SWINBURNE UNIVERSITY OF TECHNOLOGY

SWINBURNE RESEARCH IMPACT

March 2016

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SWINBURNE RESEARCH IMPACT

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ABOUT THIS MAGAZINE

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ABOUT SWINBURNE RESEARCH

Swinburne University of Technology is an internationally recognised research-intensive university that is focused on delivering research that creates economic and social impact. Our researchers are producing innovative research solutions to real-world problems across a range of disciplines and sectors. In 2015, Swinburne was listed in the world's top 400 universities in the prestigious Academic Ranking of World Universities (ARWU) and we were also named one of the world's top 400 universities by the Times Higher Education University World Rankings 2014–2015. We are committed to delivering world leading research outcomes and innovations in select areas of science, engineering and technology. In 2016 Swinburne will be launching a number of exciting initiatives that will drive our future research achievements. Our new 'Innovation Precinct' in Hawthorn, Melbourne will be a hub of world-class research-led innovation activity, and our new Research Institutes will focus on big challenges facing our industries and society. Swinburne's research future is bright. >>> research.swinburne.edu.au

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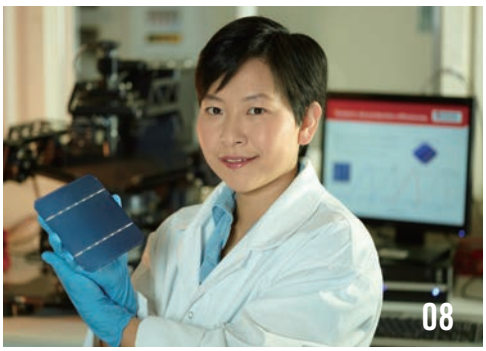

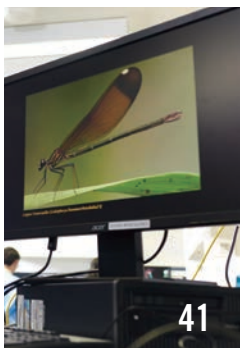

Swinburne research is world-ranked.

SWINBURNE UNIVERSITY OF TECHNOLOGY

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TRANSFORMING INDUSTRIES, SHAPING LIVES AND COMMUNITIES

I am very pleased to present Swinburne Research Impact, featuring some of the outcomes achieved by researchers at Swinburne University of Technology.

At Swinburne, our researchers are dedicated to driving economic and social impact. We are searching for solutions at the intersection of technology and humanity, pushing the boundaries of what is possible and inventing the future.

Our research is inspired and guided by our desire to make a difference through inter-disciplinary research collaborations and partnerships with industry and community.

Our achievements are recognised globally for excellence and impact in science, technology and innovation.

The stories you'll discover in this magazine come from a wide range of disciplines including astronomy, physics, materials and nanotechnology, engineering, computer science, neurosciences and psychology.

They represent some of the ways we are tackling contemporary issues and wicked problems through broad and deep research engagement.

Professor Aleksandar Subic
Deputy Vice-Chancellor (Research and Development)
Swinburne University of Technology

Rankings and ratings

- Focussed disciplines above or well-above world standard

Excellence in Research for Australia (ERA)

- Member of world's top 400 research-intensive universities with physics in top 100

Academic Ranking of World Universities (ARWU)

- Member of top 100 universities under 50 years old

Times Higher Education and QS World University rankings

ON THE COVER

Saulius Juodkazis inside Swinburne's Centre for Micro-Photonics class-1000 clean room.

Cover image: Eamon Gallagher

MAKING WAVES in global forecasting

SOPHISTICATED WAVE MODELS ARE IMPROVING CLIMATE AND WEATHER PREDICTIONS

As climate change causes the Arctic polar ice to retreat more each summer, countries and industry are anticipating the opening of faster and cheaper shipping routes. But the wave and ice conditions that ships will encounter are a big unknown.

Waves are Alexander Babanin's specialty. The Swinburne professor, and director of the Centre for Ocean Engineering, Science and Technology (COEST) is researching the rapidly changing wind and wave dynamics that will affect climate and shipping.

Babanin says this exciting and novel project, funded by the United States Office of Naval Research, involves field research and analysis of data from 20 years of satellite imaging. "The shipping route from South Eastern Asia to Europe via the Arctic is only half the distance of the traditional route via the Indian Ocean and Mediterranean. Imagine how much more economical that is." >>>

©Nikolay Tsugulievi/ iStock/ Getty Images Plus/ Getty

An icebreaker moves through chunky sea ice

Alexander Babanin's wave research has improved climate models and assisted the shipping industry.

> As Arctic ice melts and more of the ocean opens, the waves break up the remaining ice, causing it to melt faster. This in turn creates larger areas of open ocean, bigger waves and, in storms, even more ice broken.

Babanin is recognised as a world expert on wave–air interactions. Research at COEST considers how the waves, winds, currents and ice interact to affect the atmosphere, weather and climate. This metocean research is vital for industry and coastal engineering, he says. It can be applied to design better and safer ships, ports and offshore oil and gas rigs. For example, Babanin says ships that operate in a specific region can save 10 per cent on fuel consumption if they are designed to suit the particular wave conditions.

As well as his studies in the Arctic, the Russian-born scientist has been involved in developing the physics driving global wave prediction models managed by the United States' National Ocean and Atmospheric Administration (NOAA). His research is also helping scientists understand the ocean dynamics of tropical cyclones and the impact waves have on the ocean's ability to store carbon dioxide and heat, as the world warms up.

Not just waves

While there are many oceanographers in Australia, Babanin says few investigate the effects waves bring to the climate system. "That's our niche. It's not just waves, it's not just oceanography, it's the wave-coupled effects."

He explains that the missing factor in wave modelling is the physics that govern the interaction between waves and winds. Waves are generated by wind, but in turn the roughness of the sea surface changes the wind, which affects the meteorology over the ocean and the climate.

In tropical cyclones or hurricanes for instance, giant waves mix and churn up cold water from the deep ocean, changing the local current structure. An upwelling of cold water under the footprint of the cyclone can dampen it down or shut it off completely once the water reaches 26 degrees Celsius. Occasionally a downwelling can bring in warmer water and increase the power of the cyclone.

The waves produced by tropical cyclones or hurricanes are most destructive once they hit the coastline, as shown by Hurricane Sandy, which caused around US$70 billion damage in New York and New Jersey in 2012.

Babanin says our ability to predict the intensity of tropical cyclones has not improved for decades. This is due to enormous uncertainty about the dynamics of fluxes that go into the ocean and back into the atmosphere. For instance, scientists struggle to precisely measure ocean spray production.

To get more accurate measurements, Babanin negotiated with research partner Woodside Energy to set up a tropical cyclone observation site on their North Rankin Complex gas platform off Australia. "That's the first field site which is equipped to measure the whole set of air interac-

tions, the fluxes in the air, the fluxes in the water, the waves themselves and the spray," says Babanin. They recorded the first tropical cyclone from the platform last summer.

Drawn to the sea

Babanin, who was brought up in Crimea on the Black Sea, was always fascinated by oceanography. He worked as a research scientist in Russia before migrating to Australia about 20 years ago. Appointed a research fellow at the Australian Defence Force Academy in Canberra, he worked on the landmark wind-wave field experiments conducted in the shallow Lake George, about 40 kilometres north-east of the city.

The research was headed by Professor Ian Young, who later become vice-chancellor of Swinburne University and then Australian National University. Young says the Lake George study, funded largely by the United States Navy, examined "all the forces that went towards generating waves" by mimicking how waves behave in coastal areas. While the lake is only around 1.5 metres deep, the dataset from this ideal field site is now used to forecast wave conditions across the world's oceans.

"Particularly in the past five years, one of the very significant things that Babanin has been driving and building up is the new physics going into these global wave prediction models," says Professor Young. Wave models consider the impact of a range of physical processes, which determine how waves evolve, such as energy input from the wind and energy loss due to wave breaking. "It is the understanding of these terms where Babanin has made his impact," he says. In fact, Babanin updated around 60 per cent of the physics terms of NOAA's new Wavewatch 111 model, which is used by national agencies such as the Australian Bureau of Meteorology for wave forecasting, as well as by industry, surfers, ships navigators and captains.

Ships designed to suit particular wave conditions can reduce fuel consumption by up to 10 per cent, says Babanin.

Giant waves

Young, who has returned to Swinburne as an Adjunct Professor, is now researching extreme waves with Babanin. They were awarded an Australian Research Council grant to better understand and predict the most extreme storms, and the most extreme wave heights, as the climate changes.

Their modelling is based on the world's most comprehensive wind and wave dataset, which Young compiled from 30 years of satellite imaging.

Already they have found that over the past 30 years the average wave conditions across the globe have increased by about four to five per cent. The data indicates that extremes are increasing. "So you're getting more storms and more intense storms," says Young.

The largest wind-generated waves could be 35 metres high. "I've certainly never been to sea in these conditions, but it would be simply terrifying," he says.

Accurately predicting extreme waves is important for engineering and shipping. They intend using the dataset to simulate not just one in 100 year events but the highest waves that could occur in 1,000 or 10,000 years. The one in 10,000-year information is now demanded by some insurers of offshore gas rigs.

Perhaps more important in the near future is the role ocean waves play in climate change, says Young. Large amounts of heat from the atmosphere enter the oceans and, in many cases, mix into the deeper ocean. Young says the speed at which the ocean can take up carbon dioxide depends on the roughness of the ocean, so research into waves is "an important element of being able to build accurate models for what might happen to our climate in future".

GRAPHENE AIDS LENS TECHNOLOGY BREAKTHROUGH

A new super-thin lens made of graphene oxide will transform mobile phone cameras, medical diagnostic devices and photonic chips used in supercomputers

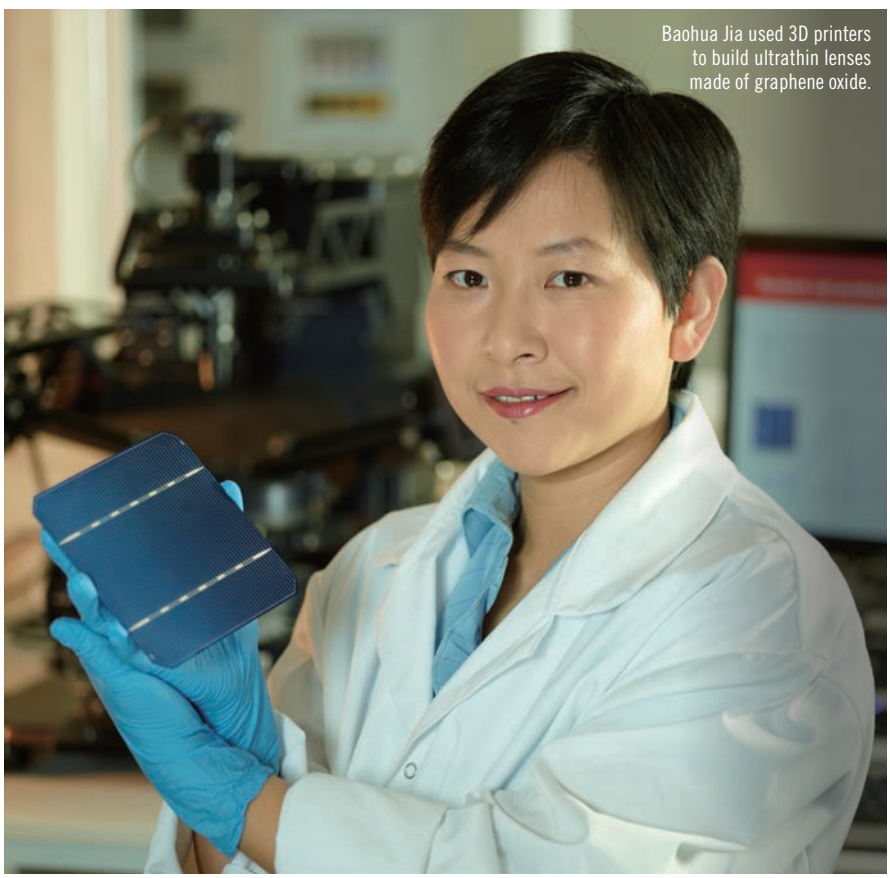
A flat optical lens just a billionth of a metre thick will let us see living creatures, as small as a single bacterium, better than ever before. The new lens, developed by researchers at Swinburne University of Technology, promises to revolutionise much of the technology around us.

Driven by developments in photonic chips and nano-optics, the global race to create a practical ultrathin lens that breaks the diffraction limit — enabling a focus less than half the wavelength of light — had been gathering pace since the turn of the millennium.

The principle had recently been demonstrated using metal-based materials — predominantly gold — but these were too inefficient and costly to mass-produce. The development of a practical prototype was hampered by the lack of a suitable material.

Just over two years ago, PhD student at Swinburne's Centre for Micro-Photonics, Xiaorui Zheng, tried fashioning a lens using graphene oxide — a variation of the super-strong, atom-thick carbon material, graphene. The team, led by Associate Professor Baohua Jia, developed a 3D printer that could quickly and cheaply produce the lens using a sprayable graphene oxide solution. Lasers were used to precisely pattern the surface, creating three concentric rings of reduced graphene oxide, which enabled its extraordinary focus.

The result is a very strong and flexible flat optical lens that is 300 times thinner than a sheet of paper and weighs a microgram — next to nothing. At the same time, it has a precise and adjustable 3D focus that allows a detailed view of objects as small as 200 nanometres long at wavelengths ranging from visible to near infrared.



Baohua Jia used 3D printers to build ultrathin lenses made of graphene oxide.

SATELLITE IMAGES

Optics researchers with Australia's Defence Science and Technology Group have begun working with Jia and her Swinburne colleagues to develop their graphene oxide lens technology for use in nanosatellites.

Nanosatellites are tiny box-like satellites weighing between one and ten kilograms that are taking off around the world.

The vast majority of the expense of satellites is bound up in the cost of the launch, which is dependent on its weight.

The optical lenses that are currently used weigh a couple of hundred grams whereas the new lenses developed by the Swinburne group weigh just a microgram. Integrating the lighter lenses with nanosatellites will mean significant cost savings as well as better pictures of Earth and space.

These are early days, but the new technology has the potential to reduce weight of mobile phones in which cameras are currently dependent on thick and heavy lenses. If that happens, it will mean that new phone cameras could focus light near the infrared spectrum, allowing thermo-imaging and possible remote medical diagnosis.

The research was only published in September 2015, but Jia and the group are already working towards integrating the lens with fibre to create a much smaller, safer and more sophisticated endoscope for non-invasive surgery.

However, it is likely that the greatest impact of this technology over the long term will be its ability to increase the efficiency of the photonic chip for use in supercomputers and superfast broadband distribution, significantly reducing energy consumption.

"We feel very excited about it," says Jia. "My team wants to let the world know that we have this fantastic technology and that it will be useful, and change their lives."

SETTING STANDARDS IN CONCRETE

Responding to a long-neglected need, a new group is facilitating comparison of critical components in the construction industry

Humdrum they may be, but the steel anchors and fasteners used in the construction industry to attach structural building components to concrete structures literally hold modern society together.

As critical components of construction, guaranteeing the reliability, longevity and safety of such fastenings is essential. It is surprising then that standards for this crucial aspect of construction have often been overlooked, leaving fastener selection and testing open to varying interpretations, until now. In response to an industry call for guidance and standards, civil engineer Professor Emad Gad from Swinburne University of Technology, with engineers from leading local and international firms, set out to establish a council of industry representatives to ensure a safe uniformity. Thus, the Australian Engineered Fasteners and Anchors Council (AEFAC) was born.

"Members of AEFAC are commercially competitive firms in the market place," says Gad. "However, within AEFAC, all members work together to develop the industry. Over our first three years, the level of cooperation and collaboration has only increased, with a growing list of achievements and recognition."

Senior engineer Joe Rametta from Hilti Australia, which supplies chemical and mechanical anchors to construction companies and is a founding member of AEFAC, says that before AEFAC's work there was a lot of confusion in the marketplace because engineers couldn't compare one fixing or anchor to another as they were tested to different criteria. As a result, there had been instances when anchors had failed because the wrong product had been used or poorly installed, he says.

Council members, with input from the wider construction industry, came together to decide on aspects of concrete fasteners requiring standard specification or testing procedures. Researchers at Swinburne then undertake the majority of the research and development with large in-kind support from AEFAC members.

"AEFAC provides us with the platform to develop solutions using our research expertise, academic rigour and university independence, but supported by consultation and input from the end-users of our standards," says Gad. >>>

AEFAC is helping establish standards to improve the reliability and safety of concrete fasteners used in building construction.

