Institute Highlights

- 11 high impact (impact factor >10) publications including Nature Communications, Angewandte Chemie and Advanced Materials
- 11 Photonics Catalyst Program (PCP) Projects enabling industry access to cutting edge expertise, equipment, capabilities and emerging laser and sensor technologies
- 214 research members
- Received a total of ~$9 million of grant funding
- Awarded ~$7 million in new grants
- Hosted three major conferences/workshops
- Trajan Scientific and Medical agreed a Strategic Partnership with the University - they have opened a R&D Manufacturing hub in The Braggs
- $100K in research donations
- 198 peer reviewed journal papers (~20% increase from 2014)
- $2.3 million in industry grant funding
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IPAS Overview

IPAS Research

Working with Industry / Commercialisation

2015 Activities

IPAS Governance and Infrastructure
Introduction from the Deputy Vice-Chancellor and Vice-President (Research)

The University’s Research Institutes bring together world-leading researchers, an appetite for tackling grand challenges, state of the art infrastructure and a highly innovative culture. The consequence is research of outstanding quality and impact.

The IPAS vision is to pursue a transdisciplinary approach that brings together experimental physicists, chemists, material scientists, engineers, mathematicians, biologists and medical researchers. They are working together to create new sensing and measurement technologies in order to solve major challenges. The new technologies created have the potential to change the questions scientists can ask, generate new commercial ventures, and train a new cohort of transdisciplinary problem-solvers.

IPAS is an outstanding exemplar of the way in which the University of Adelaide is able to accomplish world-class fundamental research while simultaneously partnering with industry. The new strategic partnership with Trajan Scientific and Medical will, for example, drive the transition of novel glass and photonics products into industry.

This report provides a fascinating overview of the vast range and quality of activities undertaken within IPAS during 2015. I congratulate staff and students on the remarkable outcomes and wish them every success in the coming year.

Professor Mike Brooks  
Deputy Vice-Chancellor & Vice-President (Research)

Report from the Board Chair

2015 was the sixth year of operation and growth for IPAS. The continued high-quality research outputs by IPAS members is evidenced by the 20% increase in publication outputs, with 198 peer-reviewed journals published during 2015.

I am always thrilled when members of the Institute receive recognition. Congratulations to Prof Mark Hutchinson, Prof Heike Ebendorff-Heidepriem, A/Prof Yvonne Stokes, A/Prof Christian Doonan, Dr Sabrina Heng and Dr Nicolas Riesen on being awarded significant prizes and awards for their research.

The South Australian State Government has also been key to our success through their continued support, and I acknowledge and thank them. The Defence Science and Technology Group have continued to provide significant support for a range of defence-related projects and I would like to thank them for their ongoing support.

In December 2015, in line with the IPAS Board governance and renewal strategy, I stepped down as Board Chair. It has been an honour to serve on the Board and I know that IPAS will continue to perform at the forefront under the leadership of Prof Andre Luiten.

I would like to acknowledge and thank my fellow members of the IPAS Board, IPAS Director Prof Andre Luiten, the IPAS Professional Team, and the researchers and staff for their tireless and instrumental contributions.

Mr Joe Flynn  
IPAS Chairman
Message from The Director

Prof Andre Luiten, IPAS Director

It is a great privilege to be Director of IPAS – it gives me the opportunity to lead a group of incredible researchers. As you will see from this report, the work of our members is impacting both fundamental science and commercial applications. Almost every week a new scientific breakthrough or new commercial partnership has been announced.

Throughout 2015 we have developed the three strategic partnerships that lie at the heart of what makes IPAS different.

The first of these foundational pillars is IPAS’s work with the South Australian State Government where we provide management of two major programs - the Photonics Catalyst Program and the Photonics Roadmap. In both cases we are exploring and demonstrating the benefits of photonics to the manufacturing industries of the State. The South Australian State Government has also supported the appointment of key researchers within IPAS through the Premier’s South Australian Fellowship Program (part of the PRIF) - they have been responsible for bringing myself in 2012 and now a new Chair of BioPhotonics (Professor Robert McLaughlin) to South Australia in 2016. Robert is going to be a key leader for IPAS.

Over 2015 we have significantly strengthened our second strategic partnership with the Defence Science and Technology Group (formally DSTO). This allows rich and frequent interactions between DST Group personnel and our researchers on many separate projects ranging from new lasers, new glass materials, optical fibres, magnetometry and new radar technology. This relationship has facilitated numerous funding agreements as well as personnel interchange between the two organisations and scholarships for students.

Our third strategic partnership is with a Melbourne-headquartered company Trajan Scientific and Medical. Trajan is a globally-leading innovator in glass materials for scientific and medical applications and analytic tools. Their focus is on developing and commercialising technologies that enable analytical systems to be more selective, sensitive and specific for biological, environmental or food related measurements - especially those that can lead to portability, miniaturization and affordability.

Trajan have staff co-located in The Braggs which will facilitate R&D and manufacturing using our facilities, and also provide an outlet for our inventions into their manufacturing chains and global sales networks. This will prove to be a very powerful relationship which I believe is going to knock down a key barrier to translation of our research into real-world products. There is a very strong concordance between the vision of Trajan and that of IPAS and I think this is going to be a transformative combination.

We are laying down the foundations for an even better 2016. I look forward to continuing to support IPAS Members to create a supportive, creative and adventurous research culture that drives translation and impact.

Professor Andre Luiten, IPAS Director
The IPAS Student Experience

Study at IPAS
IPAS Honours, Masters and PhD opportunities are world class and guided by research scientists who are global leaders in their field. As well as working on blue sky research, we also work in partnership with government and industry on projects aimed at delivering real-world outcomes e.g. new products and starting new technology companies. Our graduates have gone on to postdoctoral roles at leading research organisations worldwide, others have started up companies based on their research or have secured employment with industry partners or defence organisations (including Trajan Scientific and Medical, Ellex, Schlumberger, BAE Systems, Maptek, Coherent, Lastek, the Defence Science and Technology Group and the Australian Antarctic Division).

IPAS Science Network
The Science Network team has been created to strengthen the bond between science disciplines of the University and bring together members and non-members of IPAS for networking events and professional development activities. The IPAS Science Network represents the needs of the students within IPAS and supports students in all aspects of their postgraduate experience. The Chair of the Science Network sits on the IPAS Scientific Management Committee.

The IPAS Science Network team are Jonathan Hall (Chair), Matthew Briggs (Vice-Chair), Myles Clark (Treasurer), Elizaveta Klantsataya (Secretary), Georgina Sylvia (Media), Vincent Michaud-Belleau, Kelly Keeling, Hayden Tronnolone, Chao Zhang, Parul Mittal and Martin Cole.

IPAS Student Prizes
In January 2015, all IPAS students were invited to present their research in a five-minute talk. These prizes are designed to encourage IPAS PhD students to make compelling and effective presentations.

The winners were announced at the IPAS New Year Event held in late January.
- Mr Jesse Teo – Tanya Monro Presentation Award
- Mr Myles Clark – Merry Wickes Transdisciplinary Prize
- Ms Carly Whittaker, Mr Daniel Stubing, Mr Karan Gulati – Honourable Mention.
The IPAS Student Experience

Mr Michel Woy – Visiting MSc Student

An ongoing research collaboration between Prof Heike Ebendorff-Heidepriem (IPAS) and Prof Lothar Wondraczek (Otto-Schott-Institute, Friedrich-Schiller University, Jena, Germany) provided an excellent opportunity for me to spend seven months during my Masters studies at IPAS.

The main objective of my work during my time at IPAS was the generation of palladium nanostructures in fluoride phosphate glasses with the aim of producing a highly efficient fibre laser source in the blue spectral range. Further applications include enhanced light conversion efficiency and increased sensitivity for sensing applications.

I especially enjoyed the excellent and stimulating work environment at IPAS, which is created by a unique mixture of students and early career researchers from multiple disciplines. Not only did this lead to some great social contacts and new friends, but it also generated valuable scientific input for my project. I had great fun during my stay in Adelaide and I appreciate the time I spent at IPAS.

