



Annual Report 2017

INSTITUTE FOR PHOTONICS AND ADVANCED SENSING

adelaide.edu.au/ipas

Institute Highlights



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Introduction from the DVC-R and the Board Chair



Dr. Warren Harch IPAS Board Chair

Report from the Board Chair

2017 was the eighth year of operation for IPAS. It was a highly productive year for IPAS and again demonstrated the Institute's trend of increasing outputs from its researchers. Many of these are outlined in the body of this report.

From a board perspective it is pleasing to see both the breadth and depth of achievements.

This is illustrated by:

- A large number of awards for individual and team performance
- Recognition of Entrepreneurship & Industry partnerships with initial sales for start ups Miniprobes Pty Ltd and Cryoclock Pty Ltd.
- Demonstrated Benefits to South Australia including the launch of the Photonics Cluster workshop in collaboration with the Department for State Development (DSD) and the establishment of a major 3D printing network AMARN providing access to 3 large 3D metal printers
- Continued development of international partnerships including a new International Strategic Partnership with China for Fibre-optic Oil/gas Detection Innovation (CAFODI)

The substantial growth and capabilities of the Institute demonstrate that IPAS is tracking well in the key research strategies of IPAS excellence, innovation, global and enabled.

The Vice-Chancellor Professor Peter

Rathjen has already indicated that the University is to commence consideration of a new strategic plan in broad consultation with internal and external stakeholders. A key role for the IPAS Board during 2018 will be to ensure compatibility between the development plans of IPAS and the new strategic goals of the University.

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

Warren Harch, Board Chair

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Professor Mike Brooks Provost and Deputy Vice-Chancellor (Research)

Introduction from the Provost and Deputy Vice-Chancellor (Research)

The University's Research Mission is to conduct world-class research and innovation, engage globally, and partner with industry, government and the community to create high-value economic and social dividends. The most recent National Survey of Research Commercialisation shows that, in 2015, the University of Adelaide had the fourth highest value (\$84 million) and number (1297) of 'Research Contracts, Consultancies and Collaborations' in Australia. One of the drivers of this success has been the work of our University Research Institutes. The Institute for Photonics and Advanced Sensing (IPAS) brings together over 200 researchers, working towards creating knowledge and disruptive new technologies to solve problems for health, the environment, mining and defence. IPAS seeks to combine scientific and technical excellence with its track record of strong external engagement to facilitate industry development.

During 2017 IPAS continued to strengthen relationships with key government and industry stakeholders, as well as create new strategic partnerships with prestigious international institutions. For instance, the South Australian Additive Manufacturing Applied Research Network is a new major initiative led by IPAS that will place South Australia at the forefront of Additive Manufacturing. Also, a new Joint Laboratory for Fibre-optic Oil/Gas Detection Innovation with Shandong University, one of the largest universities in China, promises to increase commercialisation and application of research outcomes, boosting innovation and international competitiveness.

This report provides an overview of the substantial range of high-quality activities undertaken throughout 2017. It provides excellent examples of how world-class fundamental research can be undertaken in partnership with industry.

Professor Mike Brooks, Provost and Deputy Vice-Chancellor

Message from The Director

One terrific aspect of being in my position is that each year I get to write this message in which I need to search for ever-escalating superlatives to describe the breakthrough work of the previous year.

This last year is no exception: IPAS members are driving research and industry engagement on an ever-steepening trajectory. This year we have doubled our research income from industry, hitting our stretch target where industry funds now form half of our overall research income. Equally pleasing was a doubling of the number of papers published in journals with an impact factor over 10. A publication in a journal with an impact factor in this range is a demonstration of research that is in the most elite international class. Congratulations to our members for their fantastic efforts and hard work, which are living up to our mission: delivering world-class research while driving great engagement with the community outside the University. All of this is only possible because of the excellent transdiscplinary relations within our membership, continuous project management, and the support of dedicated personnel in grants and business development to generate a pipeline of new projects.

We were excited about the launch in November by Defence Industry Minister Christopher Pyne of the new University of Adelaide Defence Research and Innovation Network, which will see the Defence Science and Technology Group (DST Group), and Defence industry researchers working on campus alongside our researchers and students. IPAS and Defence have long enioved a successful relationship, starting with the formation of the Centre of Expertise in Photonics (IPAS's predecessor) a little over 10 years ago. Joint IPAS-defence projects range from new lasers, new glass materials, optical fibre technology, magnetometry as well as low noise oscillator technology. There will doubtless be many more projects growing out of these closer arrangements.

In 2017, two start-up companies originating out of IPAS made their first sales - Cryoclock Pty Ltd and Miniprobes Pty Ltd, while two new companies were incorporated. I have no doubt that over next year these new companies will also be generating revenue showing the value of our members' work. Over 2018, we will see major developments in our Advanced Manufacturing activities thanks to a \$1.4 million State Government grant which will see IPAS establish the Southern Hemisphere's most advanced, state-of-the-art 3D metal printing facility. Access to this world-leading technology in a certified facility will allow local companies to manufacture innovative parts for the growing medical device, aerospace and defence industries. This will lead to enhanced productivity and new jobs for the state.

IPAS's vision is to develop innovative sensors to make the world healthier, wealthier and safer. I think you can see from the stories contained in this document that we are accomplishing across the spectrum of our vision. As always, if IPAS can help you, or if you can help us, then please do not hesitate to contact me.

