phenomena in a scalar delay differential equation with two state-dependent delays	*SIAM Journal on Applied Dynamical Systems* **16**, 1474–1513 (2017)
Cherny, A. Y.; Caux, J-S.; **Brand, J.**	Landau instability and mobility edges of the interacting one-dimensional Bose gas in weak random potentials	*Journal of Physics B: Atomic, Molecular and Optical Physics 51*, 15301 (2017)
Cosme, J. G.; Andersen, M. F.; Brand, J.	Interaction blockade for bosons in an asymmetric double well	*Physical Review A* **96**, 13616 (2017)
Creaser, J.; **Krauskopf, B.**; Osinga, H.	Finding first foliation tangencies in the Lorenz system	*SIAM Journal on Applied Dynamical Systems* **16**, 2127–2164 (2017)
De Chiara, G.; **Kjærgaard, N.**; Mathey, L.; Windpassinger, P.	20 years of Bose–Einstein condensates: current trends and applications of ultracold quantum gases	*Journal of Modern Optics* **63**, 1743–1743 (2017)
Everitt, P. J.; Sooriyabandara, M. A.; Guasoni, M.; Wigley, P. B.; Wei, C. H.; McDonald, G. D.; Hardman, K. S.; Manju, P.; Close, J. D.; Kuhn, C. C. N.; **Szigeti, S. S.**; Kivshar, Y. S.; Robins, N. P.	Observation of a modulational instability in Bose-Einstein condensates	*Physical Review A 96*, 41601 (2017)
Fialko, O; Opanchuk, B; Sidorov, A I; Drummond, P D; **Brand, J**	The universe on a table top: engineering quantum decay of a relativistic scalar field from a metastable vacuum	*Journal of Physics B: Atomic, Molecular and Optical Physics* **50**, 24003 (2017)

AUTHORS*	TITLE	JOURNAL
Garbin, B.; Dolcemascolo, A.; Prati, F.; Javaloyes, J.; Tissoni, G.; Barland, S.	Refractory period of an excitable semiconductor laser with optical injection	*Physical Review E* **95**, 12214 (2017a)
Garbin, B.; Javaloyes, J.; Barland, S.; Tissoni, G.	Interactions and collisions of topological solitons in a semiconductor laser with optical injection and feedback	*Chaos: An Interdisciplinary Journal of Nonlinear Science* **27**, 114308 (2017b)
Garbin, B.; Wang, Y.; Murdoch, S. G.; Oppo, G-L.; **Coen, S.; Erkintalo, M.**	Experimental and numerical investigations of switching wave dynamics in a normally dispersive fibre ring resonator	*The European Physical Journal D* **71**, 240 (2017c)
Giraldo, A.; Krauskopf, B.; Osinga, H.	Saddle invariant objects and their global manifolds in a neighborhood of a homoclinic flip bifurcation of case B	*SIAM Journal on Applied Dynamical Systems* **16**, 640–686 (2017)
Gutiérrez-Jáuregui, R.; Pérez-Pascual, R.; Jáuregui, R.	Spin effects on the semiclassical trajectories of Dirac electrons	*Physical Review A* **96**, 52109 (2017)
Guo, R.; McGoverin, C.; Swift, S.; **Vanholsbeeck, F.**	A rapid and low-cost estimation of bacteria counts in solution using fluorescence spectroscopy	*Analytical and Bioanalytical Chemistry* **409**, 3959–3967 (2017)
Hansson, T.; **Leo, F.; Erkintalo, M.; Coen, S.**; Ricciardi, I.; De Rosa, M.; Wabnitz, S.	Singly resonant second-harmonic-generation frequency combs	*Physical Review A* **95**, 13805 (2017)
Hashemizadeh, I.; Tsang, D. C. W.; Ng, Y. H.; Wu, Z.; **Golovko, V.**; Yip, A. C. K.	Bio-mimicking TiO_2 architectures for enhanced photocatalytic activity under UV and visible light	*RSC Advances* **7**, 39098–39108 (2017)
Hurst, R. B.; Mayerbacher, M.; Gebauer, A.; Schreiber, K. U.; **Wells, J-P. R.**	High-accuracy absolute rotation rate measurements with a large ring laser gyro: establishing the scale factor	*Applied Optics* **56**, 1124–1130 (2017)
Horvath, M. S. J.; Thomas, R.; Tiesinga, E.; **Deb, A. B.; Kjærgaard, N.**	Above-threshold scattering about a Feshbach resonance for ultracold atoms in an optical collider	*Nature Communications* **8**, 452 (2017a)
