MACQUARIE UNIVERSITY

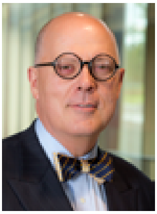
Professor Jim Piper Festschrift 2013

Thursday 20th June 2013
9am – 5pm

Cochlear, Ground Floor,
1 University Avenue,
Macquarie Park

Time	Speaker	Presentation
8:45–9:00am	Tea and Coffee on arrival	
9:00–9:05am	Prof Clive Baldock, Exec Dean Faculty of Science, Macquarie University	Introduction
9:05–9:15am	Prof Bruce Dowton, Vice-Chancellor, Macquarie University	Welcome
A/Prof Judith Dawes, Macquarie University		Chair of Session
9:20–9:50am	Dr Mark Butler, Gosford High School	National Physics Curriculum
9:50–10:20am	Dr Olivia Samardzic, DSTO Edinburgh	Future Directions of Laser-Based Defence Systems
10:20–10:50am	Prof Michael Withford, Macquarie University	Laser Direct-Write Photonics for Astronomy
10:50–11:10am	Morning Tea	
A/Prof David Coutts, Macquarie University		Chair of Session
11:10–11:40am	Scientia Professor Andrew S. Dzurak, The University of New South Wales	Quantum Computing with Single Atoms in Silicon
11:40–12:10pm	A/Prof Helen Pask, Macquarie University	Crystalline Raman Lasers
12:10–12:40pm	Prof Denis Hall, Heriot-Watt University	Lasers in High-Precision Manufacturing
12:40–1:30pm	Lunch	
A/Prof Richard Mildren, Macquarie University		Chair of Session
1:30–2:00pm	Prof Wang Pu, Beijing University of Technology	High Power Pulsed Fibre Lasers
2:00–2:30pm	Prof Tanya Monro, University of Adelaide	Fibre-Based Sensors for Biology and Medicine
2:30–3:00pm	Dr Jin Dayong, Macquarie University	High-Speed, High-Contrast Luminescence Biosensing
3:00–3:20pm	Afternoon Tea	
Prof Brian Orr, Macquarie University		Chair of Session
3:20–3:50pm	Dr Cathy Foley, CSIRO	Future Research Directions of CSIRO in Materials Science and Engineering
3:50–4:20pm	Dr Daniel Brown, Cymer Corp USA	State-of-the-Art Light Sources for Photolithography
4:20–4:50pm	Dr Larry Marshall, Southern Cross Ventures	The Entrepreneurial Journey: from Scientist to CEO to Venture Capitalist
4:50–5:00pm	Prof Jim Piper, Deputy Vice-Chancellor Research, Macquarie University	Close and Invitation to drinks and nibbles
5:00–6:00pm	Reception	

It is with great pleasure that I welcome you here today as we come together for this *Festschrift*, as Professor Jim Piper's colleagues, students and friends, to acknowledge and celebrate his distinguished career.



As an academic and a university leader, Professor Piper has been at the forefront of research and higher education development in Australia and internationally. He has authored over 260 refereed journal articles and full-length conference proceedings, and has supervised to completion more than 40 PhD students. Furthermore Professor Piper is inventor of 12 awarded patents, with substantial experience in the commercialization of research-derived IP.

Beginning with his Lectureship at Macquarie University in 1975 and throughout four decades of service, Professor Piper has made significant contributions to Macquarie University, excelling as Director of the Australian Research Council Special Research Centre for Lasers and Applications, and Dean of Information and Communications Sciences.

Since 2003, under Professor Piper's leadership as Deputy Vice-Chancellor (Research), Macquarie's Research, Higher Degree Research and Commercialisation programs have grown from strength to strength. The University's increasing research performance has been exceptional with an increase in research outputs to rank fourth in terms of overall research at the highest level, first in cognitive science, environmental science and ecology.

A true leader and visionary, Professor Piper's most recent legacy to the Australian research landscape was to establish the Australian Hearing Hub at Macquarie University. Bringing together some of the country's best researchers, educators and service providers, to improve the lives of people who experience hearing loss and/or language disorders, it was Professor Piper who initially proposed the idea to the Federal Government, and whose approval for funding helped make the establishment of the Hearing Hub a reality.

Professor Piper has gained the enduring respect and admiration of those around him, not only as a leader and academic but also as a man of integrity and affability.

Now, as we prepare to say farewell to Professor Piper on his retirement at the end of June, it is with great privilege that we take this important opportunity to recognise Jim and his many achievements.

Professor Bruce Dowton
Vice-Chancellor Macquarie University

Dr Mark Butler

Head Teacher of Science
Gosford High School, NSW
National Education Convener
Australian Institute of Physics

Dr Mark Butler is currently Head Teacher of Science at Gosford High School, the National Education Convener of the Australian Institute of Physics and a member of the CUDOS Advisory Board, the MQ Photonics Advisory Board and the Macquarie University Science/Industry Advisory Board.

Dr Butler completed a bachelor's degree majoring in Physics at Macquarie University in 1978 and a Diploma in Education at the University of New South Wales in 1979. After working for a year in the physics teaching laboratories at the University of NSW, he returned to Macquarie University where he completed an honours degree in physics and a PhD in Plasma Recombination Lasers under Professor Jim Piper. In 1985 he worked as a tutor at Macquarie University and in 1986 was appointed Deputy Principal at the Australian International School, where he remained until taking up his current position as Head Teacher of Science at Gosford High School in 1997.