Prof Andre Luiten, IPAS Director



Prof Andre Luiten, IPAS Director



IPAS Headquarters, The Braggs Building

IPAS Research Ecosystem



The Institute for Photonics and Advanced Sensing drives a transdisciplinary approach to science and excellence in research through the development of disruptive new sensing and measurement technologies.

We engage with a wide range of priority industries to understand the measurement challenges they face, that if solved, would transform industry productivity and social wellbeing. We harness the core capabilities and form interdisciplinary teams around a wide array of funded research projects.

The outcome and impact of these projects range from new Scientific Discoveries and Innovations to Spin-Out companies and new jobs created.



IPAS Governance

IPAS Board









Dr Cathy Foley



Dr Andrew Dunbar

Dr Peter Fisk









Prof Julie Owens Prof Andre Luiten Mr Piers Lincoln

Secretary

IPAS Executive Committee



Prof Andre Luiten IPAS Director



Prof Heike Ebendorff-Heidepriem IPAS Deputy Director



IPAS Institute

Manager

Prof Robert

McĽaughlin

Elodie Janvier IPAS Strategic Research Development Manager



Sara Leggatt IPAS Senior Office Administrator & Executive Assistant Manager



Research Support & Marketing Officer



Luis Lima-Marques IPAS Laboratory Manager



Tim Nelson IPAS Project Manager



Prof David Ottaway



Dr Jiawen Li SNC co-representative



Dr Ben Sparkes SNC co-representative

IPAS Scientific Leadership Committee









Prof Mark Hutchison





Prof Robert McLaughlin



Prof David Ottaway



Spooner



Prof Yvonne Stokes





Prof Christian Doonan



Prof Carolin Plewa



A/Prof Martin 0'Connor



A/Prof Tara Pukala



A/Prof Reza Ghomaschi



A/Prof Gavin Rowell

Lambert

A/Prof Tak Kee



Dr Jiawen Li



Dr John Bruning



Dr Ben Sparkes



Dr Philip Light



Dr Abel Santos



Dr Tom Avery

Dr Yinlan Ruan



Dr Erik Schartner







Dr Sanam Mustafa



Dr Stephen Warren-Smith



Luis Lima-Marques



Dr Giuseppe Carlo Tettamanzi



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, while 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, Australian Bureau of Statistics, Maptek, Coherent, Lastek, the Defence Science and Technology Group and the Australian Antarctic Division).

IPAS Science Network Committee

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The Science Network Committee 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 and ECRs within IPAS, with the added focus of supporting students in all aspects of their postgraduate experience. The co-Chairs of the Science Network sit on the IPAS Scientific Leadership Committee.



Dr Jiawen Li Co-Chair



Dr Ben Sparkes Co-Chair





Vicky Staikopolous Dr Stephen Warren Dr Akash Bachuka Smith





Dr Ruth Shaw



Sarah Scholten

Dr Tom Avery



Mohammad Shafiqur Rahman





The IPAS Student Experience

Student Prizes

Students were invited to present their 2017 research in a five-minute talk. The Tanya Monro best presentation prize and the Merry Wickes-sponsored transdisciplinary prize, both worth \$500, were on offer.

The winners were announced at the IPAS annual New Year event. We would like to thank Merry Wickes for her ongoing support of the transdisciplinary prize.

- > Ms Kathryn Palasis, PhD student Tanya Monro Best Student Oral Presentation Prize
- Mr Craig Ingram, Master student Merry Wickes Transdisciplinary Oral Presentation Prize





Ms Kathryn Palasis, recipient of the Tanya Monro Best Student Oral Presentation Prize.

Ms Kathryn Palasis, PhD student

My research, under the supervision of Prof Andrew Abell and Prof Rob McLaughlin, is on the development of drugs that can be switched between an active 'on' state and an inactive 'off' state using light. These drugs have the potential to reduce side effects often experienced by patients during treatment (e.g. chemotherapy). The switchable drugs could be administered in the inactive state and then locally activated only at the target area (e.g. tumour) using light, hence helping to reduce side effects caused by off-site toxicity including anaemia, pain and hair loss. Being part of the IPAS community has provided me with many opportunities to advance my development as a researcher. I was pleased to be able to present my work at the Student Presentation Event and I have particularly enjoyed the social/networking events which have allowed me to meet and chat to new people outside of my specific chemistry discipline. The collaborative environment of IPAS has also enabled me to work on an interdisciplinary project, involving both my principal supervisor Prof Abell in chemistry as well as Prof McLaughlin in bioengineering and imaging.



Mr Craig Ingram, recipient of the Merry Wickes Transdisciplinary Oral Presentation Prize.

Mr Craig Ingram, Master student

My research project, under the supervision of Prof. Peter Veitch and Prof. David Ottaway, is part of OzGrav's research into the design of next-generation gravitational wave detectors in collaboration with the LIGO Scientific Collaboration. These detectors may use cryogenically-cooled silicon test mass mirrors to reduce thermal noise and thus improve sensitivity, which would require a laser wavelength > 1.5um. Wavelengths near 2 um have been suggested but fused silica, which is currently used for auxiliary optics within the detectors, may absorb too much power at these wavelengths. Thus, the aim of my project is to measure the optical absorption in IR-grade (low OH) bulk fused silica at these wavelengths using a high sensitivity Hartmann wavefront sensor.

The support offered through IPAS in the form of seminars, workshops and networking events has been invaluable to help me develop as a researcher and the access to the knowledge and expertise of its local members have played an important role in my development as a research scientist.

