DODD-WALLS CENTRE
FOR PHOTONIC AND QUANTUM TECHNOLOGIES

2019
ANNUAL REPORT

DODD-WALLS CENTRE
for Photonic and Quantum Technologies

Cover image: Taking DWC research to the Pacific Islands – school children in Lautoka, Fiji

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GIFTING OF A MĀORI NAME

The Dodd-Walls Centre has been gifted the Māori name, Te Whai Ao. This represents the first beams of phosphorescent light that break through the darkness of the night and herald the coming of a new day. This saying is part of the Māori creation story, “Mai te Kore, ki te Pō, ki te Whai Ao, ki te Ao Mārama”, “From the nothingness to the dark night, to the glimmer of light, to the bright light of day”. Among other things, the phrase is used to talk about learning; with someone being in a state of te Kore when they have absolutely no knowledge of a particular subject, right through the stages of learning, te Pō, to the initial early grasp of the concept, te Whai Ao, to enlightenment, te Ao Mārama.

The name Te Whai Ao encapsulates our research, which is all about light and what we can learn and do with light. It also encapsulates what is most important about our Centre, the growth of our people. The primary outcome of our Centre is in the ability to guide our students and all our staff, young or old, along the path to enlightenment. As you will read in our report, the Centre has 135 postgraduate students in 2019 with 34 graduating during the year. Our graduates are amongst the most highly skilled, numerate, computer (programming) literate, articulate people in the country and are actively sought by NZ’s thriving knowledge-based companies. In this report you can read about some of alumni and the role of the Dodd-Walls Centre in their journey to date, you can also read contributions from some of our current students.

DODD-WALLS CENTRE
for Photonic and Quantum Technologies
Te Whai Ao

INTRODUCTION

New Zealand's Dodd-Walls Centre is a national Centre of Research Excellence involving six 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

- 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, Victoria University of Wellington, and The University of Waikato

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

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

Host University

REPORT FROM THE CHAIR

In just six years since it was first recognised by the TEC in 2014 as a Centre of Research Excellence in New Zealand, the Dodd-Walls Centre has become a significant contributor to global knowledge of photonics and quantum optics. There had been a strong legacy of active internationally important research in these fields by NZ based researchers starting with Professors Jack Dodds and Dan Walls themselves, but also continued by their students and protégés. Today the Centre is training over 130 graduate students at any time, graduating 30 or more a year. Many, if not most, of these graduating students had jobs or further study lined up significantly prior to completing their degrees. These are amongst the most highly skilled, numerate, computer (programming) literate, articulate people in the country and are actively sought by NZ's thriving knowledge-based companies, and not just in the photonics sector. Our people are the fuel for the high technology engine of New Zealand. Their ability to have fulfilling, meaningful and financially rewarding careers in NZ is one of our most important outcomes.

We have chosen this year to use the annual report to celebrate our students with some stories from our students, written by them, about their pathways. We are also taking the opportunity to profile some of our alumni. The Centre has had another big year in terms of science contributions. Our research spans the gamut from fundamental physics to technology development carried out in a research environment which celebrates entrepreneurial achievement. This year's breakthroughs range from discovering how to much more easily change the frequency of laser light in a device, through how to transport quantum information from one place to another using optical fibres, to unravelling some of the very curious properties of quantum superfluids. Our applied platforms are active in fields of immediate importance to New Zealand with projects spanning bull sperm sorting, locating blossoms on kiwifruit, and improved diagnosis of eye disease, to improved analysis of earthquake vibrations

The TEC funding we receive is used not only to support the research, but is also applied to leverage various public outcomes from the research be this educational outreach activity or engagement with industry. We have in place an array of educational outreach programmes. We help to run marae-based Science Wānanga to educate students and provide our own staff and students with an immersive cultural experience, provide rural science outreach through Lab in a Box, have helped create an award-winning science centre and travelling museum exhibition, to name but a few initiatives. Our outreach has continued its extension to the Chatham Islands and out into the Pacific.

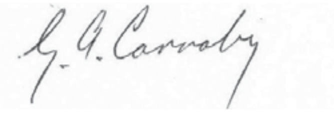
Isolated academics have few incentives to explore the commercial implications of their research. But within the CoRE we use the TEC funding to encourage entrepreneurial engagement with business. The Dodd-Walls Centre was first to create an Industry Advisory Board alongside our Science Advisory Board. Working with us produces results. This is because the DWC provides a clear point of call for harnessing the best team in New Zealand for anything to do with light, photonics and precision measurement. As well as working with established NZ industries, we are using the TEC funding to encourage entrepreneurship based on research within the Centre.

We have used the funding to create a grant pool for our researchers to develop new ideas with new collaborative ideas being given priority. We are connected with key industry players and our interactions with industry are meaningful and valuable. As well as working with established NZ industries, we are using the TEC funding to encourage entrepreneurship based on research within the Centre.

Two industry-related highlights for 2019 are:

- TechWeek Highlight Event in 2019 focussing on Professor Cather Simpson's journey of commercialisation with her Engender Spinout. This event was opened by Minister Woods, who congratulated us on being at the forefront of the science we do, and also took time to congratulate us about our carers fund, which lowers barriers for members of the DWC to engaging in career-furthering activities like conferences.
- We collaborated with Matū Fund to create a DWC specific commercialisation and ideation workshop.

Encouraging an entrepreneurial mind-set is something we encourage and support for our students and early career researchers. 2019 saw the first DWC-themed Return On Science Investment Committee meeting where several student members presented their research and gathered valuable career advice from some of the smartest independent minds in the country. We also curated a series of internships with the Prime Ministers Chief Science Advisors Office for these members to gain valuable insight into the intersection of science and policy at the highest level.



G.A. CARNABY | 9 MARCH 2020

REPORT FROM THE DIRECTOR

In this report we have chosen to cover a number of stories about our graduate students and their destinations after leaving us. In many ways these young people epitomise what the Centre is about. They are the talent we train, the future of our science, our industry and our society. We are rightly proud of them, proud of the wide range of transferable skills they acquire with us, and proud that New Zealand and worldwide businesses see their value and seek them out as employees. To quote Paul Bracewell, Managing Director of Wellington's *DOT loves data*, "We have found that PhD graduates from the [Dodd-Walls] Centre tend to be well-rounded team players who think about the practical aspects of their work. This enables them to create smart, pragmatic solutions for real world problems." We look forward to sending you more new employees soon Paul.

To have such good students, we have to be doing world-class, world leading research. The CoRE funding allows us to do this. It provides the security and stability that enables our researchers to take risks on longer term, high reward projects. This is reflected in the increase in the number of Centre publications in the highest impact journals like Science and Nature, and other more specialised journals. The increased collaboration that comes with the CoRE also leads to higher research impact and to further funding success. For example, in addition to the over $7.5M of external contracts that began in 2019, DWC researchers led five successful full Marsden bids, two Marsden Fast-Starts and four Smart Ideas projects from MBIE's Endeavour Fund, totalling more than $8.9M. DWC researchers were also AIs on two other Marsden contracts led from outside the Centre. This outstanding research track record allows us to retain our brightest students and attract top quality talent, as students and staff, from around the world.

Not only do the talented individuals we train through this research go out in to New Zealand's businesses, but they are encouraged to think about the commercialisation of their own ideas. We had eight new invention disclosures in 2019. Our industry team, with our new Business Development Officer, Shannon Scown, ran commercialisation workshops and numerous other activities. Highlights from the year would be Cather Simpson talking about her journey with her company, *Engender*, from inception to its acquisition which was a featured highlight of May's TechWeek Programme and was opened by Hon Dr Megan Woods, for whose continued support we are most grateful. In September we also continued our series highlighting the importance of emerging quantum technologies with very popular talks in Auckland and Christchurch by Jose Pozo, the Chief Technology Officer of the European Photonics Industries Consortium (EPIC) of which the DWC is a member. Furthermore, in November we launched the New Zealand Node of the Global Environmental Measurement and Monitoring (GEMM) Network – an initiative of the OSA and GSU to help improve data acquisition and monitoring technology to improve our understanding of climate change.

CoRE funding also allows us to look beyond our current horizons to the future through our education and outreach programmes, from Lab in a Box, to initiatives in the Pacific in partnership with *Far from Frozen* with the Otago Museum, supported by MFAT and MBIE's Curious Minds. A small selection of our education initiatives are captured in this report. I'd like here to thank Craig Grant, our Education Outreach Manager at the Otago Museum, and Andy Wang, our outreach coordinator in Auckland, for their sterling efforts coordinating all these activities.

Finally, the very existence of the Centre helps enable the serendipitous. A call from archaeologist, Leslie Van Gelder, led to a really rewarding collaboration looking at prehistoric cave art in the light it would have been seen in by the artists. Read more in the report, or go to Radio New Zealand's website. Leslie spoke with Jessie Mulligan on RNZ National's *Afternoons* on 16th May, which is the UNESCO International Day of Light (the national committee of which, coincidentally, I have chaired since its inauguration in 2018).

DAVID HUTCHINSON | 26 MARCH 2020

RESEARCH THEMES

THEME 1a:
Photonic Sensors and Imaging

Leader
Jon-Paul Wells, University of Canterbury

Lasers are amongst the most powerful tools of modern science. In this theme we use their extraordinary properties to see, hear, smell and feel far beyond the reach of basic human senses. When you fire a laser at an object there is a tremendous amount of information in the light that bounces back – but lasers can also see, without touching. We use different colours, pulses and powers of laser light to learn about the dynamics of the Earth itself, the structure and function of biological tissue and even test Einstein's theory of relativity.

Our expertise in interpreting the way that light interacts with matter has led to many unexpected yet 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 techniques for detecting eye disease, new methods for measuring the intensity of skin burns, force sensors for keyhole surgery and high resolution optical sensors to work in parallel with state-of-the-art X-ray scanners. We are working with geophysicists to measure earthquake vibrations and temperature deep within New Zealand's Alpine Fault and make measurements of Earth rotation that can contribute to the international time keeping service.

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 laser physics, spectroscopy and nonlinear optics – when light stops behaving according to the normal rules. We are able to exploit such nonlinear effects to create novel sensing and imaging technologies.

THEME 1b:
Photonic Sources and Components

Leader
Stéphane Coen, The University of Auckland

They say workers are only as good as their tools. This theme is about developing new and improved lasers, new optical materials, 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. The fundamental theories and numerical models that we develop are also used by top research groups across the world. We are world-renowned for our expertise in fibre lasers that are versatile, lightweight and cheap to produce. We develop these to be used as cutters, sorters and sensors for a wide variety of industrial and science applications. We are also well-known for our fundamental research in nonlinear optics and in nonlinear (micro) resonators. Here, we experimentally explore key new fundamental dynamics, devices, and materials that could in time revolutionise the internet and many other fields, such as optical frequency combs or photosensitive molecules.

THEME 2a:
Quantum Fluids and Gases

Leader
Maarten Hoogerland, University of Auckland

The quantum realm is one of the most advanced and untamed frontiers 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 portal to directly observe and interact with 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, superconductivity, and conditions just after the Big Bang. 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

Leader
Harald Schwefel, University of Otago

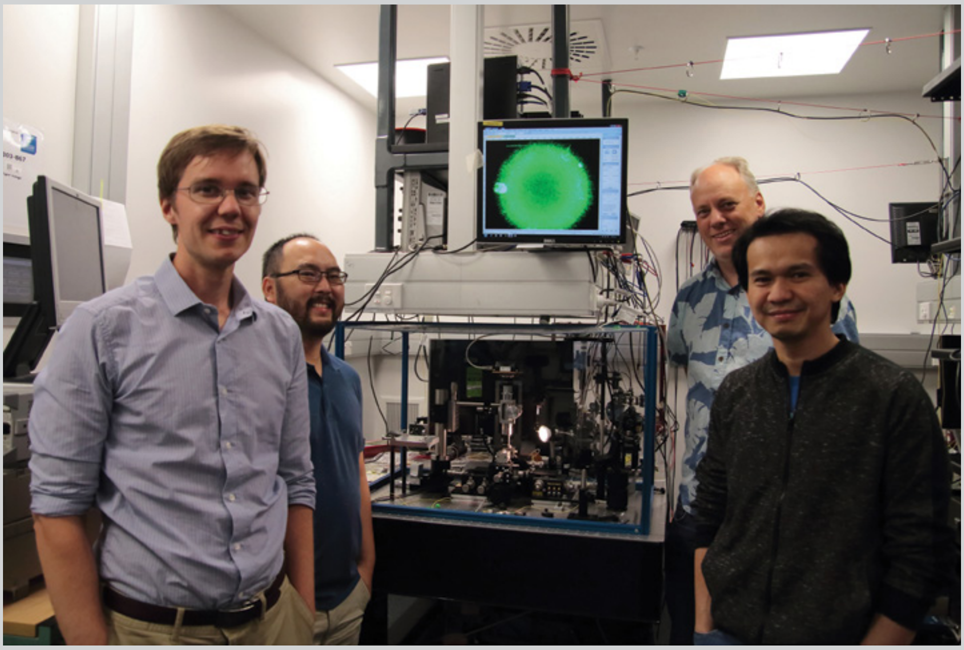
It is one thing to understand how the quantum world works yet it requires another level of precision and control to build reliable devices and systems that exploit quantum phenomena. This kind of 'quantum engineering' is the focus of this theme. Through precise observation and control of the interactions 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 lead the world in isolating and controlling 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.

A New Tool for the Information Age

An ingenious new device for changing the frequency of laser light could lead to new methods for diagnosing diseases and detecting methane and carbon dioxide in the air. This ground-breaking result is the fruition of many years of collaboration between Dodd-Walls Centre Principal Investigators Stuart Murdoch, Miro Erkintalo, and Stéphane Coen at the University of Auckland and Harald Schwefel at the University of Otago. Their work was recently published in the prestigious journal *Nature Photonics*.

Lasers are the primary tools of the information age. Every email and phone call is encoded into data and sent around the world using lasers. Lasers are used to detect diseases, chemicals, gases, pressure, vibration and force. They are used to perform surgery and for precision engineering. Each frequency or colour of laser light is like a different sized spanner suited to a different job. The problem is that some frequencies of laser light are missing from our toolbox. Frequencies in the mid-infrared, for example, are needed to detect many diseases and gases, but are very difficult to produce.



The research team in the laboratory (from left: Miro Erkintalo, Vincent Ng, Stuart Murdoch and Noel Sayson). Absent: Stéphane Coen.

The DWC team have created a simple, inexpensive and efficient technique for transforming laser light from one colour to another. This will fill some of the important gaps in the laser toolbox.

“At this stage we are focused on producing frequencies in the mid-infrared, which have very important uses,” says Miro. “The dream is to be able to produce any colour.”

It is very difficult to change the colour of laser light. You can change its brightness or direction but changing its colour is like changing its fundamental personality. It only happens under extremely intense conditions.

There are commercial devices available that achieve this, but they tend to be expensive and bulky. The new device developed by the DWC team is cheap, simple, and tiny. It centres on a disk of magnesium fluoride crystal called a microresonator, which is more than twenty times smaller than a New Zealand ten cent coin. When laser light is fed into this disk it gets trapped inside, building to an intensity that forces the light to change colour.

This recent breakthrough is the culmination of decades of pioneering research at The University of Auckland. In 2003 Dodd-Walls Principal Investigators John Harvey, Rainer Leonhardt, and Stéphane Coen discovered how to convert a single laser beam into sidebands of different colours using a special kind of optical fibre - a big breakthrough at the time. In 2010 Stuart Murdoch took the lead in building large loops of optical fibre where laser light could resonate and build in intensity. These fibre loops improved the efficiency of the process greatly and the Auckland team achieved several world record results. But when it came to practical applications these large loops required too much power to run and were unable to generate mid-infrared frequencies.

"THE COMMERCIAL POTENTIAL IS HUGE. NEXT, THE TEAM PLANS TO DEVELOP SPECIFIC APPLICATIONS LIKE SENSITIVE LOW COST MEDICAL DIAGNOSTIC TOOLS AND GAS DETECTORS WHICH COULD BE PRODUCED RIGHT HERE IN NEW ZEALAND AND EXPORTED AROUND THE WORLD."

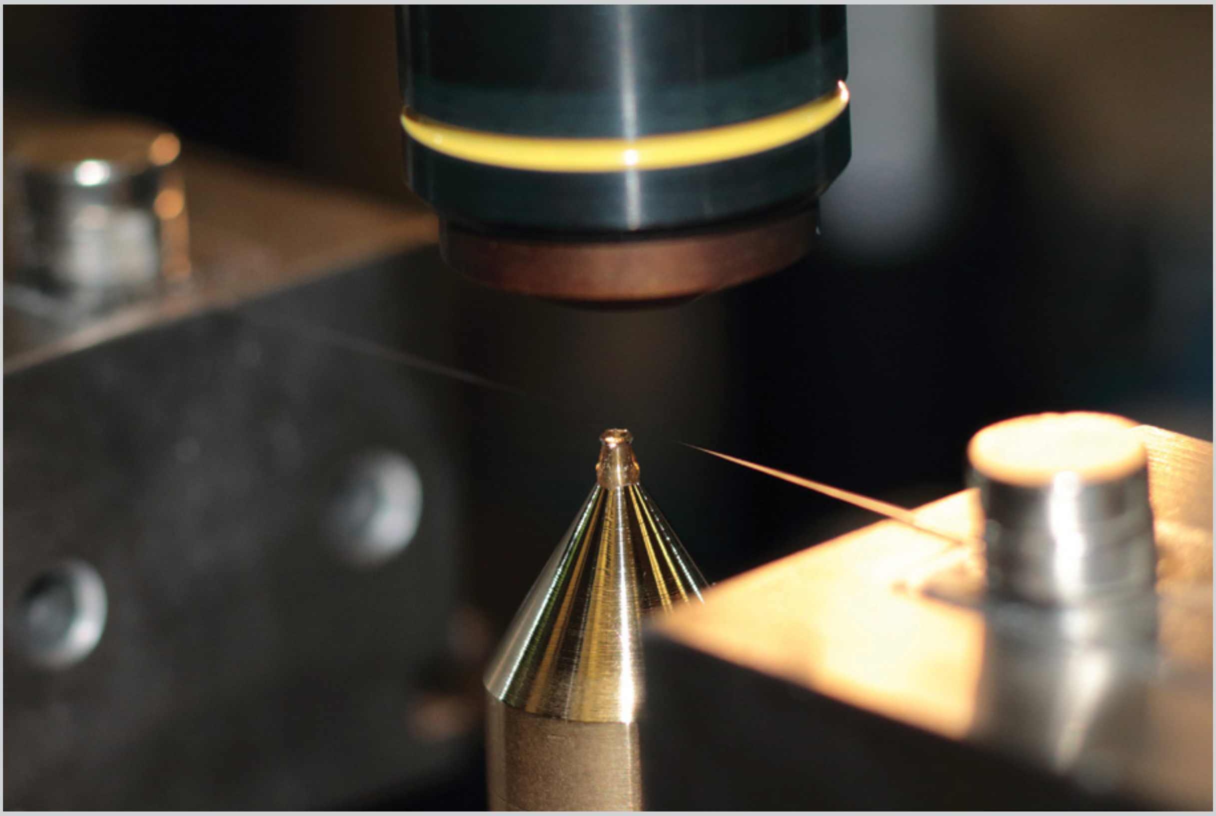
“Our magnesium fluoride microresonators have overcome all these issues,” Miro says. “They are very small and very efficient and allow for the generation of a much wider range of frequencies.”

The Auckland team first got seriously interested in microresonators around 2012. The international community was buzzing with the potential to use them to simultaneously generate many new colours of laser light – so-called optical frequency combs. But in the absence of a reliable theoretical model, they were struggling to describe the underlying physics. It was Stéphane and Miro who found the solution. They realised that the theoretical techniques they had developed for large-scale fibre loops could also work for microresonators. And indeed they did! Even though microresonators are much smaller the principles are the same. Their findings were an international hit, and their models were quickly adopted by numerous research groups around the world. Now their theories underpin many microresonator technologies.

The insight underlying the team's recent Nature Photonics paper came directly from Stuart's pioneering work with optical fibres a decade ago. But going from insight to laboratory realisation was no walk in the park. It took several years to set up the necessary experimental platforms to achieve the demonstration and Stuart has trained many students in the process. An essential contribution was also provided by Harald Schwefel, who joined the University of Otago in 2012 and brought his world-leading expertise in microresonator fabrication to New Zealand. It was a perfect match. With Stuart's masterful experimental work and Harald's microresonators, the team have delivered top results.

Now all those years of fundamental research are blossoming into world-changing applications. The commercial potential is huge. Next, the team plans to develop specific applications like sensitive low cost medical diagnostic tools and gas detectors which could be produced right here in New Zealand and exported around the world.

The project has given students invaluable skills in electronics, device development and computer modelling. Having the support of the Dodd-Walls Centre has been essential for funding equipment, providing students and creating a framework that makes collaboration easy and enjoyable.



The device developed by the team.

Physics Illuminating Culture and Heritage

At the University of Otago, a team of Dodd-Walls Centre physicists and product developers are helping to shed light on the lives of ancient people and how they created cave art. In collaboration with archaeologists, deer stalkers, a butcher and a craftsperson they have created modern lamps to mimic the flickering torch light that paleolithic cave artists worked by many thousands of years ago.

The project, made possible by Dodd-Walls Centre funding, illustrates how a little knowledge of Physics can enrich other fields of discovery. It shows the benefits of having industry experts and a product development lab to transform an idea into a robust product within a tight deadline.

At the centre of this collaboration is Leslie Van Gelder, a well-known American archaeologist, who lives in Glenorchy, near Queenstown. Leslie is a world-expert in cave-art and has worked in caves across Europe and Australia.

The ancient people of Europe used lamps made of animal fat to trek deep into caves and create images of horses, bison and reindeer. The flickering shadows on the curved cave walls gave them an illusion of volume and life and the colours appeared inky-rich and deep. But in the past few decades, open flames have been banned in heritage cave sites and replaced by LEDs.

"The flat grey and white light of the torches made with LEDs feels almost clinical and robs the animals of their warm colours and shadows," Leslie says.

A conversation with a cave guide in Europe gave Leslie the idea for creating new lamps to mimic the colour, flicker, and brightness of the ancient ones. This would give a more authentic experience of the caves and help to answer important research questions about how people moved through the caves and created the art.

An internet search led Leslie to the Dodd-Walls Centre.

"I wrote to the Director David Hutchinson and he replied straight away," she says. "I wasn't expecting it to be that easy!"

Leslie Van Gelder.

"THE FLAT GREY AND WHITE LIGHT OF THE TORCHES MADE WITH LEDS FEELS ALMOST CLINICAL AND ROBS THE ANIMALS OF THEIR WARM COLOURS AND SHADOWS."

Professor Hutchinson put Leslie in touch with Principal Investigator Harald Schwefel, a laser Physics expert at the University of Otago.

“I could see that it would be quite straight-forward and inexpensive for us to provide a solution,” says Harald. “I also thought I might get the chance to visit a prehistoric cave if I provide a lamp!”

Leslie sourced animal fat from a local deerstalker and a butcher to mimic the reindeer and bison tallow used in ancient times. She worked with a local sculptor to fashion a stone base to hold the fat. She presented these lamps to Harald and the Dodd-Walls team so they could create a modern equivalent.

“They asked me for a wish list of all the things I wanted the lamp to do,” Leslie explains. “It’s incredibly hard to find funding in the archaeology community,” Leslie says. “This was like having a fairy godfather.”

Harald brought in two PhD students as consultants and a summer student Timothy Marshall, who worked with the Dodd-Walls Centre Industry Manager, Luke Taylor. They worked in the Dodd-Walls Centre’s Development lab at the University of Otago – a unique facility set up by Luke to turn research ideas into early-prototype devices.

For Tim, working in this facility was the highlight of the project.

“The DWC Development Lab along with the electronics and physics workshops are such a valuable R&D resource,” Tim says. “We can just imagine something and then go and try it out. No planning meetings or bureaucracy. That’s quite rare around universities. I learnt so much from working with Luke. I would occasionally get lost in all the possibilities, but Luke cut through to streamline the process.”

The team discussing the lamps they developed (from left: Luke Taylor, Harald Schwefel, Timothy Marshall).

"THE PROJECT, MADE POSSIBLE BY DODD-WALLS CENTRE FUNDING, ILLUSTRATES HOW A LITTLE KNOWLEDGE OF PHYSICS CAN ENRICH OTHER FIELDS OF DISCOVERY. IT SHOWS THE BENEFITS OF HAVING INDUSTRY EXPERTS AND A PRODUCT DEVELOPMENT LAB TO TRANSFORM AN IDEA INTO A ROBUST PRODUCT WITHIN A TIGHT DEADLINE."