A passionate advocate for engaging students in science, Dr Butler has written high school textbooks, study guides and journal articles and is a sought after speaker on science education. He remains above all else a dedicated science teacher and many of his students have achieved outstanding HSC results in physics and many have pursued careers in science.

In 2007 he was appointed to the Advisory Panel for the Science National Curriculum and in 2008 he was appointed principal advisor and writer of the Senior Physics National Curriculum.

Dr Butler was the recipient of the 2002 BHP/Billiton National Science Teachers Prize, the 2004 Premier's Science Teachers' Traveling Scholarship, the 2004 Prime Minister's Prize for Excellence in Secondary Science Teaching, the inaugural NSW Scientist of the Year Award for Leadership in Secondary Science Teaching in 2008 and the NEITA Inspired Teaching Award in 2009.

National Physics Curriculum

This presentation will examine the development of the national curriculum for Australian schools with specific reference to the recently released national curriculum for senior physics.

Australian states and territories have historically developed independent school syllabuses. Mapping conducted by the federal government in 2006 showed that while approximately 90% of the content in state and territory senior science syllabuses was common; the depth, sequencing and additional content taught varied significantly between jurisdictions.

With over 70,000 high school students moving interstate each year and many students choosing to undertake tertiary study in different states, there was a clear need for increased comparability and consistency of curricula and assessment across the country. Perhaps more importantly, the development of a national curriculum for schools would enable us as a nation for the first time to specify the knowledge and skills that we believe to be essential for all Australian citizens.

The development of a national curriculum was recommended by a feasibility study into a National Certificate of Education commissioned by the Federal Government in 2005 and became a reality after the Melbourne Declaration of Educational Goals for Young Australians was accepted by the Ministerial Council in 2008. The Federal Government entrusted the development of the national curriculum to the Australian Curriculum, Assessment and Reporting Authority (ACARA). In the first phase of development ACARA was asked to develop curricula for the core learning areas of Science, English, Mathematics and History.

Only one senior course was to be developed in physics and it would have to cater for students who wished to pursue further study in science and for those who would not continue to study science beyond school level.

The senior physics curriculum was signed off by the Ministerial Council in December 2012 and has recently been published online by ACARA. The content of the physics curriculum is divided into three strands (Science as Human Endeavour, Science Inquiry Skills and, Knowledge and Understanding) and presented in 4, one semester units:

Unit 1: Thermal, nuclear and electrical physics
Unit 2: Linear motion and waves
Unit 3: Gravity and electromagnetism
Unit 4: Revolutions in modern physics.

The physics curriculum emphasises the development, use, and refinement of models, laws and theories and uses energy as a unifying concept. Teachers could use contexts, such as nanotechnology, energy sustainability, climate change, photonics, etc. to teach the content of the course but these have not been mandated in the curriculum. To provide teachers with further flexibility, the curriculum does not specify or mandate specific teaching methods. Decisions about the contexts and teaching strategies used will be left to the jurisdictions and to classroom teachers.

In spite of two extensive rounds of public consultation and over two years of refinement, the national physics curriculum remains controversial and the content chosen, and the three strands used to present it, continue to attract criticism. Only time will tell if the new course will prove to be more popular with students than the old courses and/or if it will more effectively prepare students for tertiary study in science.

Dr Olivia Samardzic

Senior Research Scientist
Defence Science and Technology Organisation
Edinburgh, South Australia

Dr Olivia Samardzic completed her PhD in experimental atomic physics, at Flinders University, in 1995. She then went on to the Lasers and Optics group at Adelaide University before going on to work at the Defence Science and Technology Organisation, where she now heads up the Electro-Optics Countersurveillance section of the Electro-Optics Technology group. Olivia has worked on both Missile and Laser Warning Systems and runs programs of work in laser countermeasures, laser systems development and evaluation, and optical protection.

Olivia also sits on the National Executive of the Australian Institute of Physics (AIP) and was the Chair of the SA branch of the AIP in 2005 and 2006 and Convenor and secretary of the SA Women in Physics group from 1994-2000. She is one of the founders of the South Australian Space School (est. 1997) and the National Space Camp and has been a Co-Director of the Centre for Australian Space Education since 2004.

Future Directions of Laser-Based Defence Systems

The concept of using a concentrated beam of light to inflict damage and hence gain military advantage has existed for some time. Ancient Greek legends tell the story of Archimedes' defence of the city of Syracuse in 212BC against a Roman siege using polished mirrors to focus sunlight onto the sails of Roman ships. Whilst this story has been hotly debated over the years it does demonstrate how long ago the idea of using focussed light in a military capacity was first postulated.

Shortly after the demonstration of the first laser in 1960 by Theodore Maiman, the US DoD realised that the laser offered unique characteristics that were superior to kinetic weapon systems, namely their ability to accurately transfer energy to remote targets at the speed of light. In these early days of the laser, the military envisaged using lasers for ballistic missile defence and anti-satellite and anti-aircraft applications, however, it would be some time before the powers generated would be sufficient to attempt to address this role. Instead the first fielded military lasers were used to support conventional weapons. In fact the first fielded military laser system was the laser rangefinder which was fielded in the mid-sixties. This was followed by the use of laser for targeting, laser designation, laser radar and laser-based countermeasures.

Since these early days the use of lasers in Defence has rapidly expanded and the supporting laser technology has rapidly advanced not only to keep up with the Defence demand but also to address the commercial uses of lasers. In fact where Defence laser development has led the way in the past, new commercial technologies are now allowing Defence to move into previously unrealised domains. This talk will not only look at the history of military laser systems but also address the future directions of laser-based defence systems.