Ms Sarah Scholten – PhD Student

My PhD project, under the supervision of Dr Richard White, Dr James Anstie and Prof Andre Luiten, aims to construct a new tool for real-time quantitative analysis of complex real-world molecular samples based on an optical frequency comb. Potential applications include contamination detection in industrial contexts, non-invasive medical diagnostics, and patient monitoring.

Being a part of IPAS has allowed me to connect with a wide range of researchers, as well as providing access to specialised equipment such as the frequency comb, without which my project could not be realised.

Mr Milad Abou Dakka – PhD Student

Researchers can look back in time millions of years by measuring the decay of noble gas radionuclides, however these measurements are limited by the atmospheric rarity of such isotopes. The goal of my PhD project is to overcome this limitation by designing the world’s most sensitive environmental detector using state-of-the-art optical techniques. Following historical changes in Earth’s climate, understanding groundwater motion and the impact of mining on ground water resources, and detecting clandestine nuclear operations are all examples of the benefits of this research.

My supervisors, Prof Andre Luiten and Dr Philip Light, have assisted me to have a smooth and highly enjoyable transition to Adelaide and IPAS, allowing me to hit the ground running with my research. Meeting and collaborating with IPAS researchers from around the world is providing a once-in-a-lifetime opportunity.
ARC Centre of Excellence for Nanoscale BioPhotonics

The ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP) saw a highly successful 2015, with the recruitment of key staff and researchers, the launch of a number of collaborative commercial and academic partnerships, strong engagement with state and federal political stakeholders, the delivery of a Centre wide annual scientific retreat, as well as of course, the progressing of some fantastic research.

Centre Director Prof Mark Hutchinson and Chief Investigators Prof Tanya Monro, Prof Andrew Abell, Prof Stephen Nicholls and A/Prof Jeremy Thompson are all IPAS members and have been central to this success.

With a vision to create windows into the body - CNBP researchers are studying and manipulating nanoscale interactions between light and matter to measure and sense inside living biological systems.

The CNBP has brought together physicists, material scientists, chemists, embryologists, neuroscientists and cardiologists from the University of Adelaide, Macquarie University and RMIT University with key international, national and industry partners.

The emerging convergence of nanoscience and photonics offers the opportunity of using light to interrogate nanoscale domains, providing unprecedentedly localised measurements. This is allowing biological scientists and clinicians to understand how single cells react to and communicate with their surroundings. This science will underpin a new generation of devices capable of probing the response of cells within individuals to environmental conditions or treatment, creating innovative and powerful new sensing platforms.

A centre of research excellence, CNBP is a leader in nanoscale biophotonics. CNBP values ensure that alongside academic excellence, CNBP researchers embrace the growing need to communicate their research to diverse audiences, commercialise research outcomes and provide a nurturing environment to train future generations of researchers.

For more information please see www.cnbp.org.au
CNBP Case Studies:

CNBP Researcher Mr Malcolm Purdey
New Dual Fibre-Optic Sensor Measures Hydrogen Peroxide and pH

The tricky process of monitoring early-stage embryos during the IVF process could become much easier with the development of a new fibre-optic sensor that can measure concurrently, hydrogen peroxide and pH (acidity-alkalinity concentrations) in solution.

The sensor, the first of its kind, was developed by CNBP researcher Mr Malcolm Purdey at the University of Adelaide and consists of a single optical fibre, the tip of which has been functionalised with a reactive fluorescent coating.

Malcolm believes the sensor has the potential to be used across a broad range of biological applications, but that it is particularly well suited to the IVF industry. This is because unregulated production of hydrogen peroxide by an embryo, as well as fluctuating levels of pH, can indicate embryonic stress, impacting embryo development.

The state-of-the-art sensor is a single strand of optical fibre that is completely non-invasive. It can be placed right next to an embryo causing no disruption to its development, monitoring critical stages of the IVF process. As current clinical examinations tend to be visually based, the new dual sensor has the potential to monitor multiple embryonic parameters objectively, with a single piece of technology.

The sensor has the potential for broader application as well, as hydrogen peroxide is an indicator of cell stress and possible illness. In the future, the sensor could be used inside of the body, to examine cells in the arteries to look for evidence of vascular disease. It could also be used to aid in cancer detection.

Next steps with this sensor will be functionality testing with cow embryos, a research pathway focused on developing a sensing tool that will have commercial viability and success.

For more information please see www.cnbp.org.au
RESEARCH THEME: Novel Light Sources

IPAS novel light sources research combines fundamental and applied physics to generate and deliver tailored light for medicine, national security, industrial and environmental monitoring, and fundamental physics applications.

Our world leading research includes:

- Fibre and planar waveguide lasers
- Frequency combs
- Ultra-narrow-linewidth lasers
- Fibre-based nonlinear devices
- High-power solid-state lasers
- Fibre-based super-continuum sources.

Real world applications for these sources include:

- High-speed and high-resolution molecular spectroscopy for trace-gas detection
- Precision measurement
- Laser radar
- Defence precision technologies
- Laser-based electronic warfare systems
- Coherent LIDAR for wind-field measurements
- Airborne methane detection using differential absorption LIDAR.

Fibre and Planar Waveguide Lasers

Our fibre and planar waveguide lasers research is focussed on developing and optimising new laser materials and concepts in fibre and planar waveguide lasers. Our research is driven by the challenge to develop lasers that operate in fringe regimes and possess extreme capabilities from compact architectures. Recent work has focussed on short-pulse generation (ns to fs), with applications including biophotonics, defence, mining, and surveying. This year we published a number of world firsts including the first air-clad fibre laser based on the holmium transition at 2 µm and the highest tuning range ever demonstrated from a fibre laser based system (3.3-3.5 µm).

Precision Measurement

A defining feature of our technological society is a hunger for more accurate and precise measurement and sensing. Important real world applications such as: the Global Positioning System (GPS), magnetic imaging, radar, optical fibre communications and even mobile phones, all rely on developing ever more accurate and precise measurements. The Precision Measurement Group works within IPAS to build instruments to meet this technological demand. We develop and extend measurement platforms of high value to fundamental physics; with an increasing focus on industrial, medical and defence contexts.

Nonlinear Optics

Our expertise in modelling nonlinear processes in nanoscale waveguides could provide future solutions for high-speed optical switches, laser sources and sensing architectures. The ongoing development of fundamental theory has led to new models that predict a novel ‘self-flipping of polarisation states’ that are being explored via two new collaborations. We hold high hopes for some very interesting new light sources in the near future.

Solid State Lasers

Solid-state laser research at IPAS focuses on the development of low noise and high-power systems for specific applications including ultra-high precision measurement, spectroscopy, and remote sensing. World-leading achievements include the highest brightness, high power cryogenic Yb:YAG laser and pulsed Er:YAG lasers that are pumped by inexpensive laser diodes for remote sensing applications. This year we have demonstrated the shortest pulses ever achieved by an Er:YAG laser, thus enabling the development of laser-range-finder systems that replace more complicated systems based on non-linear optics.
RESEARCH THEME: Novel Light Sources

**1 PRECISION LASERS**
Gar-Wing Truong (pictured), James Anstie, Andre Luiten

Development of a laser thermometer that measures the amount of thermal motion of atoms in a gas to determine the Boltzmann constant, contributing to a worldwide effort in redefining the international unit of temperature: the kelvin.

Collaboration with University of Western Australia and University of Queensland.


**2 CRYOGENIC MID-IR LASER**
Miftar Ganija (pictured), Peter Veitch, Jesper Munch

Demonstration of a cryogenic holmium laser. Provides the basis for the development of high-energy pulsed lasers at 2.1 µm. Applications in processing materials including cutting plastics.

Collaboration with DST Group.


**3 AIR-CLAD HOLMIUM FIBRE LASER**
Sebastian Ng (pictured), David Lancaster, Tanya Monro, David Ottaway

First demonstration of an air-clad holmium-doped silica fibre laser. This could be a candidate for a portable high beam quality 2.1 µm laser.

Collaboration with University of South Australia and MG Scientific Glassblowing.


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**Research Theme**

**Novel Light Sources**

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RESEARCH THEME: Chemical and Radiation Sensing

IPAS chemical and radiation sensing research uses in-house and specialty optical fibres, extensive knowledge of optical spectroscopy and unique surface coatings to develop novel optical fibre-based sensing architectures.

