2022

THE UNIVERSITY of ADELAIDE

Quantum Materials

Delivering revolutionary technologies for next-generation communications, navigation, computing, cybersecurity and biomedicine

GROUP OF EIGHT AUSTRALIA

make history.

VISION

Delivering Quantum-enabled technologies for a safer, wealthier and healthier world.

PURPOSE

We will conduct research, and translate it into new quantum technologies and devices, that will shape Australia's future industries and see our devices used every day by Australian households.

MISSION

- Establish sovereign and world-class capability in Quantum Materials (QM)
- Become a trusted partner of Defence in QM
- Be ranked in QM5, a global collaboration of the world's top-5 QM universities
- Create a quantum-educated workforce for future industries

Quantum material

Quantum Materials is an exciting new field at the boundary of condensed matter physics, quantum physics, material sciences, chemical engineering and optoelectronics.

Quantum materials make use of the extraordinary effects of quantum mechanics to give rise to exotic and often incredible properties.

While all materials exhibit quantum mechanical properties at some level, 'quantum materials' exhibit anomalously strong and unique properties such as quantum entanglement, quantum coherence, and topological behaviour. These strange properties can be exploited to deliver devices that have new capability in telecommunications, defence and medical sciences.

Creating new materials and devices that will disrupt the global markets for:

- Deep UV-C for food, water, and air sterilisation
- Digital power electronics for electric vehicles and power grids
- High energy radio-frequency electronics for Radar applications
- Directed energy laser systems for defence
- Quantum precision timing for navigation
- Quantum neurology for nerve fibre repair
- Hybrid semi- and super-conducting systems for topological quantum computing at microwave frequencies
- Quantum dots and quantum wires for novel quantum-limited light sources and secure communications

Research on Quantum Materials brings together scientists working on Grand Challenges at the frontiers of physics, materials science and engineering.

Tackling grand challenges

Health

Quantum materials offer the potential to deliver tools that will enhance health for all through creation of new sensors for personalised and preventative biomedical diagnostic health services.

Sustainable energy and resources

Quantum materials are the building block of new electronics and photonics with ultra-high efficiency, and high energy storage leading to more efficient power networks with lower emissions.

Future industries

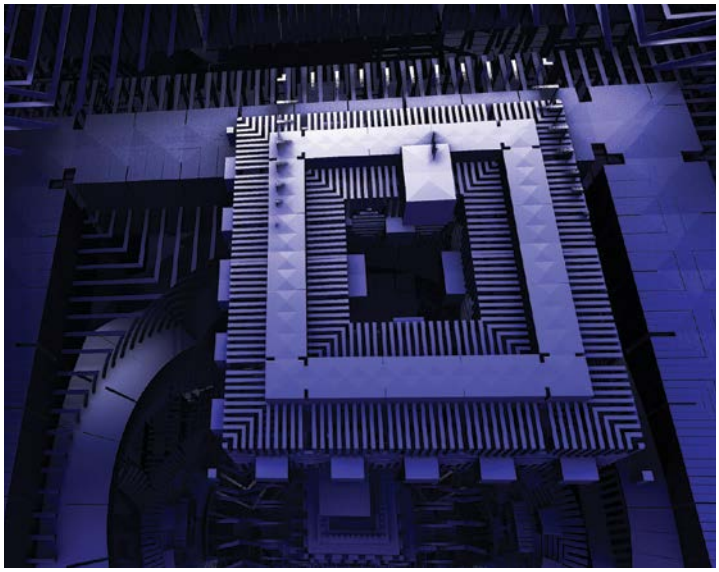
Quantum materials will be at the central core of Australia's future industries and jobs.

Secure Australia

Quantum materials offer new potential for surveillance and reconnaissance, bio-security sensors, enhanced navigation and enhanced cyber-security that will safeguard Australia from risks.

FOCI

- Accelerated Material Discovery, including III-oxide, IIIoxynitride, III-Nitride material materials, nanoparticle doped optical glasses
- Ultrawide bandgap UV Photonics – Emitters, Detectors, and Modulators
- Ultrawide bandgap power electronics – Power Amplifiers, Transistors, Power Diodes
- Single photon sources, nanoscale solid-state spin qubit, modulators
- High-power, high-temperature, mechanical wear-resistant, and ultra lightweight devices and sensors
- Integrated technologies for biological processes, food sciences, and agriculture



Why Adelaide?