"Their team did an amazing job," Leslie says. "A suitcase arrived for me in Glenorchy with six beautiful lamps. The glass for them had been hand blown by the chemistry department's glassblower, the bodies of each lamp mimicked stone from different parts of the world and they had thirteen different intensity and flicker patterns that I could change with the flick of a button."

Leslie took the lamps to a cave where she was working in Australia. There was an almost audible silence when the team of scientists, archaeologists and indigenous land owners entered the cave lit by the new lamps.

"It was very moving to see the cave in the flickering warm light," Leslie says.

This is just the beginning of the collaboration. Having discovered an ancient fire-stick in the Australian cave, Leslie hopes to work with Harald and the team alongside the local Aboriginal community to develop a new lamp to mimic its light.

The archaeology community have been inspired by the project which Harald and Leslie presented at a national conference for conservation of conservation materials in October.

"Some archaeologists told me it restored their faith in archaeology," Leslie says.

Leslie was recently invited to join a team working in the Lot Valley of France who have been working with Namibian trackers to identify some of the footprints found in the cave during the Magdalenian epoch. She is taking with her a box of the new lamps to show the team what this new light can shed onthose ancient questions.

The lamp illuminating the Australian cave.

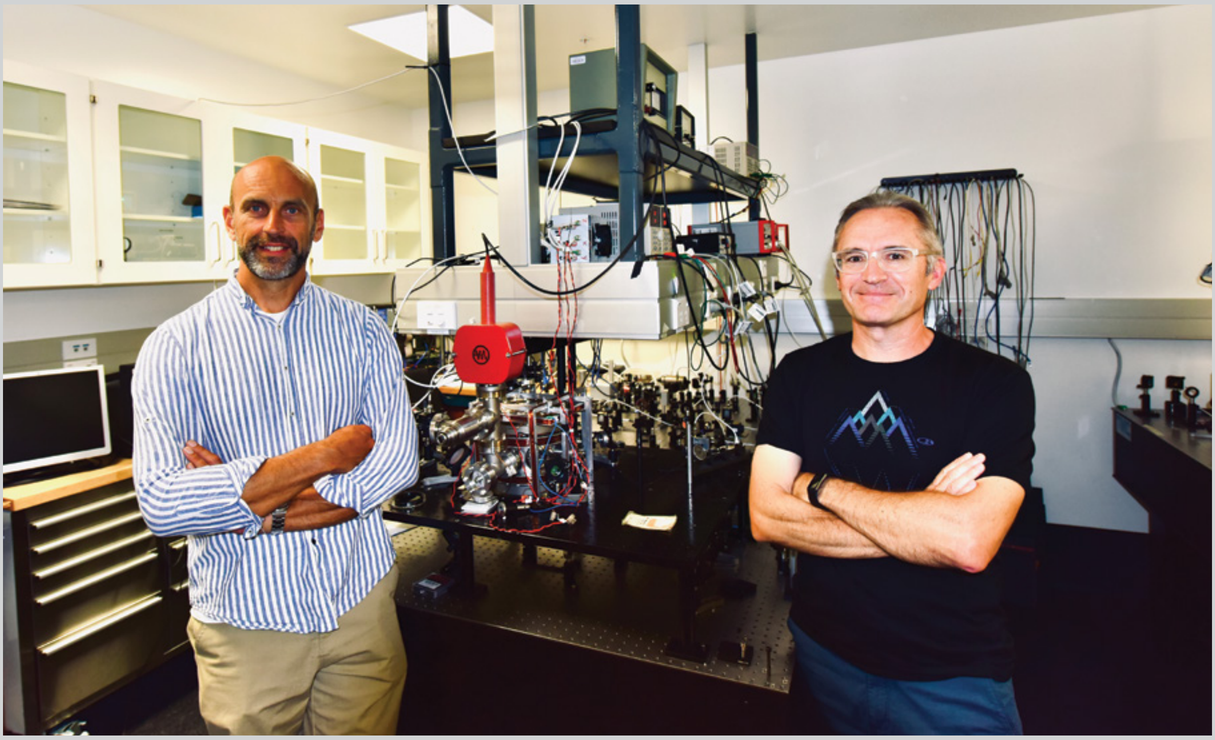
Advancing Long Distance Quantum Communication

A collaboration between researchers at The University of Auckland and Waseda University in Tokyo is delivering breakthrough results in quantum technology. Normally the mind-boggling properties of quantum physics can only be seen at the tiny scale of atoms. But here we find quantum entanglement spread across a lab bench.

In their recent paper published in *Nature Communications*, Principal Investigator Scott Parkins and his Japanese collaborator Takao Aoki present a potential solution to one of the biggest barriers to the global development of quantum computing – how to transport quantum information from one place to another. Today's most advanced quantum computing systems only work inside ultra-cold refrigerators and there is no easy way to extract quantum information or connect quantum computing units. Just as conventional computers need the internet, quantum computers will need a way of connecting.

Scott and Takao have demonstrated an early-stage quantum computing network made from optical fibres. In the future this could lead to large scale networks of quantum computers that would integrate easily with current telecommunications networks.

In their experiment, atoms separated by more than a metre communicate with each other via light travelling down optical fibres. This is an example of quantum entanglement, one of the characteristically bizarre properties of quantum physics, where distant objects instantaneously affect each other's behaviour. Takao's experiment is the first demonstration of coherent quantum entanglement over a long distance where the atoms communicate back and forth with each other.



Maarten Hoogerland (left) and Scott Parkins in the laboratory.

"THE SUPPORT OF THE DODD-WALLS CENTRE HAS MADE IT EASY FOR TAKAO AND I TO VISIT EACH OTHER REGULARLY AND FOR ME TO SEND STUDENTS TO WORK IN HIS LAB. IT HAS ENABLED A MAJOR INFLUX OF PHD STUDENTS AND POSTDOCS AND HAS HELPED BRING US TOGETHER."

The collaboration represents the fruits of many decades of research. Scott Parkins began his career with Dan Walls, namesake of the Dodd-Walls Centre (DWC), and helped to grow the field of theoretical quantum optics in New Zealand which is now world-renowned. With DWC support Scott has been able to build on this legacy to develop a network of world class collaborations.

“It takes a lot to develop a successful collaboration,” Scott says. “You meet lots of people as a researcher and ideas often pop up. Taking it beyond an idea is the difficult part. Being able to see each other regularly is a huge help. The support of the Dodd-Walls Centre has made it easy for Takao and I to visit each other regularly and for me to send students to work in his lab. It has enabled a major influx of PhD students and postdocs and has helped bring us together.”

DWC Principal Investigator Maarten Hoogerland (featured in the 2018 Annual Report) is now collaborating with Scott and Takao, and three DWC alumni have joined Takao’s group at Waseda University (you can read more about one of these graduates, Donald White, in the Alumni Stories on page 24).

Scott is an expert at creating accurate computer models to explain complex quantum systems. Due to the entanglement of all the parts, quantum systems are incredibly complex. A model to explain the interaction of just a few atoms with light can overload a conventional computer. Over the years Scott and his team have developed clever tricks to get around this problem. They used their expertise to understand and guide Takao’s experiments.

Takao, an experimental physicist, has developed an ingenious method to get atoms and light to communicate. At the centre of the experiment is a length of optical fibre just like the fibre used to connect the internet. At each end he stretches a small section of the fibre so it narrows to less than the wavelength of light. He uses lasers to suspend ultra-cold atoms in the grooves next to the narrow sections so that light within the fibre seeps out the side and bathes the atoms. In this way the light and atoms become entangled, so that any change to one instantaneously affects the other. Takao has figured out a way of increasing the intensity of light and improving the communication by building mirrors into the fibre that reflect light back and forth.

“In the future these components could form the basis for a “quantum internet”,” Scott explains. “with networks of trapped single atoms linked over large distances by optical fibres.”

Another exciting potential application for the new technology is to physically construct models to investigate quantum systems which are currently too complex to simulate on a computer such as photosynthesis.

“For decades researchers have puzzled over how plants convert sunlight so efficiently into chemical energy for the plant,” Scott says. “Some theories suggest that quantum mechanics plays a role in how energy is transported from one location to another within plant proteins. But the process is too complex to simulate on a computer so nobody has been able to test the theory. Using this technology you could potentially simulate a plant protein with atoms connected by optical fibres and interacting via light.”

These models could help us understand the quantum properties of all kinds of materials and processes from photosynthesis to superconductors. It would give us a new window into the quantum world leading to advances in medicine, sustainable energy, material design and many, many other fields.

In the more immediate future Scott will continue his collaboration with Takao and Maarten. Next he wants to explore what happens over longer distances when the finite speed of light down the fibre becomes a significant factor. Creating a model for this will take the international community a step closer to a large scale quantum computing network.

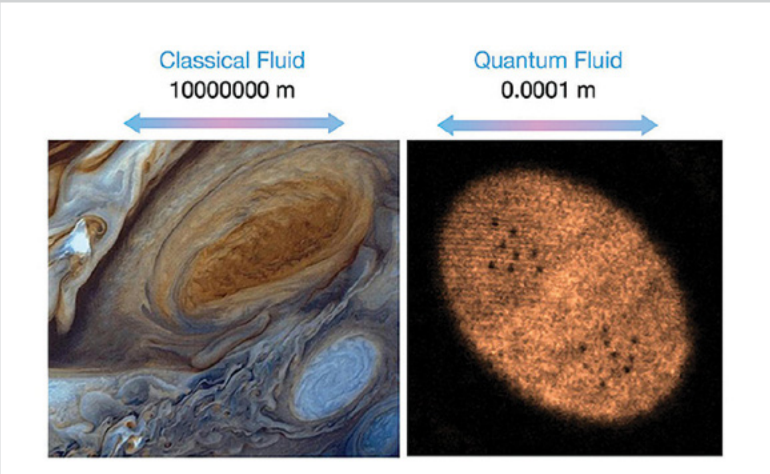
A Breakthrough in Quantum Fluids Research

The quantum world is one of the most exciting and uncharted frontiers of human understanding. It promises a revolution in new technologies but is extremely difficult to access. In their recent paper, published in the top journal Science, Dodd-Walls Centre Principal Investigator Ashton Bradley and his collaborators at Queensland University have demonstrated a breakthrough experiment which opens up a whole new field of quantum research.

Ashton Bradley is a world-expert in the theory of quantum fluids, a unique state of matter made by cooling atoms to just above absolute zero - colder than anywhere in the known universe. At these temperatures the atoms stop jiggling around and become "quantum entangled", behaving more like a single wave than a collection of separate particles. Normally, the strange laws of quantum physics can only be observed at the minute scale of atoms and molecules. But in a superfluid, quantum effects can be seen and interacted with at much larger scales in the lab. This makes them a perfect test ground for researchers.

The equations that describe quantum systems are so complex that you only need two or three atoms before the problem becomes too big to solve on an ordinary computer. So predicting the behaviour of a million atoms in a superfluid is incredibly difficult. Ashton and his team have devised clever tricks to get around this problem.

With theory support from Ashton's group, the experimental team at Queensland University was able to demonstrate a phenomenon predicted seventy years ago.



"WITH THEORY SUPPORT FROM ASHTON'S GROUP, THE EXPERIMENTAL TEAM AT QUEENSLAND UNIVERSITY WAS ABLE TO DEMONSTRATE A PHENOMENON PREDICTED SEVENTY YEARS AGO."

In 1949 the Norwegian physicist Lars Onsager did not have the technology to make a superfluid or a computer model to help him understand them. Using only clever mathematics, he managed to describe the behaviour of tiny whirl-pools or vortices generated by stirring a superfluid. He predicted that if you confined the superfluid to a two-dimensional area (a very shallow pool) then the whirlpools would sort themselves into two clusters depending on the direction they were spinning. He posed that as more energy was added, the vortices would cluster tighter and tighter until they lay on top of each other. They would keep on spinning indefinitely in that formation.

Onsager described this state as “negative temperature”. At first glance it seems as strange as water running uphill. Normally many-body systems like this get more chaotic as energy is added. In this case it is the opposite. The vortices have nowhere to escape and are forced into a more and more orderly formation as energy is added.

Onsager’s prediction has fascinated scientists ever since. But until now nobody has been able to demonstrate it. In 2016, Ashton and his PhD student Matt Reeves carried out some computer simulations that suggested it might finally be possible. Together with vortex theorist and Dodd-Walls Research Fellow Dr Xiaoquan Yu, they contacted the experimental group at the University of Queensland led by Dr Tyler Neely and struck up a collaboration.

There were a couple of factors that enabled their success. One was a method Ashton and Matt devised for generating vortices by using laser beams as tiny sticks and paddles to stir the superfluid. Vortices form in the wake of the laser beams just as whirlpools form downstream from a rock in a river. By exploring different stirring patterns, Matt worked out how to precisely control the energy of the vortices, and create the high energy states predicted by Onsager.

The other secret to their success was an ingenious new laser system developed by the Queensland University group to precisely control the shape and density of a superfluid. In the past it has been extremely difficult to control the density of superfluids which has been a major limiting factor in quantum fluids research. In most experiments the density tapers off around the edges and the vortices just fall out the side – it’s like trying to bowl on a sloping lawn. For their recent experiment the Queensland team created a perfectly even two-dimensional pool in the shape of an ellipse - an ideal stage for “the little vortices who wanted to play” as Onsager whimsically mused.

Matt Reeves.

Ashton Bradley.

Now that they have successfully demonstrated Onsager's prediction, a whole raft of new experiments are possible. With proven technology able to control superfluids with great precision, researchers can now explore a rich landscape of turbulent, high-energy superfluid dynamics.

Turbulence is something we are all familiar with. We observe it in river water flowing around rocks, in smoke when it suddenly spreads out and curls, and in rolling thunderclouds. It is very important for industrial and engineering applications as any system involving moving gases or liquids is affected by turbulence. Despite it being so common and significant, turbulence is extremely difficult to model or predict. This is because it involves things happening on vastly different scales all at once.

This collaborative research project sheds new light on this age-old problem. In some ways quantum turbulence is actually simpler to model than classical turbulence. There is no viscosity or stickiness and the vortices are located at single points in space rather than being spread out like little whirlpools. The understanding gained from quantum fluid experiments could inform more accurate and longer range weather predictions. It could lead to more efficient industrial hydraulic and cooling systems and might even improve our understanding of Jupiter's Great Red Spot, a giant storm that has been raging for centuries.

In time the breakthrough could lead to new and currently unimaginable quantum technologies. In particular, the negative temperature phenomenon could provide a way to recover energy from turbulent flows that would otherwise be lost through dissipation.

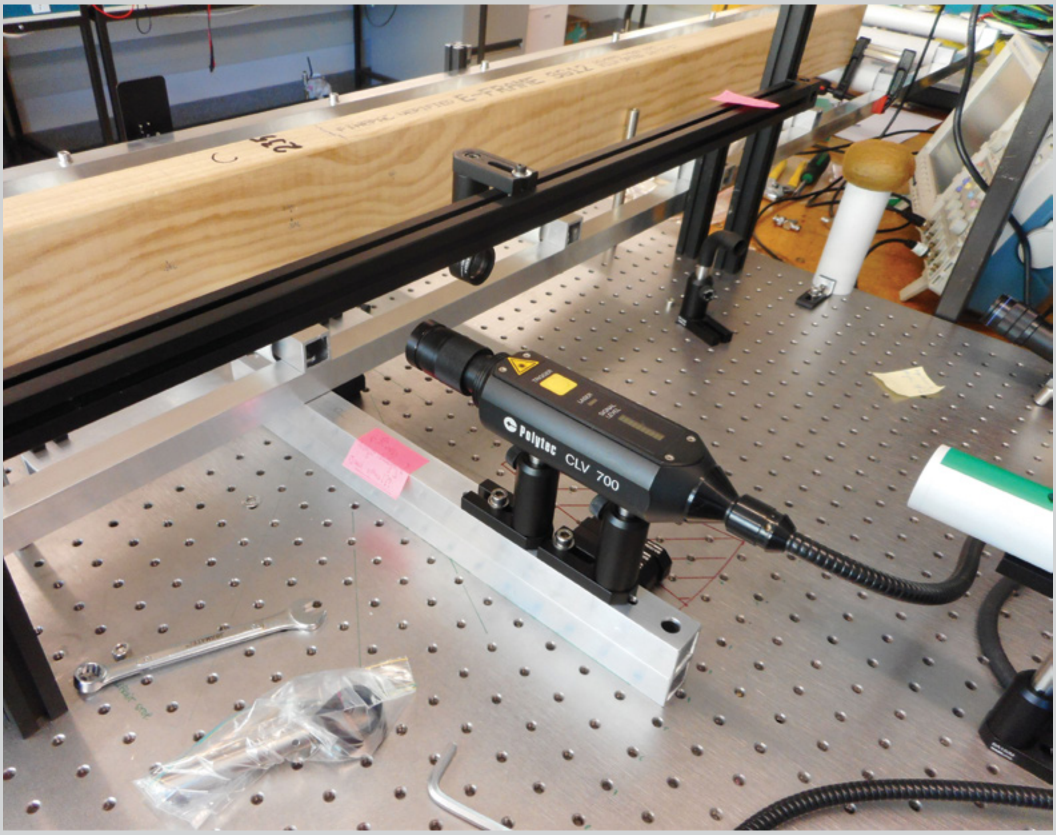
"ONSAGER'S PREDICTION HAS FASCINATED SCIENTISTS EVER SINCE. BUT UNTIL NOW NOBODY HAS BEEN ABLE TO DEMONSTRATE IT. IN 2016, ASHTON AND HIS PHD STUDENT MATT REEVES CARRIED OUT SOME COMPUTER SIMULATIONS THAT SUGGESTED IT MIGHT FINALLY BE POSSIBLE."

Novel application of laser ultrasound to boost our primary industries

Forestry is one of New Zealand's fastest growing export industries with the surface area of exotic forest increasing more than any other land-use in the past twenty years. The wood in these trees represents our future prosperity. But the wealth we derive from them depends on how we process them. An ingenious technique developed in the Physical Acoustics Lab at The University of Auckland could improve the profitability of New Zealand forestry by making it easy to select high quality timber to sell for premium prices.

The higher the quality of wood, the more you can charge for it. Higher quality beams can be used as structural elements in buildings instead of concrete or expensive laminated wood products. But due to the difficulty of making precise and accurate measurements most New Zealand timber mills cannot measure the strength of all planks. For the planks they do measure, an estimate of strength is made across the entire board. As a result, a lot of higher quality timber ends up in lower-graded batches.

The Auckland team's new technology would measure strength every few centimetres down every plank as it exits the mill. This would make it easy to select high quality planks, or even define sections of planks to be sold for higher prices. The group has been working with Luke Taylor and the Dodd-Walls Centre's industry team to develop a prototype device suited to the dirty, noisy environment of a timber mill.



Wood ready for analysis.

"AN INGENIOUS TECHNIQUE DEVELOPED IN THE PHYSICAL ACOUSTICS LAB AT THE UNIVERSITY OF AUCKLAND COULD IMPROVE THE PROFITABILITY OF NEW ZEALAND FORESTRY BY MAKING IT EASY TO SELECT HIGH QUALITY TIMBER TO SELL FOR PREMIUM PRICES."

Dodd-Walls Centre Principal Investigator Kasper van Wijk, who leads the Physical Acoustics Lab, is a geophysicist by training. The laser ultrasound technology is inspired by techniques used to study earthquakes. It uses pulses of laser light to generate tiny vibrational 'quakes' in the wood. The sound waves from these mini 'quakes' are measured with another laser, called a laser Doppler vibrometer. The system produces a picture of the wood's quality and internal structure and is completely non-contacting.

"I consider myself a seismologist," Kasper says. "We're basically doing seismology on small objects in the lab."

Kasper, Luke and the team are exploring the possibility of incorporating their technology into portable devices to use on living trees.

"We would like to measure the quality and size of rings without chopping into them," Kasper says.

A portable device would also be useful to climate change researchers.

"The ring size of trees depends on the climate," Kasper explains, "so this technique could be used on old trees to gain insights into past climates."

In March 2019 Kasper and his team published a new algorithm[1] to work out the strength of wood at different angles to the grain. Timber is one of the most anisotropic materials, which means its strength varies greatly depending on the angle at which the wood is cut. Using laser ultrasound Kasper's team discovered that the algorithm in use for thirty years was flawed.

"We got such precise measurements that we were able to see systematic problems," Kasper says. "We figured out a new model that fits the data better than anyone before us. That's our scientific contribution."

One of the brilliant things about the laser ultrasound technique is that you can use it on almost anything. Kasper's team is measuring the internal structure of rock and the annual layering of ice cores. They are developing medical imaging techniques to see inside bone and arteries and working with New Zealand's fruit industry to measure the crispness and ripeness of apples[2] and other fruits.

1. van Wijk, K., Simpson, J., and Hitchman, S. A modified hankinson equation for the wave speed of laser ultrasound in radiata pine. Wave Motion, 89:57 – 64, 2019.
2. van Wijk, K. and Hitchman, S. Apple seismology. Physics Today, 70(10):94–95, 2017.

"THE DODD-WALLS CENTRE MAKES THIS KIND OF APPLIED RESEARCH POSSIBLE," KASPER SAYS. "THEY SUPPORTED THIS PROJECT WITH STUDENTS AND FUNDING FOR EQUIPMENT TO KEEP OUR LAB GOING. THE INDUSTRY TEAM IS REALLY HELPFUL IN MAKING CONNECTIONS."

"All these examples have the same principles in terms of measurements," Kasper says. "We've got to the point where we have this setup in the lab and it's a matter of sticking something else in the laser beam and learning from the response."

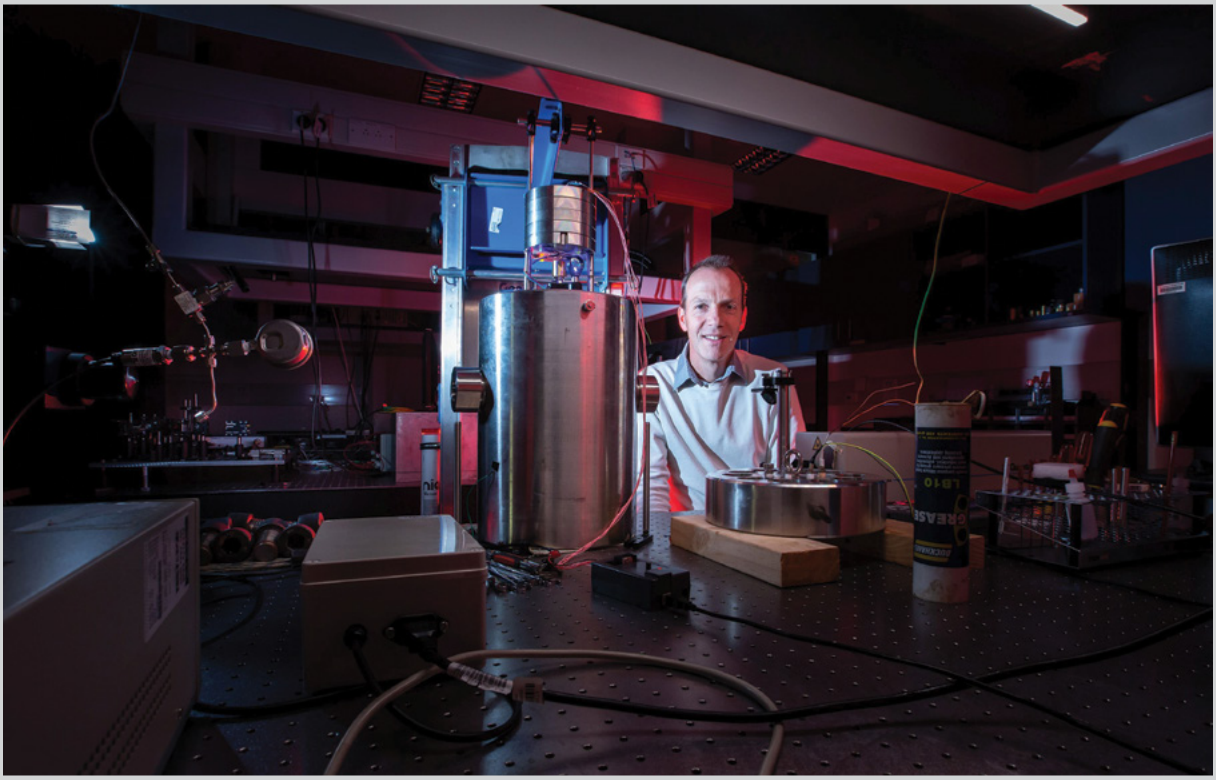
This represents a great opportunity to use New Zealand's cutting edge technology to turbo-charge our primary industries and to develop our reputation for innovation and quality.

"The Dodd-Walls Centre makes this kind of applied research possible," Kasper says. "They supported this project with students and funding for equipment to keep our lab going. The industry team is really helpful in making connections."