Congratulations



A/Prof Jonathan George

ARC Future Fellowship

Congratulations to Associate Professor Jonathan George on receiving an Australian Research Council (ARC) Future Fellowship (\$820k) to study the biosynthesis of usual antibiotic products, using marine microorganisms, towards the creation of new antibiotics.





Dr Wenle Weng

Dr Tim Zhao

Prestigious International Fellowships

Congratulations to Drs Wenle Weng and Tim Zhao for being respectively awarded prestigious Marie Sklodowska-Curie Action Fellowship (MSCA) and Humboldt Fellowships.

Wenle will be spending 2 years at the prestigious École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland investigating the synthesis of low noise microwaves using solitons locked to an ultra-stable cavity.

Tim will be spending 2 years at the world-renown Leibniz Institute of Photonic Technology (IPHT) in Germany leveraging multifunctional optical fibers for upconversion luminescence.



Dr Abel Santos

University of Adelaide Research for Impact Fellowship

Congratulations to Dr Abel Santos for being awarded a Research for Impact Fellowship, aimed at retaining, attracting and supporting early-career and mid-career researchers of outstanding research calibre and potential. Abel's project aims at developing labelfree lab-on-a-chip nanophotonic sensing systems for multiplexed and high-throughput detection of cancer biomarkers.



Prof Andre Luiten

Barry Inglis Medal Awarded to Prof Andre Luiten

Professor Andre Luiten was awarded the Barry Inglis Medal from the National Measurement Institute (NMI). Not only does the award recognise achievement in measurement research and excellence in practical measurements, the medal was presented by Dr Barry Inglis himself.



Emeritus Professor Bob Vincent

Queen's Birth Honours for Leader in Solar-Terrestrial Physics

Congratulations to Emeritus Professor Bob Vincent, whose contribution to atmospheric physics, gravity waves and radar hardware, was recognised with a Member in the General Division (AM) award in the Queen's Birthday honours. Professor Vincent's academic and research career spans 50 years, having published more than 300 articles, that have been cited more than 9500 times. Specifically, his work is in the top 0.5% by citations in Geoscience (Institute for Scientific Information, ISI, ranking).



A/Prof Tara Pukala

Bowie Medal Award for Tara Pukala

A/Professor Tara Pukala has been awarded the Bowie Medal from the Australian and New Zealand Society for Mass Spectrometry (ANZSMS) which recognises research excellence in the field of mass spectrometry by an Australian or New Zealand researcher under the age of 45 years.



Dr Jonathan Hall with Apple co-founder Steve Wozniak

2017 Asia Pacific Global Winner – Talent Unleashed Awards

Artificial Intelligence fertility startup Life Whisperer has been crowned AsiaPacific Global Winner of the 'Best Idea – One to Watch' category in the 2017 Talent Unleashed Awards. Life Whisperer's cofounder and inventor, IPAS member Dr Jonathan Hall, received his award from the tech entrepreneur and Apple co-founder Steve Wozniak.

Women's Research Excellence Award

Congratulations Dr Jiawen Li, who won a Women's Research Excellence award. Jiawen used the award to travel to RMIT University where she developed unique expertise of 3D printing freeform micro-optics for fibre-optic probes. She also travelled to Singapore and gave an invited talk on 'Miniaturized Multimodal Fiber-optic Probes: Ex Vivo and In Vivo' at Conference on Lasers and Electo-Optics (CLEO) Pacific Rim.

Gravitational Waves win Nobel Prize!

The 2017 Nobel Prize for Physics was awarded for gravitational waves. This Nobel Prize is as much a recognition of the work of Professors Weiss, Barich and Thorne as it is of the many researchers they've been working alongside as part of an extensive international collaborative team that includes many Australians, such as the LIGO and OzGrav team here at IPAS.



Prof Heike Ebendorff-Heidepriem

Prof Heike Ebendorff-Heidepriem winner of 2017 Winnovation Award category Technology and elected OSA Fellow

Congratulations to our Deputy Director Prof Heike Ebendorff-Heidepriem who has won the 2017 Winnovation Award – category Technology! IPAS Deputy Director and Director of the Optofab Adelaide Node of the Australian National Fabrication Facility (ANFF), Prof Ebendorff-Heidepriem has demonstrated her outstanding leadership role in the establishment of the Adelaide node of Optofab, a state-of-art glass science, fibre fabrication and 3D manufacturing research facility. The Winnovation Awards celebrate the successes of female innovators changing the game in South Australia.

Heike was also elected as a Fellow Member of The Optical Society (OSA), a prestigious appointment, honoring Heike specifically for her ground breaking science contributions to the field of optical glasses and fibers.



(left to right) Emeritus Professor John Wallace, Prof Grant Booker, Prof Andrew Abell, Dr Steven Polyak

Prof Abell and team featured in NHMRC top 10 projects

"Inhibitors of biotin protein ligase: A new class of antibiotic targeting Staphylococcus aureus" led by Prof Andrew Abell and his team was recognised by the NHMRC in 2017 as 1 of the best 10 NHMRC research projects. This project successfully engaged chemistry and biochemistry to discover a new antibacterial by inhibiting a key protein - known as biotin protein ligase (BPL)- as a potential mechanism for limiting bacterial survival.