Since its inception in 2012, the AEFAC has developed a number of industry tools, including the new Standards Australia Technical Specification SA TS101 for the design of post-installed and cast-in fastenings for use in concrete.

The new Technical Specification has just been added to the National Construction Code (NCC), to which every building in the country must comply.

"SA TS101 is a major step forward for the Australian construction industry and will result in improved safety and reliability of structures," says Gad.

Rametta says design engineers can now compare anchors under the same test criteria. "At the end of the day, you end up with safer buildings, and that was the aim from the start," he says.

AEFAC, which is based at Swinburne, has also developed a forthcoming program to train and certify individuals who install these fixtures.

"We respond to requests from industry due to their dissatisfaction with existing methods and lack of industry uniformity, and we are seen as the expert body on construction fastenings," says Gad.

TRACKING THE BODY'S IMMUNE CELLS

A multidisciplinary effort to map the behaviour of T–cells is a world first in immunology

Swinburne's Sarah Russell

The entire journey of the body's specialist immune cells will be tracked for the first time as part of a new project by Swinburne scientists, in collaboration with colleagues at the Peter MacCallum Cancer Centre.

In doing so, the research team will fill gaps in our knowledge of the body's innate defences and potentially transform treatments for cancers and infections.

"The immune activation response has been studied in minute detail for decades, but there remain vast gaps in our knowledge of what happens and why," says project leader and immunologist, Professor Sarah Russell, who heads laboratories at Swinburne University of Technology and Peter MacCallum Cancer Centre.

We know that when the immune system responds to an antigen, dormant T–cells are activated and then repeatedly divide over approximately five days, becoming either 'effector' cells that attack the infection, or 'memory' cells that enable the body to remember its response in case of future infection. Once the infection is defeated, the attacking cells die and only the memory cells remain.

However, when and why a cell becomes a memory cell or an effector cell is unclear and is very difficult to observe when the changes are happening over time and the cells are moving around the body.

Microfabrication technology developed at Swinburne has enabled Russell to create slides with 60-micrometre-high walls in which cells can be confined, watched under a microscope, and filmed over hours or days.

Researchers have used these 'cell paddocks' to track immune cell pedigrees over as many as seven generations or five days, in what Russell believes is a world first.

With physicists having devised the paddocks and biologists working on the immunology, software engineers and statisticians have joined the multidisciplinary team to make sense of the resultant data and determine any patterns.

Early results from the cell pedigrees have surprised the immunologists by showing that all the cells behave very similarly — without any obvious differentiation between effector or memory cells — for as many as seven generations. "If we can do

further work to determine what is different about those cells at the early stage, we'll be able to predict the response to the infection," says Russell.

Funding awarded by the National Health and Medical Research Council (NHMRC) at the end of 2015 will enable Russell and team to begin tracking their cell pedigrees beyond the first phase of activation, up to the 10-plus generations that cover the differentiation between cells, cell death and the contraction in immune cell numbers that leaves just the scattering of memory cells.

SERIAL KILLERS

The Swinburne cell-paddock technology has already enabled researchers from Peter MacCallum Cancer Centre to show that specially-modified immune cells can be reintroduced to the body to become serial killers of tumour cells.

Immunotherapy is one of the major recent breakthroughs in cancer treatment and involves the body's own immune cells being modified to attack tumours.

Phil Darcy, an immunologist at Peter MacCallum Cancer Centre, says that the technology developed by Russell and her Swinburne colleagues has provided important insight into what is occurring. "Using that technology, we've found that the modified cells can actually cause serial killing of the target cells and this explains why they can be effective," says Darcy.

However, while the treatment can eliminate cancer cells in some patients, it often fails to make any significant impact in others. Russell's hope is that the new research will provide tools to help determine why it doesn't always work and to develop techniques to boost its effectiveness.

CLOSING AUSTRALIA'S DIGITAL DIVIDE

Swinburne researchers examine Internet access in remote Indigenous communities

Andrew Crouch (left), Julian Thomas and Ellie Rennie with Imangara community residents in the Northern Territory.

©Centre for Appropriate Technology/Getty

A lack of regular Internet access for many Indigenous Australians in remote communities puts them at considerable disadvantage as essential services, including social welfare, healthcare and employment opportunities, are increasingly available online.

Now, for the first time, researchers are trying to figure out why and what measures could be put in place to improve an Internet usage rate as low as four per cent in some isolated regions.

Swinburne's Home Internet in Remote Indigenous Communities project was the first multi-year study examining Internet use and adoption in Australia's remote Aboriginal communities. One part of the project trialled home-based Internet and technology hardware in three outstations in central Australia. It also examined Internet access and use in two communities: one that had mobile Internet and another sharing a computer room. It was lauded as a "landmark study" in the Federal Government's recent regional telecommunications review.

When Swinburne University of Technology researcher, Associate Professor Ellie Rennie, and her colleagues started investigating why Internet use was so low in some Indigenous communities, they discovered several assumptions on how best to provide Internet weren't having the desired effect. "One was that a shared Internet facility, or a computer room approach, was the most culturally appropriate way to deal with the digital divide," says Rennie, an associate professor and the deputy director of the Swinburne Institute for Social Research.

In fact, they found people preferred their own devices. Communal Internet use could even be impeded by social relationships, such as when the death of a young man who had been running a computer room caused some people in his kinship network to avoid using it.

The team also found post-paid contracts were problematic, with people needing prepaid credit that could be used according to their finances. It offered recommendations such as the potential to develop businesses that would facilitate prepaid access >>>

to the Internet via satellite, similar to the way hotels sell short-term Wi-Fi.

"It's an issue that needs creative solutions and it's now up to Internet retail service providers, local organisations and stores to get involved," Rennie says.

The project was in collaboration with Indigenous organisations, the Centre for Appropriate Technology and the Central Land Council, as well as the Australian Communications Consumer Action Network. It also opened the way for other partnerships: including a new Telstra funded Cyber Safety project, which emerged when elders raised concerns about bullying.

Mark Sulikowski is the senior advisor for Indigenous Digital Capability at Telstra. When he visits remote Indigenous communities he takes the opportunity to sit down and talk with the locals. "I'm not there as a corporate, I'm just one person talking to another person," he says.

Sulikowski says Telstra funded the Cyber Safety project as part of its Reconciliation Action Plan; which also commits to improving telecommunications infrastructure for remote Northern Territory communities. "We want to use what we find to drive public policy and debate, and to ensure everyone has a positive experience in the digital world," he says.

NEW DIMENSIONS IN DATA STORAGE

Gold nanorods used to create cheap and compact multi-dimensional storage

With global data generation increasing by almost 50 per cent each year, Swinburne researchers are at the forefront of the lucrative race to devise more efficient information storage systems.

Light has been used to store information by 'burning' it into the surface of a disc since the 1970s, but work by the Swinburne University of Technology's Dr James Chon and colleagues is taking it to new levels and exponentially extending its capacity.

By adding a layer of gold nanorods, less than 100 nanometres long or about the size of a virus, up to 100 different layers of information can be encoded on the disc.

The sensitivity of the nanorods enables variations in light frequency and polarisation to be combined with light absorption for what they call multi-dimensional storage. "We predict that using this method it will be possible to store more than one terabyte per disc," says Chon. That is nearly 10 times the capacity of today's commercially available discs.

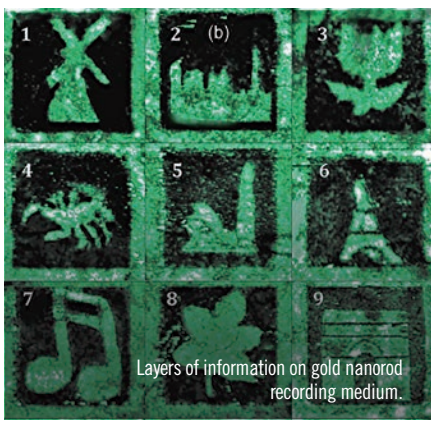
Critically, the new method, called Detuned Surface Plasmon Polarization Readout, enables light to penetrate much further into the material than conventional optical storage methods. This means much deeper layers of information can be recorded and read using existing optical storage devices such as Blu-ray.

Although the concept was demonstrated by Chon and his colleagues in 2009 and published in *Nature*, the technology, which included bulky pulsed lasers, wasn't commercially viable. In 2014, the Swinburne team showed that recording and readout could be done using a cheap, continuous laser, compatible with existing optical drives.

At this stage, creating the discs on a commercial scale remains a challenge and Chon is collaborating with nanofabrication expert, Professor Jun Taniguchi, at the Tokyo University of Science to improve the speed and efficiency of the nanorod production.

"This will enable commercial companies to adopt these fabrication techniques and put them to use," says Chon.

The business case is persuasive: it costs up to $60 to purchase a one terabyte hard drive for use in current exter-



Layers of information on gold nanorod recording medium.

GOLDEN TOUCH

Gold has many advantages as the preferred material for nanorods used in optical data storage. Among the leading benefits is that it can last a very long time — almost like permanent storage, says Chon. This contrasts with the transience of metallic tape, which is currently used by many large businesses for archival information storage. The metallic tape deteriorates quickly, meaning the information needs to be re-recorded every three to five years, a big expense in terms of time, effort and cost.

Gold is also beneficial because its nano-level sensitivities lie in the laser range that is currently being used in the optical storage devices such as Blu-ray and DVD systems.

Chon has had early discussions with Sony regarding possible use of the technology to extend the storage capacity of their archival storage discs.

nal storage devices but the five-dimensional optical storage disc that Chon is proposing would cost less than a dollar per disc. It would also be more sustainable to store discs for long periods as they don't require the energy needed to maintain hard disc drives. And the material would not decay like other storage techniques (see breakout).

Archival information storage is the immediate focus of Chon's ambitions for the technology, but in the near future he hopes it can also be used in more general applications, such as in rewritable storage devices for the home.

DAMPING DOWN ANNOYING OFFICE VIBES

A compact passive vibration damping system developed at Swinburne offers a practical solution to disruptive foot traffic vibrations in modern offices

The growing trend for open plan offices means modern office buildings are typically constructed with thinner concrete flooring slabs and longer unsupported spans than more traditional buildings. A side-effect of this type of construction is the tendency for longer spans to 'bounce' under the weight of people walking across the floor — a nuisance to staff as they concentrate on work.

Civil engineers Professors Emad Gad, John Wilson and colleagues from the Swinburne University of Technology's Centre for Sustainable Infrastructure have recently developed a floor vibration damping technology that is sufficiently compact and cost efficient to fit into existing offices. The technology has already been retrofitted in buildings in Australia and the UK.

Floor vibrations might seem a trivial problem, but movements of as little as a tenth of a millimetre can cause significant discomfort to workers seated at desks. Maximum permissible foot traffic vibration limits are now set in design guidelines around the world.

While vibrations can be reduced by increasing the stiffness of the floor with structural beams, and by 'damping' the vibrations with added weight, these approaches can often only be implemented during construction because they are too bulky to retrofit in a working office environment.

A TMD system is installed in an office affected by foot traffic vibrations.

"Modern open-plan, 'electronic' offices tend to be long span, lightweight and with little furniture," says Gad. "Floors that suffer excessive vibration due to people walking can be rendered unusable, even though they are perfectly safe. Until now, there was no proven technology that could be economically and efficiently applied to fix such problems."

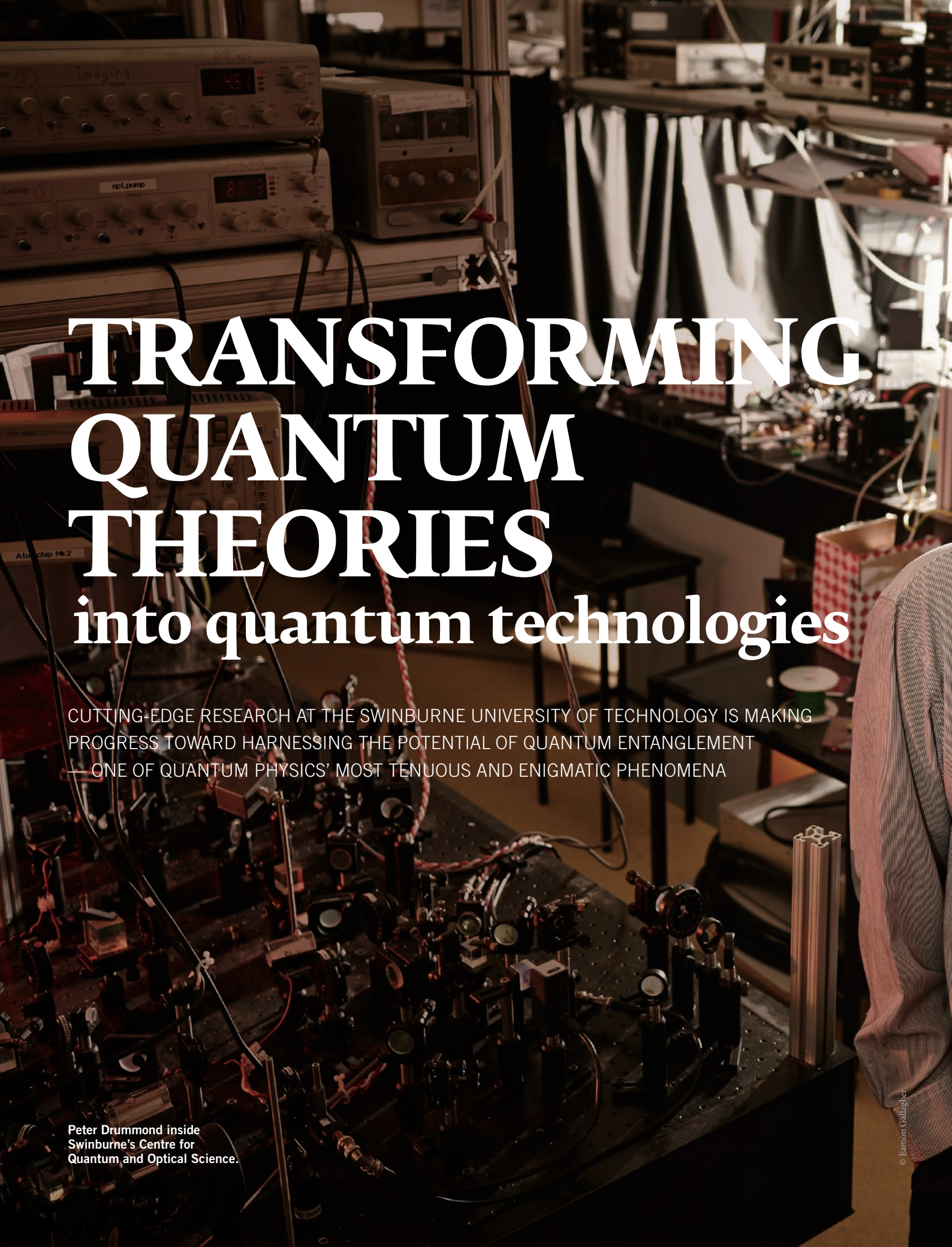
Gad and Wilson's team has developed an unprecedented solution, a tuned mass damper (TMD), which is cost-effective, proven and quick to install.

The TMD consists of multiple flat beams of viscoelastic rubber sandwiched between steel plates, each fixed at one end and weighed down with a steel plate at the other. The beauty of the design is that it requires no electrical power and is simple and cheap to construct. It is less than 15 centimetres high, so easy to install in the standard sub-floor gap found in most offices.

By matching the resonant frequency of the TMD to that of the measured floor vibration, the TMD system has been demonstrated to reduce the peak acceleration of vibration by more than 50 per cent, bringing the vibration down to levels below the threshold of discomfort — an elegantly simple solution to a growing global problem.

As this new TMD technology is now commercially available, Gad says the group will continue designing and building bespoke dampers to meet clients' needs.

