Australian Synchrotron

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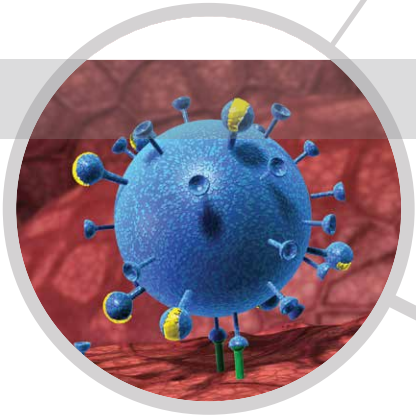

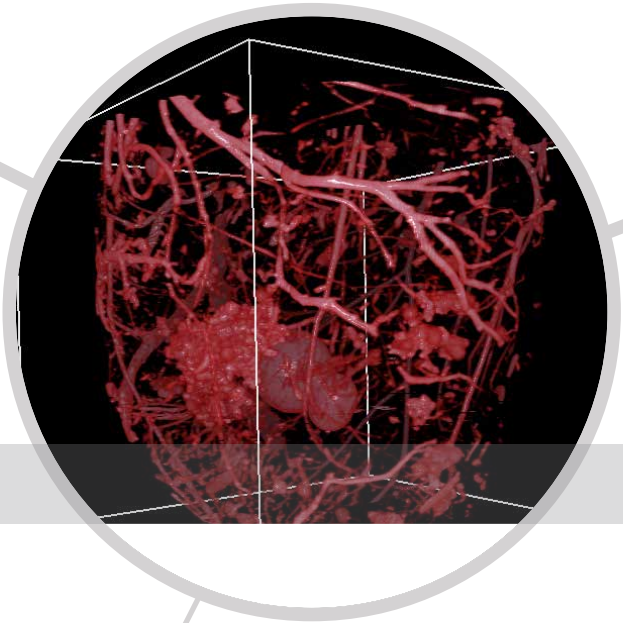

Synchrotron Light Source Australia Pty Ltd
ABN 18 159 468 256

Australian Synchrotron
Annual Report 2014

State Government Victoria

Australian Government

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Australian Synchrotron

About this Annual Report

The Australian Synchrotron Annual Report for 2014 provides an overview of the Australian Synchrotron's achievements in research excellence providing applied outcomes and industry solutions. The activities and highlights presented here illustrate the broad impact of this national landmark Australian scientific infrastructure.

This report is a public document and can be downloaded here:
http://www.synchrotron.org.au/news/publications/annual-report

Contents

About the Australian Synchrotron

The Australian Synchrotron is a world-class research facility that uses accelerator technology to produce a powerful source of light – x-rays and infrared radiation – a million times brighter than the sun.

The facility harnesses that light so researchers can see the fundamental structure, composition and behaviour of materials, on scales ranging from the atomic to the macroscopic – with a level of detail, speed and accuracy not possible using conventional laboratory-based equipment.

The Australian Synchrotron supports a broad range of high-quality research, with applications in sectors from medicine and nanotechnology to manufacturing and mineral exploration. Our highly advanced techniques and passionate staff contribute directly and demonstrably to scientific advances and industrial innovations with benefits for all Australians – with significant impacts in the areas of Health, Agriculture and Industry.

Vision

The Australian Synchrotron's vision is to be the catalyst for the best research and innovation in Australia and New Zealand. The focus for the facility is to provide a thriving environment that is conducive to creating, inspiring and nurturing the best outcomes, enabled by scientific excellence, for users and staff of the facility.

Mission

The Australian Synchrotron's mission is to enable science for the benefit of the community, by providing world-class synchrotron expertise and facilities.

Core values

The facility is driven by the core values of passion, respect, innovation, collaboration, and excellence.

Our research capabilities

The Australian Synchrotron's sophisticated scientific techniques provide benefits for diverse scientific and industrial fields and purposes, including:

Biomedicine: offering new, world-class diagnostic, imaging and therapeutic techniques and investigation of biomimetic materials (such as artificial skin and organs) as well as conducting cell imaging, and high-throughput structural biology capabilities.

Defence: enabling study of the atomic structure of materials, sensors and specialty alloys.