Professor Michael Withford
Director: MQ Photonics Research Centre
Department of Physics and Astronomy
Faculty of Science
Macquarie University

Prof. Michael Withford was awarded a PhD from Macquarie University in 1995 for his investigations developing high power metal vapour lasers. His current research explores femtosecond laser modification of transparent materials, and the development of novel 2D and 3D lightwave devices. Outcomes include fibre Bragg gratings, monolithic waveguide lasers, high power fibre lasers, quantum photonics and interferometric chips for astronomy.

Professor Withford is currently the Director for the MQ Photonics Research Centre (science.mq.edu.au/mqphotonics), which includes >80 members – staff and students. He also leads both the Macquarie University node (web.science.mq.edu.au/groups/cudos/) of Australian Research Council (ARC) Centre of Excellence: Ultrahigh-bandwidth Devices for Optical Systems (CUDOS) and the OptoFab Node (optofab.org.au) of the Australian National Fabrication Facility. He is a member of the SPIE, the OSA and the Australian Optical Society. His awards include two Fellowships funded by the Australian Research Council. He holds 2 patents and has published over 100 refereed journal papers and several hundred conference papers.

Laser Direct-Write Photonics for Astronomy

Astronomy is entering a new golden age enabled by a new generation of very large telescopes with adaptive optics that compensate for the detrimental influence of the Earth's atmosphere. These facilities will uncover new science pertaining to the formation of the universe and promote the discovery of Earth-like planets outside our Solar system. However, as the telescopes increase in size and engineering complexity, so too do the diagnostics (such as spectrometers) required to extract their full potential if conventional designs continue to be used. In addition, delivering the light from the telescope to those diagnostic systems, as they increase in size, can be challenging and inefficient.

Australia is leading a paradigm shift with regard to the design and fabrication of astronomical instruments that will meet the needs of next generation telescopes. Indeed, we are pursuing the counter-intuitive approach of developing micro-optical solutions to a problem that is couched in macro-optics. Those solutions are based on the use of "optical wires" or waveguides, an example of which are the optical fibres that underpin the internet. This research field is now known as *astrophotonics*.

At Macquarie University we are pioneering a new class of micro-photonic chip, fabricated using ultrafast laser direct write inscription. This technique uses the tightly focussed output of a femtosecond laser to modify the microscopic bond structure of transparent glasses. Waveguides and photonic circuitry can be written in both 2D and 3D when the laser beam is translated inside a block of glass. In this talk I will showcase our recent results including demonstrations of our chips on Australia's premier optical telescope, the 4m Anglo Australian Telescope.

Scientia Professor Andrew Dzurak
Director, ANFF-NSW
Australian National Fabrication Facility
School of Electrical Engineering & Telecommunications
The University of New South Wales

Andrew Dzurak is one of Australia's leading experts in nanoelectronics and quantum computing technologies. He is Director of ANFF-NSW, the NSW node of the Australian National Fabrication Facility (ANFF — see www.anff.org.au), a network of university-based laboratories that provide researchers and industry with access to state-of-the-art facilities for the fabrication of sensors, medical devices, nanophotonics and nanoelectronics.

Following a PhD at the University of Cambridge, Andrew returned to Australia in 1994 to establish nanofabrication facilities at University of New South Wales (UNSW). He also began work on an initiative to construct in Australia a solid state quantum computer and, with Bob Clark and other colleagues, established the Centre for Quantum Computer Technology in January 2000. The Centre has achieved major advances in the international effort to realize large-scale quantum information processing and is an ARC Centre of Excellence. It maintains the world's largest focused collaboration on silicon-based quantum computing. Andrew is the Centre's Work-Package Leader in this area, as well as Lead Investigator for a multi-institutional program grant in silicon quantum computing from the US Army Research Office.

Since 2010 Prof Dzurak has published three seminal experimental papers in *Nature* demonstrating the readout and control of single atom spin qubits in silicon, together with reviews on spin-based qubits in both *Nature* and *Science*. During his career he has published over 100 scientific papers and is an inventor on 9 patents. In 2011 Andrew shared the Australian Eureka Prize for Scientific Research with colleague Andrea Morello, and in 2012 he was awarded the New South Wales Science and Engineering award for Excellence in Engineering and Information and Communications Technologies. Andrew is a Scientia Professor of Nanoelectronics in the School of Electrical Engineering and Telecommunications at UNSW.

Quantum Computing with Single Atoms in Silicon

Quantum information technologies promise to revolutionize the way information is transmitted and processed. These transformational technologies require devices that enable the sensing and manipulation of individual electrons and photons. Spin-based quantum bits (or *qubits*) in silicon are excellent candidates for scalable quantum information processing due to the very long spin coherence times that are accessible in silicon and because of the enormous investment to date in silicon MOS technology [1]. This talk will discuss spin qubits based on electrons localized on single phosphorus donor atoms in silicon [2, 3] and also very recent experiments in which quantum information can be encoded on the nuclear spin of individual phosphorus atoms [4]. In the latter case, the qubit read fidelity exceeds 99.8% and the write fidelity exceeds 98%, approaching the accuracy values necessary for large-scale fault-tolerant quantum computing.

Quantum Spintronics: Engineering and Manipulating Atom-Like Spins in Semiconductors, D.D. Awschalom, L.C. Bassett, A.S. Dzurak, E.L. Hu, J.R. Petta, **Science 339**, 1174 (2013).

Single-shot readout of an electron spin in silicon, A. Morello et al., **Nature 467**, 687 (2010).