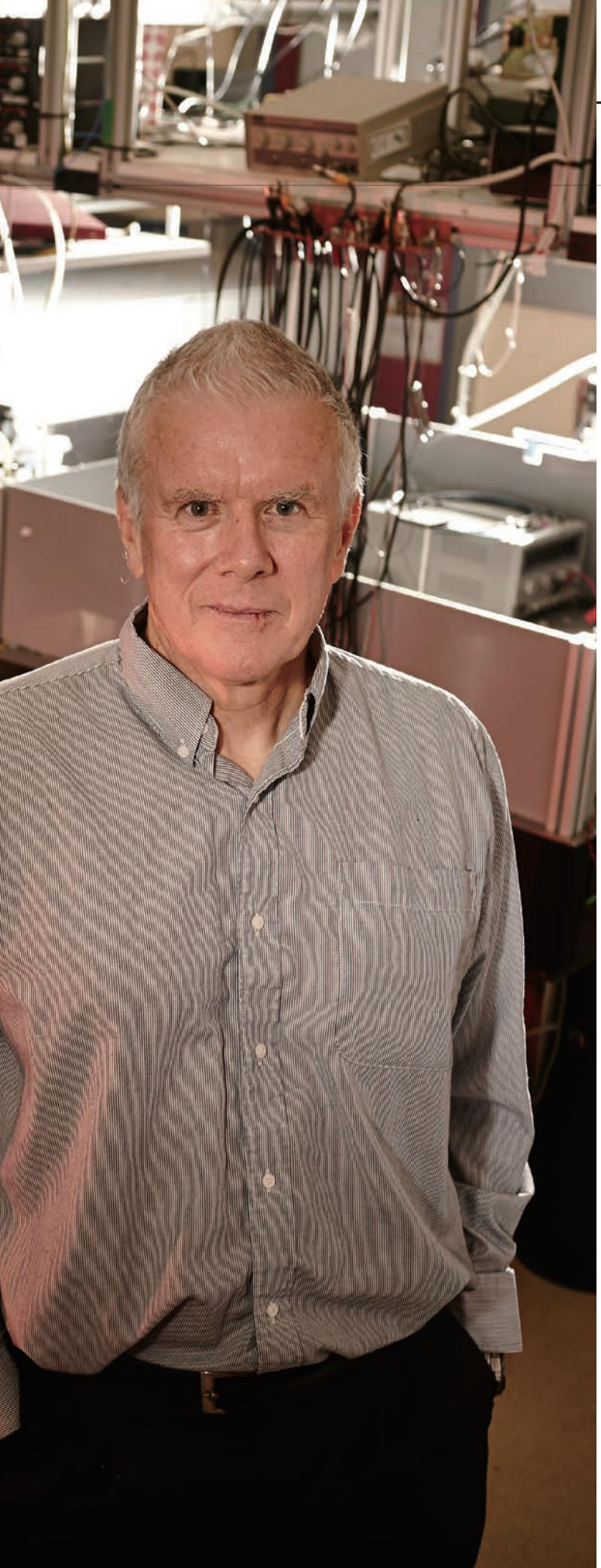
"We design and manufacture the dampers ourselves and either install them or provide instructions," says Gad.



TRANSFORMING QUANTUM THEORIES into quantum technologies

CUTTING-EDGE RESEARCH AT THE SWINBURNE UNIVERSITY OF TECHNOLOGY IS MAKING PROGRESS TOWARD HARNESSING THE POTENTIAL OF QUANTUM ENTANGLEMENT — ONE OF QUANTUM PHYSICS' MOST TENUOUS AND ENIGMATIC PHENOMENA

Peter Drummond inside Swinburne's Centre for Quantum and Optical Science.



Our world, as we commonly observe, is neatly governed by classical laws of physics — objects have mass and they move in predictable ways in responses to natural forces. Down at the sub-atomic level however, things become more nebulous, transitioning to the probabilistic world of quantum physics where the mere act of observing an object can change reality.

Professors Margaret Reid and Peter Drummond from Swinburne University of Technology lead parallel groups that are at the forefront of global research into understanding and translating some of the most exotic and peculiar quantum effects into practical technologies.

Ever since the early 20th century, in the era of Einstein, Schrödinger and Bohr, when the concepts of quantum uncertainty emerged, physicists have argued vigorously about the meaning, mechanism and implications of some of quantum physics' most intriguing phenomena. Fundamental to quantum reality is the idea that objects classically thought of as particles, like electrons, occupy not a point but an envelope in space, a kind of 'fuzzy' localisation with the character of a wave. And in the same way that an object's location may be fuzzy, so are its other properties, such as momentum and spin. Taking this a step further, quantum physics allows these wave–objects to be 'split' as a wave, resulting, for example, in one electron occupying two discrete regions of space, or two different energy levels or spin states. This 'superposition' of states persists until the object is measured or observed, which causes the superposition to collapse and the object to revert to its classical, definitive form.

As bizarre and exotic as it may sound, quantum superposition is now generally accepted as fact and experimentally observable. >>>

> For example, physicists 20 years ago demonstrated that it's possible to 'split' a stream of sodium atoms such that each atom travels two paths simultaneously, ultimately producing a self-interference pattern as evidence of the fact when the paths are recombined. So far whole atoms are the largest objects that have been put into such superposed states, but science is on the cusp of pushing the quantum-to-classical transition into the realm of larger objects to produce what quantum physicists call a Schrödinger cat — a macroscopic object like Schrödinger's theoretical cat that is both alive and dead until the box in which it sits is peered into.

Another implication of the quantum universe is the ability for two particles, often photons, to 'entangle'. In this scenario, the particles' positions and momenta are correlated, with the momentum of one particle being the inverse of the other. The two entangled particles maintain their correlated states of fuzzy superposition until measured, but once one of the pair is observed, the state of the other is influenced instantly, regardless of distance separating them. Since the measurement of one particle's position, momentum or spin appears to change the properties of the other, physicists refer to this behaviour as steering. Einstein called it 'spooky' action at a distance, and the nature of it is at the crux of current quantum physical debate.

Peter Drummond with his research team at Swinburne's Hawthorn campus.

Quantum technology

Far from being an esoteric theory limited to the subatomic domain, quantum physics has some very exciting and potentially revolutionary real-world applications. Quantum computing, which makes use of the fuzzy superposition of states to allow many calculations to be performed simultaneously, has been the vanguard for quantum technology. But such devices have very specific, niche applications like solving complex optimisation problems and simulation of quantum systems and so are unlikely to replace your laptop computer any time soon. Yet there are potentially more useful applications under investigation, most of which rely on entanglement for measurement, communication and security.

Reid's group is applying spooky entanglement for secure communications using quantum cryptography. "We know entanglement can be used for quantum cryptography using standard existing cryptography schemes," she says. While traditional digital encryption systems rely on two users exchanging a key, often a large number, to establish a secure communication channel, quantum cryptography encodes the key in the spin states of quantum bits — the basic data unit used in quantum computing and the equivalent of the 1s and 0s used in conventional digital computing. "For example, two parties can share a spin entangled pair of particles. By exchanging a choice of measurement variable via a public channel, it is possible to verify that they share the same bit value, forming a key that they can then use to read the encrypted message."

If an eavesdropper attempts to intervene and measure the bit values, this shows up as a loss of entanglement, since in quantum mechanics, a system cannot be measured without changing it.

The advantage is that due to physical laws one can be certain that a message has not been intercepted, making it ideal for communications and cryptographic encoding."

Reid and her colleagues have recently shown how the spooky steering entanglement effect can be shared among many observers, while also enabling extra security even in the presence of hacked devices, which could ultimately form the basis for a future hack-proof 'quantum internet'.

Quantum teleportation is another application of steering entanglement that could eventually provide a secure 'facsimile' capability. "In

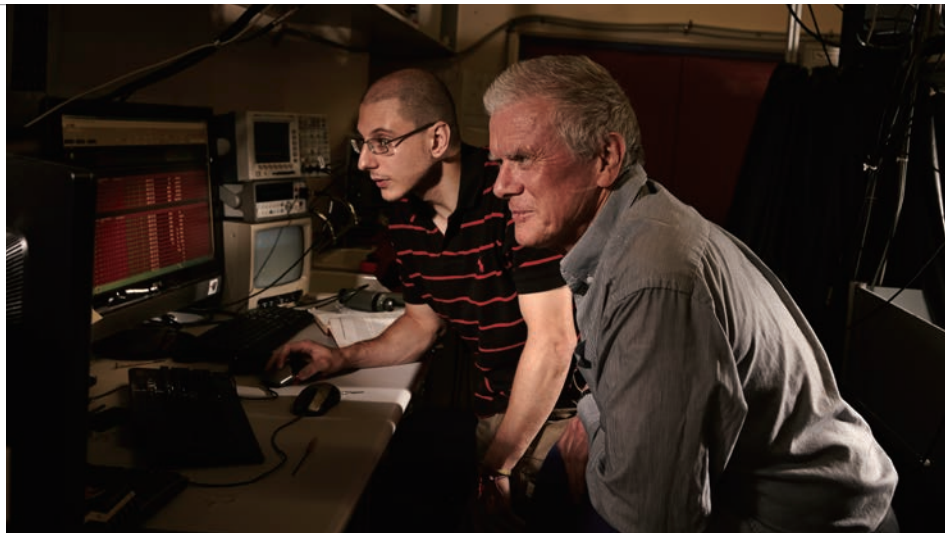
quantum mechanics one cannot clone or copy states without making the state fuzzy," says Reid. Instead, the state is 'teleported' between two agents — measurement of the source bit destroys it, and allows the bit to be reinstated exactly and instantly by its spookily entangled partner at any distance.

Quantum simulations

Drummond's research looks at the deep computational issues arising from the question of how to model and predict the behaviour of quantum systems. With quantum computers still in very early infancy, modelling a quantum system remains a task to be completed on digital computers — an endeavour deemed completely infeasible until recently. "Google's new quantum hardware is great for certain specialised optimisation problems, but the development of more general quantum hardware is still in its very early stages," says Drummond. "The software for quantum simulation my group has developed for use on digital computers outperforms all current quantum hardware for quantum simulations."

The mathematical and computational techniques employed by Drummond's group invoke a special type of probabilistic simulation called a phase-space representation, which can be calculated in classical terms. "We are able to simulate many of the most exotic quantum states known using these methods, including the idea of creating steering and Schrödinger cats with trapped atoms. This is well beyond anything carried out using quantum computers, and our results are well tested and verified in the laboratory."

This calculation scheme has allowed Drummond and his team to simulate a Schrödinger cat — a large quantum state consisting of a system of 60 quantum bits, the basic data unit used in quantum computing. "This is important in understanding how one could design and engineer quantum technology for a given task, or even to work out what quantum theory predicts, in order to test it," notes Drummond.



Peter Drummond and colleague. Drummond's work focuses on modelling quantum systems.

Coherence is key

Key to realising such applications, however, is maintaining the entanglement state, known in quantum parlance as coherence, over sufficiently long time frames.

Coherence is a touchy thing, easily disrupted or destroyed, particularly for larger particles, and more often than not measured in fractions of a millisecond. "Entanglement can be downgraded by interactions with the environment," says Reid of the challenge of maintaining coherence.

The natural jitter of atoms at temperatures above absolute zero, for example, is a major source of decoherence, but the Centre for Quantum and Optical Science has made significant progress in dealing with this thermal noise. "Here in the lab, we have atom interferometers in which atoms are 'frozen' by laser cooling, which stops the oscillating motion of the atom," says Reid. "These interferometers are capable of some of the world's longest decoherence times."

"We have modelled the full workings of this atom interferometer using our simulation techniques," says Drummond. He says, the beautiful thing about the entangled atoms we can create using this system is that this is not far away from creating a Schrödinger cat, which would give a rigorous test of the more intriguing predictions of quantum mechanics, such as whether there can be entanglement between two larger, more massive quantum objects.

"We also think we can use the atom interferometer to model and test the quantum field theory of the early universe, which would be very exciting indeed."

FORGED BY THE SUN

Using solar thermal energy to smelt iron ore could cut the carbon footprint of processing by 30 per cent

The sun's energy may soon be used to cut the cost and boost the sustainability of global iron processing, thanks to breakthrough engineering work at Swinburne University of Technology.

Researchers around the world have been trying to engineer a way to use solar power to smelt iron ore for more than 30 years but a commercially viable method has been elusive.

By incorporating two important changes to the conventional approaches to solar smelting, Swinburne metallurgical engineers Professor Geoff Brooks and Dr Ben Ekman have created an early-stage model that is sparking industry interest and may cut the carbon footprint in iron production by up to 30 per cent.

"We see the potential to dramatically lower the carbon usage," says Brooks.

Firstly, the Swinburne team designed a very simple cylindrical reactor to increase efficiency. They plan to use a hybrid power system so that it can function using conventional power when required, ensuring iron-ore processing can continue 24 hours a day.

"Our two major realisations have been the importance of simple effective geometry and the importance of developing a hybrid," says Brooks.

The researchers have recently been able to create iron and prove the concept using

SOLAR SIMULATION BREAKTHROUGH

Testing the solar smelter in laboratory conditions required a laboratory-sized sun and Ben Ekman created one that is exciting the solar energy research community.

Solar simulators have conventionally been made using Xenon arc lamps but these often have a higher intensity of light than is required and can be prone to explosions. With these considerations in mind, and aware of recent improvements in metal halide technology, Ekman decided to try metal halide arc lamps when designing the Swinburne solar simulator.

It was a success. The array of seven 6-kilowatt lamps used in the simulator mimic the sun, demonstrating how solar smelting is feasible using the Swinburne designed reactor.

"The simulator is unique because of the different lamp design," says Ekman.

There are now three such simulators in the world and Swinburne's is the only one in Australia.

Ben Ekman (left) and Geoff Brooks with their solar simulator.

a novel solar simulator developed by Ekman (see box). The lab model shows that solar thermal energy is ideal to generate heat of between 1,000 and 1,500 degrees Celsius, required to produce iron from iron ore.

Ekman says commercial heliostats, or mirrored devices, could be used to reflect sunlight directly into the furnace. He says the result would be a furnace that is up to 80 per cent energy efficient. That's a significant improvement on using steam to generate electricity, which is 10–15 per cent energy efficient. He estimates that 2,000–3,000 mirrors arrayed over 70,000 square metres would be sufficient for a 10 megawatt solar powered reactor.

The conventional blast furnace process for making iron requires up to 450 kilograms of carbon for every tonne of ore being processed — generating around two tonnes of CO_2 emissions. As much as 50 per cent of that carbon is used to provide the energy for the reaction, and this figure would be slashed by using solar energy.

In 2015, Ekman and Brooks began working with South Australian company, Cartwheel Resources, to develop a larger model and further refine its practical application. Cartwheel chief executive, Rudy Gomez, has a background in mining and mineral processing and is drawn to the project by his desire to foster sustainable energy initiatives.

Gomez, Brooks and Ekman foresee a day when Australian iron ore mined in Western Australia will be processed using the sun's rays, benefiting the Australian environment and the economy.

HEADING OFF TROUBLE AT THE PASS

A barometer for the likelihood of violent behavior by mental health patients reduces risk and stress for workers

A tool developed by Swinburne researchers to measure the risk of aggression in mental health patients is being adopted internationally to help prevent hospital violence.

According to 2014 figures, more than one in three Victorian mental health workers were physically assaulted and four out of five nurses were attacked verbally, physically or sexually within the previous 12 months. Figures from the UK show nearly 50,000 assaults in mental health and learning disability units over a similar period.

But up until recently there was little staff could do to predict imminent violence, beyond relying on their gut instincts.

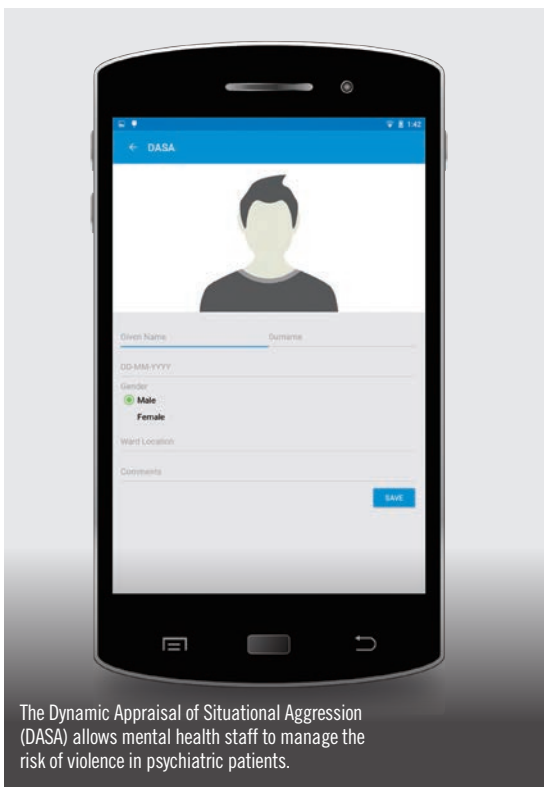
Innovative research led by clinical psychologists, Professors James Ogloff and Michael Daffern, of Swinburne University of Technology's Centre for Forensic Behavioural Science is now addressing the need to assess when a patient is likely to become violent.