When asked what Kasper would do if he could do anything in the world with his laser ultrasound setup he said:

"I would install our system on the next Rover to measure the rocks on Mars! There's a seismometer now on Mars. And once we detect Mars-quakes we'll be able to tell something about the internal structure of the planet. Those data will have to be calibrated with rock physics, which is something we would love to do."

Who knows? Maybe dreams can come true!



Kasper in his laboratory.

ALUMNI PROFILES

DONALD WHITE

Quantum Communication Dreams Come True

As a boy Donald White built radio sets and conducted chemistry experiments at home. Now he is helping to build quantum computers which could accelerate development in almost every field of science and technology and change the way we live. It is a boyhood dream come true.

After completing his PhD with the Dodd-Walls Centre at The University of Auckland, Donald has taken a postdoctoral position at Waseda University in Tokyo, Japan. He is one of three Dodd-Walls Centre alumni working in the group of Takao Aoki, a world-leader in quantum optics research. It is a large group with four labs, seven postdocs, over ten students and an impressive range of cutting edge technologies. They are creating a new type of quantum computer made with atoms linked by optical fibres – thin transparent fibres just like the ones used to connect the internet and phone networks.

This dream job opportunity came about thanks to a long-term collaboration between Donald's group leader Takao Aoki and Dodd-Walls Centre Principal Investigator Scott Parkins at The University of Auckland. (You can read about Scott's research on page 16 of this report). With the support of the Dodd-Walls Centre funding, Takao and Scott have been able to visit each other regularly and have worked together to develop this new approach to quantum computing - Scott on theory and Takao building the technology. Donald met Takao on one of his visits to New Zealand and managed to secure the job.

Globally, billions of research dollars are being spent on the development of quantum computers. But the effort faces a major roadblock. The problem with today's most advanced quantum computing systems is that there is no effective way to connect large numbers of individual computing units (known as qubits). As soon as the quantum information enters the connecting channels it gets lost or destroyed by the noise and heat of the outside world. This has limited the development of large-scale quantum computers – once they get too big, they lose their unique quantum properties.

Takao and Scott's new system solves this problem. They have figured out a way to communicate quantum information through optical fibres over large distances without loss. The entire system is built in-house. Atoms, which form the qubits of the quantum computer, are placed next to small sections of optical fibre that have been stretched so they narrow to nanometre widths. This allows the atoms and light to interact or 'talk' to each other. The team constructs resonating cavities around the narrow sections of fibre, which increases the intensity of light and improves the interaction. The key to the system's success is the ultra-high quality of these 'optical cavities' which ensure that no information is lost. They recently demonstrated communication between atoms separated by over four metres. Such breakthrough results are a major step towards scalability, meaning that many qubits can be connected together without the system losing its quantum nature.

The ability to easily transport quantum information with minimal loss makes their system one of the most promising physical bases for quantum computing available. And New Zealand is playing a major role in the development. Takao is collaborating with Donald's old supervisor, Maarten Hoogerland, at The University of Auckland who is working to develop complementary aspects of the same system. They are two of the only groups in the world working on this technology.

"It is incredibly exciting to be working on such a new system," Donald says. "It's really ground-breaking technology."

"THE ABILITY TO EASILY TRANSPORT QUANTUM INFORMATION WITH MINIMAL LOSS MAKES THEIR SYSTEM ONE OF THE MOST PROMISING PHYSICAL BASES FOR QUANTUM COMPUTING AVAILABLE. AND NEW ZEALAND IS PLAYING A MAJOR ROLE IN THE DEVELOPMENT."

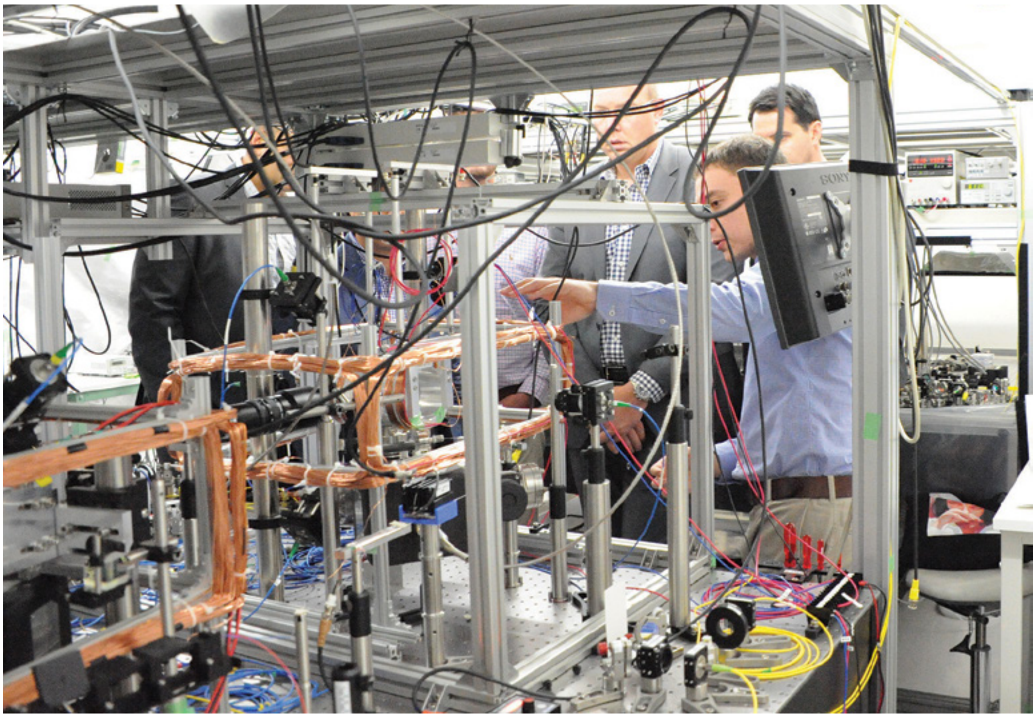
Donald was born in South Africa and came to New Zealand as a young boy. He caught his love of physics from his father, a geophysicist. As a boy Donald took to physics like a duck to water. He did his undergraduate studies at The University of Auckland and joined Dodd-Walls Principal Investigator Maarten Hoogerland's team to do his Honours and PhD.

In his PhD, Donald explored two concepts: quantum chaos, the borderland between the classical phenomenon of chaos and quantum physics; and the fundamental physics behind a phenomenon called Anderson localisation which explains why some materials don't conduct electricity. After graduating he spent six months working for the Auckland-based earth sciences company IESE, which employs a number of Dodd-Walls graduates. He helped to install a state-of-the-art fibre-optic system to measure tiny shifts in the foundations of a major motorway near Christchurch. Fibre optic cables laid along the length of the motorway can detect millimetre scale changes in the profile of the motorway. This tells engineers if the road begins to sink.

Donald is grateful for the Dodd-Walls Centre's support in establishing his career. Being part of the DWC gave him easy access to collaborators in Otago who helped with the theory in both his research projects. Not having to worry about funding for equipment left them free to focus on the important task of making discoveries.

"Internationally people are very appreciative of New Zealand's contribution to quantum optics," Donald says. "We have this fantastic history. It needs to be a future as well! And so to bring all the people and resources together in such a small country together is extremely important."

Donald would be delighted to build a career across New Zealand and Japan making the most of the strong collaboration between the two countries. He loves the culture of both places and has a sense of excitement and possibility for the future.



Donald in his laboratory at Waseda University, Japan.

ANDREW HILLIARD

The Fundamental Physics of Helping Babies Breathe

After fifteen years working in some of the world's most prestigious international quantum research teams, Andrew Hilliard returned home to Auckland to work for Fisher & Paykel Healthcare. That was three years ago. Now, as a Senior Product Development Engineer in the Infant Care team, he is using his elite problem-solving skills to develop medical devices that help premature babies breathe.

Just like the America's Cup and Formula One car racing, cutting-edge quantum science pushes people and technology to their absolute limits. Aside from specialist skills in understanding quantum systems, this research teaches an audacity of thinking, indomitable persistence and technical mastery.

"There is also an inevitable flow-on to new technologies," Andrew explains. "We wouldn't have the technology that underpins the internet if we didn't understand quantum mechanics. You simply don't know where the next revolution is going to come from."

Andrew did his undergraduate and master's degrees at The University of Auckland, his home-town. He fell in love with quantum optics during his master's research with Rainer Leonhardt (a Dodd-Walls Centre Associate Investigator). In his early experiments with lasers and atoms he explored the cross-over between the classical phenomenon of chaos and the quantum world – an area that has confounded physicists for almost a century.

For his PhD he travelled to Copenhagen, one of the birthplaces of quantum theory. Working in the same building where Heisenberg developed his famous uncertainty principle, Andrew constructed an experiment to make Bose-Einstein Condensates. This new state of matter allows researchers to study quantum physics at a scale large enough to see and interact with in the lab. Following his PhD Andrew returned to New Zealand to work with DWC Principal Investigator Mikkel Andersen at the University of Otago. Together they developed methods to achieve world-record control over individual atoms. He then worked in elite experimental groups in Denmark and France.

It was a desire to return home and contribute his skills in a new way that brought Andrew and his family back to New Zealand.

In his role at Fisher & Paykel Healthcare Andrew finds himself engrossed in an entirely new world of complexity - the human body. He works between the research team that conducts clinical trials and the product team who build devices. His role is to research how the human breathing system works and figure out ways to improve the designs. He does this by creating bench-top models of the breathing system using air pumps for "lungs" and 3D printed silicone moulds to mimic baby's "squishy faces and tubes". He studies the way air moves through these models to improve devices and to develop ideas for new therapies.

When Andrew first made the move from experimental quantum physics to medical device development he was worried the problems would not be as captivating, but he was wrong.

"The human body is such a complex thing," Andrew says. "If I keep learning for the rest of my life I'll never understand it all. There's such a lot to learn and master here. I never lose interest."

Andrew's skills in physics give him a unique ability to tackle seemingly impossible problems.

"In physics you condition yourself to enjoy that feeling of not knowing what's going on," Andrew muses. "I just love being able to immerse myself in a problem and understand it deeply. You're daunted but you carry on anyway. Persistence is a big thing. I'm a believer in taking care of the details. You strip things to their simplest parts then add element by element. That way you figure out what the actual causes and constraints are, rather than making assumptions."

"YOU STRIP THINGS TO THEIR SIMPLEST PARTS THEN ADD ELEMENT BY ELEMENT. THAT WAY YOU FIGURE OUT WHAT THE ACTUAL CAUSES AND CONSTRAINTS ARE, RATHER THAN MAKING ASSUMPTIONS."

These are some of the reasons that Fisher & Paykel Healthcare loves to hire physicists. As Andrew Somervell, the company's Vice President of Products & Technology says:

"We are particularly interested in physics and technology people. Our CEO has a degree in physics, I have a degree in physics, two of the most senior people in our R&D have degrees in physics. We like physicists. It is an important area for us and we want to hire more people out of that area rather than just engineers."

Andrew's research also adds credibility to the company's products in the international marketplace.

"It demonstrates that we're a serious organisation," Andrew says. "If I publish a paper on a particular therapy it contributes to the reputation of the company. It says - hey, we take this stuff seriously. We do our own work and the products we make come out of rigorous long time-frame work."

"IN PHYSICS YOU CONDITION YOURSELF TO ENJOY THAT FEELING OF NOT KNOWING WHAT'S GOING ON," ANDREW MUSES.

PETRA FERSTERER

A Booming Career in the Data Science Industry

Petra Fersterer went straight from her PhD in theoretical Quantum Physics to a job in the entertainment industry. She is now working as a data scientist for Wellington-based company StarNow who run a website promoting actors and models to talent agencies.

"Everyone was really confused when I told them. They thought I was going to be a model," Petra jokes. "But I think it's cool to learn about such a different industry."

StarNow's business model relies on some very clever algorithms which help to matchmake talent with opportunities. Petra works in a small team analysing the data and fine-tuning the algorithms to optimise the company's services. Although the topic is vastly different, the skills she uses are much the same as those she developed in her PhD.

The data science industry is booming in New Zealand and PhD trained physicists are ideal recruits.

"Physics taught me to always question why things happen," Petra says. "If something improves or goes down you don't just accept it, you dig down till you work out the cause. You look for the fundamental patterns underlying things."

Petra spent her PhD forging new knowledge at the frontier of quantum research. In one project she devised a new computer modelling technique to understand the intricate interplay between atoms and light. In her second project she collaborated with world-leading experimental physicists in the US and France. Her research will contribute to a revolution of new quantum technologies. It was extremely difficult, often solitary work but it has given her an incredible eye for detail and a tenacity to persevere through unbelievable challenges to reach solutions.

After this intense training Petra is excited to be applying her skills to real-world problems.

"I'm passionate about helping people achieve what's really important to them," Petra says.

Petra feels like she has hit the jackpot with her new career path.

"In Physics you can spend years working on the same problem," she says. "Here I'll do something quickly that will improve our website or save someone days of work. That's very motivating!"

Data science is used by education providers, fashion retailers, government departments, treasury, IT companies and in countless other fields. Petra's skills give her the freedom to move into any of these industries.

"I feel like I'm in the perfect place to learn skills that could take me anywhere," Petra says. "I've got a really amazing employer and I'm getting to do the sort of things that interest me. There are going to be more and more of these sorts of jobs so it feels like a good area and a safe one career-wise."

Petra is also enjoying working with a completely new set of people.

"In Physics I got used to working with people that think the same and are very analytical," Petra says. "Now I'm working with all kinds of different people whose skills are mainly interpersonal. They are often thinking about quite different goals. I'm really enjoying that diversity."

At first Petra felt nervous about transitioning to a new field but the shift has been surprisingly smooth.

"All the training from physics makes it easy to pick up the new skills," she says. "I hadn't learnt SQL (the programming language) before taking the job but it just took a day playing around to get the basics."

Petra is grateful to the Dodd-Walls Centre and her supervisors for encouraging her to make this shift to a new field.

“PHYSICS TAUGHT ME TO ALWAYS QUESTION WHY THINGS HAPPEN,” PETRA SAYS. “IF SOMETHING IMPROVES OR GOES DOWN YOU DON’T JUST ACCEPT IT, YOU DIG DOWN TILL YOU WORK OUT THE CAUSE. YOU LOOK FOR THE FUNDAMENTAL PATTERNS UNDERLYING THINGS.”

“It’s easy in academia to get a narrow idea of what success means. All the people around and at conferences are academics. I remember one speaker at a Dodd-Walls Centre conference who really helped shift that. She gave an inspirational speech about leaving her PhD midway to pursue another career path which she has been very successful in. It was a great reminder.”

Petra is very happy with her career choice.

“Honestly I’m loving this job so much. It would take a lot to make me change it now,” she says.
In the future she hopes to get more experience in other industries and apply her skills for social good. She is grateful to the Dodd-Walls Centre for being a launchpad for this exciting new career path.

NEELAM HARI

New Visions and Career Opportunities

As a child Neelam Hari dreamed of being an optometrist. "I wanted to be an optometrist because I had bad eyes," she says.

But Neelam's love of science has taken her on a different path. At The University of Auckland she discovered the power of lasers to see intricate details way beyond the reach of human eyes. In her Masters research she helped to develop a laser-technique to detect causes of eye diseases like macular degeneration and diabetic retinopathy, which are the main causes of blindness in the Western world. Now she is working in a start-up company developing a device to cheaply and effectively measure children's eyesight. Rather than becoming an optometrist herself she has found a way to improve eye-care for many.

Neelam grew up with her boots in the soil on her family's market garden in Pukekohe, a small town south of Auckland. She fell in love with the intricacies of science as a young girl but was the only one in her class at school to pursue it. Neelam did her undergraduate studies in Medical Physics and Imaging Technology at The University of Auckland. That's when she met Dodd-Walls Principal Investigator Frédérique Vanholsbeeck who was a coordinator on her course. Frédérique has been a mentor and inspiration for Neelam ever since.

"I love to explore and Fred has always opened doors and pushed me to try new things."

Neelam joined Frédérique's Biophotonics Group at The University of Auckland, a multidisciplinary group of physicists, biologists and engineers who use laser techniques to solve a range of industrial and medical challenges. In her Masters project, Neelam collaborated with Dodd-Walls researcher Jami-Shepherd Johnson in the Physical Acoustics Laboratory and Ehsan Vaghefi from the School of Vision Science, both at The University of Auckland. Together they adapted an ingenious technique inspired by seismology to measure the onset of eye disease.

"We used tiny laser pulses to vibrate the eye, a bit like an earthquake. Then we used a laser technique called OCT (Optical coherence tomography) which is able to reveal intricate layers within the eye. We developed a way to measure the firmness of the jelly-like inner section of the eye – the vitreous humour – which liquifies with age, causing disease."

The research continues today and is set to improve the value of OCT in detecting and potentially treating eye disease worldwide.

As part of her research Neelam got involved in both microbiology and chemistry lab-work, which helped her get a job as a wine analyst for AsureQuality straight out of university.

"I really enjoyed getting out of the academic environment and going into industry," says Neelam.

AsureQuality is a New Zealand-based food-testing company. They take samples from all kinds of food manufacturers and test them for metals, bacteria and nutritional content. Neelam was in the wine team, so she spent a lot of time sniffing wines and testing them in the lab. She also got lots of training in manufacturing practices, compliance, ethics and regulations - skills which are proving invaluable in her current start-up job.

Neelam was handpicked for her role as research and development engineer at Toku Eyes, a start-up company based at Auckland University set up by her Masters collaborator Ehsan Vaghefi.

"NOW SHE IS WORKING IN A START-UP COMPANY DEVELOPING A DEVICE TO CHEAPLY AND EFFECTIVELY MEASURE CHILDREN'S EYESIGHT. RATHER THAN BECOMING AN OPTOMETRIST HERSELF SHE HAS FOUND A WAY TO IMPROVE EYE-CARE FOR MANY."

"Toku Eyes" means "my eyes" in Te Reo," Neelam says. "We are making a medical device that will help monitor myopia or short-sightedness in children. Currently it's very hard to test the eyesight of a small child who can't read yet. Without an eye exam, it's difficult to tell what kind of glasses they need. We're hoping to make the device cost efficient so it can reach all demographics in NZ."

Neelam's team have completed initial testing on animal eyes with promising results and are working towards clinical trials. Once the device is developed for New Zealand they plan to make it available overseas.

Neelam is passionate about science communication and is grateful for the experience she gained through the Dodd-Walls Centre.

"I love interacting with kids and getting people excited about science," Neelam says. "If I could achieve anything in my life I would break down the stigma around science being too hard and show how cool and useful it can be."

In her Honours year Neelam helped to create an innovative multimedia art installation as part of the International Year of Light in 2015. She worked with design students from Auckland University of Technology (AUT) to build an interactive playground where children and adults could learn about the ways light is used to communicate in our modern telecommunications technologies. The exhibition, called Beambox, was installed in Aotea Square in Auckland and enjoyed by hundreds of visitors.

Following her Masters Neelam attended a two-week workshop in Fiji where she learnt to make short documentaries on cellphones about environmental changes in the Pacific Islands.

"I got to sail back to New Zealand on the Sir Peter Blake Seamaster as a journalist on the Tara expedition," Neelam says. "I learnt so much about journalism and documentary making. It's something I would definitely like to come back to."

One of the lasting benefits of being part of the Dodd-Walls Centre is the community.

"I met scientists from different fields and different regions, Neelam says. "I still collaborate with Fred and keep in touch with my old team at the Biophotonics Lab. It's so nice to be part of a community that I can reach out to if I have a problem or a question."

"WE ARE MAKING A MEDICAL DEVICE THAT WILL HELP MONITOR MYOPIA OR SHORT-SIGHTEDNESS IN CHILDREN."

"WE'RE HOPING TO MAKE THE DEVICE COST EFFICIENT SO IT CAN REACH ALL DEMOGRAPHICS IN NZ."

SAM HITCHMAN

Solving New Zealand's Industry Challenges with Lasers

From a young age Sam Hitchman loved maths, physics and tinkering with cool devices. His ultimate dream is to make a real-world Star Wars device that uses lasers to detect and analyse all kinds of biological and physical properties. In his PhD in the Physical Acoustics Lab at The University of Auckland he developed an ingenious laser device to measure the ripeness of fruit that is now helping New Zealand's kiwifruit industry improve their efficiency.

Sam now works as a postdoctoral researcher for AgResearch developing ways to use lasers to measure the quality of meat as it's processed – research that could dramatically boost profits of New Zealand's meat industry.

"I love figuring out how the world works and building things that show us what's going on," says Sam. "I don't really mind which field it's applied to. I just love solving problems."

Sam grew up in Auckland and at school threw himself into his science fair projects with great commitment. At The University of Auckland he chose a BTech programme in Medical Physics and got hooked on lasers as a powerful tool for sensing and imaging.

In his Honours year Sam joined the Physical Acoustics Lab led by Dodd-Walls Principal Investigator Kasper van Wijk. A geophysicist by training, Kasper and his team specialise in adapting geophysics techniques to solve all kinds of problems in science and industry.

Sam's first project was to build a laser-doppler-vibrometer – a portable laser device to measure the internal structure of objects that could be used in a dirty messy industrial setting. With the help of Luke Taylor, the Industry Manager at the Dodd-Walls Development Centre, Sam created a portable device to make quick, accurate measurements. The device uses a technique inspired by the way geophysicists measure earthquakes.

The project was so successful that Sam won a scholarship to do his PhD in Kasper's group. His next challenge was to develop a method to measure the crispness of apples. The key to Sam's success was an analogy between an apple and the Earth.

"If you squint, an apple is a bit like the planet," Sam says. "With its core and thin crust."

Even though the size and texture is different, the physics is remarkably similar. Sam trawled the geophysics literature to devise his new method. He adapted the models geophysicists use to describe the way earthquakes travel through the earth to understand the tiny vibrational quakes generated in the apple by the laser.

"Nobody had thought of making this connection before, which made it difficult and sometimes frustrating," says Sam. "But once it was done we had something completely new and unique. The payoff was really cool. We sat an apple on the bench and measured it as it got softer over time - a beautiful decrease in crispness."

Sam's research was published in the prestigious magazine Physics Today and his technique is now being used in other New Zealand fruit-sensing applications.

Next, Sam adapted a similar method to make quick accurate measurements of the strength of timber. This challenge was prompted by an enquiry from the timber industry who were looking for a more efficient way to measure the strength of planks as they're milled.

Sam's training with the Dodd-Walls Centre has given him the ideal skill set for his current job at AgResearch. Sam is part of a collaborative project involving meat scientists, meat industry representatives and laser experts.

"SAM NOW WORKS AS A POSTDOCTORAL RESEARCHER FOR AGRESEARCH DEVELOPING WAYS TO USE LASERS TO MEASURE THE QUALITY OF MEAT AS IT'S PROCESSED – RESEARCH THAT COULD DRAMATICALLY BOOST PROFITS OF NEW ZEALAND'S MEAT INDUSTRY."

"The aim is to figure out a way to measure the quality of every bit of meat we export in terms of fat percentage, pH, tenderness," Sam explains. "If we know the quality we can charge premium prices which would have a major impact on profits."

Sam's challenge is to adapt techniques developed for medical imaging to the very different environment of food processing.

"Many of the techniques we are investigating were developed for medical imaging," Sam explains. "But in a meat processing plant you can't rely on a doctor or technician to interpret your images. You don't need such an accurate result, but it needs to be quick – we only have five seconds to characterise the quality."

Sam is drawing on his experience in the Physical Acoustics Lab, using ultrasound techniques similar to those he used on timber and apples to characterise the meat. He is also investigating the possibilities of using research from deep-learning to interpret the images.

Sam's time with the Dodd-Walls Centre set him up with a network of contacts around New Zealand, which supports his current research. His skills and experience enable him to apply the rich discoveries of fundamental research to real-life industry problems. In the future, Sam hopes to continue his research both overseas and in New Zealand, inspired by the thrill of solving new problems and getting closer to that real-world Star Wars device.

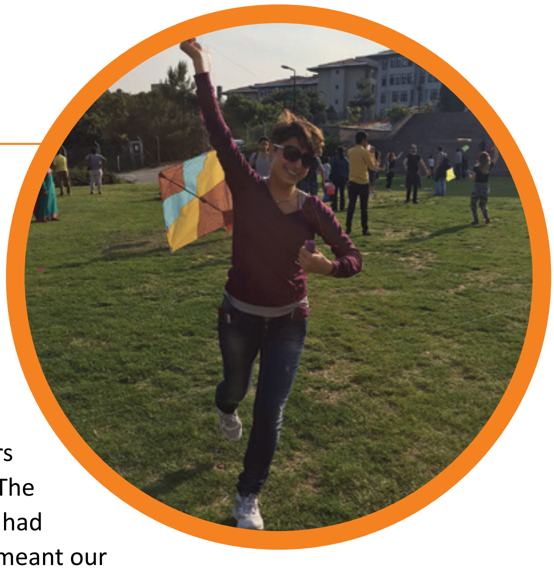
"SAM'S TRAINING WITH THE DODD-WALLS CENTRE HAS GIVEN HIM THE IDEAL SKILL SET FOR HIS CURRENT JOB AT AGRESEARCH."