We explore the limits of detection, including:
- Ultra-small volume samples
- Low concentrations
- Obtaining results in difficult to access areas
- Label-free optical sensing
- Chemical sensing of physical parameters.

Working with end-users and industry, we develop these sensors for monitoring water quality, corrosion, wine maturation, embryos, soil nutrients, radiation fields, fuel degradation and explosives. This research is also creating new forms of fibre-based radiation dosimeters for the medical, mining and defence industries.

IPAS radiation sensing also utilises luminescence produced by ionising radiation absorbed in environmental materials, both for radiation dosimetry and mapping, and as the “clock” in a wide range of collaborative luminescence dating applications with industry and academia. Research is also underway into novel applications of fluorescence for materials characterisation.

Chemical Sensing

Our chemical sensing research includes:
- Dip-sensors for hard to access regions including hazardous environments and in vivo.
- Distributed sensors to enable information across a platform or structure.
- Liquid and gas sensing approaches: fluorescence, Raman, plasmonic resonances and other spectroscopic techniques.
- Monitoring physical parameters (temperature, pH) using chemically-enhanced optical sensing for industrial and biomedical applications.
- Analytes successfully sensed include hydrogen peroxide (H₂O₂), aluminium ions (Al³⁺), nitroaromatic explosives and metal ions.

In partnership with other IPAS researchers, we have developed new functional structure surfaces to enable advanced sensor functionality. We solve problems in collaboration with irrigation companies, defence organisations, oncologists, embryologists and oenologists.

Radiation Sensing

Radiation Sensing in IPAS focuses on the development and application of new radiation dosimetry tools for both fundamental research and real-world applications, in health, defence and industry.

Examples include:
- Fibre-based distributed dosimeters for mining and industrial applications.
- Forensic luminescence techniques for detection of prior exposure to ionising radiation.
- Detection and quantification of radionuclides for mining and geochronology.
- Spatially-resolved distribution of radionuclides in solids.

Environmental Luminescence and Optical Dating

The IPAS Environmental Luminescence laboratory, now named “The Prescott Environmental Luminescence Laboratories”, hosts one of the most comprehensive suites of luminescence research equipment in the world. The suite includes the world’s most sensitive TL (thermoluminescence) spectrometer, a photon-counting imaging system (PCIS) developed in collaboration with ANU, TL/OSL/IRSL (optically-stimulated luminescence) Risoe readers, specialised apparatus for the measurement of luminescence kinetics and signal stability, and state-of-the-art fluorescence analysis facilities for UV-SWIR.

Luminescence dating techniques are highly versatile: they are able to accurately measure ages from the present day back 500,000 years and quantify doses as low as a fraction of one day’s background radiation. Our research is advancing these techniques and further extending the applicability of luminescence analysis.
RESEARCH THEME: Chemical and Radiation Sensing

Measurement of temperatures up to 1300°C has been achieved using pure glass optical fibres. These sensors will make temperature measurements possible in industries where standard electrical sensors currently fail due to either corrosive environments or electromagnetic interference.

Collaboration with University of SA.

Collaboration with Curtin University, Australian National University, University of Colorado, Boulder, University of California, Merced, DST Group, Western Australian Museum, National Museum Australia, Office Environment and Heritage, Access Archaeology & Heritage, and Infrastructure Planning and Natural Resources.

Growing world demand for gold necessitates developing easy-to-use, fast methods for detection of low concentrations of gold at exploration drilling sites. Two optical methods were developed to be suitable for detection of gold as low as 74ppb.

Collaboration with DET CRC and University of SA.

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RESEARCH THEME:
Optical Materials and Structures

IPAS delivers vertically integrated expertise and facilities, from modelling to device fabrication.

Modelling
- A suite of analytical, numerical and finite-element modelling tools to predict the optical properties of waveguides and fibres with complex structures
- New theoretical frameworks to explore waveguides and fibres with extreme properties and nanoscale features
- A pulse propagation model to predict how a pulse propagates along a fibre
- Waveguide and fibre design based on reversed engineering techniques
- A suite of numerical and finite-element modelling tools to find resonance modes of microsphere and microdisk cavities.

Fabrication of glasses and fibres
- Controlled atmosphere glass batching, melting and annealing
- Polymer, soft and hard glass preform extrusion
- Soft and hard glass preform ultrasonic milling
- Polymer, soft glass and silica fibre drawing.

Characterisation
- High-resolution electron and atomic force/scanning near-field optical microscopes (AFM/SNOM)
- Transmission spectrometers and ellipsometers spanning from the ultraviolet to the far-infrared spectral region (200 nm - 30 µm)
- Optical profiler to measure surface roughness
- Simultaneous thermal analysis (STA/TGA/DSC)
- Fibre loss measurement.

Research
Our research ranges from fundamental science to application-driven design and development, including:
- Development of glasses with enhanced infrared transmission and optical nonlinearity
- Nanophotonic glasses created by embedding nanocrystals in glass
- Advanced technologies for processing and shaping glass
- Design and fabrication of micro and nanostructured soft glass and silica optical fibres
- Design and fabrication of microspheres and fibre tapers
- Development of speciality doped, active and passive silica fibres, including singlemode germano-silica, rare-earth doped silica and double/triple clad fibres
- Advancing 3D printing of metals and ceramics
- Advanced light propagation theory within optical fibres and planar waveguides.

Key areas of strength include:
- Tellurite and fluoride glasses (both passive and active)
- Soft glasses with embedded nanocrystals (gold, nanodiamond, upconversion nanocrystals)
- Advanced preform technologies (extrusion and drilling based)
- Development of glasses and fibres capable of transmitting light in the mid-infrared that underpin new sensing platforms and lasers
- Custom silica fibres for fibre lasers, including air-clad rare-earth doped fibres
- Suspended and exposed core silica fibres for sensing.
By controlling the photonic crystal structures it is possible to alter the colour of materials. This can be used for applications as wide as including biosensing to colouring metals for branding purposes.

Developed a technique for creating high quality tellurite microspheres with embedded nanodiamonds containing nitrogen-vacancy centres. Potential to be used as a robust and relatively simple sensing platform.

A mathematical model of microstructured optical fibre drawing is derived and used to predict how internal channels deform when they are actively pressurised. This enables new fibres to be fabricated significantly faster.


RESEARCH THEME: Molecular Materials and Surfaces

IPAS research in Molecular Materials and Surfaces spans the following areas:

- Chemical surface coatings
- Surface functionalisation strategies
- Organic synthesis
- Molecular-based sensors
- Bioelectronics
- New materials for gas storage or separation for renewable energy applications
- Platforms for catalysis.

Our researchers include ARC Future and DECRA Fellows, with expertise ranging from fundamental chemistry to analyte-specific sensor development (an IPAS strength). Key infrastructure is available in the School of Physical Sciences, including:

- Synthetic laboratories (wet and dry)
- High field NMR spectroscopy and X-ray diffraction structure determination
- Mass spectrometry
- Automated and semi-preparative HPLC
- Time-resolved laser spectroscopy
- Materials characterisation capabilities.

Biological and Chemical Surface Functionalisation

Biological and Chemical Surface Functionalisation work at IPAS combines organic synthesis, supramolecular chemistry and surface science to functionalise the surface of a glass optical fibre and other surfaces, enabling the detection of specific chemicals and biomolecules.

Novel Materials Synthesis

The Novel Materials Synthesis group design and synthesise nanostructured materials. Some of these compounds display novel interactions and behaviour that we exploit to develop sensors as well as for use in separation science and as platforms for catalysis.

New Bioactive Compounds

We design, synthesise and test inhibitors to solve clinical challenges. Our investigations concentrate on proteolytic enzymes and biotin protein ligase as associated with the development of new antibiotics. We work to incorporate molecular ‘switches’ that when activated, mimic a key protein or peptide. Our aim is the improved treatment and diagnosis of Alzheimer’s, traumatic brain injury, cataracts and cancer.

Charge Transfer and Bioelectronics

Our Charge Transfer and Bioelectronics work focuses on the design and synthesis of peptides with specific secondary structures whose electronic properties we then theoretically and electrochemically evaluate on surfaces.

Functional Organic Materials

IPAS researchers working on ground breaking research in the area of Functional Organic Materials are developing the chemistry of ‘networked polymers’. These materials are synthesised from high symmetry building blocks linked via strong, irreversible covalent bonds. This emerging field has tremendous potential for new and more efficient catalysis platforms, sensing, storage and separation solutions.