"Although we need to keep in mind a patient's history of violence, the best way of determining someone's risk in the next 24 hours is to look at their current state, and we do that by looking at their presentation over the past 24 hours," says Daffern.

The seven-item Dynamic Appraisal of Situational Aggression (DASA) was developed in 2006 following a six-month study to identify and test the predictive accuracy of numerous risk factors for patient aggression. The factors that were most strongly predictive of imminent aggression were negative attitudes, impulsivity, irritability, verbal threats, sensitivity to perceived provocations, angering easily when requests are denied, and unwillingness to follow directions.

Trials in Victoria showed that the DASA, which takes nurses only a few minutes to complete, has greater reliability and predictive accuracy than the previous ad hoc methods.

In the decade since its development, DASA has been adopted by men- >>>



The Dynamic Appraisal of Situational Aggression (DASA) allows mental health staff to manage the risk of violence in psychiatric patients.

tal health units from New Zealand to the US, Singapore, Hong Kong and Canada. Most recently, the United Kingdom's leading agency advising on clinical practice, the National Institute for Health and Care Excellence (NICE), endorsed it as one of only two methods for predicting imminent violence. "That level of endorsement has created a lot of interest," says Daffern.

He and Ogloff are now working on an online application that will enable staff to use DASA electronically and link the risk assessment to preventative strategies. The application is due to be launched this year and will include the ability to track which interventions are most effective in preventing violence on a patient-by-patient basis.

A NEW LANGUAGE

Melbourne's Thomas Embling Hospital is Victoria's leading institute for forensic mental health, and is a hospital where patient aggression, as in other mental health units, is a significant issue. The facility caters specifically for those people with mental health problems who are in the criminal justice system. In the past decade there have been three deaths caused by violence.

Daffern says such events weigh heavily on both staff and patients; violence can have a real impact on staff satisfaction and work performance as well as patients' sense of safety and ability to recover from illness.

Clinical nurse consultant, Tessa Maguire, oversees the management of aggression at Thomas Embling and has been using DASA for nearly 10 years. "It makes a real difference. We now have a common language because we are all trained in DASA. It provides a much-needed structure for assessment."

They have incorporated the system into their job routine and once a day a staff member will complete the DASA for patients who pose a risk.

While homicide is a serious outcome of violence, Daffern says verbal and physical aggression also has significant costs for the mental health service sector internationally. He hopes that DASA may help to reduce both the human and financial costs incurred.

MAPPING AUSTRALIA'S DIGITAL FOOTPRINT

Understanding how Australians use the Internet is the first step towards bridging the digital divide

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Swinburne University of Technology researchers are developing a detailed picture of how Australians use the Internet to access essential services to help policy makers assist those left behind by the digital revolution.

The Australian Digital Inclusion Index (ADII) is the nation's first comprehensive assessment of the digital divide — the gap between people who have unhindered access to information and communications technology, those who have partial access, and those who are excluded.

The three-year project, initiated by Australia's largest telco, Telstra, is led by Professor Julian Thomas and Dr Scott Ewing at the Swinburne Institute for Social Research in collaboration with Professor Jo Barraket at Swinburne's Centre for Social Impact. The project brings the Institute for Social Research's experience in researching the social, political and economic impact of the Internet, along with the Centre for Social Impact's unique expertise in designing responses to complex social problems.

"Digital inclusion is the degree to which people participate in the digital economy, accessing services, business and education online," Thomas says.

In Australia 90 per cent of households are online. "Most people look at that number and think that is great," he says.

What concerns Thomas is that while 10 years ago not having an email address could be a hassle, with so many essential services now online, the cost of not being connected is much higher today.

"The digital divide has narrowed but it has deepened," he says.

In the six months since the project was launched, there have been consultations with stakeholders including Indigenous groups, charities such as the Smith Family, public libraries, government departments and local councils.

Thomas says these consultations have identified four key measures to be included in the index: access, affordability, users' online activity and digital literacy levels.

The first iteration of the index, based on publicly available data, is due to be completed in July. Telstra may also contribute information.

The project has also established a website to generate input during the consultation period, which will be updated as data is collected and made public.

The team also hopes to present a breakdown of information for regional areas, so organisations such as local governments can map areas of digital disadvantage within their areas to direct assistance more specifically. Once the index is public, Thomas believes it will help inform debate on how to bridge the digital divide. "If we are able to provide an aggregate measure then we can use that to gauge the effect and understand what really helps," says Thomas.

Robert Morsillo, Telstra's Senior Advisor on Digital Inclusion, says the collaboration came from a growing realisation that digital disadvantage is a multifaceted issue and could not be solved by the telecommunications industry alone.

"We hope the index will shine a spotlight on areas where we can most effectively invest resources where there needs to be intervention, to increase the overall level of inclusion," he says.

ADVANCES IN HOLOGRAPH TECHNOLOGY

High-resolution holographic images are no longer science fiction

A case of being in the right place at the right time has enabled a long-sought breakthrough in 3D technology that may soon make the holographic depictions of Star Wars' R2D2 a reality.

It all started when Swinburne researcher Dr Xiangping Li's work revealed the tiny refractive index of graphene in 2013. But it wasn't until his group leader, Professor Min Gu, attended an optics conference in China later that year that they realised the implications of this research for 3D holographs.

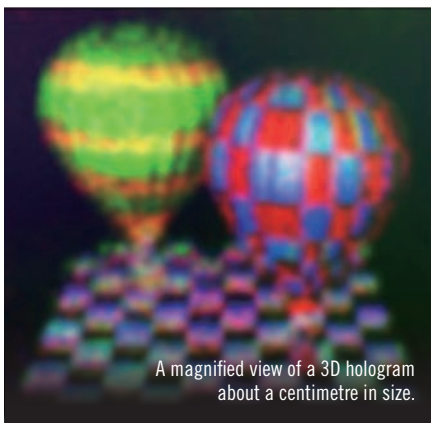
The material's tiny refractive index makes it possible to achieve a pixel size as small as 0.5 micrometre — somewhere between the size of a bacteria and a virus — when recording a hologram.

This property has many potential applications, but in China, Gu heard researchers from the Beijing Institute of Technology describe the challenge posed by pixel size for creating holographic images with a large viewing angle.

The Beijing group had been researching holograph technology for many years but had come up against the challenge of how to increase the viewing angle to create images that could be viewed without glasses or other external assistance. The viewing angle is a measure of the angular distance from viewing the hologram front-on to side-on before the image distorts.

"I asked them how they could increase the viewing angle and they talked about reducing the pixel size," says Gu. "We realised, 'Ah, we can do that now!'."

Digital holographic images have conventionally been produced using spatial >>>



A magnified view of a 3D hologram about a centimetre in size.

COOL CHANGE

The ability to rapidly and precisely convert graphene oxide to reduced graphene oxide — removing electrons from the polymer — without the use of heat, was critical for Gu, Li and their colleagues to successfully create high-resolution holographic images.

In this way, they could 'record' the image on the material — changing the refractive index where and how it was required for the holograph.

If heat was used to prompt the chemical reaction it would need to be in the realm of 1,000 degrees Celsius, making precision at the nanoscale difficult.

Their research published in *Nature Communications* in April 2015 showed that the absorption of a single femtosecond laser pulse – a femtosecond is one quadrillionth of a second – by graphene oxide allows successful reduction without temperature deviation.

modulators (SLMs) which can only produce pixels as small as 10 micrometres. Using femtosecond laser pulses to reduce graphene oxide without heat and taking advantage of the material's newly discovered tiny refractive index, the team at Swinburne's Centre for Micro-Photonics created high-resolution images with light-bending pixels 1/20th the size of SLMs. The proportional relationship between the pixel size of a hologram and the viewing angle of the holographic image it creates, means that the Swinburne-developed technique expanded the image's viewing angle from 10 degrees to 52 degrees without the need for glasses. Better still, the refractive index change created by reduced graphene oxide is consistent across the light spectrum meaning that full-colour images can be produced.

The initial static 3D images produced by the Swinburne team are very small — one centimetre — but Gu is confident that they will soon be able to engineer larger images. The Beijing Institute of Technology group with which the Swinburne team collaborated on the 3D research was originally looking to increase the viewing angle for use in military technology. However, the generation of wide-angle 3D images using graphene-based objects, with their flexibility and unusual electronic and optical properties, may also enable floating images to be projected from phones, screens and wearable mobile devices such as watches. The futuristic technology in Minority Report could soon become reality.

While Gu has now moved to RMIT University, he maintains strong links with his former team at Swinburne.

SEPARATING MILK FATS FROM FICTION

Australian boutique dairies may benefit from a successful research-industry partnership

Using ultrasound waves to separate milk from its fats may led to new, locally-manufactured food products, a team at Swinburne University of Technology has found.

The idea to use ultrasound to separate milk was proposed as part of an early stage research project initiated by Australia's Geoffrey Gardiner Dairy Foundation, which partnered with the CSIRO and Swinburne's highly regarded ultrasonics group.

Richard Manasseh, an associate professor from Swinburne's Department of Mechanical and Product Design Engineering, says, "The aim was to explore new technologies for future greenfields dairy plants that might give the Australian industry an advantage over the international competition."

While centrifuges replaced traditional creaming (letting milk stand to separate naturally) in the 19th century, and are excellent for mass processing, they can damage fat globules which are important for taste and texture. The membranes of those globules also contain proteins which may have benefits in the treatment of conditions such as Alzheimer's and breast cancer.

One aspect of the research considered the different types of milk product. While centrifugal processing skims all the fat from the milk, which is then replaced to achieve standardisation, ultrasound can achieve standardisation through measured extraction of the fat. However, whether ultrasound is a practical process to standardise milk needs to be investigated.

But this early research suggested other uses for ultrasound. For instance, ultrasound waves separate milk very gently, limiting damage to the fats which are also essential to the shelf life of dairy products. It also separates the fat globules into different sizes, each displaying different characteristics of smoothness and creaminess, which may lead to new products.

"Centrifuge milk may be very unlike the milk that most people drank for the majority of history," says Manasseh. "But ultrasound produces the same globule distribution as natural creaming."

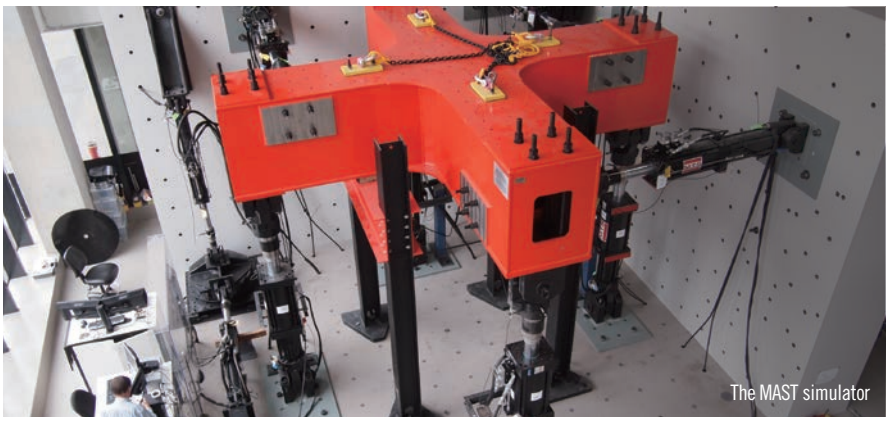
Some boutique Victorian dairies and cheese producers may be the first to trial the new technique. This means that Australian cheese makers could make products similar to Italian parmesan, gorgonzola and pecorino romano cheeses, which in Italy are made from milk separated by traditional creaming methods.

"Australia's small makers are developing products based on tradition, but natural creaming presents food safety issues due to our climate and transport distances," says Manasseh. Ultrasound offers an ideal solution. It's fast, inexpensive, portable, works on a small scale, is easy to clean, and gives small businesses cost-effective control over their processes.

"It appeals to boutique companies making traditional and innovative products. That's where commercialisation lies."

EXTREME SIMULATIONS FOR SAFER STRUCTURES

A new simulator allows engineers to test building equipment under severe conditions



The MAST simulator

TESTING THE LIMITS

Swinburne's MAST hybrid simulator can test a range of structures under extreme conditions.

In addition to buildings, Al-Mahaidi and his colleagues are already working with the automotive and aircraft industries to assess structural risk in trucks and planes.

In the case of trucks, the MAST was recently used to look at the risk of metal fatigue caused by the frequently fluctuating horizontal and vertical forces exerted on the parts that make up the connection between prime movers and their trailers.

Meanwhile, there are discussions with the Federal Government to test the outcome of the repeated extreme forces on aircraft landing gear. To do this, the landing gear will be brought into the Swinburne lab and subjected to the required forces using the MAST system. At the same time, the hybrid computer simulation will be used to gauge the impact on the rest of the plane. The results will then inform decisions about safe construction and servicing requirements.

A massive world-first structural testing system at Swinburne has engineers lining up to test individual building components under the extreme conditions caused by earthquakes, cyclones, tsunamis and other natural disasters.

The $2.1 million Multi-Axis Substructure Testing (MAST) hybrid simulator, weighing more than nine tonnes and sitting on one metre thick reinforced floor, is designed to mimic the major forces on physical structures and simulate the consequences.

The system has been developed to improve safety and resilience in the built environment, says structural engineer and head of the Swinburne University of Technology project, Professor Riadh Al-Mahaidi. "Unless we understand the behaviour of structures under extreme conditions, it is very difficult to design them to withstand the effects of natural hazards.

"This hybrid MAST system allows us to do that and helps us to create safe designs," he says.

The novelty of the simulator is that it allows users to physically test a critical structural component, such as a steel column, under the duress of six movements — vertical, lateral, longitudinal, pitch, roll and yaw movement. Engineers refer to these movements as the six degrees of freedom.

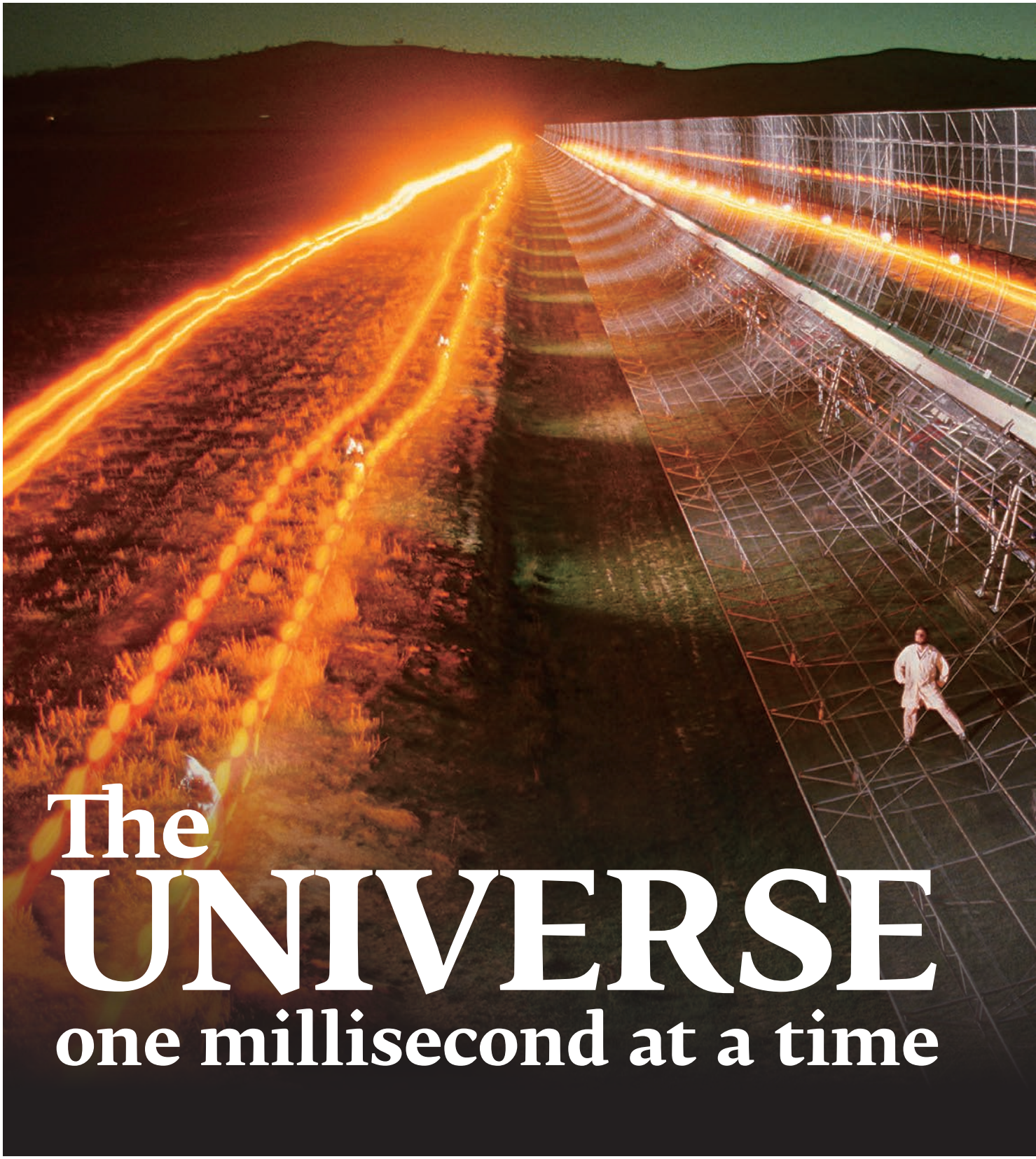
Information is fed from the simulator into a computer where the results are balanced in real time against other structural forces such as gravity and inertia, with the outcome used to influence the ongoing physical testing. This real-time feedback loop can be used to rapidly test an entire multi-storey building's response to natural hazards. "It is the closest we can come to the real testing of a real building, without the expense," says Al-Mahaidi.