LIGO & Miniprobes featured by the Australian Research Council

Published by the Australian Research Council on 1 August 2017, "Making a difference – Outcomes of ARC supported research" features IPAS and CNBP's research on Detecting Gravitational Waves & Smart Needle To Make Brain Surgery Safer in the "Understanding Our World and Translating Fundamental Research" section. This publication is a snapshot of some of the outstanding research outcomes derived from research projects funded by the Australian Government through the ARC National Competitive Grants Program.

Faculty of Science Award

Congratulations to Dr Stephen Warren-Smith who received the 2017 Faculty of Sciences Emerging Industry Research Partnerships Award for for his work on High-Temperature Sensing.

Market Driven Application Defence Technologies

Sapphire Clock

Prof Andre Luiten Adj. Prof John Hartnett A/Prof Martin O'Connor **Dr Fred Baynes** Dr Waddah Al-Ashwal

Funding: Australian Defence Forces

The Sapphire Clock, developed by Prof Andre Luiten and his group, is a cryogenic sapphire oscillator that allows time to be measured to the femtosecond scale (one quadrillionth of a second), with only a single second gained or lost every 40 million years.

In recent times, the extremely highperformance of the oscillator has found a practical and strategic application in Australian Defence by improving the performance of a key radar asset. The Jindalee Over the Horizon Radar Network (JORN), a multi-billion dollar linchpin of Australia's defence surveillance, monitors air and sea movements across 37,000 km²; playing a vital role in supporting the Australian Defence Force's air and maritime operations, border protection, disaster relief and search and rescue operations.

The sapphire oscillator offers performance more than 1000 times better (in the relevant ranges) than the current technology used by JORN. The early tests of the device were so convincing that Defence Science and Technology (DST) Group researchers believe that they are likely to obtain a significant lift in radar sensitivity. The Commonwealth has decided it will acquire



The Hon Christopher Pyne MP, Minister for Defence Industry visiting the CSO lab

the Sapphire Clock technology to support JORN through its \$1.2B Project Air 2025 Phase 6 upgrade.

The Australian Defence Forces have invested more than \$4M to drive the development up the technological readiness ladder as well as to supply 3 units. Subject to a successful demonstration in 2018, Defence will order a number of units to meet the needs of JORN. Additional strategic benefit is that this key technological advance has been underpinned by an Australian innovation, workforce and capability.

W.A. Al-Ashwal, A. Hilton, A.N. Luiten, J. G. Hartnett, Low Phase Noise Frequency Synthesis for Ultra-Stable X-Band Oscillators, IEEE Microwave and Wireless Components Letters 27, 392-394 (2017).



Jillian Moffatt, Nigel Spooner and Georgios Tsiminis with the UF facility dual-laser systems.

Upconversion Fluorescence for Real-time Stand-off **Detection and Identification** of Explosives

Adj. Prof Nigel Spooner, Prof David Ottaway, Dr Georgios Tsiminis, **Ms Jillian Moffat**

Funding: Defence Industry & Innovation Counter Improvised Threats Grant Challenge - \$788,880 awarded in 2017

IPAS members have received funding from Defence Industry & Innovation to research a potentially transformative technology for stand-off real-time explosives sensing.

There are currently no robust, rapid technologies suitable for application in the field for real-time detection and identification of explosives at stand-off ranges of 10 m or more. Other technologies exist, such as laser-induced breakdown spectroscopy or Raman spectroscopy, but all have limitations that impact their efficacy and potential for real-world deployment.

The team will use leading-edge laser technology including mid-IR lasers developed at IPAS to explore upconversion fluorescence (UF) from explosives molecules, precursors and products, aiming to demonstrate the feasibility of UF for stand-off sensing, and define the required parameters for deployable UF explosives sensors.

This research leverages extensive investment by the Australian mining industry, through CRC ORE, which has created the globallyleading UF research facility at IPAS.

Market Driven Application

Medical Diagnostics & Devices

Tiny Probe Makes a Big Difference

Prof Robert McLaughlin Dr Jiawen Li Bryden Quirk Rodney Kirk

Funding: 2017 TechInSA \$200k South Australian Early Commercialisation Fund for Miniprobes, Pty Ltd.

IPAS members, led by Prof Robert McLaughlin head of the Bioengineering Imaging Group, launched their spin-out company, Miniprobes Pty Ltd at the 2017 SPIE Photonics West Conference in San Francisco.

Designed to acquire high-resolution optical images deep within the tissue, their first product has already found its market. Integrated into a brain biopsy needle, they were shown during in vivo human trials to be able to detect blood vessels, avoiding bleeds that can potentially be fatal, thereby making brain surgery safer.

The team is now exploring other applications for their 'smart needle' technology, both in the biotech and industrial space while working on the next generation of multifunction imaging probes.

As highlighted in the Australian Research Council's recent publication *Making a difference, Understanding our world and translating fundamental research,* "The 'smart needle' is an outstanding example



Education and Training Minister Senator Simon Birmingham testing a smart needle

of how ARC-funded research can translate into real world benefits—in this case, commercially for the medical technology industry and, ultimately, improved health services for Australians".

Optical Fibre Sensing to Aid Breast Cancer Research -One Step Closer to Clinical Trials

Dr Erik Schartner Dr Elizaveta Klantsataya Prof Grantley Gill Prof Mark Hutchinson

Funding from the Adelaide Enterprise Commercial Accelerator Scheme has allowed an IPAS research team led by Dr Erik Schartner to work with clinicians at the Royal Adelaide Hospital and biomedical engineers within the Medical Device Partnering Program (MDPP) to bring their technology one step closer to clinical trials.