Horvath, S. P.; Wells, J-P. R.; van der Meer, A. F. G.; **Reid, M. F.**	An infrared pump-probe measurement of the $Sm^{3+}\,^6H_{7/2}$ lifetime in $LiYF_4$	*Optical Materials* **66**, 8–11 (2017b)
Jaurigue, L.; **Krauskopf, B.**; Lüdge, K.	Multipulse dynamics of a passively mode-locked semiconductor laser with delayed optical feedback	*Chaos: An Interdisciplinary Journal of Nonlinear Science* **27**, 114301 (2017)
Johnson, J. L.; Shragge, J.; **van Wijk, K.**	Nonconfocal all-optical laser-ultrasound and photoacoustic imaging system for angle-dependent deep tissue imaging	*Journal of Biomedical Optics* **22**, 041014–41025 (2017)
Jull, H.; Ewart, P.; **Künnemeyer, R.**; Schaare, P.	Selective surface sintering using a laser-induced breakdown spectroscopy system	*Journal of Spectroscopy* **2017**, 14788541 (2017)
Kaur, H.; Künnemeyer, R.; McGlone, A.	Comparison of hand-held near infrared spectrophotometers for fruit dry matter assessment	*Journal of Near Infrared Spectroscopy* **25**, 267–277 (2017)
Keane, A.; **Krauskopf, B.**; Postlethwaite, C. M.	Climate models with delay differential equations	*Chaos: An Interdisciplinary Journal of Nonlinear Science* **27**, 114309 (2017)
Killeen, D. P.; Marshall, S. N.; Burgess, E. J.; **Gordon, K. C.**; Perry, N. B.	Raman spectroscopy of fish oil capsules: polyunsaturated fatty acid quantitation plus detection of ethyl esters and oxidation	*Journal of Agricultural and Food Chemistry* **65**, 3551–3558 (2017a)
Killeen, D. P.; Watkins, O. C.; Sansom, C. E.; Andersen, D. H.; **Gordon, K. C.**; Perry, N. B.	Fast sampling, analyses and chemometrics for plant breeding: bitter acids, xanthohumol and terpenes in lupulin glands of hops *(Humulus lupulus)*	*Phytochemical Analysis* **28**, 50–57 (2017b)
Kjærgaard, N.	Scattering atoms catch the *d* wave	*Physics* **10**, 123 (2017)

AUTHORS*	TITLE	JOURNAL
Krishnan, G.; Al Qahtani, H. S.; Li, J.; Yin, Y.; Eom, N.; **Golovko, V. B.**; Metha, G. F.; Andersson, G. G.	Investigation of ligand-stabilized gold clusters on defect-rich titania	*The Journal of Physical Chemistry C* **121**, 28007–28016 (2017)
Langbecker, M.; Noaman, M.; **Kjærgaard, N.**; Benabid, F.; Windpassinger, P.	Rydberg excitation of cold atoms inside a hollow-core fiber	*Physical Review A* **96**, 41402 (2017)
Lowe, B. J.; Smith, C. A.; **Fraser-Miller, S. J.**; Paterson, R. A.; Daroux, F.; Ngarimu-Cameron, R.; Ford, B.; **Gordon, K. C.**	Light-ageing characteristics of Māori textiles: colour, strength and molecular change	*Journal of Cultural Heritage* **24**, 60–68 (2017)
Mahjoubfar, A.; Churkin, D. V.; Barland, S.; **Broderick, N.**; Turitsyn, S. K.; Jalali, B.	Time stretch and its applications	*Nature Photonics* **11**, 341–351 (2017)
Martin, J. W.; **Nieuwoudt, M. K.; Vargas, M. J. T.**; Bodley, O. L. C.; Yohendiran, T. S.; Oosterbeek, R. N.; Williams, D. E.; **Simpson, M. C.**	Raman on a disc: high-quality Raman spectroscopy in an open channel on a centrifugal microfluidic disc	*Analyst* **142**, 1682–1688 (2017)
Masson, . J.; Barrett, M.D.; **Parkins, S.**	Cavity QED engineering of spin dynamics and squeezing in a spinor gas	*Physical Review Letters* **119**, 213601 (2017)
McNicoll, C.; Abu Bakar, F.; **Golovko, V.**; Kemmitt, T.	Hydrothermal synthesis of mixed phase blue titanium dioxide from oxalate stabilised sols	*International Journal of Nanotechnology* **14**, 265–275 (2017)
Nickless, E. M.; Holroyd, S. E.; Hamilton, G.; **Gordon, K. C.**; Wargent, J. J.	Analytical method development using FTIR-ATR and FT-Raman spectroscopy to assay fructose, sucrose, glucose and dihydroxyacetone, in *Leptospermum scoparium* nectar	*Vibrational Spectroscopy* **84**, 38–43 (2017)