STUDENT PROFILES

In 2019 we ran a communication workshop for our students. The goal of this workshop was to equip our students with the skills to be effective storytellers. The profiles that follow in this section have been written by some of the attendees of this workshop who received indiviualised coaching following the workshop to help with the crafting of their stories. We hope that you enjoy sharing their journeys!

SONIA MOBASSEM

Empowering Women to Follow their Dreams



When I was a little girl I was ambitious and adventurous. I grew up in a small town in Iran, spending my time riding bikes with my brother, exploring, discovering, and making toys and contraptions like motor boats. I was obsessed with dinosaurs and fascinated by science. How were our planet and sun formed? Why were dinosaurs so large? How did they die out? I was reading books, trying to answer my questions, which in turn sparked my imagination. I had lots of dreams; I wanted to be a zoologist, wandering in the depths of nature, or a pilot, flying a huge airplane.

During my adolescence everything changed. I was no longer allowed to ride my bike, play outside or do any sports and I had to wear a headscarf outside. I was brought under the thumb of the Iranian regime, and their religious rules. My world was shutting down. I cried many times to my mother – why was I born in such a society?

After a while a new dream started to form: Freedom. Seeing protests decimated by the government, I knew the country had a long and difficult path to freedom. I realised that women were free in other countries but I didn't yet have the means to leave. At that time I was becoming interested in mathematics and physics, and by sixteen I knew I wanted to be a scientist. But I could see that female scientists were not taken seriously in Iran. I felt this most heavily during my bachelor's degree, which intensified my drive. At that point I decided to leave Iran but it took me ten years. Every small step was a big challenge - learning English for example. There was no proper internet, YouTube was banned and children were not allowed to speak in English. The only way to access resources was to buy them from smugglers on the street. It took me five years to learn English. The Iranian economy had collapsed which meant our currency was worth very little overseas. I took a job in the metro to raise money for external exams and application processes to overseas universities. One of the biggest challenges was remaining confident. In Iran they always told us "You can't do this! You can't do that!" and after a while that seeped in. I had to keep telling myself I could do it. I had some wonderful supervisors and the constant support of my parents to keep me going.

Two years ago I finally fulfilled my dream of living in a free country. I was offered a scholarship with the Dodd-Walls Centre to do my PhD at the University of Otago under the supervision of Harald Schwefel. Now, as I do my research, I feel a bit like that girl again – free to explore, discover and follow my dreams.

I am working on one of the hottest topics in the world – quantum computing. This pioneering technology promises to revolutionise almost every field by making it possible to solve extremely complex problems. Although much progress has been made, the current most advanced quantum computers face a serious problem. They have no way

"I AM WORKING ON ONE OF THE HOTTEST TOPICS IN THE WORLD – QUANTUM COMPUTING. THIS PIONEERING TECHNOLOGY PROMISES TO REVOLUTIONISE ALMOST EVERY FIELD BY MAKING IT POSSIBLE TO SOLVE EXTREMELY COMPLEX PROBLEMS."

to communicate or 'talk' to each other. Our group has developed a device to make this possible. At the heart of the device is a crystal with special optical properties that converts microwave photons into optical photons that can transport quantum information over large distances. Our device currently has ten thousand times the efficiency of competing devices and we are working to improve its efficiency further.

All these experiments require tremendous precision, patience and passion. For me it is thrilling to be part of such a large scale international effort. New Zealand is one of the world leaders in enabling technologies for quantum computers and the Dodd-Walls Centre provides a safe, nourishing and intellectually stimulating environment. I have had the opportunity to talk with Nobel Prize winners, participate in international conferences and learn face-to-face from my role models. The Dodd-Walls Centre's financial support enables our group to buy the expensive devices we need in our experiments.

My experience in New Zealand has opened new worlds and given me the confidence to keep pursuing my dreams. In the future I would like to help open the way for other girls. I'd like to say – "I did it! You can do better!" My mother is my inspiration. She was not allowed to go to school even though she was very curious and intelligent but she gave me all the opportunities she could. Even under the religious regime Mum got her driving licence at age 65 and started her own store. I am proud of my Mum and I am proud to be living in a country with a woman as prime minister. I hope that in my career I can contribute to more girls and women following their dreams.

"MY EXPERIENCE IN NEW ZEALAND HAS OPENED NEW WORLDS AND GIVEN ME THE CONFIDENCE TO KEEP PURSUING MY DREAMS. IN THE FUTURE I WOULD LIKE TO HELP OPEN THE WAY FOR OTHER GIRLS. I'D LIKE TO SAY – "I DID IT! YOU CAN DO BETTER!"

FANG (RACHEL) OU

A Flourishing Career in Science

I could not have imagined when I began my PhD in Physics all the fantastic experiences that would be presented to me. Four years ago, when I was completing my BTech degree at The University of Auckland I was focused on my studies and successful academically, but I lacked confidence to try new things. Since then my world has expanded to a broad interest in people, science, industry and policy. With the unfailing support of my supervisors and colleagues and lots of encouraging nudges from friends I have completely surprised myself. I started a student organisation and accepted the role as its leader; I travelled to many new countries; published several research articles and presented their results at conferences; I co-organised science outreach and professional development activities; was awarded prizes for a proposal to commercialise my research and was even invited to Switzerland in 2019 for a political economics conference where I offered my perspective as a young scientist on world issues. I am currently doing an internship at the Office of the Prime Minister's Chief Science Advisor (OPMCSA). A couple of years ago, I felt unsure where my career was heading, but now I feel excited to learn and explore all these new worlds.

It all started in 2016 when, along with a bunch of friends, I started a local student chapter of the international society for optics and photonics, SPIE. I did not intend to take a leadership role at first. I just noticed that we did not have a student chapter and asked why. In response my colleagues and supervisors suggested I start one. I was daunted at first. I had no idea how to start or lead an organisation! Simon Ashforth, a fellow PhD student who was the president of another student group, offered to mentor me. We got a group of friends together and with their support I took on the role of president. This decision proved one of the best of my life. Not only has it taught me about leadership and teamwork, it has been a wonderful opportunity to get together with like minds to work on initiatives we all felt passionate about. We have organised regular science outreach activities and invited distinguished overseas researchers to participate in our seminars and discussions. With financial and logistical support from the Dodd-Walls Centre, we have continued to grow and expand the reach and impact of our activities.

At the centre of my PhD has been my research, which I love. I work in the Biophotonics Lab at The University of Auckland under the supervision of Frédérique Vanholsbeeck. In our lab we use laser light to probe the structure, composition and function of all kinds of biological materials and organisms. I have been working on a ground-breaking new technique to detect and monitor bacteria. The ultimate aim is to develop a tool that doctors can use to quickly test the effectiveness of antibiotics on unknown infections. This would help to prevent the spread of 'superbugs' which are among the most serious health threats facing humanity. I developed a way to measure whether bacteria are alive or dead and worked with microbiologists and infectious disease experts from The University of Auckland's Medical school. I enjoy the collaborative nature of my research and have learnt all kinds of new skills and perspectives.

In my first year of PhD, my supervisors supported my interests to enter the Dodd-Walls Centre ideas competition for commercialising research. I saw the potential for my research to improve antibiotic use and was interested in exploring its commercial potential. I prepared a written business proposal describing how my research could be translated to a technology that saves lives and reduces the health-economic burden even in low-resource environments. I then pitched the idea to an investment panel, who provided valuable feedback and advice and eventually awarded me as winner. This experience opened my eyes to the business perspectives on science and technology and taught me the value of expanding scientific impact through commercial routes.

I am grateful to my supervisors Frédérique Vanholsbeeck, Simon Swift and Cushla McGoverin, who have always kept an eye out for opportunities and encouraged me to try new things. This has led to a much more holistic PhD experience.

"I HAVE BEEN WORKING ON A GROUND-BREAKING NEW TECHNIQUE TO DETECT AND MONITOR BACTERIA. THE ULTIMATE AIM IS TO DEVELOP A TOOL THAT DOCTORS CAN USE TO QUICKLY TEST THE EFFECTIVENESS OF ANTIBIOTICS ON UNKNOWN INFECTIONS. THIS WOULD HELP TO PREVENT THE SPREAD OF 'SUPERBUGS' WHICH ARE AMONG THE MOST SERIOUS HEALTH THREATS FACING HUMANITY."

Towards the end of my PhD, I became more and more interested in exploring the potential roles interdisciplinary scientists can have outside of the academic lab. I am passionate about science, but I realise that we need to learn how to work with people and understand different perspectives to solve many of the serious problems in the world. I had read and dabbled a bit in current affairs so when the opportunity came up to do an internship with the Office of the Prime Minister's Chief Science Adviser it seemed like the perfect opportunity. In my internship I have been looking at the uses of artificial intelligence for education in New Zealand. The experience has expanded my perspective of how we as scientists can contribute to policy.

Having submitted my PhD thesis two months ago I am now preparing for my next adventure. Over the next few years, I will be undertaking postdoctoral research at the Eindhoven University of Technology in the Netherlands. There, I will collaborate with industries to develop novel optical sensors. I look forward to gaining international perspectives and seeing how industries and corporations work.

Looking back, there is no way I would trade my PhD experience for anything. I am grateful for the support of my supervisors and the DWC (special mentions to Shannon Scown, AJ Woodhouse, Kasper van Wijk and Paul Hoskin) and the University of Auckland for all the ways they have shaped me on my postgraduate journey.

"I AM PASSIONATE ABOUT SCIENCE, BUT I REALISE THAT WE NEED TO LEARN HOW TO WORK WITH PEOPLE AND UNDERSTAND DIFFERENT PERSPECTIVES TO SOLVE MANY OF THE SERIOUS PROBLEMS IN THE WORLD."

MATTHEW CHILCOTT

Investigating the Fundamental Building Blocks of the Universe

I have always been curious about how things around me work. Not just knowing the pieces inside, but how they interact and why that produces the behaviour we see. At school I taught myself to programme and started doing contract work for a small electronics and engineering company. Some of the projects I worked on involved scientific instrumentation which got me interested in the tools people use to discover how the world around us works. Now, in my PhD at the University of Otago I have taken this question to an ultimate limit. By creating new forms of quantum matter using atoms and laser light I am investigating how the fundamental building blocks of the universe interact. One day this knowledge will lead to life-changing new quantum technologies. But what interests me most are the fundamental questions.

What is an atom? Most people will say something about a particle, or a thing that makes up the stuff around us. We envision an unimaginably small "ball of stuff". My lab group prepares clouds of atoms at extremely low temperatures. We don't see atoms behave as particles - at these temperatures they spread out and behave like waves.

The temperatures we work with are extreme – nearly a billion times colder than your room, and ten million times colder than the frigid void of outer space. In our experiments we smash clouds of atoms into each other very slowly. Like two waves meeting each other at sea, the two clouds pass through each other creating intricate interference patterns. We capture pictures that tell us how the atoms interact. In my particular project, I am working to produce a special cloud of atoms called a "quantum droplet". Normally clouds of atoms spread out and dissipate just like waves at sea crash on the shore. In contrast, quantum droplets hold together. They are like waves with flat tops and very steep sides that never come crashing down. These strange droplets have a host of intriguing predicted properties that we have yet to explore.

Being part of the Dodd-Walls Centre helps us connect and collaborate with researchers in similar fields around New Zealand. Their financial support for operating expenses and equipment enables us to join the international community on an even playing field.

Sometimes doing a PhD can be isolating, especially in New Zealand so far from the rest of the world. It is often hard to connect with the wider community to collaborate and find your identity in the field you research in and it is often hard to network with people in your field without an exorbitant amount of travel. The Dodd-Walls Centre has funded my travel to a conference and summer school overseas. This would not have been possible with my university's travel fund.

My time at Otago has given me a variety of opportunities to explore extra-curricular activities. Most significant has been my involvement with the Otago Optics Chapter, a student chapter of the OSA and SPIE (international organisations in optics and photonics). I have been the president for the past two years. The chapter focuses on community science outreach and professional development for research students. In both of these roles, we have been aided by the Dodd-Walls Centre, with financial and logistical support.

Outreach has been a major part of my work with the optics chapter. Our aim is to inspire future researchers and to help a wider audience understand the science of light. I have thoroughly enjoyed sharing my passion for discovery with school students. We have been fortunate to have the opportunity and resources to bring this experience to more isolated communities, in the rural South Island and in rural Malaysia, working with a Malaysian teachers college.

"BY CREATING NEW FORMS OF QUANTUM MATTER USING ATOMS AND LASER LIGHT I AM INVESTIGATING HOW THE FUNDAMENTAL BUILDING BLOCKS OF THE UNIVERSE INTERACT. ONE DAY THIS KNOWLEDGE WILL LEAD TO LIFE-CHANGING NEW QUANTUM TECHNOLOGIES."

Most recently, the chapter organised the 12th Conference on Optics, Atoms and Laser Applications, or "KOALA". This is an annual, international student conference supported under the International OSA Network of Students (IONS) programme. It was only possible with the help of our sponsors, which included the Dodd-Walls Centre.

IONS KOALA brings together research students from a variety of disciplines who share an interest in optical and quantum science. We presented talks and posters, shared research insights and got to know each other. There were physicists, chemists, and biologists, mostly from Australia and New Zealand but also from the US, UK, Philippines, Poland, and China.

We complemented the research talks with a series of plenary sessions, on optical simulation, nanotechnology and metasurfaces, precision measurement, and quantum vortices. We also had workshops and talks on career skills and science outreach. In a feedback survey, attendees reported that they enjoyed the variety of topics and made useful connections for their research and careers. They also commented on the supportive social atmosphere which took pressure off presenting and made it a lot of fun.

For me, organising KOALA was a fascinating experience and a great opportunity to develop organisational and professional skills. Now that KOALA is over I am looking forward to diving back into my research – investigating the quantum level of how things work.

"BEING PART OF THE DODD-WALLS CENTRE HELPS US CONNECT AND COLLABORATE WITH RESEARCHERS IN SIMILAR FIELDS AROUND NEW ZEALAND."

"THEIR FINANCIAL SUPPORT FOR OPERATING EXPENSES AND EQUIPMENT ENABLES US TO JOIN THE INTERNATIONAL COMMUNITY ON AN EVEN PLAYING FIELD."

ABI THAMPI
India to New Zealand: Moving Worlds with Physics

I was born in the small beautiful state of Kerala in south-western India. I grew up playing sports, fishing and looking after birds and animals. For generations my family have been farmers. But as a boy my father was stubborn. He wanted to get a higher education and so, to the shock of his family, he sold his share of land, got a degree and eventually became a teacher. My mother was a teacher too. Thanks to my parents, I had access to good education and was never told to choose a particular career path.

Physics was my favourite subject at school. I was intrigued by its real world applications and also had an amazing teacher who encouraged and inspired me. Even so there was a lot of social pressure to conform and in India there was a big push to study engineering or medicine. All my friends were doing extra tutorials to prepare for their engineering entrance exams and I joined them - even though I was never convinced that I wanted to be an engineer. It was just before my final entrance exams for engineering admission that I realised and chose to pursue physics.

After all that I seemed to be on a great track. I was accepted into St Stephen's College, the number one ranked science college in India. I was going to do what I loved the most. However things didn't go to plan. The curriculum was very theoretical with very little applied physics and no flexibility to select my interests. I found it incredibly boring and started to skip classes. I used to go to college just for clubs and sports - I never missed training for ultimate Frisbee. Fortunately I still passed with a good score. Towards the end of my degree social pressure began to loom again and the question, "What Next?". I was expected to do an MBA or find a job but somewhere deep down I still loved physics. I decided not to give up so easily and found a summer research opportunity at NIT Trichy on 'Magnetic Particle Hyperthermia to treat cancer'. This was my first ever applied research project and it changed my life. Feeling motivated again, I decided to look for a Masters in applied physics and was accepted into University College Dublin (UCD), Ireland with a full scholarship. Leaving India and my family was a major turning point in my life. Masters at UCD was a dream come true.

I enjoyed studying optics, biophysics and nanoscience and my research gave me the confidence to continue physics as my career choice. I had learned how to chase the things I love and not to give up until I had given my best!

I hoped to do a PhD in the UK after my Masters. However, life didn't give easy choices for long. One fine morning, the UK opted for Brexit and funding and scholarships for non-European students were cut. A few weeks later, I was the victim of racist abuse from a group of young students in a bus and none of the passengers came to my support. Being my first experience of racism, the agony and anger I felt was immense. But thanks to my friends and family, I overcame the difficult times. The incident took a huge toll on me but it made me more passionate to stand up for people's rights whenever I see discrimination. I started considering a country's political condition and inclusiveness when looking for a PhD position.

New Zealand has always amazed me with its beauty and the inclusiveness of the culture. I came across a PhD project titled "Optical sensors to predict the quality of meat in real time", and it was in New Zealand! Being a huge meat lover, I didn't think twice before applying. I got a quick positive response from the professors along with a scholarship from the Dodd-Walls Centre. Coming here has been one of the best decisions of my life.

My research is based in the Biophotonics Lab at The University of Auckland under the supervision of Frédérique Vanholsbeeck and Stéphane Coen. I am using a technique called optical coherence tomography (OCT) which uses laser light to study fine details of biological tissues. My mission is to figure out ways to measure the quality of meat and to test for early signs of skin cancer.

"THE DWC HAS GIVEN ME ENORMOUS SUPPORT AND ENCOURAGEMENT TO FORGE MY OWN PATH AND PURSUE MY INTERESTS. THAT'S HOW I STARTED TRAVELING AROUND NEW ZEALAND DOING OUTREACH WITH KIDS IN RURAL COMMUNITIES."

My research group is very diverse with an even mix of male and female students from Ukraine, Nigeria, Poland, China, India and New Zealand. I'm learning so much about different cultures and there are lots of opportunities to learn and socialise with each other as well as being productive.

The DWC has given me enormous support and encouragement to forge my own path and pursue my interests. That's how I started traveling around New Zealand doing outreach with kids in rural communities. I love seeing them come alive with the excitement of science. I also love the cultural experiences, like when a group of school kids performed a haka. One time we joined some kids playing football during a break and everyone joined in. All the laughter and high fives we shared reminded me of my childhood. I would like to thank the Dodd-Walls Centre for enabling these amazing experiences.

It has always been the practical side of science that has inspired me. If it's not useful to anyone, what's the point!? That's what I think! Through the Dodd-Walls Centre I have been offered opportunities to do a research innovation and commercialisation course, a science communication workshop and an internship with the Office of the Prime Minister's Chief Scientific Adviser. In my internship I have been looking at evidence for how to best measure the impacts of science education and outreach programmes with the aim of increasing their impact.

I love where I am in life at the moment but could never imagined getting here without the support and guidance of my mentors starting from my parents and school teachers all the way to the Dodd-Walls Centre and my supervisors. Interests change, as do circumstances. And sometimes life won't be easy. But I am determined to embrace the opportunities and never give up.

"COMING HERE HAS BEEN ONE OF THE BEST DECISIONS OF MY LIFE."

"MY MISSION IS TO FIGURE OUT WAYS TO MEASURE THE QUALITY OF MEAT AND TO TEST FOR EARLY SIGNS OF SKIN CANCER."

DWC RESEARCH EXCELLENCE

Dodd-Walls Centre researchers and their collaborative teams were again very 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 agriculture, 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.

OVER $9 MILLION

NEW COMPETITIVE, EXTERNAL RESEARCH FUNDING AWARDED IN 2019 IN RECOGNITION OF EXISTING RESEARCH EXCELLENCE

Investigators

Research Funding Awards

CATHER SIMPSON AND ALEX RISOS
DWC Associate Investigator (Simpson) and
DWC Postdoctoral Fellow (Risos)
The University of Auckland

MBIE Endeavour Smart Idea Grant, $999,999
Drinking water pathogen monitoring in real time (3 years)

Grant PIs

AMITA DEB
DWC Associate Investigator
University of Otago

MBIE Endeavour Smart Idea Grant, $1,000,000
Contact-free sensing of high voltages using a laser electrometer (3 years)

Grant PI

NATHANIEL DAVIS
DWC Associate Investigator
Victoria University of Wellington

MBIE Endeavour Smart Idea Grant, $999,999
Non-toxic hybrid nanomaterials for luminescent solar concentrators (3 years)

Grant PI

Marsden Fund Fast Start Grant, $300,000
Photon multiplying light harvesting antenna systems for luminescent solar concentrators (3 years)

Grant PI

SARA MILLER AND KEITH GORDON


DWC Research Fellow (Miller) and DWC Principal Investigator (Gordon)
University of Otago

MBIE Endeavour Smart Idea Grant, $999,999
Diagnosis by light: An endoscopic probe for biopsy-free diagnosis of gastrointestinal diseases (3 years)

Grant PI (Miller)
Grant AI (Gordon)

Marsden Fund Fast Start Grant, $300,000
Development and assessment of a multi-spectroscopic fiber optic probe capable of disease diagnosis in the gastrointestinal tract (3 years)

Grant PI (Miller)
Grant AI (Gordon)

BLAIR BLAKIE AND DANNY BAILLIE


DWC Principal Investigator (Blakie) and DWC Postdoctoral Fellow (Baillie)
University of Otago

Marsden Fund Standard Grant, $891,000
Binary magnetic gas – the next generation quantum-liquid (3 years)

Grant PIs

BERND KRAUSKOPF

DWC Principal Investigator
The University of Auckland

Marsden Fund Standard Grant, $689,000
Feedback loops in climate systems: the maths of delays and the consequences (3 years)

Grant PI

NIELS KJÆRGAARD AND JAMES CROFT


DWC Principal Investigator (Kjærgaard) and DWC Research Fellow (Croft)
University of Otago

Marsden Fund Standard Grant, $891,000
Reactive cold collisions in steerable optical tweezers (3 years)

Grant PI (Kjærgaard)
Grant AI (Croft)

GEOFFREY WATERHOUSE

DWC Principal Investigator
The University of Auckland

Shandong Provincial Distinguished Foreign Expert Award, $270,000
(3 years)

Grant PI

STUART MURDOCH, STÉPHANE COEN AND MIRO ERKINTALO

DWC Principal Investigators
The University of Auckland

Marsden Fund Standard Grant, $922,000
Multimode microresonator optical frequency combs
(3 years)

Grant PI (Murdoch)
Grant AIs (Coen and Erkintalo)

CLAUDE AGUERGARAY, NEIL BRODERICK AND MIRO ERKINTALO

DWC Associate Investigator (Aguergaray) and DWC Principal Investigators (Broderick and Erkintalo)
The University of Auckland

Marsden Fund Standard Grant, $960,000
New pulse dynamics for the lasers of tomorrow
(3 years)

Grant PI (Aguergaray)
Grant AIs (Broderick and Erkintalo)

Prizes and Peer Recognition

CATHER SIMPSON

Awarded the Pickering Medal by the New Zealand Royal Society Te Apārangi

KEITH GORDON

Awarded the MacDiarmid Medal by the New Zealand Royal Society Te Apārangi
Awarded the 2019 Royal Society of Chemistry Australasian Lectureship

IAN GRIFFIN

Made a Companion of the New Zealand Royal Society Te Apārangi

BRENDAN MCCANE & HAMZA BENNANI

Best Paper Award. Image and Vision Computing NZ, 2019.