Dr Schartner has developed an optical fibre probe that distinguishes breast cancer tissue from normal tissue – potentially allowing surgeons to be much more precise when removing breast cancer, avoiding removal of excessive healthy tissue, or some cancerous tissue being left behind. These results were published in the leading journal "Cancer Research."

The team is now working on taking their research from the lab to the operating theatre, developing a device that could provide a portable, cost-effective solution to prevent follow-up surgery, currently needed for 15-20% of breast cancer surgery patients where all the cancer is not removed.



Dr Elizaveta Klantsataya

Market Driven Application Mining & Mineral Processing Sensors

Ultra-high, multipoint temperature sensors

Prof Heike Ebendorff-Heidepriem **Dr Stephen Warren-Smith Dr Linh Nguyen** Prof Tanya Monro

Funding: Major new research contract with Mitsubishi Heavy Industries in 2017

Giant industrial engineering and manufacturing company, Mitsubishi Heavy Industries has signed a series of collaborative research contracts for IPAS to develop unique optical fibre based ultrahigh, multipoint temperature sensors that will enhance the efficiency of their power generation systems.

Mitsubishi came to Adelaide looking for global research partners and decided the Institute's ultra-high temperature optical fibre sensors would provide a unique opportunity to better understand and improve their world leading power generation systems.

This new collaboration represents international recognition for the quality of IPAS' research and development, and the difference these emerging disruptive technologies like photonics can make to businesses' bottom lines.

The Mitsubishi contract will build on the technology that IPAS developed with SJ Cheesman for deployment at the Nyrstar Polymetalic Smelter at Port Pirie. This provided novel temperature sensors that can withstand furnace temperatures, enabling processes within the environment of the smelter to be monitored for the first time enabling increased efficiency and significant reductions in energy use.





IPAS Node of the ARC Australian Copper-Uranium Transformation **Research Hub**

Prof David Ottawav Adj. Prof Nigel Spooner **Prof Heike Ebendorff-Heidepriem Dr Chris Kalnins Dr Ruth Shaw Michael Clarke Jarrah Mik Mick Stuckings Danielle Questiaux**

Funding: ARC Industry Transformation Research Hub - \$1.4M funding pa

The Hub, led by the Institute for Mineral and Energy Resources at the University of Adelaide, is enhancing the value of Australian copper resources by developing and testing new, cost-effective ways to remove nontarget metals from copper ores in South Australia and internationally; in partnership with researchers from the University of Queensland, Monash University, Flinders University, BHP, OZ Minerals, Defence Science and Technology Group and the Department of State Development.

IPAS member Prof David Ottaway is leading the Hub node dedicated to 'Analysing the Rocks', aiming to develop new scanning technologies to locate and quantify nontarget metals, including in real-time.

The IPAS team is developing solid state and liquid based radiation sensors for detecting natural radiation fields in copper ore. Within solid state sensing the group has created a revolutionary process to spatially locate alpha producing minerals to microscale resolution. This process will help quantify and understand mineral distribution within the ore. Liquid sensing utilises optical fibres to detect extremely low concentrations of non-target metals in real time at the mine site. Real time liquid sensing allows for rapid processing turnaround that can support a constantly operating mineral processing plant.

The Cu-U Hub has also leveraged over \$1 million of additional funding to establish a Radiation Sensing Capability to evaluate mineral processing ore samples at different stages within the plant. The University of Adelaide based capability resides in the Braggs building.

Market Driven Application

Extreme Astronomy

'Biggest discovery of the year' 2017: Observation of Gravitational Waves from a Binary Neutron Star – or how Gravitational waves revealed the origin of gold

Prof David Ottaway Prof Peter Veitch Prof Jesper Munch

Funding: ARC Centre of Excellence for Gravitational Wave Discovery

IPAS members are part of a team of Scientists, the LIGO team, who witnessed for the first time ever a merger of a binary neutron star. Published throughout several papers in the journal Physical Review Letters, this highly significant discovery marks the beginning of a new age in astronomy.

The LIGO team, whose earlier discovery of gravitational waves led to a Nobel Prize in 2017, reports that it is the first time that an astronomical phenomenon has been sensed through gravitational waves first, allowing them to pinpoint its location 130 million light-years away then observe the collision unfold through optical and electromagnetic telescopes.

Building the future of Gamma-Ray Astronomy: The Cherenkov Telescope Array

A/Prof Gavin Rowell

Funding: \$413,000 research income in 2017, from ARC and the Department of Industry, Science and Resources.

TeV gamma-ray astronomy is recognised as one of the major emerging activities in astronomy world-wide. It probes extreme processes in the Universe such as exploding stars, black holes, and mysterious dark matter.

Drawing on their extraordinary success with the High Energy Stereoscopic System (HESS), IPAS members are working with the global community of gamma-ray astronomers towards developing the next-generation instrument in this field, the Cherenkov Telescope Array (CTA).



Artist's illustration of two merging neutron stars - NSF/LIGO/Sonoma State University/A. Simonnet

Combining all these technologies means scientists can now have data on the entirety of a phenomenon. In this case, the team was able to conclude that the collision produced a radioactive "kilonova", an explosion producing gamma-ray burst generating an astounding amount of energy, allowing the generation of platinum, gold, silver, and other heavy elements, which scientists had long theorised yet never experimentally proven until now, how they had been created in our universe.