Nieuwoudt, .M. K.; Holroyd, S. E.; **McGoverin, C. M.; Simpson, M. C.**; Williams, D. E.	Screening for adulterants in liquid milk using a portable Raman miniature spectrometer with immersion probe	*Applied Spectroscopy* **71**, 308–312 (2017)
Nolan, S. P.; **Szigeti, S. S.**; Haine, S. A.	Optimal and robust quantum metrology using interaction-based readouts	*Physical Review Letters* **119**, 193601 (2017)
Novakovic, D.; Saarinen, J.; Rojalin, T.; Antikainen, O.; **Fraser-Miller, S. J.**; Laaksonen, T.; Peltonen, L.; Isomäki, A.; Strachan, C. J.	Multimodal nonlinear optical imaging for sensitive detection of multiple pharmaceutical solid-state forms and surface transformations	*Analytical Chemistry* **89**, 11460–11467 (2017)
Oosterbeek, R. N.; **Ashforth, S.**; Bodley, O.; **Simpson, M. C.**	Ablation threshold dependence on incident wavelength during ultrashort pulsed laser ablation	*International Journal of Nanotechnology* **14**, 313–322 (2017)
Ou, F.; McGoverin, C.; Swift, S.; Vanholsbeeck, F.	Absolute bacterial cell enumeration using flow cytometry	*Journal of Applied Microbiology* **123**, 464–477 (2017)
Parkins, S.	Optical quantum logic at the ultimate limit	*Physics* **9**, 129
Pasquazi, A.; Peccianti, M.; Razzari, L.; Moss, D. J.; **Coen, S.; Erkintalo, M.**; Chembo, Y. K.; Hansson, T.; Wabnitz, S.; Del'Haye, P.; Xue, Xi.; Weiner, A. M.; Morandotti, R.	Micro-combs: a novel generation of optical sources	*Physics Reports* **729**, 1–81 (2017)
Peebles, B. A.; **Gordon, K. C.**; Smith, A. M.; Smith, G. P. S.	First record of carotenoid pigments and indications of unusual shell structure in chiton valves	*Journal of Molluscan Studies* **83**, 476–480 (2017)

AUTHORS*	TITLE	JOURNAL
Rojalin, T.; Kurki, L.; Laaksonen, T.; Viitala, T.; Kostamovaara, J.; **Gordon, K. C.**; Galvis, L.; Wachsmann-Hogiu, S.; Strachan, C. J.; Yliperttula, M.	Fluorescence-suppressed time-resolved Raman spectroscopy of pharmaceuticals using complementary metal-oxide semiconductor (CMOS) single-photon avalanche diode (SPAD) detector	*Analytical and Bioanalytical Chemistry* **408**, 761–774 (2017)
Rooney, J. S.; Tarling, M. S.; Smith, S. A.F.; **Gordon, K. C.**	Submicron Raman spectroscopy mapping of serpentinite fault rocks	*Journal of Raman Spectroscopy* **49**, 279–286 (2017)
Ruddell, S. K.; Webb, K. E.; Herrera, I.; Parkins, A. S.; Hoogerland, M. D.	Collective strong coupling of cold atoms to an all-fiber ring cavity	*Optica* **4**, 576–579 (2017)
Sahni, M. O.; Trebaol, S.; Bramerie, L.; Joindot, M.; Dúill, S. P. Ó; **Murdoch, S. G.**; Barry, L. P.; Besnard, P.	Frequency noise reduction performance of a feed-forward heterodyne technique: application to an actively mode-locked laser diode	*Optics Letters* **42**, 4000–4003 (2017)
Saarinen, J.; Sözeri, E.; **Fraser-Miller, S. J.**; Peltonen, L.; Santos, H. A.; Isomäki, A.; Strachan, C. J.	Insights into Caco-2 cell culture structure using coherent anti-Stokes Raman scattering (CARS) microscopy	*International Journal of Pharmaceutics* **523**, 270–280 (2017)
Sawyer, B. J.; Horvath, M. S. J.; Tiesinga, E.; Deb, A. B.; Kjærgaard, N.	Dispersive optical detection of magnetic Feshbach resonances in ultracold gases	*Physical Review A* **96**, 22705 (2017)
Sedlmeir, F.; Foreman, M. R.; Vogl, U.;Zeltner, R.; Schunk, G.; Strekalov, D. V.; Marquardt, C.; Leuchs, G.; **Schwefel, H. G. L.**	Polarization-selective out-coupling of whispering-gallery modes	*Physical Review Applied* **7**, 24029 (2017)