The University of Adelaide has created a world-leading ecosystem of people, facilities and partnerships in Quantum Materials.

This builds on the historic underpinning strengths at Adelaide in Physics, Engineering and Material Sciences.

Through a focussed co-investment and collaboration strategy with Industry, Defence and Government, we have created the foundations required to build a billion dollar Quantum Materials industry in South Australia.

Existing Areas of Research Excellence*

Atomic and Molecular Physics; Optical Physics; Chemical Engineering; Electrical and Electronic Engineering

**Rated 5 out of 5, "well above word standard' in the 2018 Australian Research Council Excellence in Research for Australia assessment*

> $30M of Dedicated Research Infrastructure & $10M of ongoing projects

Molecular-beam epitaxy (MBE) - 5 chambers; (4x2" and 1x6"); Anechoic chamber and THz-RF; Cryogenics; Lithography

Key Partners

The Silanna Group: Australia's only semiconductor design and manufacturing company.

The Defence Science and Technology Group (DSTG): Embedded in the University of Adelaide North Terrace Campus with $3M of facilities. South Australia is home to centres of critical mass in high-power lasers.

Australian Department of Defence

Northrop Grumman: A leading provider and integrator of autonomous, C4ISR, cyber, logistics and strike systems and solutions.

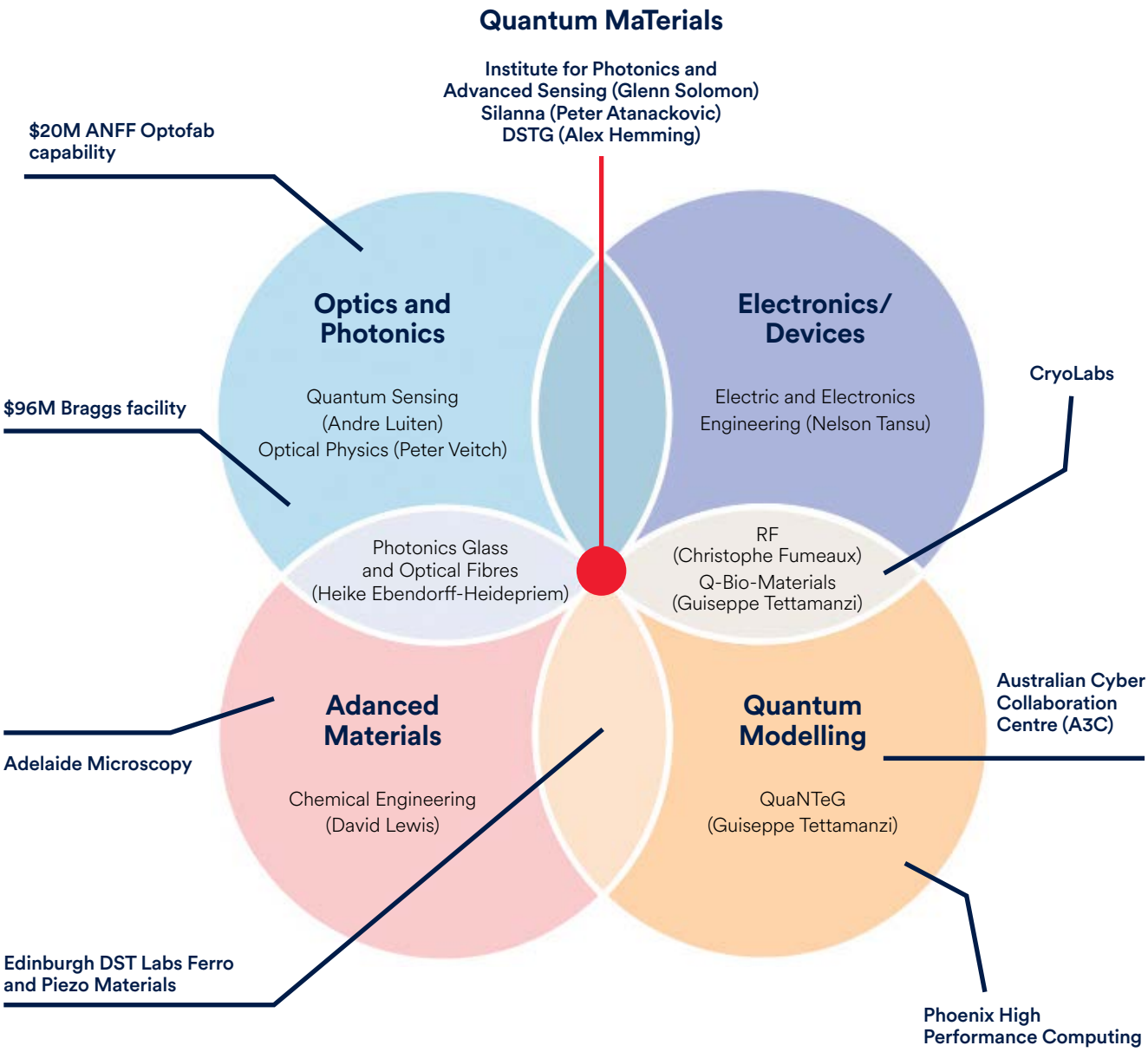
BAE Systems: Australia's most versatile defence and security company.