10 times more sensitive than the HESS, the CTA is a significant advance in very highenergy gamma-ray astronomy. Over 1000 scientists from 31 countries are involved and the first telescopes will soon be on site, at La Palma, Canary Islands, Spain in the Northern hemisphere and Paranal, Chile in the Southern hemisphere.

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Led by IPAS member, A/Prof Gavin Rowell, this project receives funding from the Australian Research Council and the Department of Industry, Science and Resources to ensure future access for Australian scientists to the most advanced TeV gamma-ray astronomy facility ever built. It will solidify Australia's commitment to this emerging field that will influence the operations of other areas of astronomy over the next decade.

CTA represents a new advancement in high energy astrophysics, and IPAS' involvement in the telescope hardware and interaction with international PIs will allow Australian scientists Abbott, B., Abbott, R., Abbott, T., Acernese, F., Ackley, K., Adams, C., . . . Woudt, P. (2017). Multi-messenger observations of a binary neutron star merger. Astrophysical Journal Letters, 848(2), L12-1-L12-59.

Abbott, B., Abbott, R., Abbott, T., Acernese, F., Ackley, K., Adams, C., . . . Bero, J. (2017). GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral. Physical Review Letters, 119(16), 161101-1-161101-18.



CTA Prototype Telescope, ASTRI

and technicians to further their experience with the cutting edge of CTA's many techniques (e.g. fast electronics, big data challenges, optics, atmospheric physics).

Environmental & Agricultural Monitoring



Australian Facility For Noble-Gas Radio-Isotope Measurements

Dr Philip Light Prof Andre Luiten

Funded by ARC Linkage Infrastructure, Equipment and Facilities Grant

Dr Philip Light, Prof Andre Luiten and partners at Griffith University and CSIRO are constructing a new facility to measure noblegas radio-isotope abundance, with a specific focus on ⁸¹Kr, ⁸⁵Kr and ³⁹Ar. Like radio-carbon dating (used to date artefacts between ~1,000-50,000 years old), noble-gases can be also used to date samples and offer much greater dating ranges, from a few years, to a million years and beyond. The facility will accurately date water and ice core samples, allowing a detailed understanding of water movement in underground reservoirs, ocean currents, and the impact of unconventional gas extraction on water systems. The facility will also be capable of detecting man-made emissions of such radio-isotopes, enabling the determination of compliance with nuclear non-proliferations treaties.

Counting the radio-isotopes in a sample is a difficult task: with abundances of ~10⁻¹⁵, finding a radio-isotope is like searching for a single grain of rice in the world's entire annual rice harvest! The facility will be one of the first globally to use the Atom-Trap Trace Analysis (ATTA) technique, which allows measurements, orders of magnitude smaller than conventional techniques such as lowlevel counting (LLC) or accelerator mass spectrometry (AMS).

Laser Airborne Methane Sensor

Prof David Ottaway Prof Peter Veitch

Funded by ARC Linkage Project Grant

The release of methane is the second biggest driver of anthropogenic climate change after CO₂. Methane is released from agriculture, natural gas delivery (leaking pipelines) and waste in landfills. In collaboration with Aerometrex Corp, a world's leading provider of aerial spatial mapping services for large constructions, infrastructure and natural resources, a team at IPAS is developing an airborne platform for detecting leaks over a broad area leading to a reduction of emissions in an economically efficient way. The new airborne methane sensor will enable methane leaks to be located and captured leading to improved environmental outcomes and improved efficiencies for natural gas companies.



Market Driven Application

Food & Beverage Analysis

Building on successful initial projects in collaboration with Industry, using sensing technologies for food and wine quality control, IPAS is partnering with the ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP) to develop and deploy new and existing technologies into food and beverage analysis; as well as consolidate our expertise in this space.

The red meat industry has its holy grail within grasp

Meat Standards Australia studies show that 77 per cent of consumers would eat more red meat if it was always tender; representing a huge market opportunity for the red meat industry.

IPAS/CNBP researchers are collaborating with SA-based company MEQ Probe to develop a hand-held probe that would provide objective measurement of the eating quality of carcases.

The probe is inserted into the carcase and sends a laser beam into the meat. Detecting the reflectance of this light and treating the signal with the help of machine learning gives a measure of the shear force and intramuscular fat of the carcase, strongly linked to the tenderness, juiciness and taste of the meat. All of the measurements are in real-time, so it easily keeps up with chain speed, and it can be used on hot carcases which currently isn't possible.



In 2017, the technology has been trialled on lamb and beef carcases in multiple abattoirs and the team is now working to deliver a probe which will be operational in an abattoir by the end of 2018.



New tools to guarantee ethical meat consumption

This project aims to create new cutting-edge chip-based technology that will be able to quantify the pain in livestock, not only the extent of current pain experienced but also a cumulative life measure of pain an animal has experienced.

IPAS and CNBP scientists have been trialling its technology in the field in pigs and hope to extend this to beef cattle in 2018.

This project has incredible implications for addressing livestock productivity and quantifying animal welfare. The team is really excited about the potential to guarantee to consumers that post culling an animal has lived a pain-free life. Not only could we know Australian livestock are clean and green but that they are also happy and healthy.

Collaborators

Global Engagement

We see an outstanding compounding growth of 57% in total research collaborations over the last 5 years. This growth is underpinned by a very strong increase in engagement with international partners. In the national sphere we are collaborating with most of the major scientific institutions in Australia.