Time-Resolved Laser Spectroscopy

Energy and charge transport in organic materials researchers at IPAS use time-resolved spectroscopic techniques to investigate energy and charge transport processes of organic photovoltaic materials. These materials, which include semiconducting polymers and organic crystals, exhibit not only the photovoltaic effect but also the abilities to sense the presence of a number of airborne chemical species. Our current work focuses on controlling the photophysical and chemical pathways to maximise generation of charged species in these materials.
RESEARCH THEME: Molecular Materials and Surfaces

1. NOVEL PHOTO-SWITCHABLE BIOSENSOR

Xiaozhou (Michelle) Zhang (pictured), Sabrina Heng, Andrew Abell

Report of a new class of spiropyran-based protease inhibitor that can be switched ‘on’ and ‘off’ by light when attached to a microstructured optical fibre. Paves the way for biosensing applications in disease diagnosis and treatment.


2. METAL-ORGANIC POLYHEDRA

Jesse Teo (pictured), Jack Evans, Chris Sumby, Christian Doonan


Collaboration with University of California, Berkeley.


3. MODELLING ENERGY TRANSPORT

Patrick Tapping (pictured), Scott Clafton, Kyra Schwarz, Tak Kee, David Huang

Simulation of energy transport through conjugated polymers. Provides information on how the arrangement of polymer chains affects the optical and electronic properties of a material. Applications in the development of plastic electronic devices.


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RESEARCH THEME: Biological Sensing and Medical Diagnostics

IPAS research in this Theme seeks to:

- Create measurement tools to enable new questions to be asked in biology and medicine (this activity is driven through the ARC Centre of Excellence for Nanoscale BioPhotonics, see pages 7 and 8)
- Develop improved medical diagnostic techniques, including ‘point of decision’
- Advance next generation proteomics technologies for cancer diagnostics and treatment
- Discover and detect biomarkers using Tissue Imaging Mass Spectrometry
- Investigate proteins and peptides underpinning the development and prevention of diseases.

Biomarker Discovery

This work investigates cancers through the identification of new biomarkers, increasing our capacity to detect, identify and quantify proteins and peptides with high sensitivity and accuracy. We use label free as well as isotopic labelling for protein quantification by mass spectrometry and 2D gel electrophoresis combined with difference gel electrophoresis fluorescence labelling for protein identification and quantification. Driven by the need for the early diagnosis of cancer and monitoring of the disease’s progression, it also provides a better understanding of the disease at a molecular level.

Tissue Imaging Mass Spectrometry

In recent years, we have implemented and improved matrix-assisted laser desorption/ionisation (MALDI) mass spectrometry imaging (MSI) in our laboratories. MALDI-MSI determines the spatial distribution of unknown compounds in tissue sections. Tissue sections prepared using the standard clinical pathology procedure, formalin fixed paraffin embedding (FFPE), can be used. MSI can look at proteins, peptides, lipids, glycans as well as drugs and metabolites and determine their spatial distribution in tissues. During the last decade this technique has been developed as a powerful tool for the discovery of new markers which correlate with disease severity or metastasis as well as for the confirmation of known markers like HER2 receptor status.

Protein Structure, Function and Interactions

Research efforts are directed towards development of new approaches (primarily using mass spectrometry and complementary biophysical methods such as nuclear magnetic resonance spectroscopy, circular dichroism, fluorescence spectroscopy, electron microscopy) to obtain insight into the 3D structure, function and interactions of macromolecules, such as proteins and DNA, important in biology.

Biosensing Platform Development

Harnessing breakthroughs from our other Themes, we create new biosensing tools for advancing biological research, and collaborate with medical researchers to enable translation to clinical applications.

New sensor architectures include:

- Small-volume in-fibre fluorescence assays
- Fibre-tip sensors for in vivo diagnostics
- A multi-channel sensor for virus, bacteria and biomarker detection for gastric cancer.

Central Nervous System Nanoscale Biosensing

Our brains and spinal cords are comprised of billions of highly diverse and specialised cells working in concert, allowing us to process a multitude of conscious and unconscious pieces of information. However, we still only understand a fraction of the complexity of brain function in health, let alone how the brain changes in disease. To tackle the new frontiers in brain and behavioural research we need to ask our scientific questions of smaller and smaller numbers of cells, in very discrete brain regions. Unfortunately, the existing technologies don’t allow this. Therefore, through the use of novel nanoscale biosensors our research aims to go beyond the limits of detection imposed by current tools. With these new tools we will ask questions of the brain and spinal cord that were once thought to be science fiction.
Research Theme

**Biological Sensing and Medical Diagnostics**

### Key Contacts:

**Biomarker Discovery and Tissue Imaging Mass Spectrometry**
Prof Peter Hoffmann  
peter.hoffmann@adelaide.edu.au

**Biosensing Platform Development**
Prof Robert McLaughlin  
robert.mclaughlin@adelaide.edu.au

**Central Nervous System Nanoscale Biosensing**
Prof Mark Hutchinson  
mark.hutchinson@adelaide.edu.au

**Adelaide Proteomics Centre**
Prof Peter Hoffmann  
peter.hoffmann@adelaide.edu.au

**ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP)**
Prof Mark Hutchinson  
mark.hutchinson@adelaide.edu.au

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**HYDROGEN PEROXIDE SENSING**

Malcolm Purdey (pictured), Erik Schartner, Tanya Monro, Jeremy Thompson, Andrew Abell

Development of new fluorescent sensors to detect hydrogen peroxide in sperm. Sensors can distinguish poor quality sperm, providing new tools for the understanding and diagnosis of male infertility.

Collaboration with University of Newcastle.


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**WHISPERING GALLERY MODES**

Tess Reynolds (pictured), Matt Henderson, Alex François, Nicolas Riesen, Jonathan Hall, Shahraam Afsharp, Stephen Nicholls, Tanya Monro

We used an analytical model to investigate characteristics of microspherical resonators including resonator diameter and refractive index. Provides the optimal whispering gallery mode sensor design for various biological sensing applications.

Collaboration with University of South Australia and South Australian Health and Medical Research Institute.


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**ENDOMETRIAL CANCER IMAGING**

Parul Mittal (pictured), Manuela Klingler-Hoffmann, Georgia Arentz, Chao Zhang, Peter Hoffmann

State of the art ‘MALDI mass spectrometry imaging’ to discriminate the regions of healthy endometrial tissue from regions of tumors.

Collaboration with Universiti Sains Malaysia and Royal Adelaide Hospital.

RESEARCH THEME: Atmosphere, Space and High Energy Astronomy

The team has a wealth of experience in developing the technologies that underpin remote sensing. Our members contribute to international projects such as the Laser Interferometer Gravitational Wave Observatory (LIGO), the High Energy Stereoscopic System (HESS) and the Pierre Auger Observatory.

Gravitational Wave Detection with LIGO

Einstein predicted the existence of gravitational waves, and our researchers are part of the LIGO team that is building a $300M instrument to detect them. We have developed a range of laser systems and optical sensors for advanced gravitational wave detection. This year was a monumental year for this field because the LIGO team detected gravitational waves for the first time. The source of these gravitational waves was the inspiral and merger of two black holes which also confirmed the existence of binary black holes for the first time.

Light Detection and Ranging (LIDAR)

We are developing differential absorption LIDAR (DIAL) to remotely sense chemicals in the atmosphere including CH₄ and CO₂. Our current projects involve the development of a new high power methane LIDAR for deployment on fixed wing platforms. When completed this LIDAR system promises to be the most cost effective means of checking trans-continental natural gas pipelines for leaks. We have also demonstrated the fundamental technologies that will underpin a new LIDAR technology for the detection of CO₂ for industrial process control. Previously we have developed coherent laser radar for the remote detection of wind-fields.

Our unique solid-state laser platforms in the near infrared (eye-safe band) and fibre lasers in the mid-infrared underpin these exciting technologies.

High-Energy Astrophysics

High-energy cosmic messengers such as gamma and cosmic rays requires advanced techniques to filter the atmospheric background and apply atmospheric transmission. Our researchers are currently working on projects including the design of gamma ray telescopes and ultra high-energy cosmic ray detectors.