Environmental technologies and services: supporting environmental remediation work and analysing soil samples, the quality and composition of fresh and salt water, air and atmospheric samples, pollutants, toxins and contaminants.

Food technology: analysing the composition of ingredients, assessing the effectiveness of food processing and determining the nutritional impact of foods.

Forensics: refining or developing new forensic processes, techniques and applications.

Manufacturing: investigating the structure and characterisation of alloys, catalysts, fibres, textiles, adhesives, polymers, plastics, surfaces, interfaces and coatings; and analysing stresses in engineered components.

Minerals: supporting all aspects of mineral exploration and mineral processing.

Natural resources: supporting the development of exploration and processing, fuel processes, and fuel cell innovations.

Life Sciences and pharmaceuticals: analysing proteins, nucleic acids, bacteria and viruses that are fundamental to healthy biological function or disease; quality control monitoring, identification and assessment of the effectiveness of drug targets.

Scientific instruments: developing detector technologies, measurement techniques, medical implants and delivery systems.

Chair's Report

On behalf of the Synchrotron Light Source Australia (SLSA) Board I thank the management and staff of the Australian Synchrotron for their collective effort in establishing the Australian Synchrotron as one of the premier landmark science facilities in the country. This is evidenced by the quality of the scientific outcomes from a broad national and international user base from universities, industry and research agencies. A developing industry engagement program and excellent operational and financial management have rounded off a good year.

Strong and effective leadership of the Australian Synchrotron was assured when Professor Andrew Peele was appointed as the facility Director after a broad international search. It is great to have Australian-grown talent and in-depth experience in synchrotron-based science at the helm.

SLSA is a wholly owned subsidiary of the Australian Nuclear Science and Technology Organisation (ANSTO). The Board recognises and acknowledges the strong contribution to the good outcomes achieved at the Australian Synchrotron from integration measures undertaken in management, human resources, engineering, external and government relations, and finance by ANSTO and Australian Synchrotron staff working co-operatively.

The strategy for the Australian Synchrotron is based upon five objectives: outcomes, people, capability, partnerships and sustainability. The SLSA Board is committed to working productively with the management and stakeholders of the Australian Synchrotron to achieve these objectives to the highest level possible.

SLSA Board directors have been working with representatives from the Victorian and Commonwealth governments, the Australian Synchrotron Holding Company (ASHCo) and its shareholders, to find a sustainable solution for the future of the Australian Synchrotron.

Dr Greg Storr

Chair, Board of Directors, Synchrotron Light Source Australia (SLSA), Operator, Australian Synchrotron

ANSTO Operations Update

The 2014 financial year has been a successful one for the Australian Synchrotron. This success builds on an earlier productive period in the first half of 2013 when ANSTO took on operations of the Synchrotron Light Source Australia subsidiary, under the governance of a Board chaired by Dr Greg Storr. I would like to thank Greg and the Board for the good governance and excellent result in a year in which we have faced some early signs that the Australian Synchrotron is not immune from ageing core infrastructure and digital facilities. I would like to thank Prof. Richard Larkins, Chair of the Australian Synchrotron Holding Company Board and Mr George Borg who both acted quickly in the context of these risks to secure the required funds for the necessary interventions. This was partnership in action and demonstrated the wisdom of the careful work to define roles and responsibilities for the asset risks that must be jointly mitigated.

During the year I consulted extensively with stakeholders on the process for the appointment of the Director. There was a competitive local and international field of candidates. On completion of the process I was happy to announce that Prof. Andrew Peele had been appointed as the new Director. He has the confidence of the synchrotron community and I have been encouraged by his vision and leadership. He is a worthy Director and is doing a very good job.

While the uncertainty of future operational and capital funding remains, there is a very carefully thought-through process in train, with the ultimate goal being the securing of predictable operational financing well before the current complex financial arrangement and structure concludes in June 2016. It would be invidious to single out all of the stakeholders who have approached this matter in a spirit of goodwill and with a clear focus on a simpler more elegant financing regime. Whatever the details of the final outcome, future funding and access must be consistent with the principles that operate at the best global synchrotrons. The New Zealand, Commonwealth and Victorian Government teams charged with this task need our support to achieve this goal.