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2017

International

2

Australia	30	
National Organisations	5	
South Australia		
Victoria		
Tasmania		
Australian Capital Territory		* <u>37</u>
Western Australia		
Queensland		and the state
New South Wales		and the second s
New Zealand	4	
North America	27	1
USA	24	
Canada	3	
South America	2	
Argentina	1	
Brazil	1	
Asia	22	
China	16	
Japan	4	
Singapore	1	
South Korea	1	
Europe	44	
UK	8	
Denmark	2	
Ireland	1	
Germany	14	
France	7	
Finland	2	
Poland	2	
Switzerland	2	
Italy	2	
Sweden	1	
Belgium	1	
Spain	3	
Greece	1	
Middle East	1	2015 2016
Israel	1	Global National



Industry Collaboration

IPAS engages with industry via consultancy, contract research, collaborative research and schemes co-funded by Federal Government and industry, such as industry-linkage grants. IPAS welcomes interactions from potential collaborators in all scientific fields. Current collaborations with commercial and development organisations include:



Trajan Scientific and Medical

TRAJAN

About the Partnership

Trajan's strategic collaboration with IPAS, supported by the South Australian Government, sees the realisation of a research and development and manufacturing hub, based on a new generation of specialty glass products for the global science and medical equipment market.

Innovations in optical material components are in great demand for Mass Spectrometry (MS) analysis, technology that is used to identify specific compounds in samples, whether it be fresh food, river water or human blood. The field of MS has expanded significantly over the past decade, in part due to the translation of the technique from the traditional chemistry laboratory, into life science and clinical settings. Improved MS will underpin progress in medical diagnostic and disease research, resulting in more rapid and accurate diagnoses.

Trajan's goal is for their new business unit – "Instruments, Sensors and Devices", based in The Braggs, to become a global centre of excellence for speciality glass, sensing and medical device technologies.

The hub will also help IPAS researchers commercialise their research into products that ultimately benefit human health and wellbeing.

IPAS Deputy Director, Prof Heike Ebendorff-Heidepriem, leads the collaboration and is working closely with Dr Anne Collins, Trajan's General Manager - Instruments, Sensors and Devices.

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Trajan Scientific and Medical named one of the top 20 leading "Businesses of Tomorrow" in Australia.

Commissioned by Westpac and conducted by Deloitte, the Businesses of Tomorrow study identified companies that are shaping Australia's future. Judging criteria included: track record of delivery, ability to meet future challenges and contribution to the community, industry or economy.

Trajan's strong collaborative relationship with researchers, such as IPAS within the University of Adelaide, allowing the company to be at the forefront of innovation, was a contributing factor in gaining a place in the top 20 list. Furthermore, Trajan's evolution from an engineering business to marketfocused company allows Trajan to "remain agile and adaptable to market needs".

Future of Photonics Innovation – finalist in 2017 Australian Financial Review Higher Education Awards!

The Future of Photonics Innovation, highlighting the strategic partnership between Trajan Scientific and Medical and The University of Adelaide, claimed a finalist place at the 2017 Australia Financial Review Higher Education Awards in the Industry Engagement category. These prestigious awards recognise innovation and achievement in Australia's higher education sector.



Trajan's General Manager - Instruments, Sensors and Devices, Dr Anne Collins.



Trajan's Principal Scientist - Photonics, Dr Herbert Foo

Photonics Catalyst Program 2.0 (PCP)



Building Collaborations Between Industry and The University of Adelaide using Light Based Technologies

The Photonics Catalyst Program 2.0 (PCP 2.0), 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 original PCP Program funded 20 new industry focussed projects between IPAS researchers and local companies. Based on the success of the original program, PCP 2.0 scheme is funding a further 5 projects.

Participants in the PCP receive a commercial and technical feasibility assessment of their project and matched funding of up to \$30,000 worth of research and development services to assist with the development of their new photonics product or prototype.

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 increasing advanced manufacturing opportunities for South Australia.

Silanna

Silanna is a semiconductor manufacturing company specialising in optoelectronic and electronic devices with offices in 7 countries and 200+ employees. Silanna owns and operates Australia's only advanced semiconductor manufacturing foundries. Silanna's silicon chip foundry manufactures silicon-on-insulator (SOI) and silicon-carbide (SiC) devices for the RF-switch and power switch markets. Silanna is also the owneroperator of the world's largest compound semiconductor foundry devoted to Gallium Aluminium Nitride ultraviolet light emitting



diodes (UV LEDs). These UV LEDs have a range of applications including water purification and the sterilisation of food processing equipment

The University of Adelaide is working with Silanna towards developing their next generation photonic semiconductor technology.

Ziltek

Ziltek is an Adelaide-based company that develops technologies for the global remediation industry. Ziltek's lead products are a handheld infrared detector 'RemScan' for in-field hydrocarbon detection in soil and RemBind, a powdered reagent for the immobilisation of polyfluoroalkyl substances (PFAS) in soil. Global customers include Chevron, Total, Shell and the United Nations.

Aqueous Film Forming Foams (AFFFs) are a class of fire-fighting foams that contain perand polyfluoroalkyl substances (PFAS). In 2009, perfluorooctane sulfonic acid (PFOS) was listed as a Persistent Organic Pollutant (POP) by the Stockholm Convention due to its potential toxicity effects, persistency, and bioaccumulation and biomagnifying properties. PFASs are generally soluble in water and so tend to readily leach from contaminated soil into groundwater, thus posing a potential risk to human health and ecological receptors. IPAS is working with Ziltek to develop rapid in-field analytical test method for PFAS.