A single-atom electron spin qubit in silicon, J.J. Pla et al., **Nature 489**, 541 (2012).

High-fidelity readout and control of a nuclear spin qubit in silicon, J.J. Pla et al., **Nature 496**, 334 (2013).

Associate Professsor Helen Pask
ARC Future Fellow
Department of Physics and Astronomy
Faculty of Science
Macquarie University

Helen M. Pask received the B.Sc. and Ph.D. degrees in physics from Macquarie University in 1987 and 1992, respectively. She was a Postdoctoral Researcher in the field of fibre lasers at the University of Southampton, U.K. from 1992–1994. In 1995, she joined Macquarie University as an ARC Postdoctoral Fellow, and has co-established a strong international research presence in the area of crystalline Raman lasers, together with Professor Jim Piper and other colleagues.

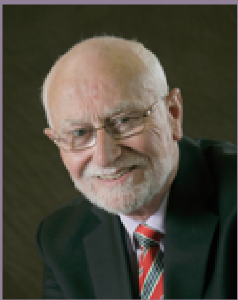
Helen held a Vice-Chancellor's Innovation Fellowship in the Department of Physics and Astronomy for 6 years, and was awarded an ARC Future Fellowship in 2012. Her main research interests include crystalline Raman lasers, remote sensing of temperature using Raman spectroscopy and Terahertz lasers and applications.

Crystalline Raman Lasers

Crystalline Raman lasers are a practical and efficient class of laser systems which can substantially increase the spectral coverage of solid-state lasers. Starting with the first report by Pask and Piper [Optics Letters, vol. 24, p 2490] in 1999 of a diode-pumped crystalline Raman laser incorporating intracavity SHG and operating in the yellow spectral region, Macquarie researchers have played a prominent role in advancing the science of these laser systems, publishing numerous world-first experimental achievements and writing key review articles.

At the same time we have been highly successful in engaging with industry partners to enable Raman laser technology to be taken up and applied to applications in defence, medicine, and remote sensing. In this talk, I will briefly review the nonlinear optical process of stimulated Raman scattering in the context of understanding the design and operation of crystalline Raman lasers, and outline how we came to discover the key design issues that underpin the realisation of this versatile class of laser devices.

Professor Denis R Hall
Professor of Photonics
Institute of Photonics and Quantum Sciences
Heriot Watt University
Edinburgh, United Kingdom



Denis Hall graduated with a BSc (Hons) in Physics at Manchester University, with MPhil at London University for cell biology research, PhD in Electrical Engineering from Case Western Reserve University (Cleveland, USA) and MBA from the Edinburgh Business School. He was a National Academy of Sciences Postdoctoral Fellow at NASA Goddard researching space-based communication systems, before moving to work on e-beam lasers at Avco Research Laboratory in Boston and then at RSRE in the UK. After 5-years he moved to Hull University, to lead the UK Satellite Laser Ranging Facility programme at Royal Greenwich Observatory, though continuing laser physics research and developing RF discharge CO2 lasers for medical/ industrial applications, later commercialised through a university spin-off, *Laser Applications Ltd*.

In 1987, he moved to Heriot-Watt University, Edinburgh, continuing research on ultra-compact high power lasers, exploiting concurrent research in RF discharge physics and planar optical waveguides to develop new laser concepts based on 2-dimensional power scaling and novel resonators. Since the early 1990s planar waveguide CO2 lasers have become highly successful commercial products manufactured by several global companies for applications in industry and medicine. More recently the HWU group extended the planar waveguide 'thin laser' concept to diode-pumped solid-state lasers and power amplifiers. His group's research, part of a conscious industrial orientation involving partnership in serial industry/university collaborative projects, has resulted in multiple commercial laser/laser-system products. Over 25 years, he has co-founded three successful start-up laser/photonics companies. From 1998–2007 he was Deputy Vice Chancellor (Research and Commercialisation) at HWU, while maintaining research activity in the EPS School, where he is Director of HW-IMRC, a forerunner of the EPSRC/ Industry-funded UK National Centre for Laser-based Production Processes to be launched at HWU in October 2013. He is a Fellow of the Royal Society of Edinburgh, the IEEE, the European Physical Society, the UK Institute of Physics, the IET, and the Optical Society of America.

Lasers in High-Precision Manufacturing

The past 25 years have seen laser machines replace many 'conventional' tools in diverse areas of manufacturing, enabling significantly increased productivity, quality and operational functionality. Industrial laser machines have produced major impact both as tool replacements, and in enabling completely new 'laser-unique' production processes to revolutionise manufacturing in key economic sectors, including automotive, aerospace and electronics.

Most laser manufacturing applications employ thermal processes requiring some spectral overlap between the laser wavelength and material absorption features, with heat energy deposition and subsequent material melting or ablation. There has been a veritable explosion in the diversity and volume of such manufacturing applications (e.g. cutting, joining, drilling, marking, surface treatment etc. of a wide range of materials), as new laser technologies and production machines have been developed. However one limitation with thermal material processing for high-precision manufacturing applications is the possible compromise to quality due to heat transfer and collateral damage in the area adjacent to the interaction zone. But recent developments of ultrafast (fs-ps) pulse lasers have given rise to a new class of laser interaction processes where the absorbed energy is concentrated within a few nm in the material, so that collateral thermal damage to adjacent regions is avoided. Also, due to the high photon densities, classical absorption laws are effectively suspended, so that virtually all materials can be processed independently of the laser wavelength used. Such lasers also allow nonlinear material modifications, so new material functions can be created and new/diverse applications of ultrafast pulse lasers are growing rapidly.