Students

JAMES HOPE
PhD candidate, The University of Auckland
Supervisor: Frédérique Vanholsbeeck

Claude McCarthy Fellowship, Universities New Zealand

ABI THAMPI
PhD candidate, The University of Auckland
Supervisor: Frédérique Vanholsbeeck

RHT Bates Postgraduate Scholarship, New Zealand Royal Society Te Apārangi

FANG OU
PhD candidate, The University of Auckland
Primary Supervisor: Frédérique Vanholsbeeck

Semi-finalist, St Gallen Wings of Excellence Award, St Gallen Symposium, Switzerland

SUZANNE OTTO
PhD candidate, University of Otago
Supervisors: Niels Kjærgaard and Amita Deb

Poster Prize, ICOLS

KEVIN STITELY
PhD candidate, The University of Auckland
Primary Supervisor: Bernd Krauskopf

People's Choice Presentation Award, Conference on Optics, Atoms, and Laser Applications (KOALA)

Presentation Award, Mathematics Student Research Conference, The University of Auckland

Best Poster Award, International Conference on Laser Spectroscopy (ICOLS

JAMIN MARTIN
PhD candidate, University of Canterbury
Supervisor: Jon-Paul Wells

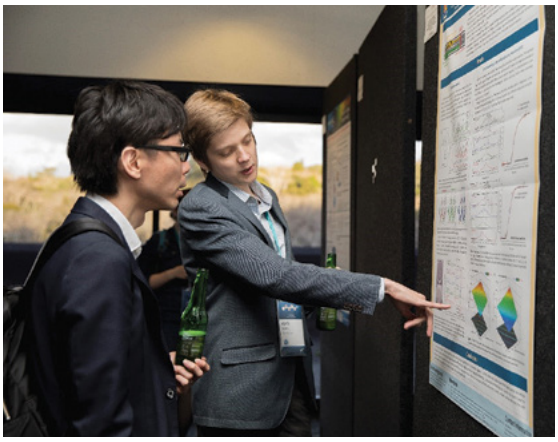
Poster Prize, DPC Conference

2019 CONFERENCE HIGHLIGHTS

In 2019 the Dodd-Walls Centre organised and hosted four major international conferences. The content of the conferences ranged from quantum clocks to the use of spectroscopy for clinical diagnosis. These conferences showcased New Zealand, and the research undertaken here in Aotearoa, to our international colleagues and collaborators and collectively the conferences brought over 770 researchers together. Here is a snapshot of a very busy year of conference hosting.

The International Conference on Vibrational Spectroscopy (ICAVS)

The ICAVS conference was held in Auckland in mid-July. It had plenary speakers from academia and industry from all over the world (including Clare Strachan from the University of Helsinki and Steve Holroyd from Fonterra Cooperative Ltd here in New Zealand). The focus of the conference was the expansive field that is vibrational spectroscopy. The presentations ranged from the fundamentals and application of plasmon-enhanced Raman spectroscopy to a talk on the journey to the use of mid-infrared technology for blood-serum brain tumour triaging into hospitals.



Kārlis Bērziņš (poster session 3 prize winner) describing his research to another ICAVS attendee.

The International Conference on Laser Spectroscopy (ICOLS)

In late July Queenstown was abuzz with scientists from all over the world who gathered to share developments and applications of precision measurement and control in atomic systems at the ICOLS conference. Arguably one of our most eminent keynote speakers in 2019 was Nobel Laureate Professor Eric Cornell. Eric is an American physicist who, with Carl Wieman and Wolfgang Ketterle, won the Nobel Prize for Physics in 2001 for creating a new ultracold state of matter, the so-called Bose-Einstein condensate (BEC). The existence of the condensate had been predicted by Albert Einstein, among others, and Cornell had been searching for it for over 10 years before his breakthough - which was discovering that chilling and slowing atoms caused them to merge into a single entity. While here as our guest, Eric also gave a public talk and was interviewed by Kim Hill on National Radio (you can find the podcast from Saturday Morning 13 July on the Radio New Zealand website).

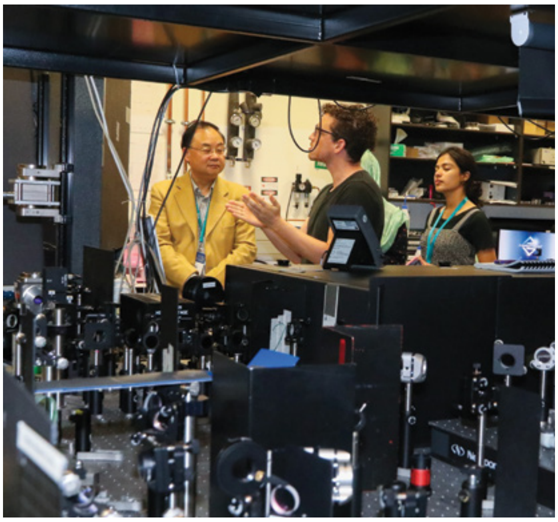
Eric Cornell snapped during a rare quiet moment at ICOLS.

The Asia Pacific Conference on Optical Sensors (APOS)

Held in November APOS brought together over 175 researchers from the Asia and Pacific with the common theme being optical sensing. Heike Ebendorff-Heidepriem (University of Adelaide) highlighted the achievements of her laboratory's research into adapting the properties of optical fibres using physical and chemical mechanisms to sensing, and how her laboratory has collaborated successfully with industry. While Helen Pask (Macquaire University) outlined her laboratory's use of Raman spectroscopy to remotely measure subsurface water temperature, the potential applications of which are easy to see as ocean temperature monitoring is becoming increasingly important. Our Deputy Director, Neil Broderick, described his forays into the field with Kasper van Wijk, James Loveday, and other national and international scientists interested in studying NZ's alpine fault pre-earthquake.

A highlight for many of the attendees were the small group tours of the Photon Factory facilities.

Another initiative at the conference was the Equity and Diversity Panel which was sponsored by the Dodd-Walls Centre. The purpose of the panel was to talk about initiatives and strategies, successful or not, that people have tried to build more equitable, inclusive and diverse environments. The panel discussion highlighted the importance of outreach and the creation of strong networks for people from under-represented groups. The panel discussions noted that outreach, particularly to rural regions, is important to normalise the idea of STEM careers in the minds of children growing up in these areas. The Dodd-Walls sponsored Great Northland Tour and Science Wānanga were cited as excellent examples of reaching hard to reach communities.



International guests touring the Photon Factory.

APOS panellists (from left) Kae Nemoto (National Institute of Informatics, Japan), Weitao Liu (Fudan University, China), Judith Dawes (MQ Photonics Research Centre, Macquarie University), Dawn Tan (Singapore University of Technology and Design, Singapore), Keith Gordon (University of Otago, New Zealand) (photo credit: Stephane Coen).

EDUCATIONAL AND PUBLIC OUTREACH

The Dodd-Walls Centre continued its commitment to Education and Public Outreach activities in 2019, delivering a range of events across Aotearoa and beyond. These events give the Dodd-Walls Centre an opportunity to share the breadth of the research conducted at the Centre and the wide range of collaborations with researchers in areas of food, health and medical technologies, geophysics and astronomy. Often the audiences are not aware of the role physics has to play in these diverse areas. Another key outcome of these activities is our ability to reach school students as they are shaping their career goals and aspirations, in line with a new programme being developed by TEC (Inspiring the Futures). As well as building on and extending outreach platforms and events that the team have used in the past, such as with the Lab in a Box and Science Wānanga, new approaches were trialled to reach non-traditional audiences you can read about these in this section.

Selected Highlights from 2019

Launch of 2nd Centre for Illumination: *Mighty Small Mighty Bright*

Following the success of the Centre for Illumination within the Otago Museum's Discovery World and now Tūhura Science Centre, planning has been underway over the last two years to develop a similar concept that could be shared more widely across New Zealand. The DWC partnered with Auckland's Museum for Transport and Technology (MOTAT) and the MacDiarmid Institute to develop *Mighty Small Mighty Bright* (MSMB).

MSMB is a mobile, modular and interactive exhibition designed to demystify the science behind photonics and showcase cutting edge photonics-based technology. Such technologies, and their applications to real life problems, are driving massive economic, environmental and social change, so a key aim for MSMB is to offer a fun way to explore these principles and inspire future scientists.

The MSMB showcase was unveiled at MOTAT on 17 May 2019, over its exhibition period up to September 2019 it attracted over 80,000 visitors. It is currently open to the public at Te Manawa Museum in Palmerston North; after April 2020 it will be on display at Nelson Museum.

Mighty Small Mighty Bright at MOTAT.

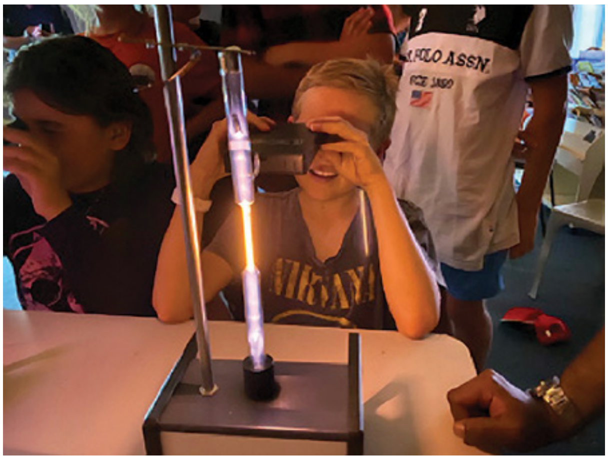
Extreme Science II: Taking Science Engagement to Aotearoa's Most Remote Communities

This DWC-based project was also supported by funding from MBIE's Unlocking Curious Minds fund ($30,000 GST excl.). Our goal was to engage geographically hard-to-reach New Zealanders to ignite and fuel enthusiasm for science.

32 school sessions and 12 public evening events, reached 2,169 individuals across six of New Zealand's most far-flung regions, including the East Cape, Fiordland, Stewart Island/Rakiura, Northland, the West Coast and Aotea Great Barrier Island. At each of these locations, we engaged with the local community through school visits and free public evening events using hands-on science activities, expert talks, and astronomy sessions in a portable planetarium.

The results were overwhelming. We far exceeded our originally anticipated target for number of people to be directly engaged (900) and every region has asked us to return for a repeat visit. The connections made with these schools and communities is an enduring and significant output, as they now have access to scientists and science communicators that they can turn to for advice and questions. The communities we reached all noted the value of this engagement at their place and how rare, but important, this was to them.

East Cape Tikitiki juniors show off their LED bracelets.



Great Barrier Island Kaitoki Primary School learning about spectroscopy.

Great Northland Science Roadshow 2.0

In support of the *Extreme Science II* project, Dodd Walls Centre students organised an extensive Northland Roadshow focussed on re-engaging schools from the previous year's Roadshow to strengthen the relationships formed. 16 PhD students worked with over 600 students and members of the public across five Northland locations. The team also hosted a public science fair at the Kerikeri Primary School hall to attract families and young learners.

Engaging Pacifika in Science

The DWC outreach team made a concerted effort to increase its engagement and connections with the Pacifika community over 2019. This ranged from supporting Pacific-centred schools and preschools to participate in science experiences by providing transport to science events, through to taking outreach activities to Pacifika communities across Aotearoa and to the Pacific Islands directly.

In 2019 the team forged a very positive relationship with Pacific PowerUP, a community-run education programme that aims to support Pacific parents, families and communities to champion their children's learning. It provides support to primary and secondary students, and a safe and culturally aligned learning environment for these children. Evening science engagement events hosted by Pacific Power Up were very well attended by over 150 people. Engagement have been undertaken in Oamaru and Dunedin, with plans to extend this to other regions in future.

Through its partnership with Otago Museum, DWC engaged with over 2,000 Tongan and Fijian students and their teachers during an extensive Otago Museum-led Pacific outreach tour of Fiji and Tonga. The positive feedback received was remarkable, and with these communities having very close ties with family and whānau in Aotearoa, the impact of these visits is likely to be far reaching.

Pukeko Preschool (Mangere East) visit MOTAT.

School visit as part of Pacific PowerUP.

Tonga High School students arrive for outreach session.

Suva school students testing diffraction glasses.

Rakiraki Methodist Primary School.

Penang High School, Fiji.

Quantum Shorts Film Festival

In partnership with the National University of Singapore's Centre for Quantum Technologies, the DWC hosted the first ever screening of the Quantum Shorts film festival in New Zealand. Entries from all over the world were received and the shortlisted finalists were screened at Otago Museum over February and March 2019. The DWC was an official science partner of the festival and the DWC Director, Professor David Hutchinson, was one of the judges. The Otago Museum was an official screening partner. These Quantum Short films were enjoyed by the public and research community alike, with sessions involving researchers from the DWC hosting Q&A sessions with the public to help interpret and discuss the quantum concepts that inspired the films.

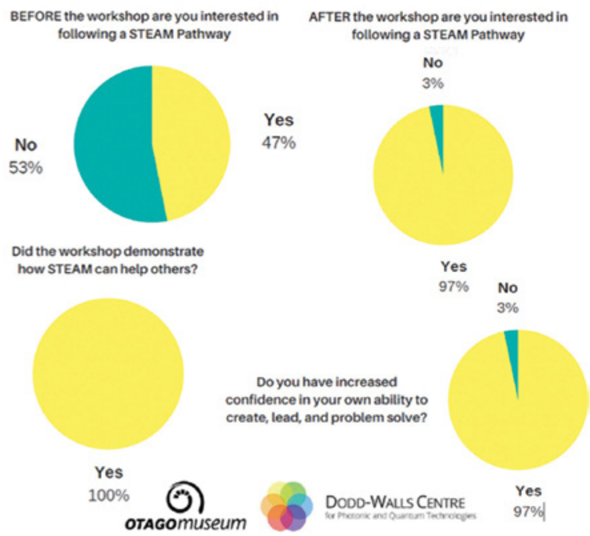
International Centre for Theoretical Physics (ICTP) Winter College on Applications of Optics and Photonics in Food Science

50 PhD students and emerging researchers from around the world attended the winter college focused on innovative applications of optics and photonics to food and agriculture. The DWC's Professor Cather Simpson was among the international organisers who developed a program on deriving impact through research and entrepreneurship. The outreach team hosted lab workshops making Raspberry Pi spectrometers, and demonstrating their light-based water quality kit. Participants each received a low cost colorimeter and spectrometer in the lab sessions run by Andy (Xindi) Wang. These low-cost hands on kits piqued the interest several of the attendees involved in science education and outreach in Pakistan, Iran and Ghana.

ICTP Winter College.

UNESCO International Day of Women and Girls in Science

To encourage young females to pursue careers in science, and, as part of the celebration of UNESCO's International Day of Women and Girls in Science, the Dodd-Walls Centre collaborated with Otago Museum to host a series of workshops lead by GirlBoss NZ's Alexia Hilbertidou. Hilbertidou's *Changemakehers* workshops welcomed Y7 – Y10 students from a range of schools across Dunedin, with very positive feedback as demonstrated in the evaluation captured (see below).



Given the success of this initiative, the DWC and Otago Museum submitted a successful proposal to the MBIE Unlocking Curious Minds fund to extend this initiative of engaging more young women in science and portraying more females as role models for careers in STE(A)M.

Enlighten – UNSECO International Day of Light Celebrations

The UNESCO International Day of Light (May 16) aims to highlight the role light plays in art, culture, science, and technology, including how it is increasingly harnessed and applied in photonic-based technologies that play roles in fields as diverse as medicine, communication and energy.

The DWC team organised and delivered a large range of events to mark the UNESCO International Day of Light, both in the lead-up to and following the day. These included:

- Taking the *Lab in a Box*, to Pioneer Park and Central Stories in Alexandra to engage locals and tourists with light and optics demonstrations, and then on to the Queenstown LUMA festival to unveil some of the science-based secrets behind LUMA's light-based sculptures and installations.
- International Day of Light Science Fair (11 May) allowed Dodd-Walls Centre students and investigators to showcase the role of photonics and optics in the role of everyday life. Collaboration with the Ellen Melville Centre in Auckland meant that the science fair was able to take advantage of the wide open space of Freyberg Square to attract a large number of families with children of various ages.
- Enlighten Open Day (18 May) at Otago Museum enabled visitors to explore the spectrum of light from infrared to ultraviolet, learn about how fibre optics makes use of total internal reflection to bring lightning fast internet speeds and discover the challenge of managing reflections in games of laser chess.

LIAB and DWC team at LUMA Festival, Queenstown.

Redefinition of the SI Units

The 20 May 2019 saw a major change to the International System of Units (SI). The SI is the globally agreed basis for expressing measurements in all areas of science and technology. Four SI base units, the kilogram, ampere, kelvin, and mole, were officially redefined using exact numerical values for the Planck constant *(h)*, the elementary electric charge *(e)*, the Boltzmann constant (k_B), and the Avogadro constant (N_A), respectively.

The DWC outreach team worked with Measurement Standards Laboratory of New Zealand (MSL) to deliver workshops throughout New Zealand over March to May 2019 to mark this event. The workshops were open to the public and industry. They outlined the reason for the changes and shared the impact the changes might bring, and were coupled with displays that helped demystify the science of precision measurement.

SI Redefinition Workshop at Otago Museum (March 2019).

Tuia 250 – First Encounters

To celebrate the anniversary of Captain Cook observing the transit of Mercury, Lab in A Box was transported to Mercury Bay Museum in conjunction with the Tuia 250 Mercury Rising project team. From 7 – 10 November, the outreach team ran school visits and community science shows about physics and astronomy on the East Coast of the North Island. Lab in A Box was then moved to Cook's Beach for an all-night Star Party and to view the transit of Mercury at sunrise on 12 November.

What's in our water: Shining a light on water quality

This MBIE Unlocking Curious Minds project ($30,000 GST excl.) was led by DWC Outreach Coordinator Andy Wang. The project made and delivered 200 water testing kits capable of quantifying dissolved nitrate in fresh and saltwater. Delivery was focused on schools and community groups in South Auckland, partnering with Te Pu a Nga Maara collective to work with young people from Manurewa, Papatuanuku and Makaurau marae. The project was extended to Northland through two wānanga at Hihiaua Cultural Centre thanks to our collaboration with maramataka tohunga (Maori lunar calendar expert) Rereata Makiha. Altogether *What's in our water* was able to reach approximately 400 individuals across Northland, Taranaki, Auckland and Tauranga. The students at Te Wharekura o Manurewa are using the water testing kits produced from this project to measure the nitrate levels of their local stream. Beginning in August 2019, students from the kura worked with DWC outreach team member Andy Wang to obtain nitrate measurements on a weekly basis providing them the opportunity to develop a high level of proficiency with the kit. The students were subsequently engaged by Auckland Council as facilitators during activations at the Wiri Catchment Pond.

New Student Chapter in global health technology

The STEM for Global Health (STEMGHNZ) student chapter has built a series of local and international relationships connecting schools in Tonga with those in Auckland. The student chapter has also used the optical heart-rate monitors in a term-long workshop at Ormiston Junior College to show the application of photonics and engineering to creating solutions for medical devices. This connection culminated in a week-long exchange trip by four students from Ormiston Junior College to Tonga High School. DWC Research Fellow, Dr Jami Shepherd, visited Tonga with STEMGHNZ president Catriona Miller and their collaborators from the University of Canterbury. Their trip took them to Vaiola Hospital and the outlying clinics on Tongatapu to learn about the healthcare facilities available and the aspirations of the medical and technical teams in these facilities: the chapter aims to send a team of students to support the local device technicians in 2020.

As well as working with primary and secondary school students, the student chapter has run an Idea-thon for students at the University of Auckland. The Idea-thon, which was attended by 25 students, served as a platform to discuss new ideas and initiatives for the student chapter. The focus for this year was the development of low-cost and easy to maintain sensor technology for better health outcomes in nations in the Pacific.

Super STEM Fair (MOTAT)

Over 1,600 visitors came to see the physics demonstrations from Dodd-Walls Centre students. The long-standing relationship between DWC researchers and MOTAT means there is continued engagement with families in Auckland. The event allows researchers of the DWC to show their work to a large number of families in their community and to discuss interesting science in an informal setting. Overall the STEM fair helps build the sense that scientists are approachable people who are good at explaining their work in a way that unravels complexities while breaking down barriers such as complex language.

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. As a Centre of Research Excellence, we aim to train an appropriately skilled workforce and to attract the world's best talent to enhance the growth of New Zealand's high-tech manufacturing industries. We are currently supporting the development of a database of photonics companies in Australia and New Zealand in collaboration with the Australian Optical Society, to quantify the importance of this sector. A recent survey of the photonics sector in Australia and New Zealand found that the photonics industry in NZ is already worth at least $1.2 billion and is growing at 10% per annum; the Centre contributed to this survey and the resultant report will be released in early 2020. 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 in the photonics marketplace are relatively low and it is considerably less complex than several other high-tech areas to establish new and profitable enterprises.

Our researchers undertake projects that range from the fundamental to the commercially focussed, exposing our students to the spectrum of research. We also offer our students opportunities such as internships and provide upskilling events, for example, workshops on intellectual property considerations in commercial research and pitching sessions. We have examples of students who have progressed as postgraduates through the Centre and have been employed in spin outs that have close ties to the Centre such as Engender Technologies and Orbis Diagnostics.

Through our wide network and the national representation of our members, we are able to engage with industry across the country and globally, in a more fully representative way than any single entity working alone. By representing our expertise at an international level, we are well placed to seek opportunities beyond our Centre members, for the wider benefit of New Zealand.

Selected Highlights from 2019

Techweek19: Lasers, Sperm and other Great Ideas: Celebrating Academic Entrepreneurship

The DWC hosted a Higlight Event in Auckland for Techweek19. It was a lively event emceed by Ngaio Merrick with speakers including Hon Megan Woods, Professor Cather Simpson and Charlotte Walshe.

The event focussed on Professor Cather Simpson's journey from an idea to acquisition (for Engender), and her thoughts on how to encourage academic entrepreneurship. Attendees includes DWC members, members of the innovation network, MBIE, Callaghan and the investment community.

Minister Woods attended and spoke in her capacity as Minister for Research, Science and Innovation. She spoke to the success of the Centres of Research Excellence (CoREs), including the importance of the role the CoREs play in the national innovation system as catalysts of ideas and ground breaking research. She commended the Dodd-Walls Centre on being a great example of a successful Centre of Research Excellence with our internationally acknowledged, ground breaking research. Our commitment to our diversity and gender equity also received a special mention with regard to our Carer's Fund.

> *"I would like to commend the Dodd-Walls Centre researchers and board members for your contribution to cutting-edge research in the fields of quantum optics, photonics and precision atomic physics, and your overall contribution to science and innovation in New Zealand."*
>
> Minister Woods, Dodd-Walls Techweek19 speech

Professor Cather Simpson enthusing the audience at her talk.

Office of the Prime Minister's Chief Science Advisor Internships

In 2019 we created and funded a series of internships with the Office of the Prime Minister's Chief Science Advisor (OPMCSA) to support capability development at the interface between research and policy and create opportunities for our students and early career researchers to gain valuable experience in the dissemination of research outcomes.

The internships are flexible terms of FTE and length, and the topic to work of mutual interest to DWC and the OPMCSA.

The first of our interns completed her internship in late 2019, here is her reflection on the opportunity:

INTERNSHIP REFLECTION: FANG (RACHEL) OU

Recent developments in artificial intelligence (AI) and machine learning is expected to have wide-reaching effects for future job markets and skills requirements. Many commentators anticipate that AI could amplify skills differences and make some jobs obsolete while emphasising others. Education is a foundational element of a nation's wellbeing, economic productivity and competitiveness, and it is crucial to prepare the next generation for the future of work appropriately.

What does AI mean for the future of learning and teaching, and how might it influence our education system? During my internship, I had the pleasure of exploring these broad questions to provide some context to facilitate further discussions regarding AI and education in Aotearoa New Zealand. AI is considered a 'general-purpose' technology and it is often compared to electricity. AI can influence so many processes in so many aspects of life, therefore, to imagine AI's full transformative potential in education we need to also consider its likely influences on work, lifestyle and social norms.

My internship focused on surveying relevant developments in the private sector worldwide and how the international political interest in AI technologies is being translated into education policy. Following the broad background scoping of key literature and international policy documents, I organised the main findings under four main ideas, each representing an opportunity of harnessing AI for education in Aotearoa New Zealand. The four opportunities are outlined in a 20-page report which described the possibilities of (i) assisting teachers via AI-augmented teaching (ii) the expansion of adaptive, equitable and inclusive learning (iii) the option to rethink the aim of education, and (iv) transforming education planning and management. I found my internship work to be extremely rewarding, and I am excited that the Office of the Prime Minister's Chief Science Advisor (OPMCSA) will continue to work in this area and build upon it in 2020.

I really enjoyed my internship at the OPMCSA. It was fascinating to explore in-depth the various possibilities of the future of education and emerging technologies – topics of personal interest. I also loved the process of scoping, synthesising and distilling broad, complex ideas into more structured and organised insights. This experience has opened my perspective of the potential ways scientists can contribute to society outside of academia and showed me how skills gained from a science training could be advantageous in the public sector.

I am very grateful to the Dodd-Walls Centre for this rare and precious opportunity to contribute to the developments of Aotearoa New Zealand in the public sector space. Special thanks to Juliet Gerrard, Stuart McNaughton and the entire team at OPMCSA for your guidance, help, fantastic company and integrating me into your exciting world of work at the intersection of science and policy!

In 2020, two members of the DWC – a PhD student and a post doc - will be completing internships with the Office, supported by the DWC.