With similar facilities planned for Canada and Switzerland, and compatible testing instruments already existing in California and elsewhere in the US, the Swinburne MAST can increase its capacity, when required, with geographically distributed testing. In that case, multiple structural elements — such the abutments and girders of a bridge — can be physically tested in separate locations and the results brought together online to determine the outcome for a structure as a whole.

All this was made possible by a federal Australian Research Council Linkage grant matched by funding from 11 other Australian universities who could see the benefit for research and industry.

Monash University was among the supporters and the head of the Monash Structures Group, structural engineer, Amin Heidarpour, says the value of the unique simulator is already being realised within his group, with new research projects set to assess the strength of steel, concrete and other materials.

Before the facility was completed and calibrated in May 2015, many of the practices in safe design rested on assumptions, says Al-Mahaidi. "We are trying to eliminate these assumptions."



The UNIVERSE one millisecond at a time

The Molonglo Observatory Synthesis Telescope's two arms have 7,744 individual radio antennae.

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A DIGITAL OVERHAUL OF THE SOUTHERN HEMISPHERE'S LARGEST RADIO TELESCOPE WILL HELP ASTRONOMERS GLIMPSE SOME OF THE FASTEST SECRETS OF THE COSMOS

About 30 kilometres east of the Australian capital Canberra stands a telescope that will soon capture images of the cosmos's most mysterious phenomena. The Molonglo Observatory Synthesis Telescope (MOST), nestled in the Molonglo Valley, is the largest radio telescope in the Southern Hemisphere and has been scanning the skies for nearly half a century.

Now, the Australian astronomy community has ambitious plans to use this telescope to understand the 'transient' Universe, short-lived phenomena that can only be detected through frequent, regular radiofrequency surveys.

But before this can happen, MOST needed to be brought into the 21st century. After operating for 50 years — a lifetime for any piece of technology, especially one as complex and sensitive as a giant radio telescope — it desperately needed an upgrade, especially to its digital technology.

While its basic structure would remain the same, the revamp of its operational >>>

> infrastructure would make it capable of churning through the masses of data generated by these surveys.

In 2012, the UTMOST project was conceived to achieve this goal when the telescope's operators, The University of Sydney, joined forces with Swinburne University of Technology, the CSIRO, Australian National University and Massachusetts Institute of Technology. Professor Matthew Bailes, an Australian Laureate Fellow at the Swinburne Centre for Astrophysics and Supercomputing, took on the task of leading the upgrade of the telescope's ageing processing system.

1,320 gigabytes a minute

When it was built in the 1960s, the Molonglo telescope discovered some of the most spectacular objects in our cosmos, such as the collapsed cores of once-massive stars, known as pulsars.

Pulsars can be as small as 20 kilometres in diameter, and can spin at up to 700 times each second. Their distinctly pulsatile radiofrequency signature results from the acceleration of particles in their super-strong magnetic fields as they spin.

Bailes anticipates the updated telescope will soon detect fast radio bursts every few weeks.

"It's fun when you find a pulsar that is spinning 700 times a second; that's faster than a kitchen blender and yet it's a star," says Bailes.

Precisely measuring the pulse rate of these celestial objects has revealed new insights into how gravity distorts the fabric of spacetime.

MOST's long structure was built to overcome the design limitations imposed on parabolic dish telescopes, which can only get so big before they topple. The telescope has two 800-metre-long half-cylinders stretching east to west. Along its two arms sit 7,744 individual radio antennae that combine their signals to create a concentrated radiofrequency beam.

The upgrade retained this design, but called for a radical overhaul under the hood, installing new signal-processing computers that could sift through 22 gigabytes of data every second, or 1,320 gigabytes per minute.

Early on, Bailes realised the upgrade couldn't rely on existing analogue systems to combine the signals to form an image — it needed a system that could digitally combine all the signals.

"I realised that some of the technology we'd developed here at Swinburne could be adapted to do that," says Bailes.

In the astronomy world, Bailes' supercomputer experience is highly sought after. In July 2015, he joined an international team awarded US$100 million to search for intelligent life elsewhere in the Universe.

Bailes' Australian team will design a new supercomputer at the Parkes telescope to analyse distant radio signals picked up by the search, which will be 50 times more sensitive than previous searches and cover ten times more sky. The project, administered by the Breakthrough Prize Foundation, will scan the skies for signals of life as well as other naturally occurring astrophysical phenomena.

"The powerful supercomputer that Bailes and Swinburne have provided makes this an exceptional telescope for exploring the transient sky with fast and flexible cadence."

Anne Green, a professor of astrophysics at the Sydney Institute for Astronomy, at The University of Sydney, says one of the major achievements of Bailes and his team has been to write

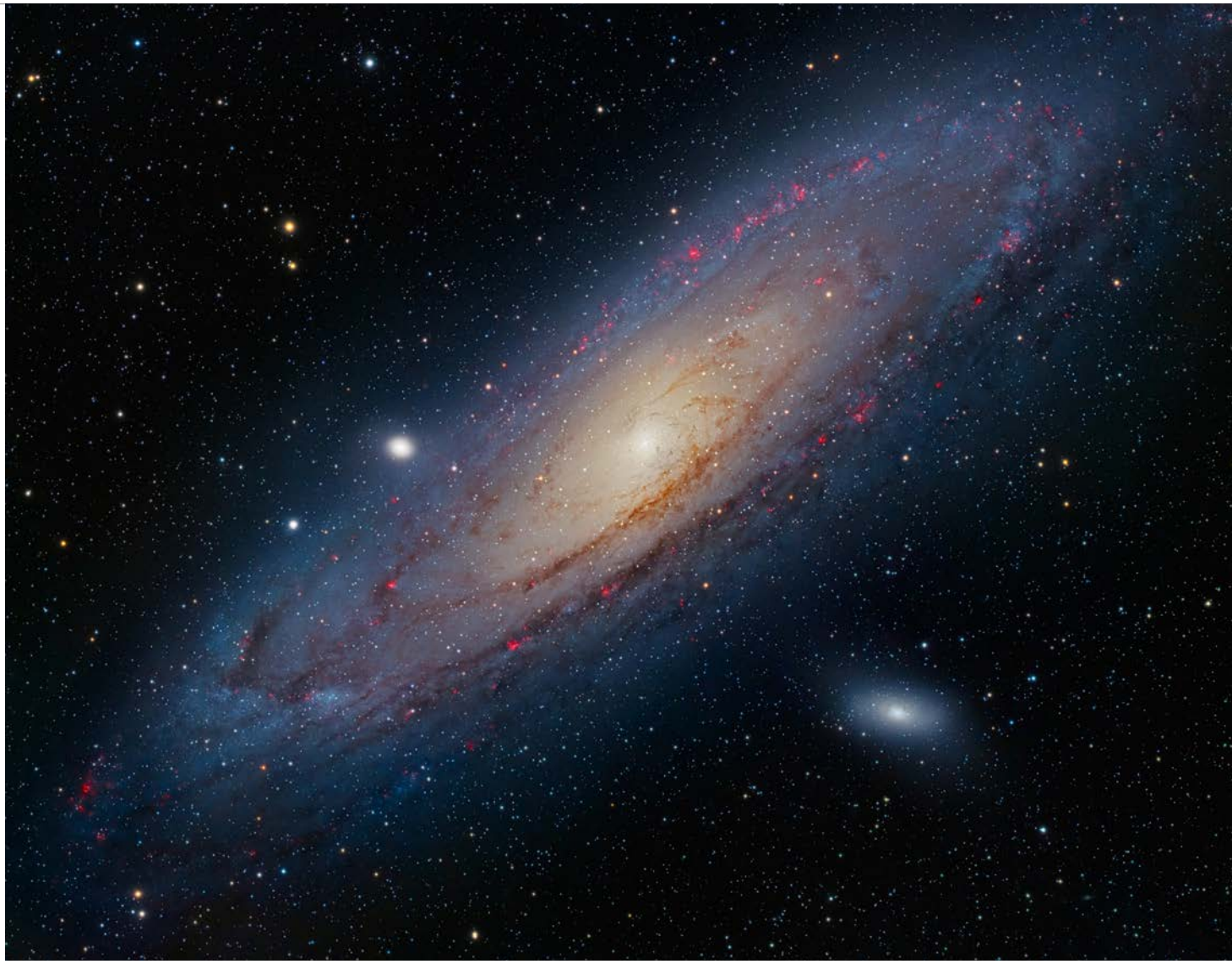


Image by Marco Lorenzi, www.glitteringlights.com/ Moment/ Getty

new software for the telescope to improve data acquisition and signal processing. The upgrades will allow astronomers to observe a large area of the sky 1,000 times a second. "The powerful supercomputer that Bailes and Swinburne have provided makes this an exceptional telescope for exploring the transient sky with fast and flexible cadence," says Green.

1,000 snapshots a second

After a five year hiatus, MOST recently began scanning the skies again. One of its first priorities will be to observe fast radio bursts — very bright, millisecond-long flashes of radio energy first observed just 10 years ago.

Only around 15 of these events have ever been observed by astronomers, some by Bailes and colleagues at Swinburne. They appear to be happening outside our Galaxy, but no one really knows what causes them.

"There are more theories than there are bursts," Bailes says. "Some people think that they occur when two neutron stars collide, others think that neutron stars become unstable and collapse into a black hole and they give off little bursts of radio emission when they do it."

Sharing data

Measuring a one centimetre change in orbit from halfway across the Galaxy, or capturing a millisecond-long burst of radiofrequency energy somewhere in the Universe, requires extraordinary technology that is found at very few locations around the world.

In recognition of UTMOST's unique capabilities, the collaboration has elected to make all the data generated by the Molonglo telescope available instantly to researchers anywhere in the world, which represents a big shift in the way astronomers communicate with each other.

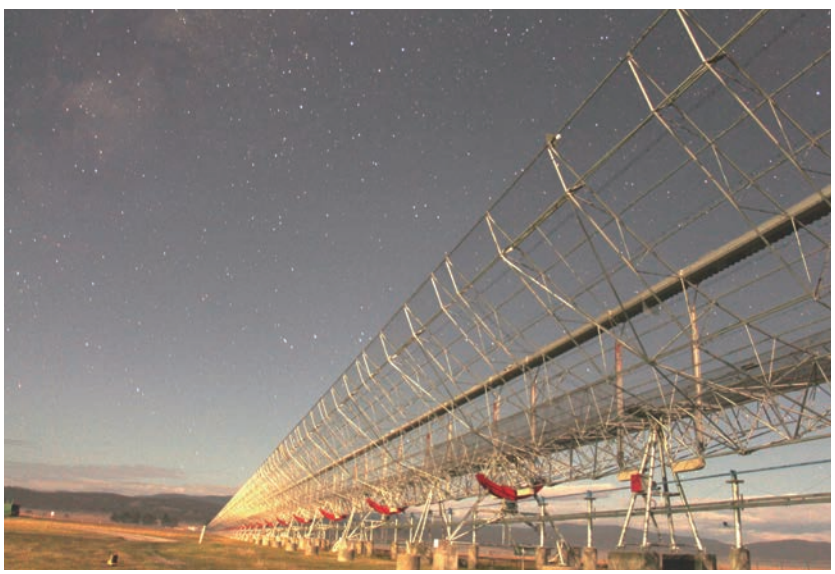
"Usually what you do is you build a telescope and you keep all the data secret and you do a grand magic reveal at the end," Bailes says.

"But with these fast radio bursts, if we did that, by the time we gave people the information it would be worthless because the thing would have faded away so we decided we'd reveal any event immediately."

Other theories suggest that they arise when black holes and neutron stars merge, or as an early warning signal of an impending supernova. There is even the suggestion that these bursts might have something to do with the atmosphere of a star that makes them appear further away than they really are.

Once every few weeks

The upgraded Molonglo telescope isn't yet fully operational, and is currently running at only a quarter of its efficiency. But Bailes is already excited about what might come when it reaches its full potential.



MOST

"The detection rate is a strong function of efficiency so we haven't been running long enough to find a fast radio burst, but we're hoping that soon we'll be finding one every few weeks."

The Molonglo telescope is also continuing its long tradition of contributing to the field of pulsar study. Bailes spends much of his time studying these spinning neutron stars as a kind of hot-house for strange gravitational behaviour.

"Neutron stars are very tiny so they can get in very close proximity to each other, which means that they travel very quickly around each other and they allow us to test gravity in ways that we can't normally do," Bailes says.

These rapidly waltzing pairs might even provide insights to a puzzle left by Einstein. The great physicist predicted the existence of a peculiar type of gravitational 'radiation' called gravitational waves, recently observed for the first time. In theory, pulsar pairs should emit these waves. Astronomers can detect the changes to the orbits of these spinning pairs as tiny amounts of energy carried off by the gravitational waves.

"These waves are mysterious and difficult to detect but they actually cause the orbit of the neutron star to shrink by one centimetre per day, which might not sound like much, but using the upgraded telescope we can measure the position of neutron stars so accurately that we can even begin to see that effect."

Given the fundamental importance of this work, it will certainly be time well spent.

THE SOUTH'S FIRST DARK MATTER DETECTOR

Swinburne researchers join the hunt for one of the Universe's most mysterious phenomena

Researchers Jeremy Mould (left) and Alan Duffy inside the Stawell Underground Physics Laboratory.

In an Australian gold mine, a kilometre underground, an international team are searching for the Universe's dark side.

There are invisible particles that, combined, outweigh all the atoms in all the planets, stars and galaxies that we can see, by five times. These particles are called dark matter, and their lack of interaction with light confers them with phantom-like properties, so that they can fly through atoms of solid matter as if they were empty space. Understanding the nature of these particles would give scientists insights into one of astronomy's biggest mysteries.

One way researchers could learn more about dark matter is from the headwind of dark matter the Earth ploughs through at approximately 220 kilometres per second. As this dark matter wind 'blows' through the Earth, it will occasionally collide with the nucleus of an atom causing the atom to recoil. Spotting these chance collisions is the pursuit of the Southern Hemisphere's first dark matter detector, SABRE (Sodium-iodide with Active Background REjection), an experiment locally co-led by Swinburne University of Technology's Professor Jeremy Mould and the University of Melbourne's Elisabetta Barberio.

"SABRE exploits an unusual property of sodium iodide crystals doped with thallium. Recoiling atoms emit a faint flash of light on colliding with dark matter," says Swinburne's Dr Alan Duffy, an astrophysicist involved with the project.

The challenge is that many extraneous flashes will be emitted due to collisions with cosmic rays and muons from space or background radiation. SABRE itself would also emit radiation, but to negate this, the Melbourne researchers have drawn on the expertise of Princeton University's Frank Calaprice and his team. They have grown one of the purest crystals ever attempted to limit the radiation from SABRE.

To escape the constant bombardment from space the SABRE team, in collaboration with Newmarket Gold and Northern Grampians Shire, created the Stawell Underground Physics Laboratory (SUPL) a kilometre underground in a gold mine in Victoria. Team members from the national nuclear agencies of Australia >>>

(ANSTO) and Italy (INFN) and CoEPP, Australia's ARC particle physics centre of excellence, will ensure that SUPL will be one of the lowest-radiation locations on Earth. With $3.5 million funding from the Victorian government and Australia's national government, and in-kind support from partner institutes, SABRE will be operative in a year. "Swinburne, along with the rest of Australia, will then be at the forefront of the world's efforts to uncover the nature of dark matter," says Duffy.