An elegant strategy and continued good governance will liberate the committed staff and users of the Australian Synchrotron to continue the work of research and innovation for academia and industry. The practical and high potential outcomes achieved to date regularly receive high praise from a strong and informed stakeholder community.

My thanks extends to the Scientific Advisory Committee, who supply excellent advice and the User groups and beamline committees who work to ensure the quality, utility and safety of the merit access and industry programs.

Finally, I would like to thank and celebrate the achievements of the staff of the Australian Synchrotron. They represent the highest values of excellence and service delivery and they have my full confidence and respect. ANSTO remains committed to the effective and, to the greatest extent possible, sustainable operations of the Australian Synchrotron.

Dr Adi Paterson

Chief Executive Officer, ANSTO

Director's Report

The Australian Synchrotron, operated by the Australian Nuclear Science and Technology Organisation (ANSTO), continues to achieve excellence in enabling science for the benefit of the community through the provision of world-class synchrotron expertise and facilities.

Widely reported research results in the year to 30 June 2014 include advances in the understanding of diabetes and coeliac disease, a rapid and inexpensive test for early-stage malaria, improved gold prospecting methods, innovative new devices and technologies, and research, cited by the Cancer Council, showing how the body's natural defences deal with zinc oxide nanoparticles in sunscreen. Awards to staff and researchers using the facility included the 2013 Eureka Prize for Scientific Research (Dr Lars Kjer-Nielsen and Prof Jamie Rossjohn from Monash University and Prof James McCluskey from The University of Melbourne), three Victorian fellowships, and the Walter and Eliza Hall Institute's Burnet Prize, which was shared by Dr Peter Czabotar whose work is outlined in our feature story (see page 6). The Synchrotron's Dr Mark Boland was awarded a Fulbright Professional Scholarship and the Australian Synchrotron Stephen Wilkins Thesis Medal 2013 went to Dr Stephen Dubsky, whose work could revolutionise diagnosis and treatment of asthma and lung cancer.

This degree of excellence is matched by increasing throughput and output. In the last year the Australian Synchrotron hosted more than 4000 researcher visits from every Australian state, New Zealand and nine other countries corresponding to over 800 experiments. Users and staff contributed 443 refereed publications in leading research journals and added more than 250 protein structures to the worldwide Protein Data Bank.

Diversity, excellence and sustained effort are important for successfully translating research into economic and societal benefits – a journey that may involve many different contributors over a period of some years. The Australian Synchrotron is proving to be particularly adept at supporting industry. Our team of dedicated industry support scientists work with large industry partners such as Hospira Australia, and small to medium enterprises such as Aqua Diagnostic. The team has grown a NSW Government-funded industry access scheme to the point where NSW industry is now directly accessing, and benefiting, from the Synchrotron's technical capabilities and staff expertise.

These results are underpinned by exceptional people and operational performance. For example, when a key component of the linear accelerator system malfunctioned in 2013, it was the combined efforts of staff from all areas of the organisation and ANSTO that ensured the diagnosis and changeover went smoothly and, remarkably, without loss of beamtime. Our commitment to operational excellence is underlined by certification under the ISO14001 environmental management, ISO9001 quality assurance and AS4801 safety management standards. While these are important systems, it is our people and their passion and commitment to achieving outcomes for researchers that make the Australian Synchrotron a special place that is strongly supported by the research community.

That support is manifested in the funding commitment to the facility by our five funding partners, which is characterised by pro-rata allocation of beamtime to those partners in a manner that upholds the principles of proposal merit and experimental excellence, that has always been a hallmark of the Australian Synchrotron.

The Australian Synchrotron's ongoing commitment to excellence and linking research to translational outcomes is an essential part of our strong claims for future funding. This year has seen the development of productive dialogue between all stakeholders in the facility that will continue during the coming year. With the Australian Synchrotron's final transfer to, and continued operation by, ANSTO under a stable funding environment, I believe the Synchrotron will consolidate its claim as one of Australia's most significant piece of national landmark research infrastructure – and will be in a good position to grow its beamline offerings and realise its true potential.

Thank you to all staff at the Australian Synchrotron and to our research users and other stakeholders. Your ongoing support enabled last year's successes and continues to build a secure future for this essential and remarkable facility.