Return On Science

Dr Nate Davies, Associate Investigator and lecturer at Victoria University of Wellington, presented his Smart Ideas application and discussed his implementation pathway with the Return On Science Physical Sciences Committee. The Committee was able to give direction, advice and contacts to strengthen his bid. This strengthened his bid and he was awarded $1 million over three years for his research *'Non-toxic hybrid nanomaterials for luminescent solar concentrators.'*

In May, the Committee held a meeting dominated by the Dodd-Walls Centre with presentations being made by three DWC students (Abi Thampi, Fang Ou and Rakesh Arul). The students presented to Committee on their research topics and career plans. The Committee provided advice and feedback to the students who not only gained insight into the Committee, its role and its members but they also benefitted from the connections of the Committee members.

Better Metrics for Environmental Monitoring: The Inaugural New Zealand Global Environmental Measuring and Monitoring (GEMM) Network Meeting

The Dodd-Walls Centre, in collaboration with The Optical Society of America (OSA) and the American Geophysical Union (AGU), held the inaugural workshop of the New Zealand Node of the Global Environmental Measuring and Monitoring (GEMM) network in Wellington on 15th November 2019 at the Royal Society Te Apārangi. This workshop was the first step in the establishment of the New Zealand GEMM node; once established, this will be the only node in Australasia.

The GEMM Network is a collaborative network between groups from diverse backgrounds and skill sets, dedicated to developing new monitoring technologies enabling improved collection of environmental data. The network has nodes spread around the world, each of which concentrates on issues which are of particular importance locally. For example, California's local issues focus on air quality caused by forest fires, while the Canadian node focuses on melting of the permafrost. Their aim is to use the improved data to help inform decision making in response to climate change.

Jose Pozo public talks

In October 2019 the Dodd-Walls hosted two presentations with Jose Pozo, Chief Technology Officer of the European Photonics Industry Consortium, in Christchurch and Auckland.

Whilst quantum computing and quantum cryptography gain all the headlines in the popular press, new quantum technologies are scheduled to transform all industries – including the manufacturing, biomedical and sensing sectors. Jose summarised the plans for the world's largest companies for the introduction of a range of quantum technologies on a time scale of 3, 5 and 10 years.

Our Christchurch event was run in collaboration with the Ministry of Awesome and Te Ōhaka - Centre for Growth & Innovation. The two events stimulated some great discussions and provided an opportunity to see the investments being made in quantum technologies in the northern hemisphere. The audience at both events saw representatives from the consultancy sector, industry, the research sector, the public and government including the Prime Ministers Chief Science Advisor (Dr Juliet Gerrard).

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:

CAPITAL INPUTS

- Human and intellectual capital
- Manufactured capital (physical assets)
- Financial capital

STRUCTURE AND OPERATIONS

- Research and collaboration (nationally and internationally)
- Competence and capacity development of researchers and students
- Engagement and collaboration with industry
- Educational and public outreach activities
- Excellent governance and management practices
- Strong scientific and industry advisory panels comprised of leading scientists and industry leaders respectively

ACTIVITIES AND OUTPUTS

- Excellence in research outputs and professional activities
- Creation of new knowledge
- IP commercialisation and co-creation of IP with partners in R&D contracts
- Training and career developpment for researchers and students
- Educational activities and resources
- Productive national and international relationships
- Increased collaborations and increased external funding

IMPACTS AND OUTCOMES

- **Short term:** direct impact of DWC research, training, industry contracts, education outreach
- **Medium term:** contribution to future workforce, wealth generation and increased science literacy; increase in number of STEM students; increased connectivity between the science and industry sectors
- **Long term:** capability development for industry through high quality training of a research workforce skilled in the application of research; contributions to the place of science in society and the economy; growth of the high-tech industry sector in NZ and new high-value products; better decision making through increased science literacy; increased wellbeing through improved economic performance and equity

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

A 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, whānau and the general public
- Scientific educational materials generated as part of the programmes is available to teachers

WE CONTINUE TO BE RANKED IN THE TOP TEN INSTITUTIONS FROM NEW ZEALAND IN THE NATURE INDEX (IN 8TH POSITION IN 2019).

WE WORK WITH SOME OF NEW ZEALAND'S LARGEST COMPANIES AND WE HAVE FOSTERED START-UP BUSINESSES SUCH AS ENGENDER TECHNOLOGIES.

OUR RESEARCH EXTENDS FROM FUNDAMENTAL TO THE COMMERCIALLY FOCUSSED AND WE HAVE HAD SPIN-OUT COMPANIES FORMED. THIS BREADTH OF RESEARCH PROVIDES EXPOSURE FOR OUR STUDENTS ACROSS THE RESEARCH SPECTRUM AND WE WORK CLOSELY WITH OUR STUDENTS TO PROVIDE THEM OPPORTUNITIES THAT BENEFIT BOTH THEM AND THE COMPANIES THEY JOIN.

THE OPPORTUNITIES OFFERED TO OUR STUDENTS MAKE OUR GRADUATES SOUGHT AFTER IN THE MARKETPLACE, THEY ARE PROVIDED OPPORTUNITIES FROM START-UP WORKSHOPS TO LEARNING TIKANGA MĀORI THROUGH PARTICIPATION IN WĀNANGA.

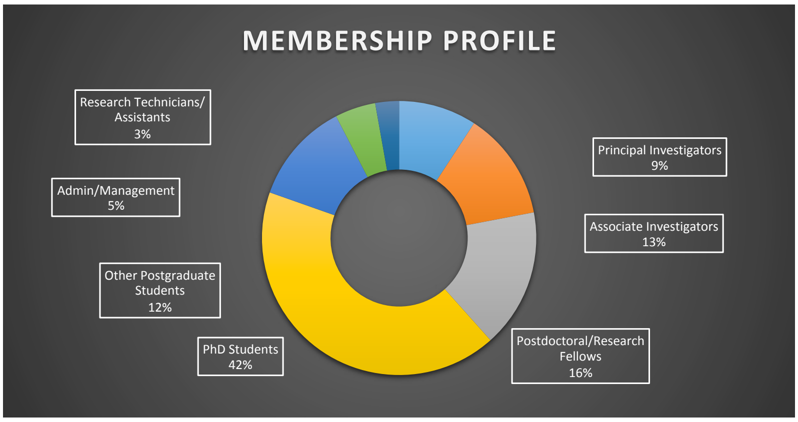
OUR RESEARCHERS SERVE IN ROLES ON NUMEROUS PUBLIC SECTOR PANELS AND BOARDS; THEY ENGAGE WITH GOVERNMENT AGENCIES TO ADD EXPERTISE TO DECISION MAKING OR DATA ANALYSIS AND PROVIDE EXPERT ADVICE. EXAMPLES OF 2019 SERVICE INCLUDE THE DEFENCE TECHNOLOGY AGENCY (DTA), NEW ZEALAND DEFENCE FORCE (NZDF), MINISTRY FOR PRIMARY INDUSTRIES (MPI), CALLAGHAN INNOVATION AND MINISTRY OF FOREIGN AFFAIRS & TRADE (MFAT).

THROUGH OUR EDUCATIONAL OUTREACH PROGRAMMES WE CONTINUE TO MAKE A SIGNIFICANT CONTRIBUTION TO IMPROVING THE SCIENTIFIC LITERACY OF ALL NEW ZEALANDERS AND OUR PACIFIC NEIGHBOURS. WORKING WITH MUSEUMS AND OTHER PARTNERS, WE CREATE PROGRAMMES AND RESOURCES TO PROVIDE OPPORTUNITIES FOR ONGOING LEARNING AND DISCOVERY.

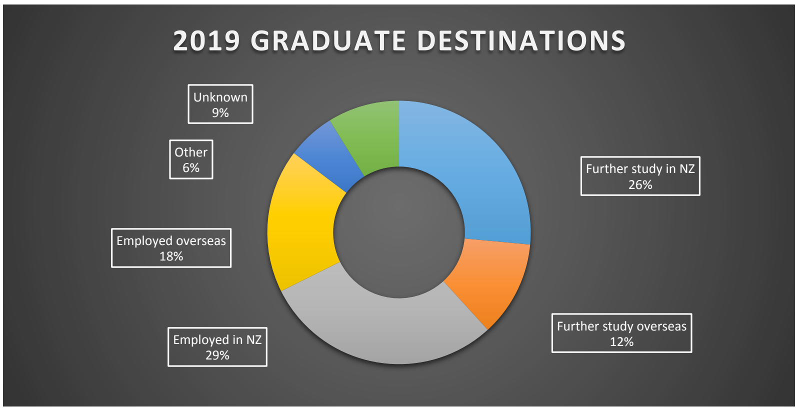
FACTS AND FIGURES

Broad category	Detailed category	Y5 (2019)
Value of CoRE funding from TEC ($M)		5.04
FTEs by category	Principal Investigators	2.95
	Associate Investigators	3.92
	Postdoctoral Fellows	14.09
	Research Technicians	2.13
	Administrative/Support	4.90
	Research Students	118.19
	Total	**146.18**
Headcounts by category	Principal Investigators	23
	Associate Investigators	32
	Postdoctoral Fellows	41
	Research Technicians	7
	Administrative/Support/ Management	12
	Research Students	135
	Total	**250**
Peer reviewed research outputs by type	Journal articles	139
	Books	0
	Book chapters	2
	Conference papers	21
	Other	1
	Total	**163**
Value of external research contracts awarded by source ($M NZD)	Vote Science and Innovation contestable funds	7.74
	Other NZ Government	0.06
	Domestic - private sector funding	0.56
	Overseas	0.13
	Host/Partner Support	0.22
	Total	**8.74**
Commercial activities	Patent applications	3
	Patents granted	2
	Invention disclosures	8
	Total number of spinouts (2015-2019)	**2**
Students studying at CoRE by level	Doctoral degree	105
	Other	30
	Total	**135**
Number of students completing qualifications by level	Doctoral degree	15
	Other	19
	Total	**34**
Immediate post-study graduate destinations	Further study in NZ	9
	Further study overseas	4
	Employed in NZ	10
	Employed overseas	6
	Other	2
	Unknown	3
	Total	**34**

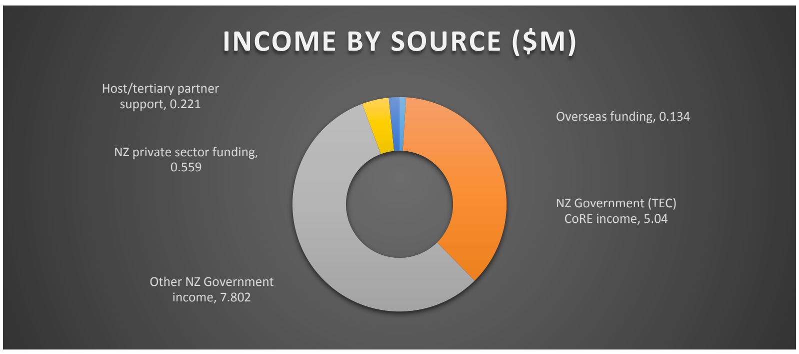
The DWC has a total of 55 Investigators (including the Director and Deputy Director) and 41 other research staff. Doctoral students comprise 42% of the total membership of the DWC and in addition to research training, many of our strategic activities involve students including educational outreach activities, Ka Hikitia, and industry interface and R&D. DWC strategic and central activities are led and supported by 4 managers and 8 administrative/support 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.



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.



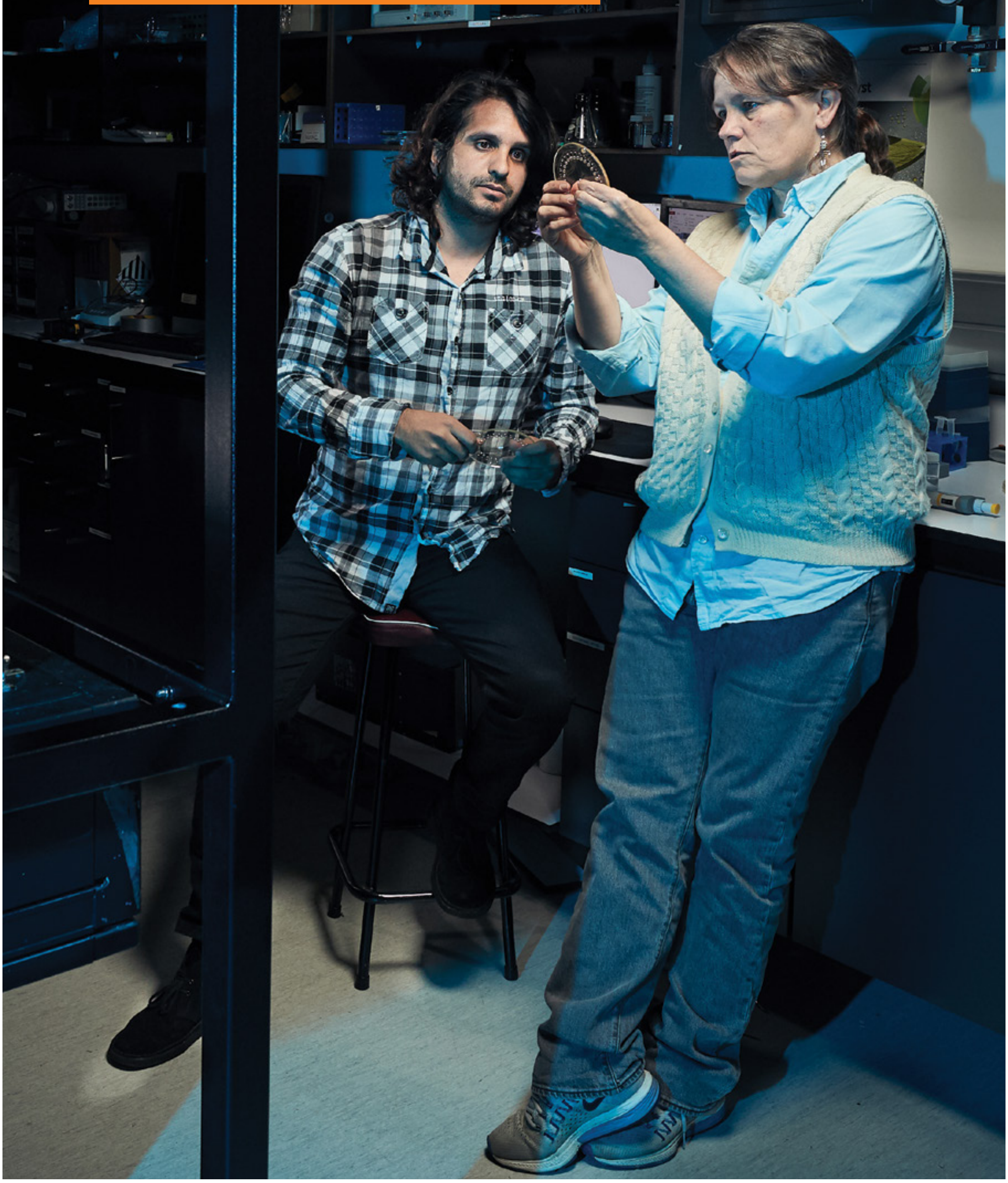
FINANCES

Report by Programme 2019

	Actual	Budget
Income	5,039,000	5,039,000
Salaries and related costs		
Director, PI and AI	453,223	386,434
Postdoctoral Fellows	1,255,263	1,335,728
Others - Managers & Salary-related costs	193,873	224,136
Total salaries and related costs	**1,902,359**	**1,946,298**
Overheads	**1,694,650**	**2,096,182**
Research operating expenditure and depreciation		
Theme 1a Photonic sensing & imaging	226,085	288,000
Theme 1b Photonic sources & components	205,740	231,000
Theme 2a Quantum fluids & gases	122,629	150,000
Theme 2b Quantum manipulation & information	126,098	241,998
Pool opex (New & Emerging Researchers)	57,294	-
Total research operating expenditure	**737,846**	**910,998**
Scholarships awarded	**1,075,344**	
Scholarships pool	**-**	**520,263**
Strategic operating expenditure		
Industry Outreach & consultants	249,867	213,000
Educational Outreach	66,890	80,000
Ka Hikitia	723	30,000
Total strategic operating expenditure	**317,479**	**323,000**
Centre operating expenditure		
Travel Pool (Research)	376,195	100,000
other centre costs	267,765	315,000
Total centre operating expenditure	**643,960**	**415,000**
Total expenditure	**6,371,638**	**6,211,741**
Net surplus	**-1,332,637**	**-1,172,741**

Professor Cather Simpson and Dodd-Walls Centre alumni Dr Matheus Vargas standing outside of Orbis Diagnostics testing station. Orbis Diagnostics is our spinoff company focused on “point of cow” diagnostics – measuring key components of milk automatically every cow, every milking.

Professor Simpson was the recipient of the Pickering Medal from Royal Society Te Apārangi in 2019. This recognised her pioneering research and commercialisation of innovative photonic technologies. Orbis Diagnostics is a fantastic example of the innovative research that Cather undertakes.



MEMBERS, GOVERNANCE AND MANAGEMENT

DWC Board members

DR GARTH CARNABY, CHAIR
FRSNZ, MNZM, CNZM

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 Wool Industry Research Ltd. 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.

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 and export sectors. Charlotte is current a director on the Board of New Zealand Trade and Enterprise, and was CEO of Dynamic Controls for more than a decade prior to joining Jade Software.

DR DIANNE MCCARTHY
CRSNZ, ONZM, CNZM

Dianne has extensive experience in a number of senior management and governance roles in the tertiary education, science and health sectors. The former CEO of the Royal Society of New Zealand, she is now Chair of the New Zealand Institute of Economic Research, a Director of the Cawthron Institute, a member of the Healthier Lives National Science Challenge Governance Group, and Chair of the Ageing Well National Science Challenge Governance Group. She is a Trustee of the Malaghan Institute of Medical Research and the Hearing Research Foundation (NZ). 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.

MR IAN TAYLOR

CNZM

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 2019 New Zealand Innovator of the Year, the 2013 Outstanding Māori Business Leader of the Year and the 2010 New Zealander of the Year. In 2012, Ian was appointed a Companion of the New Zealand Order of Merit for services to television and business.

PROFESSOR RICHARD BLAIKIE

FRSNZ

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. He currently serves as a Director of Auckland UniServices Limited, REANNZ and the New Zealand Synchrotron Group.

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. Richard is a current director on the Boards of Oritain Global Ltd, Brain Research New Zealand, Dinsdale Ltd and the Riddet Institute.

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
Aguergaray	Claude	Dr	The University of Auckland	Associate Investigator
Albert	Michael	Professor	University of Otago	Principal Investigator
Andersen	Mikkel	A/Professor	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
Borbely	Joseph	Dr	Callaghan Innovation, MSL	Associate Investigator
Bradley	Ashton	Dr	University of Otago	Principal Investigator
Brand	Joachim	Professor	Massey University	Principal Investigator
Brasch	Nicola	Professor	Auckland Uni. Of Technology	Associate Investigator
Bubanja	Vladimir	Dr	Callaghan Innovation	Associate Investigator
Carmichael	Howard	Professor	The University of Auckland	Principal Investigator
Cheyne	Juliette	Dr	The University of Auckland	Associate Investigator
Coen	Stéphane	A/Professor	The University of Auckland	Principal Investigator
Craigie	Cameron	Dr	AgResearch NZ Ltd	Associate Investigator
Croft	James	Dr	University of Otago	Associate Investigator
Davis	Nathaniel	Dr	Victoria Uni. Of Wellington	Associate Investigator
Deb	Amita	Dr	University of Otago	Associate Investigator
Erkintalo	Miro	Dr	The University of Auckland	Principal Investigator
Golovko	Vladimir	A/Professor	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
Hoogerland	Maarten	Dr	The University of Auckland	Principal Investigator
Jin	Jianyong	Dr	The University of Auckland	Associate Investigator
Jones	Marcus	Dr	Auckland Uni. Of Technology	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	Dr	University of Otago	Associate Investigator
Le Ru	Eric	Professor	Victoria Uni. of Wellington	Associate Investigator
Leonhardt	Rainer	A/Professor	The University of Auckland	Associate Investigator
Longdell	Jevon	A/Professor	University of Otago	Principal Investigator
McCane	Brendan	Professor	University of Otago	Associate Investigator
McGoverin	Cushla	Dr	The University of Auckland	Associate Investigator
Miller	Sara	Dr	University of Otago	Associate Investigator
Murdoch	Stuart	Dr	The University of Auckland	Principal Investigator
Nieuwoudt	Michel	Dr	The University of Auckland	Associate 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	Principal Investigator
Shepherd	Jami	Dr	The University of Auckland	Associate Investigator
Simpson	Cather	Professor	The University of Auckland	Associate Investigator
Smith	Catherine	Dr	University of Otago	Associate Investigator
Taylor	Luke	Dr	University of Otago	Prototype Manager
Van Wijk	Kasper	A/Professor	The University of Auckland	Principal Investigator
Vanholsbeeck	Frédérique	A/Professor	The University of Auckland	Principal Investigator
Vogt	Dominik	Dr	The University of Auckland	Associate Investigator
Waterhouse	Geoff	A/Professor	The University of Auckland	Associate Investigator

Last Name	First Name	Title	Institution	Role in the DWC
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
Woodhouse	AJ	Mrs	University of Otago	Programme Manager
Scown	Shannon	Ms	The University of Auckland	BD Manager
Lam	Ash	Ms	University of Otago	Administrator
Baikie	Susan	Ms	University of Otago	Administrator
Miles	Dee	Ms	The University of Auckland	Administrator
Sirisena	Premika	Ms	The University of Auckland	Administrator
Dailey	Brett	Mr	University of Otago	Accountant
Joe	Kiel	Mr	The University of Auckland	Finance Administrator
Lata	Avinesh	Ms	The University of Auckland	Accountant

Postdoctoral and Research Fellows

Last Name	First Name	Title	Institution	Position
Balabhadra	Sangeetha	Dr	University of Canterbury	Postdoctoral Fellow
Baillie	Danny	Dr	University of Otago	Postdoctoral Fellow
Bonesi	Marco	Dr	The University of Auckland	Postdoctoral Fellow
Calderon	Miguel Martinez	Dr	The University of Auckland	Postdoctoral Fellow
Canela	Victor	Dr	The University of Auckland	Postdoctoral Fellow
Cobus	Laura	Dr	The University of Auckland	Postdoctoral Fellow
Ding	Boyang	Dr	University of Otago	Postdoctoral Fellow
Ebling	Ulrich	Dr	Massey University	Postdoctoral Fellow
Giraldo	Andrus	Dr	The University of Auckland	Postdoctoral Fellow
Haneef	Shahna	Dr	The University of Auckland	Postdoctoral Fellow
Hasse	Thomas	Dr	The University of Auckland	Postdoctoral Fellow
Helm	John	Dr	University of Otago	Postdoctoral Fellow
Holtcamp	Hannah	Dr	The University of Auckland	Postdoctoral Fellow
Isarov	Maya	Dr	University of Otago	Postdoctoral Fellow
Jeszsenski	Peter	Dr	Massey University	Postdoctoral Fellow
Kolenderska	Sylwia	Dr	The University of Auckland	Postdoctoral Fellow
Kumari	Madhuri	Dr	University of Otago	Postdoctoral Fellow
Lambert	Nicholas	Dr	University of Otago	Postdoctoral Fellow
Low	Jeffery	Dr	The University of Auckland	Postdoctoral Fellow
Ma	Li	Dr	University of Otago	Postdoctoral Fellow
Major	Jan	Dr	Massey University	Postdoctoral Fellow
Mallett	Ben	Dr	The University of Auckland	Postdoctoral Fellow
Maria	Michael	Dr	The University of Auckland	Postdoctoral Fellow
Minnee	Thomas	Dr	Massey University	Research Fellow
Monahan	Nick	Dr	Victoria University of Wellington	Postdoctoral Fellow
Ng	Vincent	Dr	The University of Auckland	Postdoctoral Fellow
Novikova	Nina	Dr	The University of Auckland	Postdoctoral Fellow
Pal	Sukla	Dr	University of Otago	Postdoctoral Fellow
Price	Mike	Dr	Victoria University of Wellington	Postdoctoral Fellow
Ramavararamaja	Kishor Kumar	Dr	University of Otago	Postdoctoral Fellow
Reza	Armani	Dr	The University of Auckland	Postdoctoral Fellow
Risos	Alex	Dr	The University of Auckland	Postdoctoral Fellow
Robertson	Julia	Dr	The University of Auckland	Postdoctoral Fellow
Ruschel	Stefan	Dr	The University of Auckland	Postdoctoral Fellow
Schumayer	Daniel	Dr	University of Otago	Postdoctoral Fellow
Shamailov	Sophie	Dr	University of Otago	Postdoctoral Fellow
Thomas	Ryan	Dr	University of Otago	Postdoctoral Fellow
Weyland	Marvin	Dr	University of Otago	Postdoctoral Fellow
Xu	Gang	Dr	The University of Auckland	Postdoctoral Fellow
Yiqing	Xu	Dr	The University of Auckland	Postdoctoral Fellow
Yu	XiaoQuan	Dr	University of Otago	Research Fellow