The wider industrial and scientific communities are also showing interest in the unique SUPL facility. The low background radiation environment is ideal for testing novel neutron detectors, which can be used to help spot smuggled nuclear material. The facility's detector technology can also perform tomographic scans of the surrounding mine to locate heavy metals. This is because metals such as bodies of gold ore block muon particles, much like bones block X-rays in medical scans.

FEATHERS, ROCKETS AND FAIR PRICES

A Swinburne economist is highlighting irregular pricing movements in everyday living costs

Too many Australians, the rise and fall of petrol prices and mortgage interest rates can appear to be controlled by unknown forces.

But the recent work of Swinburne University of Technology economist, Professor Abbas Valadkhani, has been an eye-opener for many governments and consumers, and prompted news headlines and policy change.

Valadkhani's empirical analyses of interest rates and petrol prices found that Australian prices rise faster than they fall, supporting the widespread economic hypothesis that prices shoot up like a rocket but fall down like a feather.

"It takes a very long time for prices to come down to the equilibrium, but when the prices go below the equilibrium they will return almost immediately," says Valadkhani.

The research uses modelling frameworks to determine the full asymmetric effects of external market forces on prices, with allowance for time lags between when external forces change and prices are affected. Valadkhani's calculations can determine how balanced the fluctuations in interest rates and prices are in response to outside influences such as changes in the crude oil price and shifts in the cash rate.

It has been valuable evidence for politicians, media, policy makers and pricing regulators, who have widely cited his published findings. Most recently, Valadkhani

RISE AND FALL

September 2012
Valadkhani publishes his research into the movement of petrol prices at 111 retail locations around Australia. His results show that prices rise faster than they fall at one quarter of petrol stations.

December 2014
The Australian Competition and Consumer Commission (ACCC) changes its price-monitoring regime to compel petrol stations to report changes in pricing behaviour quarterly, rather than annually. Valadkhani's research is quoted in the media reporting about the changes.

The Journal of Asia Pacific Economy publishes research by Valadkhani and colleagues into the movement of Australian credit card interest rates. They find that lenders are more likely to pass on increases in the Reserve Bank cash rate than decreases.

September 2015
Valadkhani presents his findings on credit card interest rates to the Australian Senate Economic References Committee.

December 2015
The Senate committee's report is published and quotes Valadkhani and his research at length. Its recommendations include encouraging greater competition between lenders to better manage interest rate settings.

was called to appear before the Australian Senate's Economic References Committee for an inquiry into credit card interest rates. The subsequent report, released in December 2015, leaned heavily on Valadkhani's research (see timeline).

In regard to petrol prices, Valadkhani says that in 2014 his work helped prompt the Australian Competition and Consumer Commission to change the price-monitoring regime to collect information on pricing behavior quarterly rather than annually. "As a result of that they have conducted a deep dive investigation into the fuel market."

A push for greater transparency, efficiency and fairness is at the heart of his research, says Valadkhani. "It is important to use our knowledge and discipline toolbox to find real solutions to real world problems, otherwise we may end up finding complicated solutions to non-existent problems."

To that end, he is planning to undertake similar analyses of diesel pricing in the near future.

SUSTAINABLE SOLUTIONS FOR WINE WASTE

A range of industrial applications could result from reprocessing grape pomace


Grape pomace

Ways to recycle the vast amount of plant waste produced by the wine industry are under investigation by chemistry and biotechnology researchers at Swinburne University of Technology.

Grape pomace is the skins, pulp, seeds and stems remaining after the fruit has been pressed for juice. While pomace contains tartaric acid, a common additive used to balance the acidity of the wine, it is of limited nutrient value. It is also too hard for animals to digest so can't be used as feed, and degrades too slowly to be useful as compost. Given the size of Australia's wine industry, a lot of plant waste ends up in landfill.

Swinburne researchers, led by Professor Enzo Palombo, chair of the department of chemistry and biotechnology, are collaborating with the CSIRO to find a solution and have developed a technique for converting the waste into compounds with potential value as biofuels or medicines.

Four fungi are used in the process — *Trichoderma harzianum*, *Aspergillus niger*, *Penicillium chrysogenum* and *Penicillium citrinum*. A 30-minute heat-activated pre-treatment breaks down the biomolecules. Then, a bioreactor containing the fungal blend takes up to three weeks to break down the biomass. The breakdown produces alcohols, acids and simple sugars with industrial and medicinal applications. Among the extracts is tartaric acid, which can be reused in the winemaking process.

"We have demonstrated this technique in the laboratory, but it can be scaled up to an industrial level," says Palombo.

"Our newer modified process involves a simplified and rapid extraction method that can be performed on-site, thus recycling the waste directly back into the winemaking process," he says.

Since tartaric acid is one of the biggest costs to winemakers, its effective extraction for reuse reduces their costs significantly. The residual post-process biomass has reduced toxicity and can be safely composted or used as animal feed.

Southern Estate Wines will be working with Swinburne on further research to better understand the fungal-based conversion process, which the group hopes will result in sustainable, efficient, novel and economical methods of grape pomace degradation and bioconversion.

Swinburne will extend this work to other agricultural industries. There's already interest in applying the new method to treating large amounts of toxic citrus waste and creating innovative ways to reduce and recycle wastewater.

The agricultural, food, paper, textile and related industries produce abundant plant-based waste. But because not all biomass waste is easily biodegradable for compost or suitable for biofuels or animal feed, biodegradation is a key research focus.

MEASURING THE ROAD TO SUCCESS

Cutting-edge social network analysis by Swinburne researchers is helping the CSIRO to better understand the paths to successful innovation and commercialisation

TIMELINE

1963 CSIRO scientist Doug Waterhouse develops Aerogard and it is first publicly used to keep flies off Queen Elizabeth II during her Australian visit. CSIRO gives the product to Mortein to market and develop and receives two dozen aerosol cans in return.

1998 CSIRO develops the reversible addition-fragmentation chain-transfer (RAFT) polymerization process. The researchers involved are now considered candidates for the Nobel Prize, together with other scientists who led the development of controlled radical polymerization techniques.

2014 Swinburne and CSIRO begin work on identifying the best networks for innovation through observation of the commercialisation of the CSIRO's RAFT polymer technology.

2015 Swinburne's first social network analysis using exponential random graph models (EGRMs) is done for the CSIRO project looking at the links within and between seven research institutes working with RAFT. Among other things, it identifies the importance of attending professional conferences.

2017 The Swinburne team will produce a final report outlining the social and organisational networks that are beneficial to innovation and those which may hamper it.

The CSIRO's mission has changed significantly since it first gave away the recipe for its fly repellent, Aerogard, in return for two-dozen cans of the spray. Today, the national research organisation is looking to maximise scientific and economic returns for Australia, which means improving technology transfer and commercialisation of its discoveries.

To help achieve this, it has turned to social network analysts at Swinburne's Centre for Transformative Innovation (CTI) to map the links between organisations and people that are necessary for rapid and rewarding innovation.

The Swinburne group, led by CTI associate director, Dr Dean Lusher, is a world leader in statistically analysing these networks on multiple levels using a new technique called exponential random graph modelling (ERGM).

The different levels of networking may include connections on an organisation-to-organisation level, such as the CSIRO and its industry and research partners being linked through formal contracts, and also at the personal level, such as advisory relationships. Statistical analysis led by Lusher and his colleague, Peng Wang, enables them to look at why and how those networks arise.

"They're seen as the most sophisticated network models in the world and we're one of the few groups in the world who are developing them," says Lusher.

CSIRO Director of Research, Manufacturing, Greg Simpson, says they are excited by the early outcomes from the Swinburne work which is centred on the developing research and commercial networks associated with its revolutionary polymer technology, RAFT, which has been used to develop electronics, paints and medical devices.

One of the early insights of the analysis identified the importance of researchers attending professional conferences. In responding to the finding the organisation is already adjusting its operations, including clarifying how different roles in CSIRO link to equivalent roles in industry and academia.

"If we can better understand how to

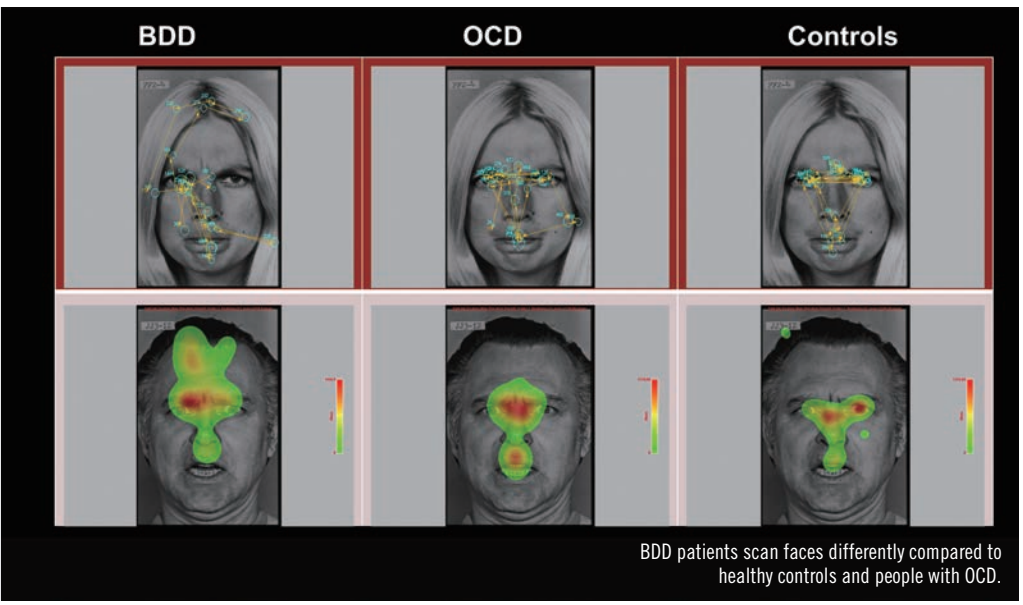
build innovation networks then we are much better placed to understand how industries work and to improve those industries," says Lusher.

The Swinburne group has already successfully applied ERGM methodology across a range of other projects to identify important links within various networks. Previous analyses include the examination of community networking following Victoria's Black Saturday bushfires, the mapping of the links between Australia's biotech clusters, and an exploration of team culture within the Australian Football League. They are also using their ERGM expertise in ongoing work with Boeing and other corporate groups.

"Whether it be biotechnology or the manufacturing sector — it seems a cheap and easy way that we can make gains in the innovation space," says Lusher.

RECALIBRATING VIEWS ON BODY IMAGE ILLNESS

Better treatments for a distressing condition may emerge from studies of its biological cause



BDD patients scan faces differently compared to healthy controls and people with OCD.

Most of us are dissatisfied with something about our appearance, but for people with body dysmorphic disorder (BDD), perceived flaws become an obsession with distressing effects.

New research from Swinburne University of Technology offers encouraging insights into the condition. Studies conducted by the university's Professor Susan Rossell show that it is triggered by biological factors, illuminating options for treatment.

Professor Rossell, a cognitive neuropsychologist, worked with colleagues from St Vincent's Hospital in Melbourne to study a visual network of the brain using MRI data. She found that the frontal and occipital brain regions in people with the condition were smaller than in a control group of unaffected individuals.

The results suggest that the visual networks of people with the disorder have particular characteristics, says Rossell. "People with BDD don't move their eyes in the same way as other people. They don't see the whole picture, and become overly focussed on small details."

These differences also affect how the brain processes visual signals, she says. "The information going into the brain is piecemeal, and then that limited information is processed differently, due to differences in the cortex that deal with integration of visual information."

Men and women affected by BDD become fixated with a perceived flaw in their appearance, usually a specific part of the body. In some cases, patients seek plastic surgery to 'fix' their 'fault' but cannot discern any difference afterwards.

Clinicians use mirror and visual training to help patients accurately look at and evaluate the body part they fixate on and the depression or anxiety that can result from BDD can be addressed by therapy.

Recognition of BDD's neuro-biological basis offers opportunities to expand treatment approaches, Rossell says, including better screening before using plastic surgery. For people with the condition, she thinks her work may have a similar impact to other research she conducts on people who experience auditory hallucinations.

"When patients understand how auditory hallucinations work in the brain, it really reduces the stigma and stress for them," she says. "They know it's not a weird supernatural thing: it is part of their biology. They're comforted by knowing there's a reason for it."

GROWING OUR SOCIAL ECONOMY

Social enterprise is a mature sector in Australia, but a Swinburne analysis has shed light on its function, scope and impact

World-leading analysis by Swinburne University of Technology sociologist, Professor Jo Barraket, is providing valuable insight into Australia's large and rapidly growing social enterprise sector.

The sector comprises organisations that seek to engineer social impact through commerce, from Fair Trade groups to community-based recycling and labour-market operations, and charitable business ventures. It employs an estimated 9 per cent of Australia's working population across 20,000 separate operations, but until recently little was known about its purpose, scope or impact.

To address this, in 2010 and 2015 Barraket used online surveys, focus groups and data-mining to map where, why and how social enterprises operate.

The initial report, Finding Australia's Social Enterprise Sector (FASES) 2010 provided the first academically produced evidence related to the field and the first Australian definition of what social enterprise is (see box).

"It helped explode a few myths such as the idea that social enterprise was something brand new," says Barraket, the Director of the Swinburne Centre for Social Impact. "In fact the research showed quite clearly that social enterprise was a mature and sustained sector in Australia. It also provided credibility for governments to make investments."

The work was done in partnership with the Melbourne-based national social enterprise support agency, Social Traders, and has provided a wealth of evidence for policy makers, the public and those working in the sector for planning and investment purposes.

"It's been a critical piece of work in terms of social enterprise in Australia," says Social Traders managing director, David Brookes.

The Finding Australia's Social Enterprise Sector (FASES) 2010 work was quoted by the Federal Parliamentary Secretary for Social Inclusion, Ursula Stephens, at the 2010 launch of the $40 million Social Enterprise Development and Investment Fund.

The report has shaped policy frameworks at federal and state levels, as well as internationally. This includes initiatives in New Zealand, Tasmania and in Western Australia, where a $10 million fund has

Summerland House farm in Northern New South Wales is a social enterprise that employs 90 people with a disability.

DEFINING TERMS

Jo Barraket and David Brookes have long histories working in the social enterprise sector and when the initial FASES report was discussed, they recognised the requirement for a comprehensive definition.

"The definition was a very concrete need for everyone. Governments and organisations couldn't fund it if they didn't know what it was," says Barraket.

She empirically generated an initial definition though focus group discussions and tested the result in a survey of more than 500 relevant organisations.

The final definition sets out that social enterprises are led by an economic, social, cultural, or environmental mission consistent with a public or community benefit; trade to fulfil their mission; derive a substantial portion of their income from trade; and reinvest the majority of their profit/surplus in the fulfilment of their mission.

It has now been adopted by stakeholders and participants, says Brookes, and is one of the most valuable outcomes of the work. "It's now a broadly accepted definition by government at the state and federal level in line with the international concept of social enterprise."

House With No Steps

been established. Barraket has also advised researchers in Germany and Switzerland, along with multiple government agencies within Australia over the past year.

FASES 2015 focussed on the challenges and opportunities facing the sector. When the interim report was released in June 2015 it pointed to particular difficulties in balancing the governance requirements of social enterprise organisations against the flexibility required in a business environment.

The results also indicate increased opportunities for social enterprise in the disability and aged care sectors, as well as markets where ethical consumption is becoming more popular.

In the meantime, Barraket is studying the impact of social enterprise initiatives on individuals and in the communities where they operate.

SEEING EPILEPSY WITH SURGICAL PRECISION

An advanced neuroimaging technique improves severe epilepsy treatment

A project imaging the brains of people with severe epilepsy has changed the way a major Melbourne hospital manages the treatment of patients with the disorder.

The three-year collaboration between Swinburne University of Technology and St Vincent's Hospital Melbourne (SVHM) used the university's magneto-encephalographic (MEG) machine and magnetically-shielded chamber to conduct simultaneous MEG and electroencephalographic (EEG) recordings on patients with medically uncontrolled focal epilepsy.

The technique interprets brain function to pinpoint the suspected location of the `electrical storms' that precede an epileptic event. This gives previously ineligible patients the option of epilepsy surgery involving removal of that part of the brain that triggers the seizures.