Prof Andrew Peele

Director

Industrial Innovation: A Synchrotron Research Example

The Australian Synchrotron is growing Australia's capacity for innovative drug development, facilitating the advance of world-class disease and drug research through to local drug trials. Access to the Synchrotron's advanced capabilities underpins the world-renowned Australian biomedical research community's ability to attract major international pharmaceutical collaborations and significant investment.

The Australian Synchrotron has played a crucial role in the discovery of a new cancer drug, now in advanced clinical trials in Melbourne, for treatment of chronic lymphocytic leukaemia (CLL).

Each year in Australia, around 350 people die from CLL and 1300 new cases are diagnosed, making this the nation's most common leukaemia. Eighty per cent of CLL patients are aged 60 or older.

The research was performed at the Walter and Eliza Hall Institute (WEHI) in partnership with two major international pharmaceutical companies. WEHI structural biologist Dr Peter Czabotar said the Synchrotron was "key to discovering the drug".

"The highly detailed 3D images of protein structures that the Synchrotron provides were crucial," Peter said. "We needed this level of detail to develop a drug that targets one single protein – and not the other four very similar proteins in the same family – critical for minimising potential side-effects."

The drug discovery and development work has taken five to 10 years to reach the trial stage. It was underpinned by more than 20 years of basic biology research, dating back to WEHI's discovery that the BCL-2 family of proteins protects cells against apoptosis – the 'programmed cell death' process that the body uses to remove old or dangerous cells.

"It's taken a long time to fully understand the function of BCL-2 proteins and turn this basic knowledge into drugs that can stop cancer cells from progressing into cancer." Peter said.

"If we started a similar project now, our access to the Synchrotron would rapidly accelerate the identification of suitable drug targets and the development of potential drug candidates for clinical trials.

Australian Synchrotron staff keep their beamlines in top shape, and their scientific skills help us solve protein structures and develop compounds to stop target proteins in their tracks."

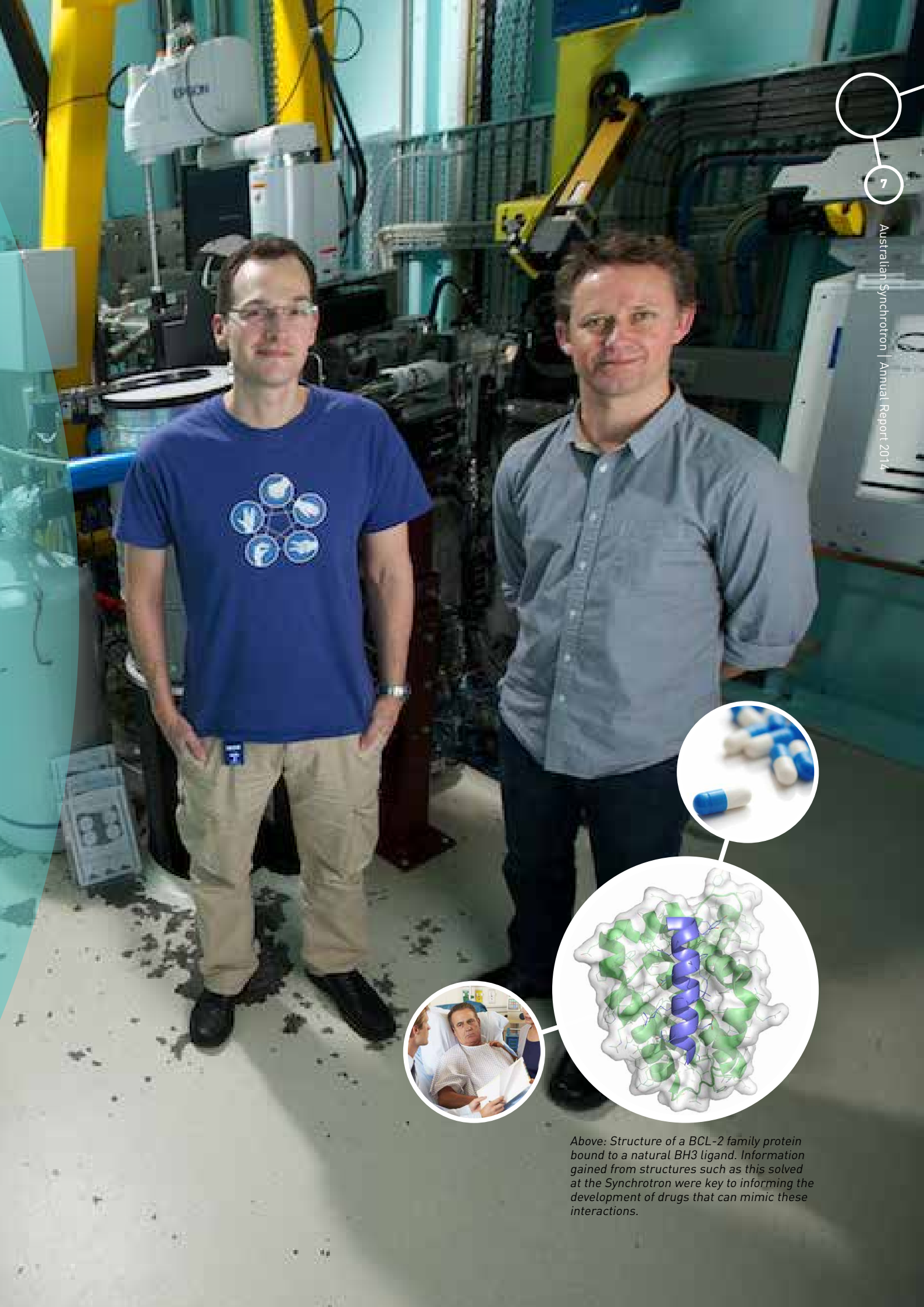
Head of Business Development at WEHI, Julian Clark added: "the Synchrotron was instrumental in enabling researchers to achieve world-class synchrotron technical skills and attract major industry partners, contributing to Australia's growing ability to host clinical trials for important new drugs".