Electro Optic Systems: A leading ASX-listed Australian owned Defence and Space company.

The Commonwealth Scientific and Industrial Research Organisation

Australian Research Council South Australian State Government

A unique ecosystem



Top 10 University of Adelaide QM leaders

Prof Glenn Solomon
Inaugural Hicks Chair of Quantum Materials

Quantum optics techniques, semiconductor crystal growth and processing to investigate semiconductor quantum optics.

Prof David Lewis
Head of Chemical Engineering

Fluid mechanics, thermodynamics, reaction kinetics, and process control.

Prof Nelson Tansu
Head of Electrical and Electronic Engineering

Quantum electronics, quantum devices, semiconductor lasers, photonics, power and nano-electronics, and hybrid integration.

Prof Christophe Fumeaux
Applied Electromagnetics

Antennas and propagation, microwave and milimeter-wave technology, optical micro- and nano-structures, computational electromagnetics.

Prof Andre Luiten
Chair of Experimental Physics

Quantum atom photonics, quantum and precision sensing: quantum clocks, quantum magnetometers.

Dr Giuseppe Tettamanzi
Head of QuaNTeG

Quantum modelling, silicon-based quantum metrology, novel hybrid superconductor-semiconductor, single atom transistor devices.

Prof Heike Ebendorff-Heidepriem
Head of Photonics Materials

Photonics glass and optical fibres for mid-infrared highpower devliery and lasers, high nonlinearity, supercontinuum generation.

Dr Petar Atanackovic
Silanna Chief Scientist
Adjunct Fellow

Optoelectronics, quantum electro-optical devices, molecular beam epitaxy.

Prof Peter Veitch
Head of Physical Sciences

Advanced high-power lasers and sensors, short-duration high-energy pulsed mid-infrared lasers.

Alex Hemming
DSTG Visiting Research Fellow

Semiconductor laser diodes, high-power fibre lasers.

Silanna

The University of Adelaide has partnered with global technology powerhouse Silanna Group and the South Australian Government to set up "picoFAB" and "Q FAB" at the University.

These advanced laboratories allow designing and engineering of new semiconductor materials at the level of individual atoms.

The Silanna Group was founded in 2006 and is Australia's only semiconductor design and manufacturing company. With its head office in Brisbane and additional operational, manufacturing and design centres in Sydney, USA, UK and Singapore, Silanna supplies high-technology microelectronic chips to the global communications, space, defence and medical markets. The company's silicon-on-sapphire radio-frequency antenna switch, for example, is used extensively in smart phones and space satellites, as well as in NASA's Mars rovers.

Located at the University of Adelaide's North Terrace campus, the picoFAB has been collaboratively designed by Silanna and the University of Adelaide, and brings world-leading capability to South Australia, not least to the Quantum-materials, sensing and communication research at IPAS, enabling precise engineering of new semiconducting crystal structures for use in the commercialisation of new and innovative semiconductor devices.

With over $25m in new facilities, Silanna is currently leading the development of the next (4th) Generation Gallium Oxide Semiconductor materials in Adelaide, which opens up the deep UV to the mid IR spectrum.

Silanna

Australian Government
Department of Defence
Defence Science and Technology Group

The University of Adelaide – a trusted defence partner

The University of Adelaide has a long and proud history of partnering with Australia's defence sector. Our involvement has ranged from co-developing Australia's first satellite and rocket-launch capability with Defence in the 1960s, to working with Defence and industry on game-changing autonomous systems research and radar-enhancing technology today.