Gamma-Ray Astronomy

The High Energy Stereoscopic System (HESS) is an array of five gamma-ray telescopes in Namibia and is being used to reveal the nature of cosmic-ray and electron accelerators in our galaxy and beyond. The Adelaide team focuses on gamma-ray sources in our Milky Way galaxy and how these objects can influence its evolution. The team also leads Australia’s efforts in developing the next generation gamma-ray facility known as the Cherenkov Telescope Array (CTA) which will be 10 times more sensitive than HESS using an array of up to 100 telescopes.

Cosmic-Ray Astronomy

The Pierre Auger Observatory (PAO) in Argentina is the world’s largest cosmic-ray detector. Cosmic-rays are the charged particles continually raining down on Earth from outer space and their origin remains a mystery. PAO is being used to measure the energies, directions and elemental composition of the highest energy cosmic-rays. The Adelaide team leads efforts in reconstructing these cosmic-ray parameters and the calibration of this data by accurately measuring the atmosphere’s properties at the PAO site.

Space and Atmospheric Physics

We use a network of radars, LIDARs and passive optical instruments to study the structure and dynamics of the atmosphere to validate numerical weather and climate models provided by CSIRO and BOM. We use an extensive instrument cluster located at Buckland Park Field Site to map the winds, temperature and density of the atmosphere from the ground to 90 km. We also contribute to the instrument cluster at Davis Station in Antarctica.
RESEARCH THEME: Atmosphere, Space and High Energy Astronomy

1. GRAVITATIONAL WAVES DETECTED

David Ottaway (pictured), Peter Veitch (pictured), Jesper Munch, Elli King

A global team of researchers have for the first time detected gravitational waves - ripples in space and time caused by cataclysmic events in the distant universe that were predicted by Einstein in his general theory of relativity 100 years ago.

LIGO Scientific Collaboration and Virgo Collaboration.

2. REMOTE SENSING OF GREENHOUSE GASES

Ori Henderson-Sapir (pictured), David Ottaway.

Development of an infrared optical fibre laser that can detect small concentrations of greenhouse gases at considerable distances (200-300 m). Opens up the prospect of differentiating between various potential emission sources. Collaboration with Macquarie University.


3. NEW GAMMA RAY SOURCES

Gavin Rowell (pictured), Phoebe de Wilt, Nigel Maxted

Three new gamma-ray sources discovered in our neighbouring galaxy the Large Magellanic Cloud (LMC). Provides insight into the role that massive star evolution has in accelerating cosmic-rays.


Key Contacts:

Gravitational Wave Detection (LIGO)
A/Prof David Ottaway
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Light Detection and Ranging (LIDAR)
A/Prof Peter Veitch
peter.veitch@adelaide.edu.au

High Energy Astrophysics
A/Prof Gavin Rowell
gavin.rowell@adelaide.edu.au

Atmospheric and Space Physics
Prof Iain Reid
iaan.reid@adelaide.edu.au
Pilot Project Scheme

Each year, IPAS opens up the ‘IPAS Pilot Project’ Scheme and offers funding to seed new research projects which have the potential to become externally funded research initiatives. The scheme supports new science as the forerunner for compelling fundamental science grant applications, and enables research that creates new industry engagement.

The Scheme encourages collaborative projects within and across discipline boundaries, and provides the IPAS Scientific Management Committee (SMC) with information on IPAS activities, capabilities, strengths, and opportunities to enable strategic decision-making.

In 2015, $118,000 of funding was allocated to IPAS members across the following nine projects:

- **UV-guiding silica hollow-core fibre for biological sensing** – Dr Philip Light, Dr Sabrina Heng, Dr Chris Perrella, Prof Heike Ebendorff-Heidepriem
- **Characterisation of aquaporin-1 (AQPI) ion channel activity in migrating cancer cells using a novel photoswitchable fluorescent probe** – Dr Andrea Yool, Dr Sabrina Heng, Dr Jinxin (Victor) Pei
- **Micro-Machining Exposed Core Fibre: Taking Sensing to the Next Level** – Dr Chris Perrella, Prof Charles Ironside, Dr Philip Light
- **Rapid phenotyping of human stem cells sub-populations using optical spectroscopy** – Dr Georgios Tsiminis, Dr Erik Schartner, A/Prof Simon Koblar, Prof Mark Hutchinson
- **Free-Space Optical CO2 Sensing for Heap Leaching** – Dr James Anstie, Mr Ori-Henderson Sapir, Prof Jerome Genest, A/Prof David Ottaway
- **Microplasma generation in an optical fibre for atomic emission spectroscopy** – Dr Matt Henderson, Dr Agnieszka Zuber, Dr Sameer Al-Bataineh
- **High-Precision All-Optical Physical Sensor Platform** – Prof Andre Luiten, Dr Wenle Weng, Dr Mirko Lobino

Dr Andrea Yool and Dr Sabrina Heng working on their Pilot Project

- **First Steps Towards a Cancer Biosensor** – Dr Niels Krogsgaard-Larsen, Dr John Bruning, Miss Alaknanda Alaknanda, Prof David Callen, Ms Xiaozhou Zhang
- **“Single-Grain Sorter and Loader” for Optical Dating** – Adj Prof Nigel Spooner, Prof Ben Cazzolato, Mr Don Creighton, Dr Lee Arnold, Dr Martina Demuro, Ms Daniele Questiaux

The 2015 Scheme has led to many positive outcomes including a successful ARC Discovery Grant (DP160104641), as well as multiple journal publications and conference talks.
Working with Industry / Commercialisation
Trajan Scientific and Medical

In November 2015 Trajan Scientific and Medical (Trajan) announced the opening of a new business unit – ‘Instruments, Sensors and Devices’ based in The Braggs at the University of Adelaide. Trajan’s co-location with the Institute for Photonics and Advanced Sensing (IPAS) is part of a new landmark collaboration agreement between Trajan and IPAS, and is supported by the South Australian State Government.

Trajan’s goal is for the business unit to become a global centre of excellence for specialty glass, sensing and medical device technologies. This strategic collaboration will help IPAS researchers commercialise their research into products that ultimately benefit human health and wellbeing.

Prof Heike Ebendorff-Heidepriem, IPAS Deputy Director leads the collaboration. She is working closely with Dr Anne Collins, Trajan’s General Manager - Instruments, Sensors and Devices and Dr Herbert Foo, Trajan’s Principal Scientist - Photonics.

Left: Dr Anne Collins with preforms of tellurite glass photonics crystal fibre and bismuth glass capillary.

Right: Dr Herbert Foo with a lead silicate glass drop, from the 4 meter fibre drawing tower for soft glass and polymer fibres fabrication with UV lamp for in-line fibre coating.

Contact: Dr Anne Collins
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Contact: Mr Piers Lincoln
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Industry Collaboration

IPAS engages with industry via consultancy, contract research, collaborative research and Federal Government grants such as industry-linkage schemes.

Commercial contracts with IPAS are handled by Adelaide Research and Innovation (ARI), who manage The University of Adelaide’s commercial research and consultancy partnerships, form new business ventures based on University expertise and develop the University’s innovative ideas and technologies with commercial potential.