PhD Students

Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Abbas	Navid	The University of Auckland	
Ahmmed	Fatima	University of Otago	
Alizadeh	Yashar	University of Canterbury	S
Arabamadi	Eshan	University of Otago	S
Arshad	Faiza	University of Otago	
Ashforth	Simon	The University of Auckland	
Azeem	Farhan	University of Otago	S
Baber	Logan	The University of Auckland	S
Bandara	Ravindra	The University of Auckland	S
Bangalore Shashidhar	Vinay Bharadwaj	Auckland University of Technology	S
Berzins	Karlis	University of Otago	
Brown	Dylan	The University of Auckland	S, C
Chan	Andrew	The University of Auckland	
Cheung	Pang Ying	The University of Auckland	
Chilcott	Matthew	University of Otago	
Chima	Robert	University of Otago	
Choudhury	Sarthak	Massey University	S
Cink	Ruth	Auckland University of Technology	C
Clarke	James	The University of Auckland	S
Cormack	Maddy	University of Otago	S
Dillon	Owen	The University of Auckland	C
Dong	Yusong	The University of Auckland	
Dosado	Aubery Gabasa	The University of Auckland	S
Emeny	Chrissy	University of Canterbury	
Esan	Ayomikun Samuel	The University of Auckland	S
Fersterer	Petra	University of Otago	C
Garagoda	Samanali	University of Otago	S
George	Anand	The University of Auckland	
Goh	Hwan	The University of Auckland	S, C
Goodwin (prev. Brown)	Matthew	The University of Auckland	
Groiseau	Caspar	The University of Auckland	S
Hendry	Ian	The University of Auckland	
Hennin	Geraud	The University of Auckland	S
Hensley	Noah	University of Otago	C
Honney	Claire	The University of Auckland	S, C
Hope	James	The University of Auckland	
Hosking	Peter	The University of Auckland	
Ismael	Fouad	Auckland University of Technology	S
Jamil	Mahamood	The University of Auckland	
Jeszenszki	Peter	Massey University	S, C
Jobbitt	Nicholas	University of Canterbury	S
Jones	Tobin	The University of Auckland	
Jose	Ashly	The University of Auckland	S
Kaur	Harpreet	University of Waikato	
Kazemzadeh	Mohammadrahim	The University of Auckland	S
King	Gavin	University of Otago	
Kristofferson	Andreas	The University of Auckland	
Laouby	Zahra	The University of Auckland	

Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Lee	Au Chen	University of Otago	
Lee	Lia	The University of Auckland	
Jull	Harrisson	University of Waikato	C, S
Loveday	James	The University of Auckland	S
Mapley	Joseph	University of Otago	
Martin	Jamin	University of Canterbury	S
Masson	Stuart	The University of Auckland	C
Mautner	Ira	The University of Auckland	
McDonald	Rob	University of Otago	C
McPhail	Vivian	The University of Auckland	S
Mobassem	Sonia	University of Otago	S
Mothkuri	Sagar	University of Canterbury	
Neiman	Alex	University of Canterbury	
Nemet	Nikolett	The University of Auckland	S, C
Nesbitt	Sam	University of Canterbury	
Ngaha	Jacob	The University of Auckland	
Nielsen	Alexander	The University of Auckland	S
Oh	Sue Ann	University of Otago	C
Onyema	Chikezie	University of Canterbury	
Otto	Suzanne	University of Canterbury	
Otupiri	Robert	The University of Auckland	S
Ou	Rachel (Fang)	The University of Auckland	C
Rajkumar	Damenraj	University of Otago	
Rooney	Jeremy	University of Otago	
Ruksasakchai	Poramaporn (Up)	University of Otago	
Rwizinkindi	Dominique	Auckland University of Technology	S
Sadeghi	Mohammad	The University of Auckland	S
Sales	Ruth	University of Otago	S
Savoie	Maxime	University of Canterbury	
Sawyer	Bianca	University of Otago	
Sayson	Noel	The University of Auckland	S
Scott	Jonty	University of Canterbury	
Shikhali Najafabadi	Mojdeh	University of Otago	S
Shillito	Georgina	University of Otago	
Simpson	Jonathan	The University of Auckland	
Smith	Joseph	University of Otago	
Solanki	Pratik	University of Canterbury	S
Solis	Daniel	University of Otago	
Stitely	Kevin	The University of Auckland	
Sun	Jason	University of Waikato	C
Sutton	Joshua	University of Otago	
Tesana	Siriluck	University of Canterbury	
Thampi	Abi	The University of Auckland	S
Thorn	Karen	Victoria Uni. of Wellington	
Trainor	Luke	University of Otago	
Urbanska	Magdalena	The University of Auckland	S
Vargas	Matheus	The University of Auckland	
Wang	Mark	The University of Waikato	S

PhD Students continued

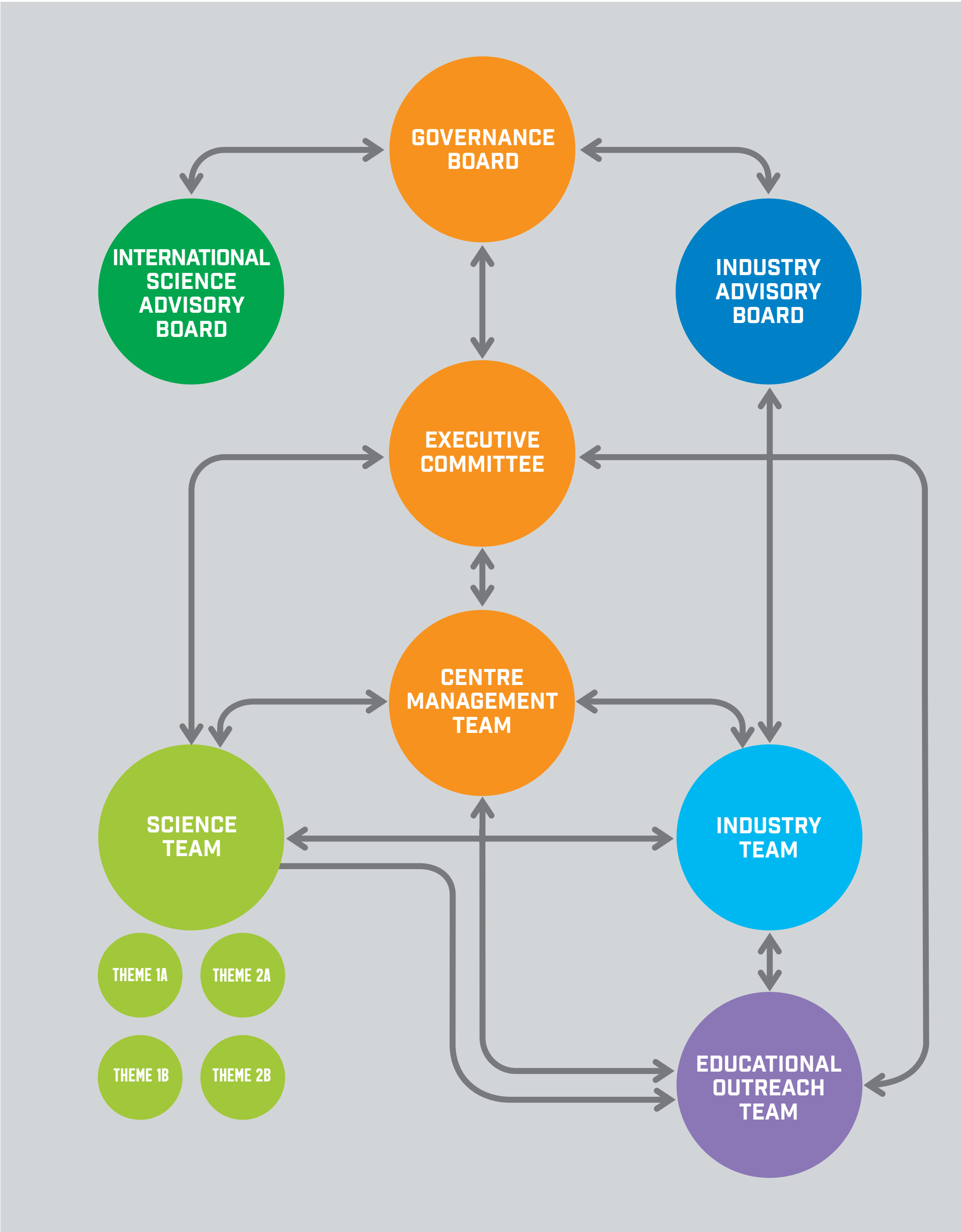
Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Wang	Qing	The University of Auckland	
Wang	Xindi (Andy)	The University of Auckland	
White	Joni	The University of Auckland	
Wu	Yimei	The University of Auckland	
Yang	Mingrui (Ray)	Massey University	
Ye	Piao (Tracy)	The University of Auckland	
Zhou	Huihua	The University of Auckland	S
Zlygostiev	Mykola	The University of Auckland	S
Zou	Dian	University of Canterbury	S

Other Research Degree Students

Last Name	First Name	Institution	Completed (C) DWC Scholarship (S)
Arul	Rakesh	The University of Auckland	
Barnett	Peter	Auckland University of Technology	C
Bi	Toby	The University of Auckland	C
Chiang	Jessica	The University of Auckland	
Chung	Stephen	The University of Auckland	
Chung	Yeon Wook (John)	University of Otago	
Clarke	Jordan	University of Otago	
Devane	Patrick	University of Otago	C
Elliott	Alex	The University of Auckland	S, C
Everts	Jono	University of Otago	
Harrison	Jacob	University of Otago	C
Hayton	Chris	University of Otago	C
Hobbs	Rhys	University of Otago	C
Jones	Angus	The University of Auckland	
Lee	Au-Chen	University of Otago	C
Li	Zongda	The University of Auckland	
Mansuri	Nema	The University of Auckland	C
Mitchell	Nikolas	University of Otago	C
Ngaha	Jacob	The University of Auckland	S, C
Ostrowski	Lucas	The University of Auckland	S
Qureshi	Pierce	The University of Auckland	C
Simpson	Jonathan	The University of Auckland	S, C
Soule	Juliette	The University of Auckland	C
Su	Andrew	The University of Auckland	
Taine	Win	University of Otago	C
Tang	Stanley	The University of Auckland	C
Tay	Elliot	University of Otago	
Underwood	Andrew	University of Otago	
Wang	Yourong (Frank)	The University of Auckland	C
Wolfgramm-Russell	Vincent	The University of Auckland	C

ORGANISATIONAL AND COMMITTEE STRUCTURE OF THE DODD-WALLS CENTRE

The DWC is organised 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)	AJ Woodhouse	University of Otago
Secretary	Susan Baikie	University of Otago

Executive Committee

Director	David Hutchinson (Chair)	University of Otago
Deputy-Director	Neil Broderick	The University of Auckland
Principal Investigator	Michael Albert	University of Otago
Principal Investigator	Blair Blakie	University of Otago
Principal Investigator	Maarten Hoogerland	The University of Auckland
Principal Investigator	Harald Schwefel	University of Otago
Principal Investigator	Frédérique Vanholsbeeck	The University of Auckland
Principal Investigator	Cather Simpson	The University of Auckland
Principal Investigator	Stéphane Coen	The University of Auckland
Principal Investigator	Jon-Paul Wells	University of Canterbury
Industry Team Leader (ex officio)	John Harvey	The University of Auckland
Programme Manager (ex officio)	AJ Woodhouse	University of Otago
Secretary	Susan Baikie	University of Otago

Industry Advisory Board

Dr Simon Poole (Chair)	Finisar Australia Pty Ltd

Education Outreach Team

Principal Investigator	Bernd Krauskopf	The University of Auckland
Principal Investigator	Kasper van Wijk	The University of Auckland
Director	David Hutchinson	University of Otago
Education Manager	Craig Grant (Chair)	Otago Museum
Director of Otago Museum	Ian Griffin	Otago Museum
Outreach Co-ordinator	Andy Wang	The University of Auckland
Secretary	Susan Baikie/Ash Lam	University of Otago

Dodd-Walls Centre Management Team

Programme Manager	AJ Woodhouse	University of Otago
Director	David Hutchinson	University of Otago
Deputy Director	Neil Broderick	The University of Auckland
Administrator and PA to Director	Susan Baikie	University of Otago
Administrator	Ash Lam	University of Otago Administrator
Dee Miles		The University of Auckland
Finance Accountant	Kiel Joe/Avinesh Lata	The University of Auckland
Finance Accountant	Brett Dailey	University of Otago

Science Advisory Board

Professor Bill Phillips	Joint Quantum Institute, U.S.A.
Professor Artur Ekert	Centre for Quantum Technologies, Singapore & University of Oxford, UK
Professor Nergis Mavalvala	Massachusetts Institute of Technology, USA
Professor Ian Walmsley	Imperial College, UK
Professor John Dudley	University Bourgogne Franche-Comté, France

Industry Team

Industry Team Leader	John Harvey	The University of Auckland
Director	David Hutchinson	University of Otago
Deputy Director	Neil Broderick	The University of Auckland
Principal Investigator	Keith Gordon	University of Otago
Principal Investigator	Frédérique Vanholsbeeck	The University of Auckland
Industry Manager	Luke Taylor	University of Otago
Business Development Manager	Shannon Scown	The University of Auckland
Programme Manager	AJ Woodhouse	University of Otago
Secretary	Dee Miles	The University of Auckland

Science Team

Deputy Director	Neil Broderick	The University of Auckland
Director	Nominee: Blair Blakie	University of Otago
Theme Leader (1a)	Jon-Paul Wells	University of Canterbury
Theme Leader (1b)	Stéphane Coen	The University of Auckland
Theme Leader (2a)	Maarten Hoogerland	The University of Auckland
Theme Leader (2b)	Jevon Longdell	University of Otago
Industry Team Leader (ex-officio)	John Harvey	The University of Auckland
Programme Manager	AJ Woodhouse	University of Otago
Secretary	Susan Baikie	University of Otago

Theme 1a – Photonic Sensors and Imaging (PSI)

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

Dr Juliette Cheyne	The University of Auckland, Physiology
Dr Nathaniel Davis	Victoria University of Wellington, Chemical and Physical Sciences
Dr Michel Nieuwoudt	The University of Auckland, Physics
Professor Cather Simpson	The University of Auckland, Physics
Dr Catherine Smith	University of Otago, Dodd-Walls Centre
Dr Marcus Jones	Auckland University of Technology, Chemistry
Professor Nicola Brasch	Auckland University of Technology, Chemistry
Dr Jami Shepherd	The University of Auckland, Physics
Dr Sara Miller	University of Otago, Chemistry

Theme 1b – Photonic Sources and Components (PSC)

Associate Professor Stéphane Coen	THEME LEADER, The University of Auckland, Physics
Professor Neil Broderick	The University of Auckland, Physics
Dr Miro Erkintalo	The University of Auckland, Physics
Dr Jianyong Jin	The University of Auckland, Chemistry
Professor Bernd Krauskopf	The University of Auckland, Mathematics
Associate Professor Rainer Leonhardt	The University of Auckland, Physics
Associate Professor Stuart Murdoch	The University of Auckland, Physics
Dr Harald Schwefel	University of Otago, Physics
Associate Professor Geoff Waterhouse	The University of Auckland, Chemistry
Dr Claude Aguergaray	The University of Auckland, Physics
Professor Cather Simpson	The University of Auckland, Physics
Dr Dominik Vogt	The University of Auckland, Physics

Theme 2a – Quantum Fluids and Gases (QFG)

Dr Maarten Hoogerland	THEME LEADER, The University of Auckland, Physics
Associate Professor Niels Kjærgaard	University of Otago, Physics
Dr Danny Baillie	University of Otago, Physics
Emeritus Professor Rob Ballagh	University of Otago, Physics
Professor Blair Blakie	University of Otago, Physics
Dr Ashton Bradley	University of Otago, Physics
Professor Joachim Brand	Massey University, NZ Institute for Advanced Study
Professor Howard Carmichael	The University of Auckland, Physics
Dr Amita Deb	University of Otago, Physics
Professor David Hutchinson	University of Otago, Physics
Associate Professor Scott Parkins	The University of Auckland, Physics
Professor Ulrich Zūlicke	Victoria University of Wellington, Chemical and Physical Sciences
Dr James Croft	University of Otago, Physics

Theme 2b – Quantum Manipulation and Information (QMI)

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

2019 PEER-REVIEWED JOURNAL PUBLICATIONS

AUTHORS*	TITLE	JOURNAL
Hendry, Ian; Garbin, Bruno; Murdoch, Stuart G.; Coen, Stéphane; Erkintalo, Miro.	Impact of desynchronization and drift on soliton-based Kerr frequency combs in the presence of pulsed driving fields	Phys. Rev. A **100**, 23829 (2019)
Nielsen, Alexander U.; Garbin, Bruno; Coen, Stéphane; Murdoch, Stuart G.; Erkintalo, Miro.	Coexistence and Interactions between Nonlinear States with Different Polarizations in a Monochromatically Driven Passive Kerr Resonator	Phys. Rev. Lett. **123**, 13902 (2019)
Hari, Neelam; Patel, Priyanka; Ross, Jacqueline; Hicks, Kevin; **Vanholsbeeck, Frédérique**.	Optical coherence tomography complements confocal microscopy for investigation of multicellular tumour spheroids	Scientific reports **9**, 10601 (2019)
Turnbull, Steven Martin; Locke, Kirsten; **Vanholsbeeck, Frédérique**; O'Neale, Dion R. J.	Bourdieu, networks, and movements: Using the concepts of habitus, field and capital to understand a network analysis of gender differences in undergraduate physics.	PLOS ONE **14**, 46753 (2019)
Hope, J.; Aqrawe, Z.; Lim, M.; **Vanholsbeeck, F.**; McDaid, A.	Increasing signal amplitude in electrical impedance tomography of neural activity using a parallel resistor inductor capacitor (RLC) circuit	Journal of Neural Engineering **16**, 66041-66056 (2019)
Vargas, Matheus J. T.; **Nieuwoudt, Michel; Yong, Rui Ming; Vanholsbeeck, Frederique**; Williams, David E.; **Simpson, M. Cather**.	Excellent quality microchannels for rapid microdevice prototyping: direct CO2 laser writing with efficient chemical postprocessing	Microfluidics and Nanofluidics **23**, 1-13 (2019)
Kaipio, Jari; Huttunen, Tomi; Luostari, Teemu; Lähivaara, Timo; Monk, Peter.	A Bayesian approach to improving the Born approximation for inverse scattering with high contrast materials	Inverse Problems **35(8)**, 84001-84020 (2019)
Castello, Daniel; **Kaipio, Jari**.	Modelling Errors due to Timoshenko approximation in Damage Identification	International Journal for Numerical Methods in Engineering **120(9)**,1148-1162 (2019)
Thompson, K.; **Brand, J.; Zülicke, U**.	Chiral two-dimensional p-wave superfluid from s-wave pairing in the Bose-Einstein-condensate regime	Phys. Rev. A **101**, 13613 (2019)
Majic, Matt; Pratley, Luke; Schebarchov, Dmitri; Somerville, Walter R. C.; **Auguié, Baptiste; Le Ru, Eric C**.	Approximate T - matrix and optical properties of spheroidal particles to third order with respect to size parameter	Phys. Rev. A **99**, 13853 (2019)
Jeszenszki, P.; Alavi, A.; **Brand, J.**	Are smooth pseudopotentials a good choice for representing short-range interactions?	Physical Review A **99**, 33608 (2019)
Bērziņš, Kārlis; **Sutton, Joshua J.**; Loch, Carolina; Beckett, Deanna; Wheeler, Benjamin J.; Drummond, Bernadette K.; **Fraser-Miller, Sara J.; Gordon, Keith C.**	Application of low-wavenumber Raman spectroscopy to the analysis of human teeth	Journal of Raman Spectroscopy **50**, 1375-1387 (2019)
Anyi, C. L.; Thirkettle, R. J.; MacDonald, G. J.; Schreiber, K. U.; **Wells, J-P R.**	Gyroscopic operation on the 3s(2) -> 2p(10) 543.3 nm transition of neon in a 2.56 m(2) ring cavity	Optics Letters **44**, 3074-3077 (2019)

AUTHORS*	TITLE	JOURNAL
Barnsley, Jonathan E.; Findlay, James A.; **Shillito, Georgina E.**; Pelet, William S.; Scottwell, Synøve Ø.; McIntyre, Sam M.; Tay, Elliot J.; **Gordon, Keith C.**; Crowley, James D.	Long-lived MLCT states for Ru(ii) complexes of ferrocene-appended 2,2′-bipyridines	Dalton Trans. **48**, 15713-15722 (2019)
Xu, Yiqing; Murdoch, Stuart G.	Real-time spectral analysis of ultrafast pulses using a free-space angular chirp-enhanced delay	Opt. Lett. **44**, 3697-3700 (2019)
Hoang, Vo Van; Giang, Nguyen Hoang; **Bubanja, Vladimir.**	Hexa ↔ tetra silicene crystal–crystal phase transition	Philosophical Magazine **100:5**, 551-570 (2019)
Auguie, Baptiste; Darby, Brendan L.; **Le Ru, Eric C.**	Electromagnetic interactions of dye molecules surrounding a nanosphere	Nanoscale **11**, 12177-12187 (2019)
Langer, Judith; Jimenez de Aberasturi, Dorleta; Aizpurua, Javier; Alvarez-Puebla, Ramon A; **Auguié, Baptiste**; Baumberg, Jeremy J; Bazan, Guillermo C; Bell, Steven E J; Boisen, Anja; Brolo, Alexandre G; Choo, Jaebum; Cialla-May, Dana; Deckert, Volker; Fabris, Laura; Faulds, Karen; García de Abajo, F Javier; Goodacre, Royston.	Present and Future of Surface Enhanced Raman Scattering	ACS Nano **14(1)**, 28-117 (2019)
Schebarchov, D.; **Le Ru, E. C.**; Grand, J.; **Auguie, B.**	Mind the gap: testing the Rayleigh hypothesis in T-matrix calculations with adjacent spheroids	Opt. Express **27**, 35750–35760 (2019)
Alonso-Serra, Juan; Safronov, Omid; Lim, Kean-Jin; **Fraser-Miller, Sara J.**; Blokhina, Olga B.; Campilho, Ana; Chong, Sun-Li; Fagerstedt, Kurt; Haavikko, Raisa; Helariutta, Ykä; Immanen, Juha; Kangasjärvi, Jaakko; Kauppila, Tiina J.; Lehtonen, Mari; Ragni, Laura; Rajaraman, Sitaram; Räsänen, Riikka-Marjaana; Safdari, Pezhman; Tenkanen, Maija; Yli-Kauhaluoma, Jari T.; Teeri, Teemu H.; Strachan, Clare J.; Nieminen, Kaisa; Salojärvi, Jarkko.	Tissue-specific study across the stem reveals the chemistry and transcriptome dynamics of birch bark	New Phytologist **222**, 1816-1831 (2019)
Saarinen, Jukka; Gütter, Friederike; Lindman, Mervi; Agopov, Mikael; **Fraser-Miller, Sara J.**; Scherließ, Regina; Jokitalo, Eija; Santos, Hélder A.; Peltonen, Leena; Isomäki, Antti; Strachan, Clare J.	Cell-Nanoparticle Interactions at (Sub)–Nanometer Resolution Analyzed by Electron Microscopy and Correlative Coherent Anti-Stokes Raman Scattering	Biotechnology Journal **14(4)** (2019)
Akabar, Nurshadrina; Chaturvedi, Vishal; **Shillito, Georgina E.**; Schwehr, Bradley J.; **Gordon, Keith C.**; Huff, Gregory S.; **Sutton, Joshua J.**; Skelton, Brian W.; Sobolev, Alexandre N.; Stagni, Stefano; Nelson, Delia J.; Massi, Massimiliano.	Photophysical and biological investigation of phenol substituted rhenium tetrazolato complexes	Dalton Trans. **48**, 15613-15624 (2019)
Barnsley, Jonathan E.; **Shillito, Georgina E.**; Larsen, Christopher B.; van der Salm, Holly; Horvath, Raphael; **Sun, Xue Zhong**; Wu, Xue; George, Michael W.; Lucas, Nigel T.; **Gordon, Keith C.**	Generation of Microsecond Charge-Separated Excited States in Rhenium(I) Diimine Complexes: Driving Force Is the Dominant Factor in Controlling Lifetime	Inorganic Chemistry **58**, 9785-9795 (2019)