The University of Adelaide is a destination of choice for world-leading defence-focused researchers, high-achieving students, and government and industry partners.

Our Defence stakeholders include:

- DSTG
- Vice Chief of the Defence Force Group
- Defence Chief Information Officer Group
- Deputy Secretary Capability Acquisition and Sustainment Group
- Australian Geospatial-Intelligence Organisation
- Australian Signals Directorate
- US Air Force Office of Scientific Research
- Direction générale de l'armement, France
- BAE Systems Australia
- Lockheed Martin Australia
- Boeing Defence Australia
- Dassault-Systèmes
- Australian Submarine Corporation
- Naval Group (France)
- Raytheon
- Inovor Technologies
- Defence Teaming Centre
- Electro Optic Systems.

The University is also a founding member of South Australia's Defence Innovation Partnership.

Prof Glenn Solomon

Inaugural Hicks Chair of Quantum Materials, School of Physical Sciences

Professor Glenn Solomon is an esteemed scientist whose research has pushed the boundaries of our understanding of the interaction of light with semiconductor materials and device structures.

His research combines quantum optics techniques and semiconductor crystal growth and processing to investigate semiconductor quantum optics.

Glenn is the inaugural Hicks Chair of Quantum Materials at the University of Adelaide. He is a Fellow of both the Optical Society (2018) "for pioneering the development of semiconductor quantum dot optical materials and device structures for solid-state quantum optics" and of the American Physical Society (2007) "recognizing extensive contributions to the study of quantum optics with quantum dots". Before joining the University of Adelaide, he was a fellow at the Joint Quantum Institute at the University of Maryland in the USA, and a physicist at the US National Institute of Standards.

Glenn is one of few scientists in the world who has both fabricated nanostructures of quantum dots and performed quantum optics experiments on devices made from them. He is among the founders in using self-assembled, epitaxial crystal growth techniques to make nanostructures. With over 14,500 citations, Glenn's prolific body of work has not only had an extraordinary impact on Quantum Materials, but he has also generated 16 patents and founded CBL Technologies Inc., a start-up company that develops flexible hybrid GaN vapor-phase epitaxial growth techniques based in California.

Glenn is leading the University of Adelaide's world-class quantum materials program, bringing together physicists, engineers, material scientists, and key strategic industry partners, including Silanna and DSTG to identify and provide solutions to variety of near- and long-term problems where quantum materials and solid-state quantum devices can affect impactful change.

Prof Peter Veitch

Head of School, Physical Sciences, and Prime Minister's Prize for Science 2020, joint recipient

Professor Peter Veitch's extensive body of work focuses on the development of advanced lasers and sensors, including high-energy pulsed mid-infrared lasers that are of critical interest to Defence for Directed Energy applications.

Professor Veitch is an esteemed physicist, Head of School of Physical Sciences, and the Leader of the University of Adelaide node of the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav).

He was elected a Fellow of the Optical Society of America "for development of techniques essential to the successful high optical-power operation of gravitational wave detectors and contributions to Advanced LIGO", and is also a Fellow of the Australian Institute of Physics.

Peter is one of four scientists who together were awarded the country's most prestigious award in scientific research, the Prime Minister's Prize for Science in 2020. The PM's Prize was awarded for their role in the detection of gravitational waves, a scientific breakthrough recognised by the 2017 Nobel Prize in Physics. Peter has played a key role in the technological leap that has enabled the construction of the Advanced LIGO gravitational-wave detector, led by the global LIGO Scientific Collaboration.

The field of Directed Energy will benefit highly from the collaborative development of new quantum materials and devices, with research at the University of Adelaide spanning the divide between fundamental materials research and the applied devices continuum.

Creating the jobs of the future in the industries of tomorrow

Education and training will be a key component of the Quantum Materials ecosystem at the University of Adelaide.

There is currently a dearth of suitably trained scientists and engineers in the field. Interaction between the future leaders of the field and industry will be an attractant for partners in the Quantum Materials future at Adelaide.

The new Masters in Quantum Materials and Technology delivered by the Schools of Physical Sciences and Electrical and Electronic Engineering will provide a state-of-the-art education in the field including access to new MBE material growth, device fabrication, advanced computational and modeling, and device and quantum measurement facilities.

It is a unique opportunity, unprecedented in Australia. Components of these courses will be repackaged for micro-credentialing to offer opportunities for the professional development of industry and defence personnel.