IPAS welcomes interactions from potential collaborators in all scientific fields. IPAS already collaborates with many commercial and development organisations including:

- Aerometrex P/L
- AOFR P/L
- Arkwright Technologies P/L
- ASC P/L
- ATRAD P/L
- Austofix
- Australian Cultural Heritage Management P/L
- Australian Seafood CRC
- BAE Systems Australia Ltd
- BHP Billiton Ltd
- Bionomics Ltd
- Bioplatforms Australia
- Biosis P/L
- Bruker Daltonik GmbH
- Bruker P/L
- Calpain Therapeutics P/L
- CF Rail Services P/L
- Chevron Energy Technology P/L
- Cook Medical Australia
- Coopers Brewery Ltd
- CRC ORE - Optimising Resource Extraction
- CPR Pharma Services P/L
- CRC for Plant Biosecurity
- CSL Ltd
- Deep Exploration Technology CRC
- Defence Science and Technology (DST) Group
- Diemould Tooling Services P/L
- ElectroMagnetic Imaging Technology P/L (EMIT)
- Ellex Medical P/L
- Fertility SA
- Flinders Fertility
- Garon Plastics P/L
- Hephaestus P/L
- Heraeus, Germany
- Hills Cider Company
- Lambda Scientific P/L
- Lastek P/L
- Maptek P/L
- Medical & Scientific Services P/L
- Menlo Systems GmbH, Germany
- MOG Laboratories P/L
- Norseld P/L
- Olympus Australia P/L
- OZ Minerals
- Pernod Ricard Australia
- Phebra P/L
- Precise Machining and Manufacturing P/L
- Quintessence Labs P/L
- Red Chip Photonics P/L
- Reproductive Health Science P/L
- SA Pathology
- Scantech International P/L
- SJ Cheesman
- SMR Technologies
- Trajan Scientific and Medical P/L
- Treasury Wines Estates
- Venture Next P/L
- Yalumba Wines
- Ziltek

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Photonics Catalyst Program

Building Photonics based collaborations between Industry and the University of Adelaide

The Photonics Catalyst Program (PCP), a joint initiative between the Department of State Development (DSD) and IPAS, is connecting South Australian Industry with emerging laser and sensor technologies capable of transforming their businesses. It is creating a South Australian-based ecosystem of expertise and capabilities in photonics supporting the development of cutting-edge photonic products through unique project based collaborations between researchers, industry, end-users and government.

The Program facilitates the development of advanced photonic devices by coordinating the efforts of key stakeholders. It provides funding mechanisms for engagement, the development of prototypes, testing of photonic devices and the adoption of new light based technologies. We have a particular focus on finding solutions, creating new products and advanced manufacturing opportunities for South Australia.

The $1M Program is funding 20 new industry-focussed projects between IPAS researchers and local companies. Participants in the PCP will receive a commercial and technical feasibility assessment of their project and up to $30,000 worth of research and development services to assist with the development of their new photonic product or prototype.

Revolutionary wrist fracture device developed by Austofix and IPAS
Photonic Catalyst Program

Examples of projects funded under this Program are:

**Trajan Scientific and Medical**
The development of new speciality glass devices for mass spectrometry. This led to the strategic alliance with the University of Adelaide, the establishment of a Trajan operation in SA employing two people.

**Austofix**
The manufacturing team at IPAS and Austofix engineers prepared 263 prototypes of a new orthopaedic implant for testing by clinicians. The new product will be launched in 2016.

**S J Cheesman**
The engineering and testing of high temperature optical fibre sensors at the Nystar Metals and Minerals Processing Facility, Port Pirie. This has led to a successful ARC Linkage Project.

**Coopers Brewery**
Developing new photonic analytical methods to improve the quality of brewed products. The Adelaide Proteomics Centre have launched a new service for breweries across Australia based on the work under this project.

**CF Rail**
The advanced manufacturing team at IPAS are working with rail services company CF Rail to investigate the use of metal 3D printing for maintenance and innovative new product design.

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Commercialisation

One of the key aims of IPAS is to combine research excellence with a strong industry focus and collaborative culture. The team at IPAS work closely with the commercialisation arm of the University, to create a culture of innovation within the Institute, foster industry-led collaborations, contract research, and to develop technology licence agreements.

The commercial objectives of IPAS are to accelerate the process of getting products to market, helping the growth of photonics and advanced sensing sectors in Australia, creating new opportunities and jobs for graduates and researchers outside traditional academic roles and securing an untied income stream to the Institute. Through their research, IPAS members have built a significant portfolio of patents.

IPAS Patented Technologies

**Distributed high temperature sensing for furnace monitoring and control**

A technology for accurately measuring real time high temperature sensing in a harsh industrial environment which is currently undergoing trials. This technology is in licensing negotiations.

**Dual wavelength pumped laser system**

David Ottaway, Jesper Munch and Ori Henderson-Sapir have developed the first erbium doped zirconium-fluoride-based glass fibre laser operating well beyond 3 μm with significant power. This fibre laser achieved 260 mW in CW at room temperature. The use of two different wavelength pump sources allows us to take advantage of the long-lived excited states that would normally cause a bottleneck, and this enables maximum incident optical-to-optical efficiency. This technology was funded by the ARI Commercial Accelerator Scheme to further develop the technology and is under evaluation by an interested third party.

**Microstructured fibres and nanowires**

Our microstructured optical fibre sensors, developed in both soft and silica glasses, allow us to measure ultra-low concentrations of chemicals in nanolitre volumes of liquids. Active IPAS programs are developing this technology for sensing a range of analytes in applications such as IVF, wine production, soil nutrient monitoring, corrosion and mineral exploration.

**Optical fibre pH probe**

We have developed a probe that differentiates between tumour and normal tissue by measuring the extracellular pH and preliminary results on human breast cancer and melanoma samples shows a significant difference between tumour and normal tissue. The probe can be used during surgery for immediate feedback on the presence of tumour at the sample margin.

**Gastric cancer biomarkers**

Peter Hoffmann and his team have discovered a panel of biomarkers that may potentially be used to diagnose gastric cancer in humans. This technology received additional funding through the ARI Commercial Accelerator Scheme in 2014 for additional research. We expect results validating the discovery in late February 2016.

**Autoantibody biomarker candidates for early ovarian cancer**

Peter Hoffmann, Martin Oehler and Karina Martin identified a panel of auto-antibodies which have been shown to be discriminators between early ovarian cancer and healthy/benign controls. Ovarian cancer is the leading cause of death from gynaecologic malignancies in Australia. It presents at a late clinical stage in more than 80% of patients, and is associated with a 5-year survival of only 35% in this group. In contrast, the 5-year survival for patients with organ-confined stage I ovarian cancer exceeds 90%, and most patients are cured of their disease.
Q-switched laser
Major applications for this include coherent laser radar (LIDAR) and other remote sensing applications, including gas detection. This technology was licensed in 2015 and a second license is under negotiation in 2016.

A new class of antibiotic
Andrew Abell and his team have patented a new class of antibiotic for treating Staph aureus infections. Further research has identified a new candidate molecule that will be tested for antimicrobial activity in 2016.

Waveguide chip laser
The Waveguide laser is a new laser architecture based on waveguides written in rare earth doped fluoride glass. These lasers have achieved near-perfect beam quality lasing at 1.1 µm, 1.9 µm, 2.1 µm, and 2.9 µm with broad tunability, and are potentially the longest wavelength planar waveguide lasers ever demonstrated. The lasers are anticipated to be used in gas detection, long-range laser radar applications, free-space optical communication, medical diagnostics, laser surgery, optical pumping of longer wavelength lasers, material processing and security applications. This technology was licensed to a South Australian based start-up Red Chip Photonics.

Whispering gallery mode sensor
Our whispering gallery mode sensor comprises microspheres attached to the end of optical fibres. This kind of architecture allows very sensitive measurements to be made in vivo.

Device and method for sensing a chromatic property of foodstuff (browning sensor)
A novel browning sensor was developed by a team of researchers working at IPAS. The Institute is delighted that a new sensing technology developed by its researchers is being commercialised by a new start-up company led by the inventors who have licensed the technology from the University of Adelaide and due to commercial advancements the technology has been assigned to the company.

Optical fibre radiation sensor
We have developed an optical fibre radiation dosimeter capable of instant readouts of ionising radiation and accumulated radiation doses. We are now working with oncologists to understand how this highly accurate measure of the radiation dose applied to tumours during radiotherapy can be clinically applied.

An optical sensor
A novel method for coating of temperature-sensitive materials has been developed to allow for rapid fabrication of probes for bio-applications. This dip coating method allows the temperature to be recorded at the tip of a standard silica optical fibre with good spatial resolution.

High performance portable optical clock
This clock is anticipated to provide a new standard in accuracy and stability for use in applications including data transfer in telecommunications, stock market transactions, GPS, navigation systems, precision measurement radio astronomy and timekeeping.

Improved method and apparatus for fabricating microstructured optical fibres
This method automatically determines an internal geometry for preform used in the fabrication microstructured optical fibre and determining fibre draw parameters.

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2015 Activities
Congratulations

James McWha Award of Excellence
Professor Mark Hutchinson has been awarded a 2015 James McWha Award of Excellence. This award recognises outstanding alumni who have graduated from the University of Adelaide within the past 15 years and are making a significant contribution as emerging leaders within their profession or their community.