AUTHORS*	TITLE	JOURNAL
Barnsley, Jonathan E.; Pelet, William; McAdam, John; Wagner, Klaudia; Hayes, Patricia; Officer, David L.; Wagner, Pawel; **Gordon, Keith C.**	When “Donor–Acceptor” Dyes Delocalize: A Spectroscopic and Computational Study of D–A Dyes Using “Michler’s Base”	The Journal of Physical Chemistry A **123**, 5957-5968 (2019)
Bērziņš, Kārlis; Fraser-Miller, Sara J.; Rades, Thomas; **Gordon, Keith C.**	Low-Frequency Raman Spectroscopic Study on Compression-Induced Destabilization in Melt-Quenched Amorphous Celecoxib	Molecular Pharmaceutics **16**, 3678-3686 (2019)
Chandrabose, Sreelakshmi; Chen, Kai; Barker, Alex J.; **Sutton, Joshua J.**; Prasad, Shyamal K. K.; Zhu, Jingshuai; Zhou, Jiadong; **Gordon, Keith C.**; Xie, Zengqi; Zhan, Xiaowei; Hodgkiss, Justin M.	High Exciton Diffusion Coefficients in Fused Ring Electron Acceptor Films	Journal of the American Chemical Society **141**, 6922-6929 (2019)
Killeen, Daniel Patrick; Card, Asli; **Gordon, Keith Christopher**; Perry, Nigel Brian.	First Use of Handheld Raman Spectroscopy to Analyze Omega-3 Fatty Acids in Intact Fish Oil Capsules	Applied Spectroscopy **74**, 365-371 (2019)
Aidan P. McKay; **Joseph I.; Mapley Prof. Keith C. Gordon**; Dr. David A. McMorran.	RuII and IrIII Complexes Containing ADA and DAD Triple Hydrogen Bonding Motifs: Potential Tectons for the Assembly of Functional Materials	Chemistry - An Asian Journal **14**, 1194-1203 (2019)
Olejar, Kenneth J; Ricci, Arianna; Swift, Simon; Zujovic, Zoran; **Gordon, Keith C**; Fedrizzi, Bruno; Versari, Andrea; Kilmartin, Paul A.	Characterization of an Antioxidant and Antimicrobial Extract from Cool Climate, White Grape Marc	Antioxidants **8**, 232 (2019)
Sutton, Joshua J.; Dr. Thanh Luan Nguyen; Prof. Han Young Woo; **Prof. Keith C. Gordon.**	"Variable-Temperature Resonance Raman Studies to Probe Interchain Ordering for Semiconducting Conjugated Polymers with Different Chain Curvature"	Chemistry – An Asian Journal **14**, 1175-1183 (2019)
Salim, Malinda; **Fraser-Miller, Sara J.; Sutton, Joshua J.**; Bērziņš, Kārlis; Hawley, Adrian; Clulow, Andrew J.; Beilles, Stéphane; **Gordon, Keith C.**; Boyd, Ben J.	Application of Low-Frequency Raman Scattering Spectroscopy to Probe in Situ Drug Solubilization in Milk during Digestion	The Journal of Physical Chemistry Letters **10**, 2258-2263 (2019)
Tarling, M. S.; Smith, S. A. F.; **Scott, J. M.**; Rooney, J. S.; Viti, C.; **Gordon, K. C.**	The internal structure and composition of a plate-boundary-scale serpentinite shear zone: the Livingstone Fault, New Zealand	Solid Earth **10**, 1025–1047 (2019)
Mallett, B. P. P.; Marsik, P.; Munzar, D.; Bernhard, C.; Dubroka, A.	"Signatures of the bonding-antibonding splitting in the c-axis infrared response of moderately underdoped bilayer and trilayer cuprate superconductors"	Phys. Rev. B **99**, 54513 (2019)
Müllner, Silvia; Crump, Wayne; Wulferding, Dirk; **Mallett, Benjamin P. P.**; Lemmens, Peter; Keren, Amit; Tallon, Jeffery L.	"Systematic Raman study of optical phonons in $R\mathrmBa_2\mathrmCu_3\mathrmO_6+\ensuremath\delta$ ($R=\mathrmY$, Dy, Gd, Sm, Nd): Antiferromagnetic coupling strength versus lattice parameters"	Phys. Rev. B **99**, 94525 (2019)
Xu, Baler; Cappelluti, E.; Benfatto, Lara; **Mallett, B. P. P**; Marsik, Premysl; Sheveleva, E.; Lyzwa, F.; Wolf, Th; Yang, Run; Qiu, Xufeng; Dai, Yaomin; Wen, H. H; Lobo, Suzana; Bernhard, Christian.	Scaling of the Fano Effect of the In-Plane Fe-As Phonon and the Superconducting Critical Temperature in Ba 1 − x K x Fe 2 As 2	Physical Review Letters **122(21)**, 217002 (2019)
Khmaladze, J.; Sarkar, S.; Soulier, M.; Lyzwa, F.; de Andres Prada, R.; Perret, E.; **Mallett, B. P. P.**; Minola, M.;Keimer, B.; Bernhard, C.	Granular superconductivity and charge/orbital order in $\mathrmYBa_2\mathrmCu_3\mathrmO_7$/manganite trilayers	Phys. Rev. Materials **3**, 84801 (2019)

AUTHORS*	TITLE	JOURNAL
Keren, Amit; Crump, Wayne; **Mallett, Ben P. P.**; Chong, Shen V.; Keren, Itai; Luetkens, Hubertus; Tallon, Jeffery L.	Relevance of magnetism to cuprate superconductivity: Lanthanides versus charge-compensated cuprates	Phys. Rev. B **100**, 144512 (2019)
Zou, Dian; Anyi, Caroline L.; Thirkettle, Robert J.; Schreiber, K. Ulrich; **Wells, Jon-Paul R.**	Sensing Earth rotation with a helium-neon laser operating on three transitions in the visible region	Appl. Opt. **58**, 7884-7891 (2019)
Horvath, S P; Wells, J-P R; Reid, M F; Yamaga, M; Honda, M.	Electron paramagnetic resonance enhanced crystal field analysis for low point-group symmetry systems: C2v sites in Sm3+:CaF2/SrF2	Journal of Physics: Condensed Matter **31**, 15501 (2019)
Bandyopadhyay, Soumik; Bai, Rukmani; **Pal, Sukla**; Suthar, K.; Nath, Rejish; Angom, D.	Quantum phases of canted dipolar bosons in a two-dimensional square optical lattice	Phys. Rev. A **100**, 53623 (2019)
Geiregat, Pieter; Tomar, Renu; Chen, Kai; Singh, Shalini; **Hodgkiss, Justin M.**;Hens, Zeger.	Thermodynamic Equilibrium between Excitons and Excitonic Molecules Dictates Optical Gain in Colloidal CdSe Quantum Wells	The Journal of Physical Chemistry Letters **10**, 3637-3644 (2019)
Tomar, Renu; Kulkarni, Aditya; Chen, Kai; Singh, Shalini; van Thourhout, Dries; **Hodgkiss, Justin M.**; Siebbeles, Laurens D.A.; Hens, Zeger; Geiregat, Pieter.	Bottleneck Opens Up Nonexcitonic Gain Mechanisms in Colloidal CdSe Quantum Wells Charge Carrier Cooling	The Journal of Physical Chemistry C **123**, 9640-9650 (2019)
Tamming, Ronnie R.; Butkus, Justinas; **Price, Michael B.**; Vashishtha, Parth; Prasad, Shyamal K. K.; Halpert, Jonathan E.; Chen, Kai; Hodgkiss, Justin M.	Ultrafast Spectrally Resolved Photoinduced Complex Refractive Index Changes in CsPbBr3 Perovskites	ACS Photonics **6**, 345-350 (2019)
Griffiths, J. T.; Rocca Rivarola, F. Wisnivesky; **Davis, N. J. L. K.**; Ahumada-Lazo, R.; Alanis, J. A.; Parkinson, P.; Binks, D. J.; Fu, W. Y.; De La Pena, F.; **Price, M. B.**; Howkins, A.; Boyd, I.; Humphreys, C. J.; Greenham, N. C.; Ducati, C.	Effect of Size on the Luminescent Efficiency of Perovskite Nanocrystals	ACS Applied Energy Materials **2**, 6998-7004 (2019)
Allardice, Jesse R.; Thampi, Arya; Dowland, Simon; Xiao, James; Gray, Victor; Zhang, Zhilong; Budden, Peter; Petty, Anthony J.; **Davis, Nathaniel J. L. K.**; Greenham, Neil C.; Anthony, John E.; Rao, Akshay.	Engineering Molecular Ligand Shells on Quantum Dots for Quantitative Harvesting of Triplet Excitons Generated by Singlet Fission	Journal of the American Chemical Society **141**, 12907-12915 (2019)
Booker, Edward P.; Griffiths, James T.; Eyre, Lissa; Ducati, Caterina; Greenham, Neil C.; **Davis, Nathaniel J. L. K.**	Synthesis, Characterization, and Morphological Control of Cs2CuCl4 Nanocrystals	The Journal of Physical Chemistry **C 123**, 16951-16956 (2019)
Price, Michael B.; Paton, Andrew; Gorman, Jeffrey; Wagner, Isabella; Laufersky, Geoffry; Chen, Kai; Friend, Richard H.; Schmidt, Timothy W.; **Hodgkiss, Justin M.; Davis, Nathaniel J. L. K.**	Inter-ligand energy transfer in dye chromophores attached to high bandgap SiO2 nanoparticles	Chem. Commun. **55**, 8804-8807 (2019)
Gorman, Jeffrey; Pandya, Raj; Allardice, Jesse R.; **Price, Michael B.**;	Excimer Formation in Carboxylic Acid-Functionalized Perylene Diimides Attached to Silicon Dioxide Nanoparticles	The Journal of Physical Chemistry C **123**, 3433-3440 (2019)

AUTHORS*	TITLE	JOURNAL
Schmidt, Timothy W.; Friend, Richard H.; Rao, Akshay; **Davis, Nathaniel J. L. K.** Ahumada-Lazo, Ruben; Alanis, Juan A.; Parkinson, Patrick; Binks, David J.; Hardman, Samantha J. O.; Griffiths, James T.; Wisnivesky Rocca Rivarola, Florencia; Humphrey, Colin J.; Ducati, Caterina; **Davis, Nathaniel J. L. K.**	Emission Properties and Ultrafast Carrier Dynamics of CsPbCl3 Perovskite Nanocrystals	The Journal of Physical Chemistry C **123**, 2651-2657 (2019)
Davis, Nathaniel. J. L. K.; Allardice, Jesse R.; Xiao, James; Karani, Arfa; Jellicoe, Tom C.; Rao, Akshay; Greenham, Neil C.	Improving the photoluminescence quantum yields of quantum dot films through a donor/acceptor system for near-IR LEDs	Mater. Horiz. **6**, 137-143 (2019)
Gasparinetti, Simone; Besse, Jean-Claude; Pechal, Marek; Buijs, Robin D.; Eichler, Christopher; **Carmichael, Howard J.**; Wallraff, Andreas.	Two-photon resonance fluorescence of a ladder-type atomic system	Phys. Rev. A **100**, 33802 (2019)
Minev, Z. K.; Mundhada, S. O.; Shankar, S.; Reinhold, P.; **Gutiérrez-Jáuregui, R.**; Schoelkopf, R. J.; Mirrahimi, M.; **Carmichael, H. J.**; Devoret, M. H.	To catch and reverse a quantum jump mid-flight	Nature **570**, 200-204 (2019)
Boyang Ding Zhepeng Zhang Yu-Hui Chen Yanfeng Zhang; **Richard J. Blaikie**; Min Qiu.	Tunable Valley Polarized Plasmon-Exciton Polaritons in Two-Dimensional Semiconductors	ACS Nano **13**, 1333-1341 (2019)
D. W. Vogt; M. Erkintalo; R. Leonhardt.	Coherent continuous wave terahertz spectroscopy using Hilbert transform	Journal of Infrared, Millimeter, and Terahertz Waves **40**, 524–534 (2019)
Sayson, N. L. B.; **Bi, T.; Ng, V.**; Pham, H.; **Trainor, L. S.; Schwefel, H. G. L.; Coen, S.; Erkintalo, M.; Murdoch, S.G.**	Octave-spanning tunable parametric oscillation in crystalline Kerr microresonators	Nature Photonics. **13**, 701-706 (2019)
Nuno, J.; Finot, C.; **Xu, G.**; Millot, G.; **Erkintalo, M.**; Fatome, J.	Vectorial dispersive shock waves in optical fibers	Communications Physics **2(1)**, 1-9 (2019)
Wei Tewa, X; **Fraser-Miller, S; Gordon, K**; Morison, K.	A comparison between laboratory and industrial fouling of reverse osmosis membranes used to concentrate milk	Science Direct **114**, 113-121 (2019)
Simpson, J.; van Wijk, K.; Adam, L.; **Smith, C.**	Laser ultrasonic measurements to estimate the elastic properties of rock samples under in situ conditions	Review of Scientific Instruments **90**, 114503 (2019)
Schumayer, D.; Hutchinson, D. A. W.	Peculiarities in the gravitational field of a filamentary ring	American Journal of Physics **87**, 384 (2019)
Lee, C. K.; **Najafabadi, M. S.; Schumayer, D.**; Kwek, L. C.; **Hutchinson, D. A. W.**	Environment mediated multipartite and multidimensional entanglement	Scientific Reports **9**, 9147 (2019)
Ou, F.; McGoverin, C; Swift, S.; **Vanholsbeeck, F.**	Near real-time enumeration of live and dead bacteria using a fibre-based spectroscopic device	Scientific Reports **9**, 4807 (2019)
Hope, J.; Aristovich, K.; Chapman C. A. R.; Volschenk, A.; **Vanholsbeeck, F.**; McDaid, A.	Extracting impedance changes from a frequency, multiplexed signal during neural activity in sciatic nerve of rat: preliminary study in vitro	Physiological Measurement **40**, 34006 (2019)
Robertson, J.; McGoverin, C; Vanholsbeeck, F.; Swift, S.	Optimisation of the Protocol for the LIVE/DEAD® BacLightTM Bacterial Viability Kit for Rapid Determination of Bacterial Load	Frontiers in Microbiology **10** (2019)

AUTHORS*	TITLE	JOURNAL
Ou, F.; McGoverin, C.; Swift, S.; **Vanholsbeeck, F.**	Rapid and cost-effective evaluation of bacterial viability using fluorescence spectroscopy	Analytical and Bioanalytical Chemistry **411**, 3653-3663 (2019)
Turnbull, S. M.; Locke, K.; **Vanholsbeeck, F.**; O'Neale, D. R. J.	"Bourdieu, networks, and movements: Using the concepts of habitus, field and capital to understand a network analysis of gender differences in undergraduate physics"	PLOS ONE **14**, 222357 (2019)
Vargas, M. J. T.; **Nieuwoudt, M. K.**; Yong, R. M.; **Vanholsbeeck, F.**; Williams, D. E.; **Simpson, M. C.**	Excellent quality microchannels for rapid microdevice prototyping: direct CO2 laser writing with efficient chemical postprocessing	Microfluids and Nanofluids **23**, 124 (2019)
Zhou, Y.; **Cink, R. B.**; Seed, A. J.; **Simpson, C.**; Sampson, P.; **Brasch, N. E.**	Stoichiometric Nitroxyl Photorelease Using the (6-Hydroxy-2-naphthalenyl)methyl Phototrigger	Organic Letters **21**, 1054-1057 (2019)
Zhou, Y.; **Bharadwaj, V.**; Rahman, M. S.; Sampson, P.; **Brasch, N. E.**; Seed, A. J.	Synthesis and photochemical studies of 2-nitrobenzyl-caged N-hydroxysulfonamides	Journal of Photochemistry and Photobiology A: Chemistry **384**, 112033 (2019)
Ashforth, S. A.; Oosterbeek, R. N.; Bodley, O. L. C.; Mohr, C.; **Aguergaray, C.; Simpson, M. C.**	Femtosecond lasers for high-precision orthopedic surgery	Lasers in Medical Science Nov 2019 online
Schreiber, K. U.; Gebauer, A.; Kodet, J.; Anyi, C. L.; **Wells, J.-P. R.**	Rotation Sensing Lasers in General Relativity: Some Technical Notes and Current Advances	MDPI - Universe **5**, 190 (2019)
Horvath, S. P.; Rakonjac, J. V.; **Chen, Y. H.; Longdell, J. J.**; Goldner, P.; **Wells, J.-P. R.; Reid, M. F.**	"Extending Phenomenological Crystal-Field Methods to C1 Point-Group Symmetry: Characterization of the Optically Excited Hyperfine Structure of 167Er3+ : Y2SiO5"	Physcial Review Letters **123**, 57401 (2019)
Cawte, M. M.; Yu, X.; Anderson, B. P.; **Bradley, A. S.**	Snell's Law for a vortex dipole in a Bose-Einstein condensate	SciPost Physics **6**, 32 (2019)
Sompet, P.; Szigeti, S. S.; Schwartz, E.; **Bradley, A. S.; Andersen, M. F.**	Thermally robust spin correlations between two 85Rb atoms in an optical microtrap	Nature Communications **10**, 1889 (2019)
Guillaume, G.; Reeves, M. T.; Yu, X.; **Bradley, A. S.**; Baker, M. A.; Bell, T. A.; Rubinsztein-Dunlop, H.; Davis, M. J.; Neely, T. W.	Giant vortex clusters in a two-dimensional quantum fluid	Science **364**, 1264-1267 (2019)
Bisset, R. N.; **Blakie, P. B.**; Stringari, S.	Static-response theory and the roton-maxon spectrum of a flattened dipolar Bose-Einstein condensate	Physical Review A **100**, 13620 (2019)
Williamson, L. A.; **Blakie, P. B.**	Anomalous phase ordering of a quenched ferromagnetic superfluid	SciPost Physics **7**, 29 (2019)
Schmied, C.-M.; Gasenzer, T.; **Blakie, P. B.**	Violation of single-length-scaling dynamics via spin vortices in an isolated spin-1 Bose gas	Physical Review A **100**, 33603 (2019)
Fersterer, P.; Safavi-Naini, A.; Zhu, B.; Gabardos, L.; Lepoutre, S.; Vernac, L.; Laburthe-Tolra, B.; **Blakie, P. B.**; Rey, A. M.	Dynamics of an itinerant spin-3 atomic dipolar gas in an optical lattice	Physical Review A **100**, 33609 (2019)
Nemet, N.; Carmele, A.; **Parkins, S.**; Knorr, A.	Comparison between continuous- and discrete-mode coherent feedback for the Jaynes-Cummings model	Physical Review A **100**, 23805 (2019)
Lüdge, K.; Jaurigue, L.; Lingnau, B.; **Terrien, S.; Krauskopf, B.**	Semiconductor mode-locked laser with external feedback: emergence of multi-frequency pulse trains with an increasing number of modes	The European Physical Journal B **92**, 1-11 (2019)
Jambrina, P. G.; **Croft, J. F. E.**; Guo, H.; Brouard, M.; Balakrishnan, N.; Aoiz, J.	Stereodynamical Control of a Quantum Scattering Resonance in Cold Molecular Collisions	Physical Review Letters **123**, 43401 (2019)
Sawyer, B. J.; Chilcott, M.; Thomas, R.; **Deb, A. B.; Kjærgaard, N.**	Deterministic quantum state transfer of atoms in a random magnetic field	The European Physical Journal D **73**, 1-7 (2019)

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Masson, S. J.; Parkins, S.	Preparing the spin singlet state of a spinor gas in an optical cavity	Physical Review A **99**, 138019 (2019)
Masson, S. J.; Parkins, S.	Extreme spin squeezing in the steady state of a generalized Dicke model	Physical Review A **99**, 23822 (2019)
Kato, S.; **Nemet, N.**; Senga, K.; Mizukami, S.; Huang, X.; **Parkins, S.**; Aoki, T.	Observation of dressed states of distant atoms with delocalized photons in coupled-cavities quantum electrodynamics	Nature Communications **10**, 1160 (2019)
Masson, S. J.; Parkins, S.	Rapid Production of Many-Body Entanglement in Spin-1 Atoms via Cavity Output Photon Counting	Physcial Review Letters **122**, 103601 (2019)
Nemet, N.; Parkins, S.; Knorr, A.; Carmele, A.	Stabilizing quantum coherence against pure dephasing in the presence of time-delayed coherent feedback at finite temperature	Physical Review A **99**, 53809 (2019)
White, D. H.; Kato, S.; **Nemet, N.; Parkins, S.**; Aoki, T.	Cavity Dark Mode of Distant Coupled Atom-Cavity Systems	Physcial Review Letters **122**, 253603 (2019)
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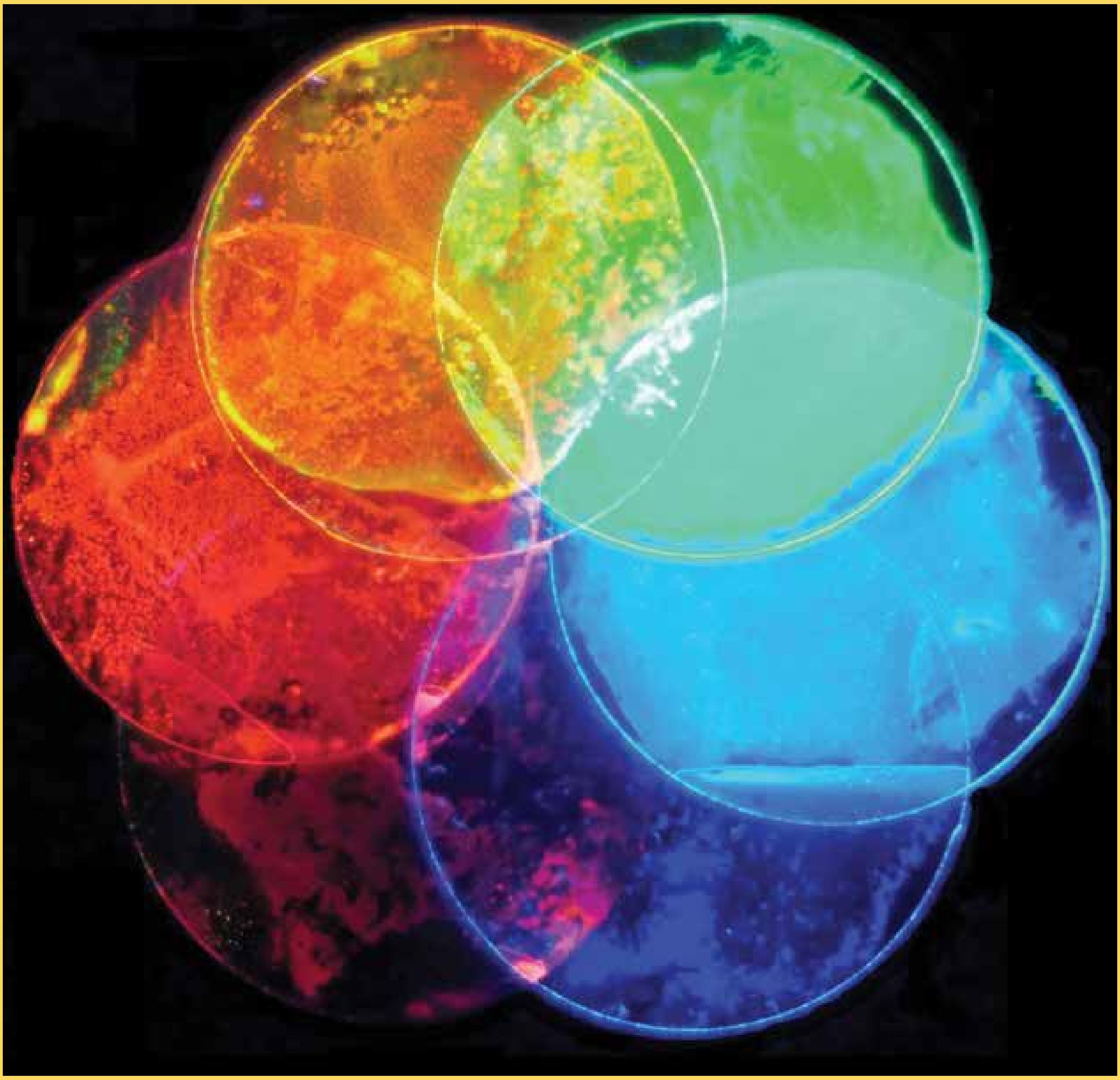

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Colloidal quantum dots are revolutionising the material industry through their tuneable bight emissions.

The image shows caesium lead halide nanocrystals, $CsPbX_3$ (where X = Cl, Br, I). The image was made by mixing different ratios of $CsPbCl_3$, $CsPbBr_3$, $CsPbI_3$, together to achieve the desired emission colour under UV excitation (365 nm). These nanocrystals exhibit photoluminescence quantum efficiencies approaching 100% without the core-shell structures usually used in conventional semiconductor nanocrystals. These high photoluminescence efficiencies make these crystals ideal candidates for light-emitting diodes.

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2019 ANNUAL REPORT