Quantum materials roadmap

Infrastructure

2020

DSTG small fab (device fabrication)
Silanna pico fab and Q fab (quantum materials engineering and device fabrication)
University of Adelaide CryoLabs (device simulation and testing)
ANFF Optofab (specialty glass and optical fibre fabrication, Advanced Manufacturing)
Adelaide Microscopy (micro and nano-imaging)
Australian Cyber Collaboration Centre (A3C) (cyber infrastructure to support product testing and training)
University of Adelaide Phoenix (high performance computing)
DSTG Edinburgh (ferro and piezo materials lab)

2021

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DSTG Edinburgh (ferro and piezo materials lab)
University of Adelaide HTS MBE
University of Adelaide Quantum optics labs

2025

New QM Precinct at Adelaide's Innovation Hub at Lot 14

A roadmap for success

Research capability

Culture & capacity building

Education & training

Innovation & translation

Economic growth

Key recommendations

01
Create a formal, global organisation that brings together the top 5 QM universities

02
Develop a business model to support growth and collaboration of QM research and translation at Adelaide, including progressive IP arrangements

03
Develop an infrastructure strategy linked to growth in QM teaching and research

04
Attract a talented cohort to grow the pool of QM academics, with a focus on ARC Future and DECRA Fellows as well as joint industry appointments

05
Recruit and retain diverse leadership teams

2022	2025	2030	2050
QM ARC Laureate Fellowship	Top #5 QM Universitities worldwide $7M ARC training Centre in QM	$40M ARC Centre of Excellence in QM $10M p.a. research income	
1 QM ARC Future and 1 DECRA Fellows	4 new Fellows At least 30% women representation (incl 1 of the new fellows)	6 new Fellows At least 50% women representation (incl 3 of the new fellows)	
Industry specific diploma, Masters and PhD	QM 5 ERA Rating	50 diploma, 20 Masters and 10 PhD p.a.	
Deep UV sterilisation for PPE	Quantum clock launched on small satellite for Australian sovereign GPS	Next-gen chip in every Australian smartphone	
$10M p.a.	$25M p.a.	$250M p.a.	$1B p.a. 5K new jobs

Appendix: Staff bios

Prof Glenn Solomon

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Prof Nelson Tansu

Head of School, Electrical and Electronic Engineering, Professor of Quantum Electronics

Professor Nelson Tansu has made great contributions to the advancements in materials, devices, computational sciences, and integrated technologies based on ultrawide-bandgap semiconductors for sustainability, biomedical sciences, power electronics, and quantum materials.

Nelson is the new Head of School of Electrical and Electronic Engineering, and Professor of Quantum Electronics. Prior to joining the University of Adelaide, Nelson was the Director of the Center for Photonics and Nanoelectronics and the Daniel E. '39 and Patricia M. Smith Endowed Chair Professor in the Department of Electrical and Computer Engineering at Lehigh University, Pennsylvania, USA. He is a Fellow of the US National Academy of Inventors (NAI Fellow; elected in 2016), IEEE Fellow (elevated in 2021), and a Clarivate Analytics Highly Cited Researcher (2018).

Nelson's works on quantum materials, quantum electronics, and photonics have resulted in new scientific concepts and key patents, which are implemented into today's commercial products. These products include solid-state lighting, display, power electronics, semiconductor, and biomedical industries in the US, Europe, and Asia. He has raised over US$13M for research and authored more than 160 refereed journals, 325 conference publications and 18 US patents. His work has been cited more than 8,950 times with an h-index of 52.

Nelson has recently been focusing on connecting machine learning and quantum materials for photonics and nanoelectronics devices – an exciting and rapidly developing area. His research works have impacts on advancing sustainable and renewable engineering, biomedical engineering, advanced sensors, and new technologies for security, space, and resilient infrastructures.

Prof Andre Luiten

Chair of Experimental Physics and Director, Institute for Photonics and Advanced Sensing

Prof Andre Luiten FAIP GAICD FTSE is internationally recognised for developing a sequence of precision measuring instruments that show the highest performance that the world has ever seen. These devices are bringing a step-change in the capability of several key industry sectors, including Defence and Space.

Andre is the Director of the Institute for Photonics and Advanced Sensing (IPAS) and Chair of Experimental Physics at the

University of Adelaide. He is a Fellow of the Australian Institute of Physics and of the Australian Academy of Technology and Engineering.