This talk will focus on an area of laser-based precision-processing where basic research on laser interaction with silica glass has opened the door to the development of a completely new and powerful manufacturing technology for micro-optics. This research has enabled fully-automated, wafer-scale fabrication of high-performance, bespoke free-form optical components, at low cost and with rapid design-to-manufacture turn-around time. The research revealed that two distinct manufacturing functions can be generated with appropriate laser irradiation conditions. For the first function, we demonstrated that the strong IR absorption (short penetration depth) of silica at the 10μm CO_2 laser wavelength enables precisely-controlled pulse trains to be highly effective for laser micro-machining, and capable of producing arbitrary sub-micron scale (refractive) features to considerable depths in silica. In addition, the same laser can be used for the second function, to produce <1nm surface-smoothing of the micro-structured silica substrate so to produce low scatter-loss high quality optical surfaces.

The combination of these two direct-write processes has become the basis of a novel industrial process for low cost and high speed manufacture of bespoke, freeform optical components now commercialised by an HWU spin-off, *PowerPhotonic Ltd*. The talk will cover the basic physics of the key laser-material interaction processes as well as describing some important applications of *custom* micro-optics, including high power diode laser array (bar/stack) beam correction. Other applications include diode wavelength-locking and tuning, micro-resonator mirror fabrication, array beam reformatting and single-mode laser beam-shaping. Also, multiple distinct optical functions can be realised using a single micro-optic element.

Professor Wang Pu

Professor, College of Laser Engineering
Beijing University of Technology
Beijing, China

Wang Pu received a BSc degree in Physics from Shandong University in 1986 and a Master degree in Condensed Matter Physics from the National Laboratory of Crystal Materials, Shandong University in 1991. He joined the Australian Research Council Special Research Centre for Lasers and Applications at Macquarie University for his postgraduate study in 1996 and completed his Ph.D degree in Laser Physics in 1999. He joined the Optoelectronics Research Centre, University of Southampton, UK in 2002 as Research Fellow and was promoted as Senior Research Fellow later on.

Wang Pu is now a Professor at The College of Laser Engineering, Beijing University of Technology, P. R. China. His research has been based mainly in the general area of fibre and solid-state laser source, with particular emphasis on investigating techniques for ultrashort pulse generation in these devices, and on studying the physical principles of operation at high power levels.

High Power Pulsed Fibre Lasers

High power pulsed fibre lasers are very attractive because of their high reliability, application flexibility and relatively low cost. They have been found to have a vast range of applications in recent years including optical imaging, remote sensing, laser medicine and material processing. In the first part of this presentation I will give an overview of the development of pulsed fibre lasers at Beijing University of Technology for the past three years. This mainly involved passively mode-locked or Q-switched pulse generation in all-fibre scheme in Yb-doped, Er-doped fibre lasers. The saturable absorbers used for the pulse generation included Semiconductor Saturable Absorber Mirrors (SESAMs), few-layer graphene and graphene oxide, respectively.

In the second part of this presentation I will introduce the work on 2.0 µm thulium-doped pulsed fibre lasers in our group. After reviewing our work on Tm-doped graphene oxide mode-locked fibre laser, I will report our recent progress in development of the mode-locked thulium-doped fibre laser with SESAM as the saturable absorber and the amplification of the picosecond pulse in a three stage Tm-doped all-fibre power amplifier. The average output power at 2.0µm was 115 W and pulse width was 20 ps. This kind of high power pulsed laser source has great potential to generate high power super continuum at Mid-IR wavelength range.

Professor Tanya Monro
ARC Federation Fellow and Director
Institute for Photonics and Advanced Sensing
University of Adelaide

Professor Tanya Monro is an ARC Federation Fellow and Director of the Institute for Photonics and Advanced Sensing (IPAS), a transdisciplinary research institute at The University of Adelaide. She is a Fellow of both the Australian Academy of Science (AAS) and the Australian Academy of Technological Sciences and Engineering (ATSE), a member of the AAS National Committee for Physics and the SA Premier's Science & Industry Council. Awards recognising Tanya include the AAS Pawsey Medal for 2012, being named South Australia's "Australian of the Year" for 2011 and the Prime Minister's Malcolm McIntosh Prize for Physical Scientist of the Year award in 2008. Tanya obtained her PhD at The University of Sydney and was awarded the Bragg Gold Medal for the best Physics PhD in Australia in 1998. In 2000 she received a Royal Society University Research Fellowship at the University of Southampton (UK). She came to Adelaide in 2005 as inaugural Chair of Photonics. She has published over 500 papers and raised over $86M for research. Her research focuses on creating disruptive photonic sensing technologies.

Tanya has also been active in research and research leadership, she serves on international, national and state committees and boards on matters of science and research policy and science evaluation and assessment.

Fibre-Based Sensors for Biology and Medicine

Recent advances in materials science and nanophotonics have underpinned the demonstration of new approaches to measurement that promise to revolutionise the way we detect and treat disease, and that will enable biologists to ask powerful new questions in their research. New forms of optical fibres that have air holes within their cross-section with sizes ranging from more than 20 microns to less than 20 nm have enabled the realization of a powerful new class of optical sensing devices. When these transverse features are comparable to or smaller than the wavelength of light guided by the fibre, it is possible to ensure that a significant proportion of the light guided within the fibre is located within the voids. Then, simply by loading samples in liquid or gas form into the fibre, it is possible to utilize the strong light-matter interactions to probe these samples.