Women’s Research Excellence Awards
Prof Heike Ebendorff-Heidepriem and A/Prof Yvonne Stokes were recognised in the University of Adelaide’s inaugural Women’s Research Excellence Awards. Prof Heike Ebendorff-Heidepriem for her research in the field of optical glasses and fibres and A/Prof Yvonne Stokes for research in applied mathematics.

Executive Dean’s Research Awards – Faculty of Sciences
Order of Merits for Early Career Researcher Award were awarded to Dr Sabrina Heng (Edith Dornwell Category) and Dr Nicolas Riesen (Daniel Walker category). The Mid Career Research Excellence Award was awarded to A/Prof Christian Doonan. The awards recognise research excellence by Researchers within the Science Faculty of the University of Adelaide.
IPAS Global Collaborators

IPAS members collaborate with academic organisations across the world, seeking complementary skills and teams in order to solve global research challenges. In 2015 IPAS members collaborated with researchers located in the following organisations:

**CANADA**
- University of Laval
- University of Toronto

**CHINA**
- Beijing University of Technology
- Center for Space Science & Applied Research, CAS
- East China Normal University
- Huazhong University of Science & Technology
- Institute of Geology and Geophysics, CAS
- Peking University
- Shanghai Jiao Tong University
- Shanghai University of Electric Power
- Shenzhen University
- Yanshan University

**JAPAN**
- Japan Atomic Energy Agency
- Nagoya University
- University of Tokyo

**KOREA**
- University of Seoul

**EUROPE**
- City University London, UK
- Danmarks Technical University, Denmark
- Dublin Institute for Advanced Studies, Ireland
- Heinrich-Heine-Universität Düsseldorf, Germany
- Helmholtz-Zentrum Geesthacht, Germany
- Helmholtz Zentrum München, Germany
- Humboldt University, Germany
- Institut d’Optique, France
- Institute for Atmospheric Physics at the University of Rostock, Germany
- Jagellonian University, Poland
- Laboratoire de Météorologie Dynamique, Ecole Polytechnique, France
- Leibniz - Institut für Analytische Wissenschaften, Germany – ISAS – e.V., Dortmund, Germany
- Leibnitz Institute of Photonic Technology, Jena
- Max Planck Institut für Kernphysik, Germany
- Nicolaus Copernicus University, Poland
- Optoelectronics Research Centre, University of Southampton, UK
- Physikalisch-Technische Bundesanstalt, Germany
- Université Claude Bernard Lyon 1, France
- Université de Neuchâtel, Switzerland
- University of Aberystwyth, UK
- University of Bonn, Germany
- University of Bordeaux, France
- University of Cologne, Germany
- University of Copenhagen, Denmark
- University of Freiburg, Germany
- University of Jena, Germany
- University of Leicester, UK
- University of Limoges, France
- University of Milan, Italy
- University of Nottingham, UK
- University of Trento, Italy
- University Paris-Sud, France
- Uppsala University, Sweden
- Vrije Universiteit Brussel, Belgium

**NEW ZEALAND**
- Lincoln University
- University of Auckland
- University of Canterbury
- University of Otago

**SINGAPORE**
- Defence Science Organisation

**SOUTH AMERICA**
- São Paulo State University, Brazil
- University of Buenos Aires, Argentina

**USA**
- Baylor University
- California Institute of Technology
- Clemson University
- CREOL, The College of Optics & Photonics, University of Central Florida
- Georgia Institute of Technology
- Massachusetts Institute of Technology
- National Center for Atmospheric Research
- National Institute of Standards & Technology
- NorthWest Research Associates
- Naval Research Laboratory
- Princeton University
- Syracuse University
- University of California, Berkeley
- University of California, Davis
- University of California, Merced
- University of Colorado, Boulder
- US Army Research Laboratory
IPAS Australian Collaborators

IPAS members collaborate with universities, research organisations and defence industries across Australia. Major collaborators are shown on the adjoining map:

- **NATIONAL**
  - Australian Defence Force Academy (ADFA)
  - Australian Nuclear Science & Technology Organisation (ANSTO)
  - Commonwealth Scientific & Industrial Research Organisation (CSIRO)
  - Defence Science & Technology Group (DST Group)
  - National Measurement Institute (NMI)

- **SOUTH AUSTRALIA**
  - Flinders University
  - SA Pathology
  - South Australian Government
  - South Australian Museum
  - South Australian Health & Medical Research Institute (SAHMRI)
  - South Australian Research & Development Institute
  - University of South Australia

- **NEW SOUTH WALES**
  - Macquarie University
  - University of Newcastle
  - University of New South Wales
  - University of Sydney
  - University of Western Sydney

- **QUEENSLAND**
  - Griffith University
  - Mater Medical Research Institute
  - University of Queensland

- **WESTERN AUSTRALIA**
  - Curtin University
  - University of Western Australia

- **TASMANIA**
  - Australian Antarctic Division

- **VICTORIA**
  - Monash University
  - RMIT University
  - Swinburne University
  - University of Melbourne

- **AUSTRALIAN CAPITAL TERRITORY**
  - Australian National University

- **NATIONAL**
  - Australian Defence Force Academy (ADFA)
  - Australian Nuclear Science & Technology Organisation (ANSTO)
  - Commonwealth Scientific & Industrial Research Organisation (CSIRO)
  - Defence Science & Technology Group (DST Group)
  - National Measurement Institute (NMI)
## IPAS Visitors

In 2015 IPAS hosted the following visitors:

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Country</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr Naveed Ahmed</td>
<td>University of Applied Sciences (Ernst-Abbe-Hochschule)</td>
<td>Germany</td>
<td>8 months</td>
</tr>
<tr>
<td>Dr Lina Geng</td>
<td>Hebei Normal University</td>
<td>China</td>
<td>6 months</td>
</tr>
<tr>
<td>Mr Nicolas Bourbeau Hebert</td>
<td>University of Laval</td>
<td>Canada</td>
<td>1 year</td>
</tr>
<tr>
<td>Mr Klaus Doeringshoff</td>
<td>Humbolt University</td>
<td>Germany</td>
<td>5 weeks</td>
</tr>
<tr>
<td>A/Prof Jaime Garcia-Ruperez</td>
<td>Universitat Politécnica de València</td>
<td>Spain</td>
<td>4 months</td>
</tr>
<tr>
<td>Prof Jerome Genest</td>
<td>University of Laval</td>
<td>Canada</td>
<td>1 year</td>
</tr>
<tr>
<td>Ms Mengke Han</td>
<td>East China University of Science and Technology</td>
<td>China</td>
<td>6 months</td>
</tr>
<tr>
<td>Emeritus Prof David Huntley</td>
<td>Simon Fraser University</td>
<td>Canada</td>
<td>2 months</td>
</tr>
<tr>
<td>Mr Shaheer Maher</td>
<td>Assiut University</td>
<td>Egypt</td>
<td>1.5 years</td>
</tr>
<tr>
<td>Dr Louis Marmet</td>
<td>National Research Council</td>
<td>Canada</td>
<td>1 year</td>
</tr>
<tr>
<td>Mr Vincent Michaud-Belleau</td>
<td>University of Laval</td>
<td>Canada</td>
<td>1 year</td>
</tr>
<tr>
<td>Prof Harvey Rutt</td>
<td>University of Southampton</td>
<td>UK</td>
<td>3 months</td>
</tr>
<tr>
<td>Ms Jun Shi</td>
<td>Huazhong University of Science and Technology</td>
<td>China</td>
<td>1 year</td>
</tr>
<tr>
<td>Ms Laura Strodtmann</td>
<td>Otto-Scholt-Institute for Materials Science</td>
<td>Germany</td>
<td>3 months</td>
</tr>
<tr>
<td>Dr Marcin Witkowski</td>
<td>Nicolaus Copernicus University</td>
<td>Poland</td>
<td>6 months</td>
</tr>
<tr>
<td>Mr Michel Woy</td>
<td>Otto-Scholt-Institute for Materials Science</td>
<td>Germany</td>
<td>8 months</td>
</tr>
<tr>
<td>Mr Peng Zhang</td>
<td>Huazhong University of Science and Technology (HUST)</td>
<td>China</td>
<td>1 year</td>
</tr>
<tr>
<td>Dr Enming Zhao</td>
<td>Harbin Engineering University</td>
<td>China</td>
<td>1 year</td>
</tr>
</tbody>
</table>
IPAS Governance and Infrastructure
IPAS Committees

IPAS Board

Joe Flynn    Mike Brooks    Cathy Foley    Andrew Holmes    Warren Harch    Neil Bryans    Peter Gray    Andrew Dunbar    Amanda Heyworth

IPAS Scientific Management Committee

Andre Luiten    Heike Ebendorff-Heidepriem    Peter Hoffmann    Andrew Abell    Nigel Spooner    James Anstie    Mark Hutchinson    Georgios Tsiminis

Tak Kee    Gavin Rowell    David Ottaway    Dusan Losic    Sabrina Heng    Carolin Plewa    Jonathan Hall

IPAS Annual Report 2015 / IPAS Governance and Infrastructure
IPAS Professional Team

Piers Lincoln
Institute Manager

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Opening the doors to world-class infrastructure is only the first step.