Andre has published 6 book chapters and authored 131 journal papers with over 5,600 citations and has raised over $34M for research. The excellence of his research has been recognised by a number of awards and fellowships, including the Barry Inglis Medal from the National Measurement Institute, which acknowledges outstanding achievement in measurement research and excellence in practical measurements, the Australian Institute of Physics' Alan Walsh Medal for Service to Industry and the prestigious 2018 Eureka Prize for Outstanding Science in Safeguarding Australia.

He is also the co-founder and managing Director of QuantX Labs, a successful start-up commercialising the world's most precise clock (Cryoclock) and developing the highest precision timing and sensor products.

Andre's scientific expertise in Quantum Technologies and overall strategic leadership will contribute greatly to the success of establishing South Australia as a hub for Quantum Materials innovation.

Prof Heike Ebendorff-Heidepriem

Head of Photonics Materials and Deputy Director, Institute for Photonics and Advanced Sensing

Prof Heike Ebendorff-Heidepriem's research has pushed the limits of glass science and technology, disrupting existing knowledge and creating new paradigms and tools for designing and fabricating novel photonic glasses and structures.

Heike is the Deputy Director of the Institute for Photonics and Advanced Sensing (IPAS) and Director of the Optofab Adelaide Hub at the Australian National Fabrication Facility (ANFF).She is also Senior Investigator at the ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP). In 2017, she became a Fellow of the Optical Society of America, an honour awarded by peers for having "made significant contributions to the advancement of Optics".

Heike has applied her knowledge and skill and has held prestigious fellowships in several countries, including Germany, the UK and Australia. She has received numerous awards highlighting her research excellence in innovation and technology. Heike has published over 370 refereed journal papers and conference proceedings, including 5 review papers and 9 postdeadline papers, and raised over $32.8M in research funding.

Her experience will contribute greatly to the Quantum Materials program through her continued research and development of the next generation of semiconductor laser diodes and crystal-glass hybrid fibres for fibre laser and quantum sensing applications, and the development of extremely low-loss fluoride fibre for long-haul transmission of flying qubits for the quantum internet.

Prof Peter Veitch

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Prof David Lewis

Head of School, Chemical Engineering and Advanced Materials

Professor David Lewis' academic focus is on leadership, education and commercialisation of research. He is experienced in developing business opportunities for project executions and brings this knowledge with him to the team.

David currently serves as the Head of the School of Chemical Engineering and Advanced Materials at the University of Adelaide, where is he building capability in the field of materials and bioprocess engineering. As an experienced Chartered Chemical Engineer and Fellow of the Institute of Chemical Engineers, David's industry and academic careers have provided him the opportunity to work in the petroleum, mining, automation, hospitality, and defence industries on process design and optimisation.

From 2012 to 2016 David led a technology start-up company developing new commercial opportunities focused on production of sustainable oils from hydrothermal liquefaction using renewable feedstocks such as biomass and organic wastes. With both industry and academic careers, David has been fortunate to have worked on process development from conception to commercialisation.

David leads a team of chemical, bioprocess and materials engineers undertaking transdisciplinary R&D focussed on advanced materials and next generation bioprocesses. In particular the team is leveraging the unique quantum, electronic, and excitonic properties of crystalline solids for biosensing and bio-imaging; and developing innovative solutions for the production of semiconductors, with a focus on optimising atomic layer etching to provide cost-effective and sustainable advanced manufacturing opportunities.

Prof Christophe Fumeaux

Applied Electromagnetics, School of Electrical and Electronic Engineering

Professor Christophe Fumeaux (FIEEE) has made distinguished contributions in the fields of antenna technology, microwave engineering, and the application of RF design principles to optical micro/nano-structures. He has extensive experience in applied computational electromagnetics and has proposed novel antenna structures with unique properties for defence and industrial applications.

Christophe is a Professor within the School of Electrical and Electronic Engineering. He has pioneered concepts of optical nano-structures operating as antennas in sensors and optical components. His significant contributions to low-order dielectric resonator antennas across the spectrum led to his elevation to Fellow of the IEEE.

From 2011 to 2015, he was a Future Fellow of the Australian Research Council and was the recipient of the 2018 Edward E. Altshuler Prize, and the 2014 IEEE Sensors Journal and 2004 ACES Journal best paper awards. He was the recipient of the University of Adelaide Stephen Cole the Elder Award for Excellence in Higher Degree by Research Supervisory Practice in 2018.