Such micro and nanostructured optical fibres can serve as a powerful scaffold to which further functionality can be added such as the capacity to bind specific biomolecules or to identify specific chemicals. This requires strategies for functioning the surface of the glass to enable the attachment of these molecules. Once such specificity has been added to the platform, a range of approaches that can be taken to exploit the interaction between the guided light and any materials loaded into the holes including absorption, fluorescence, Raman and label-free techniques.
An overview of sensor architectures demonstrated to date based on micro and nanostructured optical fibres will be presented, including dip sensors capable of nanolitre-scale sampling, distributed sensors, architectures including resonators for biosensing and sensors with photoswitchable surfaces.

A range of applications being pursued based on these emerging fibre sensing architectures will be discussed, including advanced proteomics technologies, tests for early stage gastric cancer, a virus detection platform, a test for cardiac stress markers, and more. Developments at this interface between optical physics and surface chemistry have the potential to create a suite of disruptive new technologies for point of decision diagnostics and improved laboratory tools for biological and medical scientists. Ultimately, the capacity of optical fibres to make measurements in sub-cellular fluids and in remote locations means that they will enable biochemical measurements to be made in currently poorly understood environments such as within the living brain.

Dr JIN Dayong

Senior Lecturer
ARC Australian Postdoctoral Fellow
Department of Physics and Astronomy
Faculty of Science
Macquarie University

Dr JIN, Dayong completed his PhD research in 2007 under the supervision of Professor Jim Piper. As a significant breakthrough in cytometry science, he invented the "time-gated fluorescence flow cytometry" (US patent application, and two featured articles in *Cytometry A 2007*). The system is capable of analysing cells at over 100,000-events per second and pinpoint rare pathogen microorganisms even when there are only less than 10 cells from billions.

Dr Jin has been a successful recipient for the Australian Research Council Postdoctoral Fellowship (2010–2012), Australian Research Council International Collaboration Award (2010–2012), Macquarie University Research Fellowship (2008–2010), International Society for Advancement of Cytometry (ISAC) Scholar (2007–2012) and the Macquarie Early Career Researcher of the Year 2010 Award. In 2012, Dr Jin won the prestigious Macquarie University Vice-Chancellor's Innovation Fellowship as his third consecutive fellowship within 5 years. His MQVCIF targets the development of transformational research, new technologies, research commercialization and strong industry partnerships (2013–).

Dr Jin has been establishing and directing an internationally-oriented group "Advanced Cytometry Laboratories @ Macquarie" to network and challenge the bio-sensing limits of sensitivity, specificity, speed, throughput and resolution. In 2011 and 2012, Dr Jin and his collaborators secured over AU$ 1 Million from the Australian Research Council and Macquarie University to combine the current and future cytometry and imaging infrastructures. The interaction of laser photonics, biotechnology, nanotechnology and medical researchers at Macquarie leads to a synergy and fosters a local and national cross-discipline research collaboration platform.

Dr Jin (co-)authored 51 internationally peer-reviewed papers (35 key journal papers published in 22 premium multi-disciplinary journals with top 10% rankings). Dr Jin has been invited to deliver over 15 presentations and seminars at international conferences and leading research institutes. Dr Jin serves as an international referee for over 20 multi-disciplinary journals, scientific societies, and international funding agencies (including Australian Research Council, the Netherlands Organisation for Health Research and Development, and the Belgium FWO Research foundations).

High-Speed, High-Contrast Luminescence Biosensing: Finding a Needle in a Haystack

Detection, quantification, or localisation of particular cells or molecules – quickly, sensitively and accurately – is fundamental to both modern biomedical research and industry: from understanding sub-cellular processes and biochemical pathways to the early detection of diseases in clinical settings. However, molecules that are altered as a result of a pathological condition are generally present in low numbers, and are extremely difficult to detect. This is particularly true in the early stages of disease development, posing a "needle-in-a-haystack" problem that demands both sensitivity and speed.

Current tests are either slow or not sensitive enough to detect the few altered cells that indicate a disease. For example, in order to identify disease-causing pathogens in water and food, analytical techniques must be sensitive enough to detect a single particular microorganism (e.g., *Cryptosporidium parvum* and *Giardia lamblia*) in 10 litres of water containing billions of other microorganisms and particles. Potentially fatal cancers, and various heart and neuronal diseases may go undetected for many years because of the difficulty of detecting as few as ten target cells in 10 ml of blood or other biofluids in the early stages of the diseases. No current techniques are capable of this level of sensitivity.

Working in the cross-disciplinary field of physics, chemistry and biology, the research group of the Advanced Cytometry Labs at Macquarie University, has invented a package of novel technologies for the rapid detection of single cells. We call this **suite of technologies our SAAB technology platform**, short for **S**uper-bright dots, **A**utomated-scanning microscopy, **A**ccessible library of molecular probes, and **B**ackground-free imaging.

Background-free imaging is achieved by our foundation technology known as "time-resolved luminescence assay", that employs a long-lived luminescent probe which glows for longer than non-target background cells. Therefore time-gated detection renders non-target cells, debris and other particles practically invisible.

Our new generation of patented **S**uper dots can specifically tag the target cells to produce an amplified luminescence signal. This further delivers high contrast, typically three orders of magnitude more sensitive than conventional commercial "dots" or nanoparticles such as quantum dots.

Our proprietary device, an **A**utomated scanning microscope, can rapidly find rare pathogenic microorganisms from water and dirt on a glass slide within 3 minutes. In collaboration with US firm BD Biosciences, Olympus Australia and Newport Instruments (USA), our group successfully demonstrated that it can accurately distinguish rare abnormal cells when molecular disease biomarkers are expressed on the cell membrane at very low abundance.