Instead of undergoing invasive surgery to locate the triggering nerve cells, the patient sits under a helmet-shaped sensor surface, which measures femto-tesla level brain magnetic activity — signals far fainter than even a household magnet. Both subject and equipment are shielded from the potential interference of ambient magnetic fields in a special chamber.

Once the abnormal tissue, which can trigger multiple seizures a week, is provisionally located, the surgical team at SVHM can investigate the option of excising it, leaving healthy brain tissue unaffected.

To date, 10 patients have been operated on using the MEG/EEG results.

"Each of these patients had suffered long-standing epilepsy, with seizures every week or so," says Professor David Liley, one of the key project researchers, from Swinburne's Brain and Psychological Sciences Research Centre.

"The surgery has greatly reduced the number of seizures the patients are experiencing, such that many of the patients are completely seizure free. It's a major improvement in their quality of life. This means that they and their families have their lives back and are freed from the constant dangers and uncertainty of uncontrolled epilepsy," Liley says.

No other surgical epilepsy service in the world uses the combination of high density EEG and MEG. The clinical results are so successful that SVHM, which has one of the largest adult surgical epilepsy programs in Australia, is now receiving referrals from other Australian hospitals, including The Royal Children's Hospital and Austin in Melbourne, and from overseas.

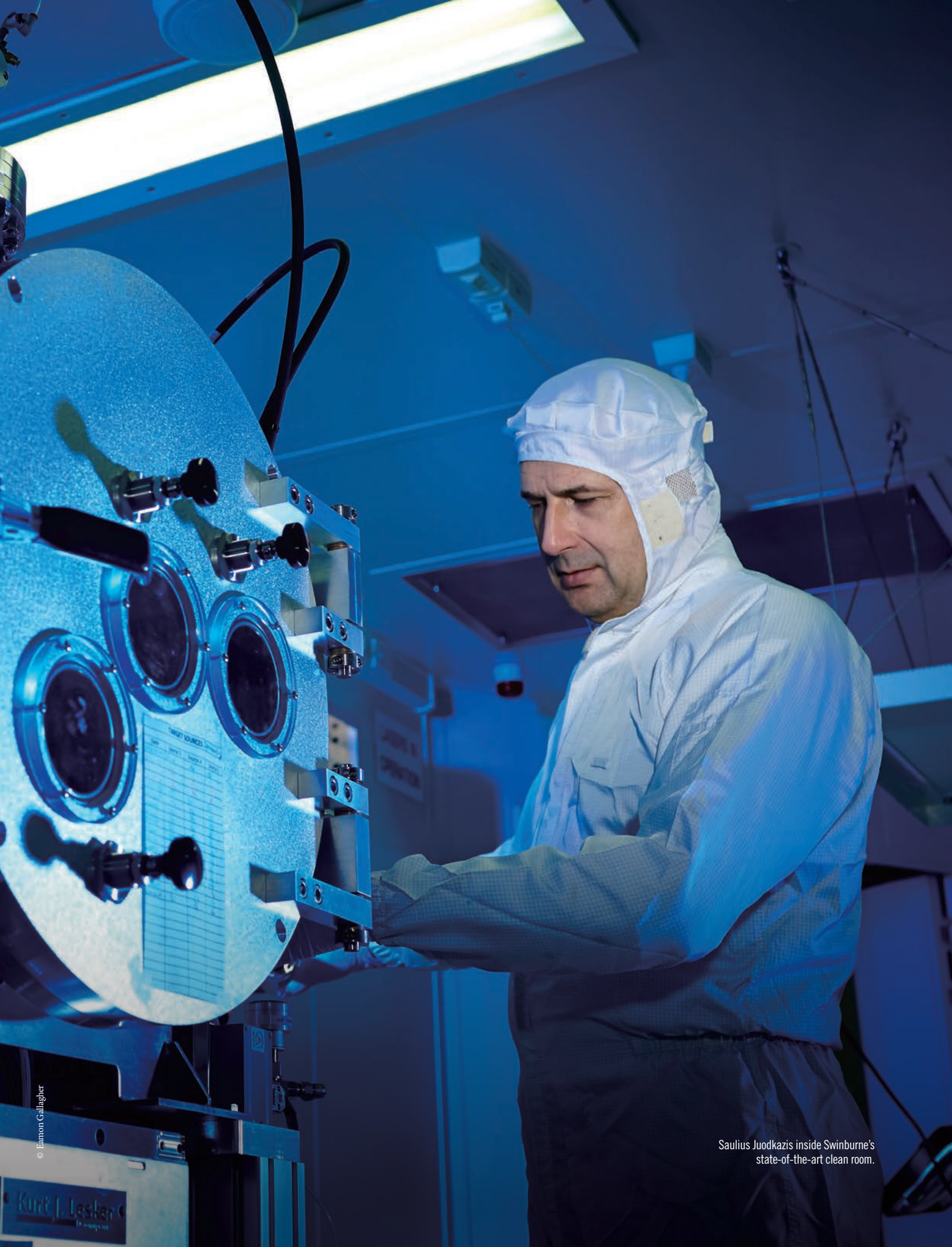
Researcher Johanna Stephens inside Swinburne's cutting-edge magneto-encephalography (MEG) machine.

Focal epilepsy affects about 60 per cent of all epilepsy sufferers. An estimated 5,000 new cases are diagnosed in Australia each year. The precision of the MEG/EEG technique offers a safe and powerful tool for diagnosis, and is redefining best practice for treatment.

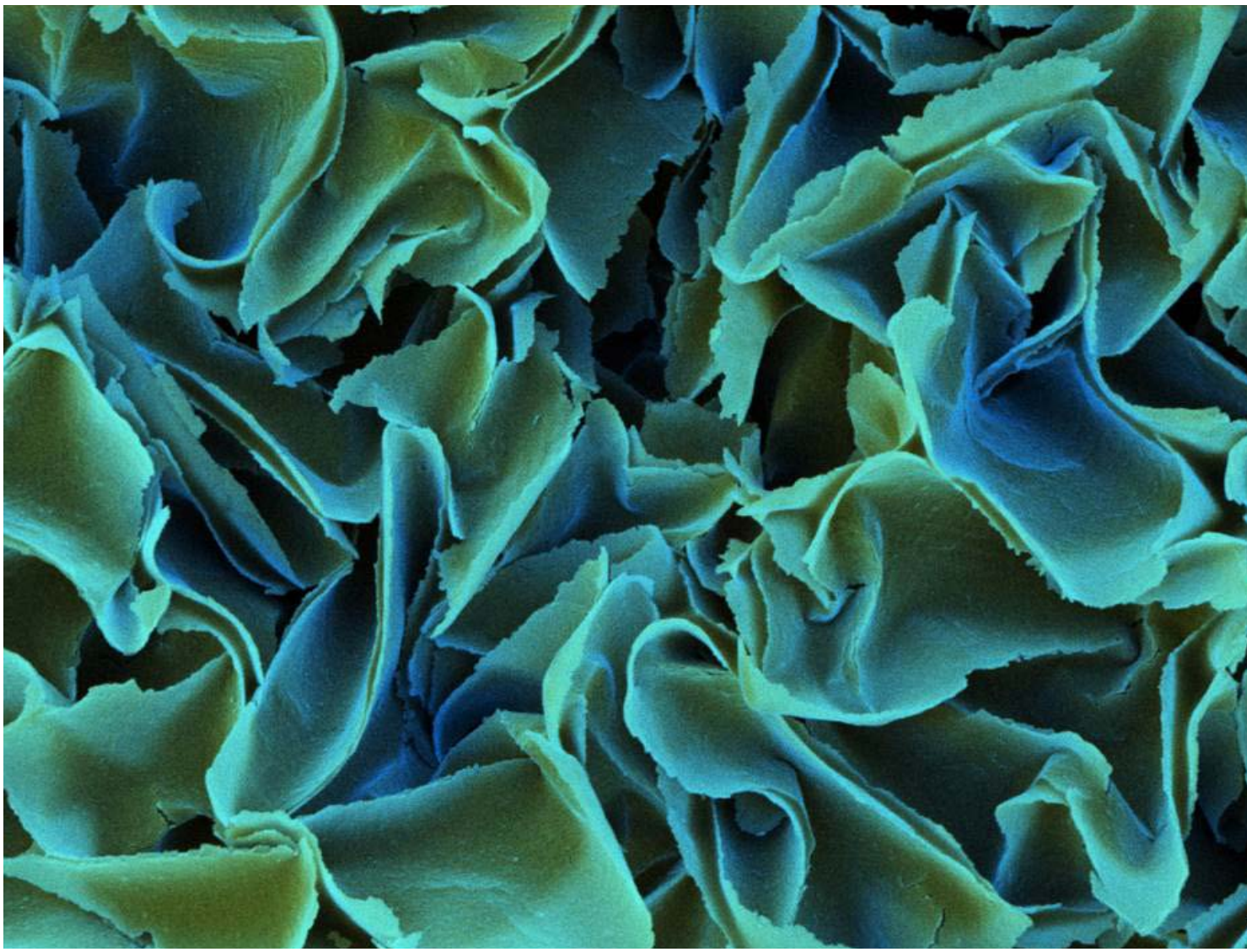
MEG/EEG examinations are expected to become a rebatable item on the Australian Medical Benefit Schedule in the near future. The technique may also have applications in targeted radiotherapy or stem cell therapy.

Shining a light on ALZHEIMER'S DISEASE

INSECT-INSPIRED MATERIALS DESIGNED BY RESEARCHERS AT SWINBURNE AND THEIR COLLABORATORS HAVE A RANGE OF MEDICAL APPLICATIONS



Saulius Juodkazis inside Swinburne's state-of-the-art clean room.



Nanotextured surfaces made of polystyrene plastic sheets (above), gold-coated black silicon (top right) and black silicon (bottom right).

With dementia now the second leading cause of death in Australia, Melbourne scientists have taken inspiration from some of nature's smallest creatures to help solve an enormous problem.

A team led by Swinburne University of Technology researchers has developed surfaces with features measuring billionths of a metre that mimic the extraordinary textured surface of insect wings. Their unique response to light makes these surfaces highly effective sensors, able to detect markers of disease at extremely low concentrations.

> **"It is projected that diagnosed cases of dementia in Australia will reach almost 950,000 by 2050, according to Alzheimer's Australia."**

Swinburne Professor of Nanophotonics, Saulius Juodkazis, has developed nanotextured surface technology that is being used in

proof-of-principle studies to look for biomarkers associated with Alzheimer's disease, the most common form of dementia. It is projected that diagnosed cases of dementia in Australia will reach almost 950,000 by 2050, according to Alzheimer's Australia.

No tests for biomarkers have been validated and Alzheimer's is currently diagnosed through observations of a patient's mental decline, by which stage the disease is already well established. Among the goals of scientists in the field is to develop simple and accurate tests that can detect early signs of the disease before symptoms appear. Their hope is that early detection will allow treatments to significantly slow progression of the disease.

Light fantastic

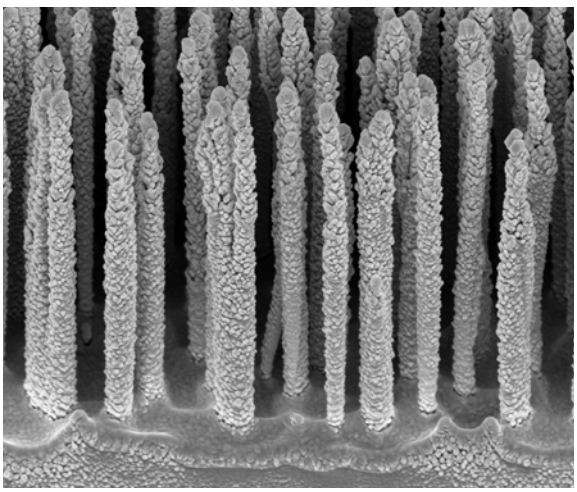
Professor Juodkazis has long been interested in the relationships between light and materials. Since earning his doctorate in experimental physics and material science from Vilnius University in Lithuania and Lyon-I University in France, in 1997, he has studied the mechanisms and applications of interactions between light and matter in many different settings.

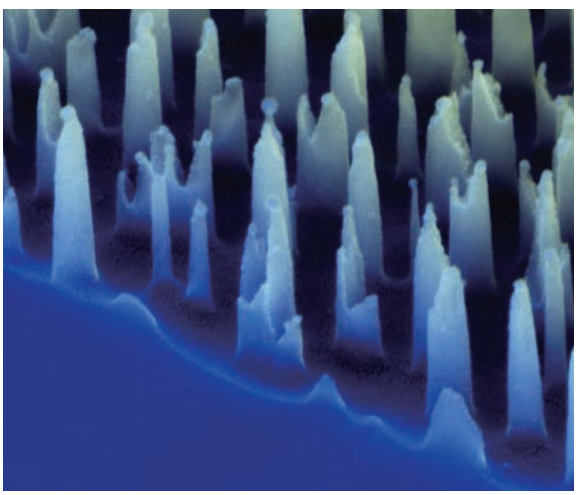
After joining Swinburne University of Technology in 2009, he established an Applied Plasmonics research group to find industrial applications in the fields of nanotechnology and nanophotonics.

In 2011, his group joined an international collaboration that created a version of aluminium 40 per cent denser than metal in its normal form, using an extremely short laser pulse to create a huge concentration of energy in a tiny crystal composed of aluminium oxide.

"Using this focused laser technique, we may now be able to create a range of superdense metals that have extraordinary properties," Juodkazis told *Asian Scientist* magazine during the collaboration. "The creation of superdense silver or gold, for example, could lead to many new possibilities for bio-sensing and plasmonics."

In 2012, he and colleagues collaborated with laser physicist Professor Esa Jaatinen from Queensland University of Technology on another application of light, creating a prototype sensor to detect chemicals that are present in many explosives.





The story of the prototype's development was the focus of media reports that described the sensor as being based on a one-millimetre square corrugated gold surface that picks up traces of explosives floating in the air. Laser light shone on to the surface is altered in a particular way depending on the nature of the explosive chemical.

Also in 2012, Juodkazis established the Nano-Lab, Swinburne's nanofabrication facility in the class-1000 cleanroom of the university's architecturally striking $100 million Advanced Technologies Centre, an architecturally innovative and environmentally sustainable >>>

Swinburne's Centre for Micro-Photonics class-1000 clean room has a range of lithography tools for fabricating materials.

> building that houses $40 million worth of world-class research infrastructure.

Detecting disease

The inspiration for the Alzheimer's biomarker work emerged when Swinburne biotechnologist Professor Elena Ivanova reproduced the pattern found on dragonfly wings on a silicon surface. Juodkazis found the surface had an unusual effect on light.

> **"When you shine light on that surface, light is scattered all directions, but locally there will be places where intensity is much higher"**

A dragonfly's wing is covered with spikes a couple of hundred nanometres tall and tens of nanometres in diameter (see Antibacterial Solutions Inspired by Nature, page 41) While the surface scatters light so effectively that it appears black to the naked eye, at the nanoscopic level, the picture looks quite different. "When you shine light on that surface, light is scattered all directions, but locally there will be places where intensity is much higher," says Juodkazis.

When light waves are squeezed into nanoscale spaces they concentrate to an incredibly high intensity — up to a thousand times higher, he says. This super-high intensity light 'floats' on the material's surface, a bit like a liquid.

Juodkazis realised this property could be harnessed to look for molecules, even at very low concentrations. Once a molecule crosses into one of the light hotspots, the energy of the light will be scattered in a unique pattern — a telltale signature of that particular molecule.

The researchers have used this approach to test for beta amyloid, a biomarker of Alzheimer's disease, at extremely low concentrations. Using a synthetic beta amyloid, Juodkazis and colleagues showed that a nanotextured surface made with sapphire could detect the molecule at the sort of concentrations found in the spinal fluid of individuals with early-stage Alzheimer's disease.

Juodkazis has also found nanotextured silicon surfaces to be good sensors. The beauty of nanotextured silicon, or 'black silicon', is that it's relatively cheap and easy to manufacture, using a technique known as plasma etching. During this process, a 'mask' covers most of the surface of the material before a stream of plasma etches a pattern on the area not covered by the mask. With nanotextured silicon, however, etching is allowed to happen randomly, without a mask to guide the stream of plasma. As the plasma etches away the surface, nanoscale islands of residue build up and protect the underlying silicon, while the silicon around those islands is etched away, leaving the spiky structure. "It's really random and self-organised, and that's why it is not expensive," says Juodkazis.