Miniprobes

Miniprobes Pty Ltd is a high-tech South Australian company that develops and manufactures miniaturised fibre-optic imaging probes. We are the first commercial provider of imaging needles, where an imaging optical fibre is integrated into a medical needle, creating a 'smart needle' that can see where it is going.

Miniprobes and The University of Adelaide are collaborating to develop a low-cost scanner for the pharmaceutical industry. The product has the potential to help pharmaceutical companies test the quality of their tablets during production, leading to safer, more effective medicines. Building on their imaging needle technology, first developed for medical applications such as brain surgery, this project repurposes the imaging technology for high-tech manufacturing. The project uses a microlens on the end of an optical fibre, the thickness of a human hair, to focus a light beam and acquire a high-resolution image that reveals the internal structure inside a tablet. The project will allow Miniprobes to develop new international market opportunities in pharmaceuticals and other manufacturing industries.

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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 works closely with the commercialisation arm of the University, Adelaide Enterprise, 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.



Prof Andre Luiten and Adj. Prof John Hartnett created a high-precision sapphire oscillator, or more colloquially, a 'sapphire clock'.

The technology offers a deployable signal generation solution with an output 1000 times purer than existing and comparable commercially available products. They have identified three separate fields in which this technology immediately offers a step-change in performance: military radar, quantum computing and radio-astronomy.

To exploit the commercial potential, Luiten and Hartnett spun out a company, **Cryoclock Pty Ltd**, in 2016. The company has attracted a significant order in its first year of operation, supplying a clock to boost the performance of a quantum computing lab.

The extremely high-performance of the oscillator has found a practical and strategic application in Australian Defence, by improving the performance of a key radar asset. The Jindalee Over the Horizon Radar Network (JORN), a multi-billion dollar linchpin of Australia's defence surveillance, monitors air and sea movements across 37,000km²; playing a vital role in supporting the Australian Defence Force's air and maritime operations, border protection, disaster relief and search and rescue operations. Defence has already invested more than \$4M to drive the development of the technology.





Mirage Photonics is a start-up launched in 2016 by Dr Ori Henderson-Sapir. At the forefront of fibre-based mid-infrared (IR) laser development, it brings innovative solutions to the R&D and environmental sensing sector.

Mirage Photonics' first product, Mid-IR MFL-3500, is a continuously tuneable Mid-IR fibre laser operating at 3.5 μ m featuring broadband tuning with efficient room temperature operation.

As the first of its kind, it provides a new benchmark in efficiency and portability for 3.5 µm laser sources, with excellent beam quality. The MFL-3500 is ideal for atmospheric and environmental monitoring applications where tunability and portability are vital.





Miniprobes Pty Ltd is a South Australian startup incorporated by three IPAS researchers (Robert McLaughlin, Bryden Quirk, Rodney Kirk) to commercialise their smart needle technology. The team builds exquisitely small imaging probes, each encased in a medical needle, and able to acquire high resolution images deep inside the body. Their first product was launched in January 2017, and is a handheld imaging needle that allows potential industry partners to prototype the technology into their own product lines.

Miniprobes have collaborated with The University of Adelaide and Sir Charles Gairdner Hospital to complete the first human trial of their smart needle technology, demonstrating its ability to detect blood vessels in brain surgery.

The company is working closely with TechInSA to setup manufacturing facilities in South Australia, positioning Miniprobes as an OEM provider of this technology to a range of medical device manufacturers.

Miniprobes low-cost 3D scanning probe will be released in October 2018 – watch the video on Youtube here: <u>https://www.youtube.</u>

com/watch?v=tfaqRDyG_Pk.

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Facilities

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

5-Axis Ultrasonic Mill

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

DMU-20 Linear Ultrasonic Mill 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 highperformance materials, which have been traditionally difficult to machine.



3D Metal and Ceramic Printer

3D printing facilitates 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, reducing the time and cost of designing metal or ceramic parts by printing them directly from digital input. In September 2014, IPAS commissioned a Phenix PXM (3D Systems ProX 200) selective laser melting printer, which is now available to both Researchers and Industry for their 3D printing requirements.

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 at an hourly rate or via a 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 underpinning 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 researchers in IPAS and across the University and offer contract services to researchers and companies across the world.

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Notes

Notes



Prof Andre Luiten IPAS Director



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 114 journal papers (with over 4,120 citations), over 110 conference papers and has raised over \$20M 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. The excellence of his research has been recognised by the award of the Barry Inglis Medal from the National Measurement Institute, which acknowledges outstanding achievement in measurement research and excellence in practical measurements.

Prof Heike Ebendorff-Heidepriem IPAS Deputy Director



Prof Heike Ebendorff-Heidepriem IPAS Deputy Director

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

Heike obtained her PhD in chemistry from the University of Jena, Germany in 1994 and subsequently held two prestigious fellowships. From 2001-2004 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, The University of Adelaide Women's Research Excellence Mid-Career Award in 2015, and the Winnovation SA Technology Award from the SA Women in Innovation and Technology in 2017. Heike has published over 290 refereed journal papers and conference proceedings, including 5 review papers and 9 postdeadline papers, and raised over \$22M in research funding. Heike's research focuses on the development of novel optical glasses, fibres, surface functionalisation and sensing approaches.

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