Furthermore, through a successful Discovery Project funded by the Australian Research Council (Piper & Jin 2010–2012), we built an **A**ccessible library of molecular probes, so that thousands of molecular disease biomarkers can be analysed simultaneously in a single test, which has the potential to decode the gene signatures of individual patients at high speed.

Dr Cathy Foley
Chief of Materials Science and Engineering
CSIRO

Dr. Cathy Foley is Chief of CSIRO Materials Science and Engineering – the Division of Materials Science and Engineering responsible for 880 staff, students and associates. She has worked in the Superconducting Devices and Applications Project which is developing superconducting systems for mineral exploration, detection of metal for quality assurance in manufacturing, terahertz imaging and submarine and unexploded ordnance detection. Her team is responsible for the development and commercialization of LANDTEM which has been responsible for the discovery of over $6B of mines worldwide.

Cathy has a world-class reputation in her field being a Fellow of the Institute of Physics in the UK, Past President of the Australian Institute of Physics, Fellow of the Academy of Technological Sciences and Engineering (ASTE) and the Immediate Past President of Science and Technology Australia where she represented 68,000 Australian scientists and technologists. She is also a personally appointed member of the Prime Minister's Science, Engineering and Innovation Council and a member of the Questacon Advisory Board. She is on numerous advisory boards and review committees, conference organizing committees and has most recently been appointed at the Editor in Chief of the IOP journal of Superconductor Science and Technology after being the Fast Track Editor since 2008.

Cathy is a graduate of Macquarie University from where she received a BSc(Hons), Dip Ed and PhD, after studying from 1976 to 1984.

Dr. Foley is well known for her interests in physics, science education, women in science, science in the media (she was a regular weekly guest on ABC radio 2BL for 5 years) and nuclear disarmament. Cathy was awarded a Public Service Medal on Australia Day 2003, and won the 2003 Eureka Prize for the promotion of Science, and was the NSW and National winner of the Telstra Women's Business Award for Innovation in 2009. Cathy was awarded the AUSIMM MIOTA Prize in 2011 and is the 2013 NSW Premier's Woman of the year.

Future Research Directions of CSIRO in Materials Science and Engineering

CSIRO is a mission directed research organisation expected to assist industry and society address the challenges that the various global and local changes create. The Division of Materials Science and Engineering (CMSE) provides a fundamental part of the innovation needed to assist Australia in a global context to meet these challenges. The question as the leader of this Division is: what research will be needed now, in the near future and in the long term? How do we maintain and develop a "portfolio" of research that provides the solution for the challenges while preparing for the future challenges we don't even know about yet?

This presentation will give an overview of the range of research undertaken at CMSE and how we balance the need for preparing for the unknown needs of the future while delivering innovative solutions and impact now. Examples of new ways to undertake research and some platform technologies, along with some stories of past successes, will be presented.

Dr Daniel Brown

Vice President of Technology Development
Cymer (An ASML Company)
San Diego, USA

Daniel Brown is currently Vice President of Technology Development since the completion of Cymer's merger with ASML Holding, Ltd. in May 2013. Preceding the merger, he served as Vice President and Technology Development Officer for Cymer, Inc. from 2010–2013. Prior to 2010 he held the positions of Vice President, Technology Development and Vice President, Engineering within the Deep-Ultraviolet Product Group at Cymer. He is presently chartered with directing the technology activities within Cymer for both the company's Extreme Ultraviolet (EUV) laser-produced plasma light source development and Deep-Ultraviolet (DUV) light source products (based on high-repetition-rate excimer lasers), in order to meet the demands of the lithography exposure tool manufacturers selling into the semiconductor manufacturing industry.

Prior to joining Cymer in 2000, he served for over 11 years in various Australian Research Council Fellow positions at the Centre for Lasers and Applications (CLA) at Macquarie University including Australian Senior Research Fellow and Australian Research Fellow.

In addition, he held the position of Associate Director within the CLA from 1995–2000. His research was focused on metal vapour laser development and applications, as well as the development of novel high-power ultraviolet laser sources based on nonlinear frequency conversion of high-pulse-rate visible laser systems. He holds a PhD in physics, and a Bachelor's degree in Science, from the University of New England (Armidale).

State-of-the-Art Light Sources for Photolithography

Photolithography is the key step in semiconductor device manufacturing where the circuitry is patterned onto a silicon wafer. As the process name indicates, the step involves exposing a photosensitive chemical (resist) coated onto a silicon wafer with short-wavelength radiation that transfers the desired circuit pattern (from a photomask) onto the silicon wafer. The requirements for the photolithography process have evolved many orders of magnitude since the 1960s, driven by the desire to manufacture devices with ever increasing processing speed and higher memory capacity. The rate of technology change is often described by Moore's Law (stated as "the number of transistors on integrated circuits doubles approximately every two years"), which has been enabled by aggressive shrinking of semiconductor device critical circuit dimensions for over thirty years.

In order to enable this continuing reduction in the dimensions of lithographically exposed features, the technology of lithography exposure tools has evolved rapidly in sophistication and precision. This presentation will begin with briefly reviewing the photolithography process and the technology of exposure tools, describing how the key lithographic challenges of Imaging, Overlay and Throughput have been addressed over time to yield current state-of-the-art performance for high-volume manufacturing of sub-38nm resolution, < 5:5nm overlay reproducibility, and > 175 wafers-per-hour productivity. One critical building block of lithography exposure tool capability has been the (purpose-designed) light source, with characteristics such as source wavelength, optical bandwidth, stability, and power of the source all being fundamental to the ability to image circuit features with the required resolution, repeatability and speed. The remainder of this presentation will focus on reviewing the current state-of-the-art in lithography light source technology, as well previewing the next generation of light sources.