And because the nanotextured surface is so effective at scattering light, it could also have military applications in making surfaces appear invisible, he says. ■

ANTIBACTERIAL SOLUTIONS INSPIRED BY NATURE

Nano-patterns copying the texture of insect wings may have medical applications

By mimicking the highly textured surface of insect wings, Swinburne University of Technology researchers hope to develop nano-structured materials that kill bacteria.

In 1945, scientists — including a pioneer of antibiotics Alexander Fleming — accurately predicted that microbes could develop resistance to antibiotics. Seventy years on, their warning has been realised as a significant healthcare challenge.

Elena Ivanova, a professor at Swinburne's Faculty of Science, Engineering and Technology, and her research team, including scientists from a range of disciplines and universities, were studying self-cleaning surfaces in nature when they discovered bacteria being killed on the wings of the clanger cicada. Tiny spikes — nano-pillars — on the surface of cicada and dragonfly wings provide a physical rather than a chemical model for killing bacteria, which, when caught on the tips of the nano-pillars, stretch and rupture.

The team developed a biophysical model of the interactions, showing how the mechanical properties of bacteria, particularly cell rigidity, are key factors in determining resistance to the spikes. More rigid cells have a greater natural resistance to the effect. Further experiments found that using microwaves to irradiate bacteria cells reduced their rigidity, making them more susceptible to the destructive effects of the nano-pillars.

"There's strong interest from biomedical industries," says Ivanova, "Surface modification doesn't change biocompatibility, mechanical or other properties of the implantable biomaterials. That means an implant with nano-structured surfaces could be used straight away."

More work is necessary before practical applications are available, but the team is excited by its potential.

"This discovery is conceptually very new," says Ivanova, "A lot of work has to be done. We have to learn how to fabricate nano-structured materials on large areas — an extremely challenging task. Our latest findings indicate that even a small variation in the >>>

Elana Ivanova's nanotextured surfaces were inspired by insect wings, including dragonflies.

nano-structure may result in decreased antibacterial activity."

The need for new technologies and techniques to manufacture the required nano-structured materials opens new avenues for researchers. Once the technology is cracked, however, the commercial potential for the discovery is significant.

Bactericidal nano-surfaces can be applied to the metallic surfaces of biomedical implants. Antibacterial plastic surfaces could be used on biomedical plastic consumables such as catheters, as well as soft drink and water bottles, and bactericidal air and water purification filters. Antibacterial surfaces will also be valuable in the food handling industry and for surfaces subject to high levels of germs, such as those in public toilets.

Future research will focus on understanding more about the mechanisms through which nano-pillars mechanically rupture bacterial cells.

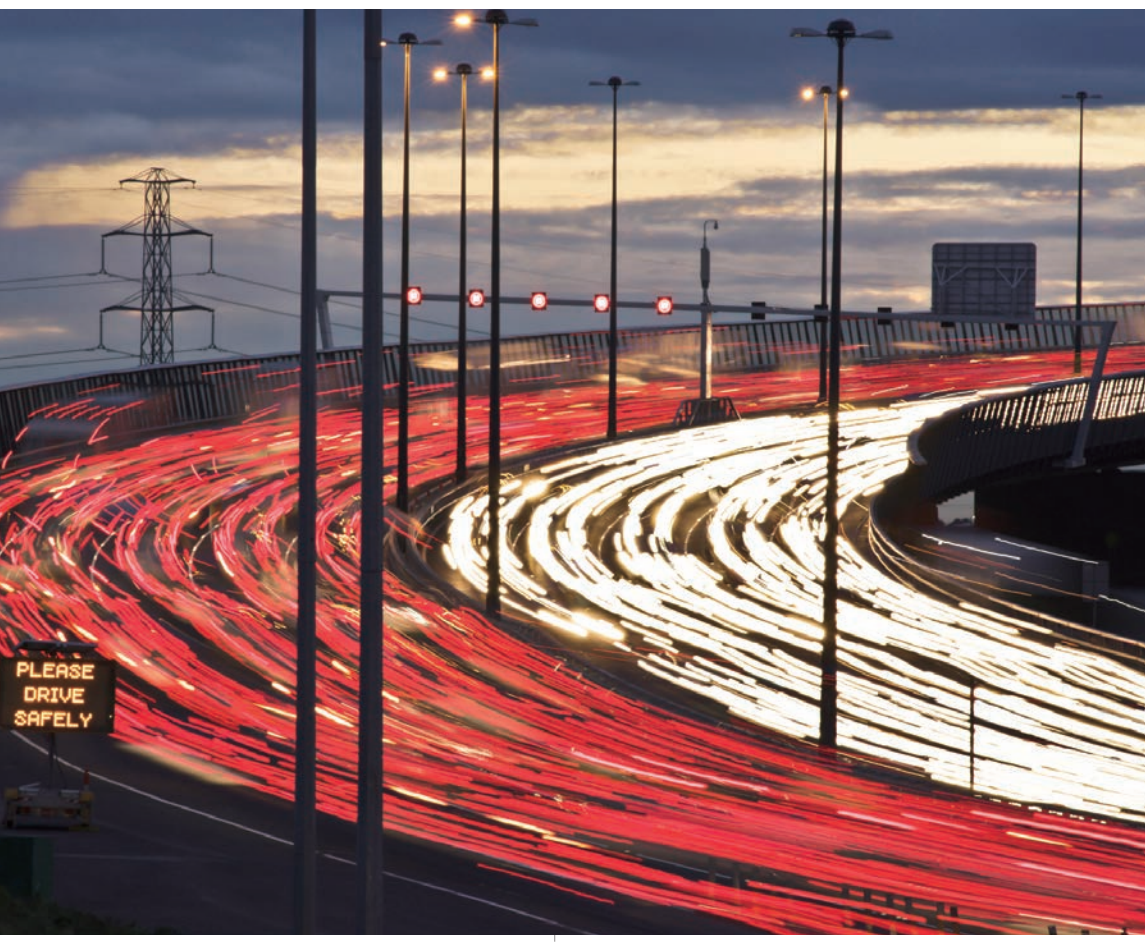
"This is critical for knowledgeable design of novel antibacterial nano-patterns, along with further research towards the development of larger scale nano-technologies," says Ivanova.

MODELS REDUCE TRAFFIC MAYHEM

A partnership between Swinburne and Government may ease Melbourne's traffic problems

A mathematical model that could significantly reduce traffic congestion by combining data from existing infrastructure, remote sensors, mobile devices and their communication systems has been developed by a Swinburne University of Technology research team.

As populations and economic activities increase, demand for greater mobility and rapid transportation has grown. Traffic management is problematic, however, resulting in frequent congestion on road networks, which brings economic, ecological and social challenges.



Swinburne's 'Congestion Breaker' project utilises intelligent transport systems (ITS), an emerging field of research that combines information and data from a range of sources for effective traffic control.

Led by Professor Hai L. Vu and developed in collaboration with VicRoads, the government body responsible for road management, through an Australian Research Council (ARC) Future Fellowships grant, the Congestion Breaker project has developed a mathematical approach that uses limited and incomplete data from existing operational traffic management systems to build a predictive control

framework to minimise congestion.

The model optimises the traffic flows over a finite period, taking into account the short-term demand and traffic dynamic within links of the network. The resulting algorithm explicitly considers any spill-back due to a queue built-up and travel time on the road between intersections and is capable of producing systems which would reduce congestion significantly.

Further innovative distributed control mechanism created in this project is inspired by research developed for packet scheduling in wireless networks. It can handle a large network containing thousands of sensors and actuators in real time.

The outcome is a comprehensive traffic management framework with computational flexibility accurate enough to reflect real urban traffic networks. It produces a scalable algorithm that can be integrated with current operating traffic management systems to reduce congestion and make better use of the existing road network infrastructure.

"Our novelty is in developing an integrated traffic control scheme that combines linear model predictive control with route guidance to manage urban traffic flows, and making it scalable for large networks," says Vu.

The model has potential industry impact as a state-of-the-art, integrated, efficient traffic network management system. It's a smart, scalable and easily integrated solution.

Such work is already making a significant difference in the Netherlands, where so-called Integrated Network Management (INM) using the model predictive control principle was applied on a comprehensive scale to tackle the traffic congestion of Amsterdam.

VicRoads is funding the first phase of a pilot project of the INM system for Melbourne.

"Similar pilot projects can be developed for many other cities around the world," says Vu. "And there are many possibilities for commercial applications in Australia and overseas in terms of smart mobility, sustainable cities for growing populations, and its concentration in big cities."

CHILDHOOD AND THE TOUCHSCREEN REVOLUTION

Swinburne's Babylab is exploring the way children interact with touchscreen computers

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Concerns that tablet computers may harm children's development appear to be unfounded, early research by Swinburne University of Technology scientists suggests.

Children began to play with tablet computers as soon as they came out in 2010, immediately generating fears that the technology might harm their development.

"Some people think touchscreen computers are ushering in a new age of learning; others believe they're ruining childhood, but there hasn't been much evidence either way," says Dr Jordy Kaufman, of Swinburne University of Technology's Babylab, one of the first Australian research facilities specialising in child cognitive brain research and social development.

Although excessive television viewing is known to have an adverse effect on children's cognitive development, those conclusions cannot necessarily be applied to touchscreens, which are interactive.

Kaufman has investigated how children learn from new media, measuring attentiveness, impulsivity and >>>

learning with children aged two to seven. The attention spans and problem-solving abilities of children using touchscreens were compared with children using traditional toys.

"We give them creative activities such as drawing and block building," Kaufman says. "So far, there's been no difference between touchscreen and real-world activities when it comes to slow-paced creative activities. We're not finding any difference in their skills whether they are using a tablet or a toy. If you are careful with the applications you choose, we haven't found any negative effects on attention span."

Kaufman says the key consistent message in his findings is that it's the activity that matters rather than the medium.

HOMES OF THE FUTURE

Reviving Melbourne's well-established suburbs

An innovative solution to satisfy housing demand in Melbourne as the population expands has been developed by a Swinburne University of Technology researcher.

Melbourne is a city under pressure. With a population expected to double to around seven million by 2055, there is commensurate pressure on resources, transportation and planning efforts. But current strategies to meet housing demand such as putting up high-rise apartments in 'brownfield' zones, piecemeal rebuilding in the suburbs, and the development of vacant rural-urban fringe 'greenfields' areas are not delivering sustainable housing.

Swinburne's Professor Peter Newton believes a solution lies in established 'greyfields' suburbs — long-established residential areas within 25 kilometres of the city centre, where the value lies in the land rather than the buildings.

Greyfield suburbs are rich with services, transport, amenities and employment opportunities. But the way these suburbs have expanded and evolved is less ideal. Individual properties are replaced piecemeal with new townhouses typically providing only two to four dwellings, which is insufficient to meet the housing demands or a growing population.

New software selects city regions with high redevelopment potential.

Professor Newton believes these have potential for a more cohesive and sustainable redevelopment if new models and instruments for precinct scale regeneration can be created. He's exploring these possibilities at Swinburne's Institute for Social Research in collaboration with the Cooperative Research Centre for Spatial Information (CRCSI).

The Greening the Greyfields (GtG) project identifies the most promising greyfields precincts across the city with ENVISION, software that locates properties with high redevelopment potential. ENVISION develops 3D computer-aided design models of suitable medium-density housing designs for the precinct, assessed for their environmental performance.

The project considers the market and community dynamics necessary to encourage precinct redevelopment. Also taken into account are ways of building a range of cost-effective, low-rise, medium-density housing that retains or improves sustainability in terms of water conservation, waste disposal and recycling, and carbon neutrality.

The benefits of regenerating greyfields precincts include keeping city sizes manageable, preserving greenspace, developing more sustainable and resilient communities, and ensuring affordable housing. Greyfields redevelopment would also save on infrastructure costs and reduce dependence on cars, a significant contributing factor to lack of sustainability in Australian city development.

"By neglecting the regeneration of greyfields, governments are consigning our big cities to less sustainable, liveable and competitive futures," says Newton.

The GtG project also investigates the types of planning policies that could facilitate more efficient redevelopment of housing in city suburbs.

"This project looks at why we're not building more medium-density housing in the middle suburbs and what can be done about it. What design, construction, manufacturing and labour force innovations can be brought to bear? What new institutional and governance arrangements need to be established?"

The answers to these questions aim to align with nation-wide objectives for sustainable development of Australia's expanding cities.

THE COGNITIVE BENEFITS OF SPICE

Scientists are investigating the health properties of a popular ingredient in a much-loved cuisine

A compound in a popular spice used to make curries can improve brain function, a Swinburne University of Technology study has found.

While the brain is a hungry engine, greedy for glucose and oxygen delivered through a rich blood supply, it is also vulnerable to stress from inflammation or blood flow reduction.

However, past studies have observed that older people living in cultures where curry is a staple have a lower prevalence of dementia and better cognitive function. A likely cause was identified as a compound found in turmeric: curcumin.

Professor Andrew Scholey, director of Swinburne's Centre for Human Psychopharmacology, has been researching the effects of herbs, spices and extracts on the human brain for the last two decades.

"Curcumin has multiple physiological effects," says Scholey. "It's known to reduce inflammation and improve blood flow. It influences multiple processes that nudge brain function in a positive direction."

Scholey and a PhD student, Kate Cox, conducted a study, funded by Verdure Sciences, which confirmed the positive effects of curcumin on the brains of healthy 60–85 year olds.

Compared with subjects taking a placebo, those taking the curcumin compound — more readily absorbed than pure curcumin — had significantly improved attention spans and working memory within an hour of taking the supplement. Use over four weeks also improved general energy, calmness, contentedness and stress levels.

The results are already available to the community and were published in the *Journal of Psychopharmacology* in mid-2015. The curcumin compound is now licensed in Australia by Blackmores.

Last year, the project was recognised as University Research of the Year in the inaugural NutraIngredients Awards.

The Centre for Human Psychopharmacology is conducting a further curcumin study, looking at neuroimaging and genetic markers to better understand curcumin's potential psychological and cognitive benefits.

The centre, which boasts a world-class facility, was set up specifically for clinical research.

Other projects includes an investigation of the effect of diet on the generation of new cells in the hippocampus — the region of the brain responsible for memory — and the impact of a Mediterranean diet and mild exercise on cognitive function for people in retirement homes.

"The main things older people fear about ageing are the loss of energy and the loss of mental function," says Scholey. Research undertaken by Swinburne and its partners will help to address those fears.

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READING BETWEEN THE LINES

Swinburne researchers are using new methods to analyse masses of data generated by an Internet-linked world

Whether tracking the movement of shoppers in a mall, or the patterns of stars in the night sky, the new Swinburne University of Technology Centre for Big Data and Data Analytics is set to streamline the sorting of millions of lines of data to generate faster answers.

"We want to collaborate with other researchers at Swinburne and external stakeholders, in solving complex data analytics problems," says Professor Timos Sellis, who has been appointed the centre's director.

Sellis is an international leader in the field of data science and has an illustrious history of developing new methods for better analysis of non-numerical data. He was the primary inventor, in 1987, of a database structure that improved the storage and retrieval of vast quantities of non-numerical information. The method, known as the R+-Tree, was adopted by industry, and has since been referred to by many companies including IBM, Microsoft and Oracle in patents.

While data science was once purely the domain of finance, it is now applicable across many fields, from health to urban design and the natural sciences.

The new centre will come up with ways to best perform complex analysis on information incorporated from different sources and formats.

"If you ask any company working on an application that uses data, they spend 90 per cent of their time preparing the data and then 10 per cent of the time to actually process the data. First, you have to clean it and make sure that it's well formatted," he says.

The centre will also explore ways to quickly and accurately process continuous data feeds from moving sources, such as cars and people.

Sellis is talking with management teams of large shopping complexes about how to process data collected from anonymous shoppers' phones via their Wi-Fi connection. "We use this information to get an idea of how people move in the shopping mall. This can be useful for security and to understand the behaviour of shoppers — are they there for the supermarket, window shopping or do they mostly come to eat at the food court?"

On campus, Sellis is also looking forward to his centre working with the Swinburne Centre for Astrophysics and Supercomputing to develop new methods to process the vast quantities of astronomical data continuously collected.

SOCIAL DATA

In 2015 Timos Sellis was awarded a $270,000 Australian Research Council Discovery Project to develop tools to analyse social networks such as Facebook.

"I want to find the users who are very influential on other users and also to look at that dynamic from the perspective of geographic locality," Sellis says.

The grant enables him to combine two areas of great interest, the ability to make sense of information drawn from different sources and in varying formats, together with the efficient use of continuous data collection to track location information.

New arrival: Timos Sellis heads Swinburne's new Centre for Big Data and Data Analytics.

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