He has published more than 150 refereed journal articles, attracting over 7,250 citations and is currently serving as the Editor-in-Chief for the IEEE Antennas and Wireless Propagation Letters journal.

Christophe's world-leading expertise in computational physics has recently been transferred and used to develop several ab-initio approaches used for the modelling and the anticipation of the behaviour of quantum materials. Indeed, these advanced fundamental techniques in electromagnetic modelling are proving to be a critical enabler and ongoing development tool for novel Quantum Materials design.

Dr Giuseppe C. Tettamanzi

Head of QuaNTeG, School of Physical Sciences

Dr Giuseppe C. Tettamanzi is an emerging leader in the field of Solid-State Systems whose work explores theoretical prediction on the behaviours of nano-devices, their fabrication, and their low-temperature characterisation via state-of-the-art ultra-low noise electrical measurements techniques. He has developed several novel concept devices; including the smallest existing DC SQUID design and the first implementation of a Single Atom-based Single Electron Source (funded under a prestigious ARC DECRA fellowship), studying highly complex quantum phenomena in these nano-devices.

Giuseppe is head of the QuaNTeG group at the University of Adelaide and part of the winning team of the prestigious 2018 Eureka DSTG Prize for Outstanding Science in Safeguarding Australia.

Giuseppe has secured over $4.5M to drive his research program and published 45 manuscripts, 90% in the top journals of his field. The strength of Giuseppe's research is also demonstrated by the numerous invited oral presentations at leading international conferences, including the International Conference on Advanced Materials and Nanotechnology (AMN) held every two years in New Zealand, the CMOS Emerging Technologies Conference held every year in Whistler, Canada, and funded visiting positions at the INRS–EMT, Univ. du Québec, Varennes, Canada and the NEST Laboratory of the "Scuola Normale Superiore" of Pisa.

As coordinator of the Engineering of Semiconductor Materials and Quantum Materials courses within the University of Adelaide, Giuseppe is heavily involved in student development. He is a Chief Investigator on large funding bids that have allowed the installation of key sovereign Quantum capabilities at the University of Adelaide, including a new $20M+ microfab facility.

Dr Petar Atanackovic

Silanna Chief Scientist, Adjunct Fellow

Dr Petar Atanackovic developed the key intellectual property for the manufacture of Quantum Engineered deep ultraviolet diodes.

Petar is the Chief Scientist of SILANNA Semiconductor Pty Ltd. He joined Silanna in 2009 as one of the founders of the commercial 150 mm III-V production facility pioneering commercial scale gallium nitride molecular beam epitaxy (MBE). He holds over 40 granted US patents in semiconductors and devices. In 2001-2008 he founded a technology start-up named Translucent Inc. attracting investment in excess of US$15M. The technology was awarded a DARPA technology investment grant.

Prior to founding Translucent, Petar was an invited visiting scholar to Stanford University (1998-2001) and Senior Research Scientist at the Defence Science and Technology Organisation, Edinburgh, South Australia, where he pioneered optical analog-to-digital conversion technologies.

Petar is leading the Silanna/University of Adelaide collaboration, building an environment for knowledge creation and training in Quantum Materials to rapidly scale and meet the skilled workforce needs of South Australia's high-tech sector.

Alexander Hemming

DSTG Visiting Research Fellow

Alex Hemming leads research into a range of laser technologies primarily based on fibre sources for Defence applications.

Alex is a Research Scientist with the Defence Science and Technology Group (DSTG) in Adelaide, South Australia.

He has authored over 80 journal and conference papers including 14 invited conference papers primarily on the power scaling of Short Wavelength Infrared (SWIR) fibre sources.

Alex is currently leading the establishment of the MBE based semiconductor laser diode capability for Defence applications in collaboration with the University of Adelaide.

Further enquiries

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CRICOS 00123M

Kaurna acknowledgement
We acknowledge and pay our respects to the Kaurna people, the original custodians of the Adelaide Plains and the land on which the University of Adelaide's campuses at North Terrace, Waite, and Roseworthy are built. We acknowledge the deep feelings of attachment and relationship of the Kaurna people to country and we respect and value their past, present and ongoing connection to the land and cultural beliefs. The University continues to develop respectful and reciprocal relationships with all Indigenous peoples in Australia, and with other Indigenous peoples throughout the world.