For the current state-of-the-art lithography exposure tools used in high-volume manufacturing, deep-ultraviolet (DUV) light sources based on ArF excimer lasers are employed. These light sources produce 60 { 90W of 193nm radiation with narrow optical spectrum (< 0:35 nm, 95% integral) at high repetition rate (6 kHz) and with extremely high wavelength and energy stability. The drivers for these challenging requirements, and the technology developed to deliver this performance, will be reviewed in detail.

For the next generation of lithography exposure tools, there is a plan for a paradigm shift in the light source technology to the extreme ultraviolet (EUV) spectral region at 13.5 nm, which is being driven by the need for even higher resolution at the wafer and extensibility to smaller device features over the coming years. We will review Cymer's laser-produced plasma technology for EUV generation, which is based on high-power short-pulse CO_2 drive lasers and tin (in droplet form) as the fuel material.
The specifc technical requirements and light source architecture will be described in detail, as well as the performance characteristics of light sources presently under evaluation.

Dr Larry Marshall
Managing Director
Southern Cross Ventures
USA

Dr. Larry R Marshall is Managing Director of Southern Cross Ventures, a Venture Capital firm based in Silicon Valley, Shanghai and Sydney, specializing in growing Australian technology companies in Asia and the US. He has a longstanding partnership with SoftBank China, China's most successful VC firm, and co-manages the Renewable Energy Fund, founded in 2012, with SoftBank China. He has lived in the US for 25 years and founded and/or was CEO of Light Solutions, Iridex (Nasdaq: IRIX), Iriderm, Lightbit, Translucent, AOC, Arasor (ASX: ARR), and the Renewable Energy Fund; driving two of them to successful Initial Public Offerings (IPOs).

Larry began his career as an engineer with a PhD in Physics and over 100 publications and presentations; he became an inventor, with 20 patents protecting numerous commercial products generating over $200M in revenue; then became an entrepreneur, raising over $100M in funding and creating companies with over $1B in market capital, and is now an investor with $400M under management. He has served on 20 boards of high tech companies operating in the US, Australia, and China.

Larry is currently on the boards of Mocana, Quantenna, Wave, Nitero, SBA, Advance, SXVP, REVCF and Laser Focus World, and serves as Chairman of RIO, Crossfiber, and Advance Innovation, and is co-Chairman of Blackbird, and Brismat. He is a passionate supporter of Australian innovation and Australian entrepreneurs.

The Entrepreneurial Journey: from Scientist to CEO to Venture Capitalist

Australia faces a crisis of confidence in our ability to innovate. While we excel at mining material resources from the ground, we have a poor track record of Technology Mining and value creation. We frequently mistake invention for innovation. We spend over $6B per year on R&D, and less than $100M on investing in startups. A large part of the solution to Australia's innovation dilemma is to teach innovation early in the education cycle, and to encourage far more scientists and engineers to become entrepreneurs rather than relying on traditional business people to create and lead startups.

Dr Marshall has undergone a 25 year evolution from scientist to inventor, to entrepreneur, to CEO, to Venture Capitalist. He has founded 6 companies, and created two IPOs and numerous trade sales. He has invested in over 50 companies and sat on over 20 boards. He has a PhD in Physics, but no business education of any kind.

This presentation will take the listener through the entrepreneurial evolution experienced by a scientist learning how to commercialize technology the hard way. We will focus on the process of turning unique technology into viable and sustaining companies through real world examples of the companies created by the speaker. Rather than focusing on the outcome, the talk will drill down into the mistakes made and lessons learned. In particular, we will address the illusion of intellectual property, crossing the valley of death, core vs. context, the 7 things that really matter, the crucial near death experience, how to value technology, how to sell technology and company, how to raise money, how to exit and how to take the team along with you on the journey.

Professor Jim Piper

Professor Jim Piper joined the Macquarie University community in 1975 when he was appointed as a Lecturer in the Department of Physics. In 1984 Jim was appointed to the Chair of Physics and in 1988 he was awarded as Chief Investigator of the ARC Special Research Centre for Lasers and Applications. Jim was appointed as Head of the Division of Information and Communication Sciences, and in 2003 Jim took up the role of Deputy Vice-Chancellor (Research).

Jim's research interests are in laser and optical physics, including applications in biology, medicine and engineering. He is particularly known for research in high-power visible gas and liquid lasers, all-solid-state (crystalline Raman) visible lasers, applications of lasers in biomedical diagnostics, nanobiophotonics, and laser microfabrication. Jim is (co)author of over 300 publications, has supervised over 40 PhD students, and has a strong record of supporting and mentoring postdoctoral research fellows.

Jim is passionate about building international collaboration in research and research training and he has established valued and productive collaborative research relationships with several leading researchers, particularly in China, over a period of 20 years.

Jim has been awarded the Pawsey Medal (Australian Academy of Sciences), the Walter Boas Medal (Australian Institute of Physics), and the AOS Medal (Australian Optical Society) for his contributions to optics, laser physics and technology. He was elected Fellow of the Optical Society of America in 1994. In 2004 he was awarded the Carnegie Centenary Professorship and in 2006 he was awarded an Honorary Degree of Doctor of Science by Heriot-Watt University.

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