Optofab – Facilities at University of Adelaide

The Australian National Fabrication Facility

Established under the National Collaborative Research Infrastructure Strategy, the Australian National Fabrication Facility (ANFF) links eight university-based nodes to provide researchers and industry with access to state-of-the-art fabrication facilities. The capability provided by ANFF enables users to process materials (glasses, metals, composites and ceramics, polymers and polymer-biological moieties) and transform these into structures that have applications in sensors, medical devices, nanophotonics and nanoelectronics.

The ANFF difference

Opening the doors to world-class infrastructure is only the first step. Without dedicated staff to support access, breakthrough research remains just an idea. Each ANFF node has experts on hand who are experienced in meeting user requirements and maintaining leading-edge instrumentation to assist researchers. Over 60 technical staff positions are funded through the program. Researchers can either work at the node under expert guidance, or contract for the fabrication of specialised products.

Optofab node of ANFF

Optofab, led by Prof Michael Withford of Macquarie University, consists of four facility centres at Macquarie University, Bandwidth Foundry International, University of Sydney and the University of Adelaide. The headquarters are located at Macquarie University.

5-Axis Ultrasonic Mill

New high-tech materials and much higher demands being placed on surface quality and precision have made the utilisation of new manufacturing technologies and machining methods indispensable.

Funded under the Australian National Fabrication Facility (ANFF), IPAS has installed a DMG DMU-20 Linear Ultrasonic that offers the perfect solution by combining precision and versatility at a level of efficiency that was inconceivable only a few years ago. Specialised machining requirements are now available for soft, hard and advanced high-performance materials which have been traditionally difficult to machine.

3D Metal and Ceramic Printer

3D printing facilitates offer rapid prototyping and manufacturing, allowing for the fast availability of functional prototypes for product development, as well as on demand manufacturing for research projects and industry requirements. 3D printing complements traditional development and manufacturing methods and reduce the time and cost of designing metal or ceramic parts by printing them directly from digital input. In September 2014, IPAS commissioned a Phoenix PXM (3D Systems ProX 200) selective laser melting printer, which is now available to both Researchers and Industry for their 3D printing requirements.
Optofab – Facilities in Adelaide

Optofab – Facilities in Adelaide specialises in optical fibre, glass and functional optical materials production. The range of key services offered include:

- Soft glass fabrication
- Soft and hard glass and polymer preform extrusion
- Doped silica preform fabrication
- Soft glass fibre drawing including microstructured fibres
- Silica fibre drawing including microstructured fibres
- Surface functionalisation of glasses and fibres
- Scanning Near Field and Atomic Force Microscopy (SNOM/AFM)
- DMG DMU-20 Linear Ultrasonic, 5-axis milling machine with ultrasonic milling capability for machining of glass, ceramics and metals
- 3D printing – metals and ceramics

Accessing the Facilities

The ANFF seeks to enhance national and international collaborations and enable world-class research by providing access to specialised facilities. Direct access to instrumentation is provided on an hourly rate or Fee-for-Service basis. Research Collaborations, Contract R&D and Consulting are also welcomed. Dedicated staff are on hand to discuss your requirements, and assist accessing these leading-edge research capabilities.

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IPAS Research Facilities

The Braggs is a unique transdisciplinary building that enables the co-location of IPAS researchers and students from a broad range of scientific disciplines and facilities including:

- Precision measurement of time, temperature and frequency
- Photonic sensor development
- Advanced manufacturing including 3D ceramic and metal printing (ANFF Optofab)
- Glass and optical fibre development and processing
- Laser development
- Luminescence dating and radiation measurement
- Synthetic and surface chemistry.

The Braggs is an accelerator facility, designed to speed up the pace of research by bringing together all the people working in these disparate disciplines and providing them with facilities required to progress further than would be possible in a traditional physics or chemistry lab (for example we now have the ability to bring clinical samples into the laboratories to test them using new measurement tools developed within our labs a critical enabler for our new ARC Centre of Excellence for Nanoscale BioPhotonics).

Other world-class research facilities underpin the vital research conducted by IPAS members include:

- The Adelaide Proteomics Centre
- The STARR Lab (Reproductive BioPhotonics)
- Atmospheric Physics – Buckland Park
- Advanced LIGO and the Gingin Facility
- Bragg X-ray Crystallography Facility

These facilities service the needs of IPAS researchers and offer contract services to researchers and companies across the world.

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Prof Andre Luiten
IPAS Director

Prof Andre Luiten is 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.

Prof Andre Luiten obtained his PhD in Physics from the University of Western Australia in 1997, for which he was awarded the Bragg Gold Medal. He has subsequently held three prestigious Fellowships from the ARC. For his efforts Andre was the joint inaugural winner of the WA Premier’s Prize for Early Career Achievement in Science. Andre came to the University of Adelaide in 2013 to take up the Chair of Experimental Physics and a South Australian Research Fellowship from the Premier’s Research and Innovation Fund. He has published 6 book chapters and authored over 100 journal papers (with over 3,300 citations) and over 100 conference papers, and has raised over $18M for research. Andre’s research focuses on the development of state-of-the-art instrumentation, across many diverse areas of physics, to solve problems and make measurements that were not previously possible.

Prof Heike Ebendorff-Heidepriem
IPAS Deputy Director

Prof Heike Ebendorff-Heidepriem is Deputy Director of the Institute for Photonics and Advanced Sensing (IPAS) and Associate Director of the Optofab Adelaide node of the Australian National Fabrication Facility (ANFF). She is Senior Investigator of the ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP).

Heike obtained her PhD in chemistry from the University of Jena, Germany in 1994 and subsequently held two prestigious fellowships. From 2001 to 2004 she was with the Optoelectronics Research Centre at the University of Southampton, UK. Heike came to the University of Adelaide in 2005. She was awarded the Woldemar A. Weyl International Glass Science Award in 2001, the International Zwick Science Award in 2009 and the University of Adelaide Women’s Research Excellence Mid-Career Award in 2014. Heike has published over 230 refereed journal papers and conference proceedings, including 5 review papers and 9 postdeadline papers, and raised approximately $12M for research. Heike’s research focuses on the development of novel optical glasses, fibres, surface functionalisation and sensing approaches.

Prof Peter Hoffmann
IPAS Deputy Director

Prof Peter Hoffmann is Deputy Director of the Institute for Photonics and Advanced Sensing (IPAS), Director of the Adelaide Proteomics Centre and Director of the National NCRIS facility for Tissue Imaging Mass Spectrometry. Peter is a HUPO Council Member, the Vice President of the Australasian Proteomics Society, Conference Chair for the National Meeting of the Australasian Proteomics Society, and the South Australian Representative of the Australian Peptide Society.

Peter obtained his PhD in Analytical Chemistry from Saarland University, Germany in 1999. He came to the University of Adelaide in 2005 to establish the Adelaide Proteomics Centre. He has published over 85 papers in refereed journals and raised approximately $8.9M for research. Peter’s research is focussed on biomarker discovery in cancer, detection of protein phosphorylation and Tissue Imaging Mass Spectrometry. He recently formed the spin out company Onco DX to commercialise patented biomarkers for the early detection of ovarian and gastric cancer.
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