Shahlori, R.; **Waterhouse, G. I. N.**; Darwish, T. A.; Nelson, A. R. J.; McGillivray, D. J.	Counting crystal clusters – a neutron reflectometry study of calcium phosphate nano-cluster adsorption at the air–liquid interface	*CrystEngComm* **19**, 5716–5720 (2017)
Shahlori, R.; **Waterhouse, G. I. N.**; Nelson, A. R.J.; McGillivray, D. J.	In-situ ellipsometric study of calcium phosphate biomineralisation on organic thin films	*International Journal of Nanotechnology* **14**, 375–384 (2017)
Shamailov, S. S.; Brand, J.	Corrigendum: Dark-soliton-like excitations in the Yang–Gaudin gas of attractively interacting fermions (2016 New J. Phys. 18 075004 [http://doi.org/10.1088/1367-2630/18/7/075004])	*New Journal of Physics* **19**, 119502 (2017)
Shang, L.; Liang, Y.; Li, M.; **Waterhouse, G.**; Tang, P.; Ma, D.; Wu, L-Z.; Tung, C-H.; Zhang, T.	"Naked" magnetically recyclable mesoporous Au-*y*-Fe_2O_3 nanocrystal clusters: a highly integrated catalyst system	*Advanced Functional Materials* **27**, 1606215 (2017)
Shi, R.; Cao, Y.; Bao, Y.; Zhao, Y.; **Waterhouse, G. I. N.**; Fang, Z.; Wu, L-Z.; Tung, C-H.; Yin, Y.; Zhang, T.	Self-Assembled Au/CdSe nanocrystal clusters for plasmon-mediated photocatalytic hydrogen evolution	*Advanced Materials* **29**, 1700803 (2017)
Shi, R.; Li, Z.; Yu, H.; Shang, L.; Zhou, C.; **Waterhouse, G. I. N.**; Wu, L-Z.; Zhang, T.	Effect of nitrogen doping level on the performance of N-doped carbon quantum dot/TiO_2 composites for photocatalytic hydrogen evolution	*ChemSusChem* **10**, 4650–4656 (2017)
Shi, R.; **Waterhouse, G.**; Zhang, T.	Recent progress in photocatalytic CO_2 reduction over perovskite oxides	*Solar Rapid Research Letters* **1**, 1700126 (2017)
Shitara, N.; Bir, S.; Blakie, P. B.	Domain percolation in a quenched ferromagnetic spinor condensate	*New Journal of Physics* **19**, 95003 (2017)
Smith, G. P. S.; Holroyd, S. E.; Reid, D. C. W.; **Gordon, K. C.**	Raman imaging processed cheese and its components: Raman imaging processed cheese and its components	*Journal of Raman Spectroscopy* **48**, 374–383 (2017a)

AUTHORS*	TITLE	JOURNAL
Smith, G. P. S.; Huff, G. S.; **Gordon, K. C.**	Investigating crystallinity using low-frequency Raman spectroscopy: applications in pharmaceutical analysis	*Spectroscopy* **31**, 42–50 (2017b)
Smith, G. P. S.; McLaughlin, A. W.; Clarkson, A. N.; **Gordon, K. C.**; Walker, G. F.	Raman microscopic imaging of electrospun fibers made from a polycaprolactone and polyethylene oxide blend	*Vibrational Spectroscopy* ***92***, 27–34 (2017c)
Sutherland, R.; Townend, J.; Toy, V.; Upton, P.; Coussens, J.; Allen, M.; Baratin, L-M.; Barth, N.; Becroft, L.; Boese, C.; Boles, A.; Bou lton, C.; **Broderick, N. G. R.**; *et al.*	Extreme hydrothermal conditions at an active plate-bounding fault	*Nature* **546**, 137–140 (2017)
Su, S-W.; Liu, I-K.; Gou, S-C.; Liao, R.; **Fialko, O.; Brand, J.**	Hidden long-range order in a spin-orbit-coupled two-dimensional Bose gas	*Physical Review A* **95**, 53629 (2017)
Symes, L. M.; Blakie, P. B.	Solving the spin-2 Gross-Pitaevskii equation using exact nonlinear dynamics and symplectic composition	*Physical Review E* **95**, 13311 (2017a)
Symes, L. M.; Blakie, P. B.	Nematic ordering dynamics of an antiferromagnetic spin-1 condensate	*Physical Review A* **96**, 13602 (2017b)
Terrien, S.; Krauskopf, B.; Broderick, N.	Bifurcation analysis of the Yamada Model for a pulsing semiconductor laser with saturable absorber and delayed optical feedback	*SIAM Journal on Applied Dynamical Systems* **16**, 771–801 (2017a)
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