Ease of access to synchrotron techniques was an important factor behind the recent construction of new WEHI facilities worth $150 million, funded by philanthropic sources and the federal and state governments. One floor of the new space is occupied by WEHI's high-powered structural biology team. Over the last five years, the structural biology team has achieved over 50 publications, 10 patents and more than $20 million in research funding from industry just for the programmed cell death work, which is one of four major projects.

"This drug is potentially a major advance for patients with CLL that doesn't respond adequately to currently available treatments," according to Prof. Andrew Roberts, WEHI Head of Translational Research. "Early-stage clinical trials suggest that the drug may lead to complete remission in one-quarter of patients with advanced CLL that isn't responding to other therapies. The clinical trials now underway will take at least three years."

If the advanced clinical trials are successful, the CLL drug will be developed for market, benefiting sufferers globally. The CLL work may also assist development of treatments for breast cancer and other diseases where cell death is not occurring at the appropriate rate.

Opposite: Dr Tom Caradoc-Davies (left), is the Principal Scientist of the Macromolecular- and micro crystallography beamlines responsible for a large proportion of the structural biology work conducted at the Australian Synchrotron. On the right is Dr Peter Czabotar, from the Walter and Eliza Hall Institute of Medical Research, who is using MX2 as part of an international collaboration to tackle chronic lymphocytic leukaemia.



Above: Structure of a BCL-2 family protein bound to a natural BH3 ligand. Information gained from structures such as this solved at the Synchrotron were key to informing the development of drugs that can mimic these interactions.

Research Impact Areas

The Australian Synchrotron community is proud of its role in catalysing the best in research and innovation, which is essential for the ongoing health and wealth of Australians and New Zealanders.

Synchrotron facilities have become an indispensible tool for advanced countries to gain an edge in discovery, innovation and entrepreneurship. It is not surprising that researchers in Australia, New Zealand, and beyond, have embraced the highly advanced imaging and other characterisation techniques provided by the Australian Synchrotron – allowing them to compete at world-class levels in the race for research breakthroughs.

Following is a small selection of the more than 440 scientific papers published this year, which demonstrates the breadth and impact of scientific discovery and industrial problem-solving enabled through the Australian Synchrotron.

Areas of impact

Synchrotron techniques are able to study almost all matter in astonishing detail. Changes in how researchers apply the techniques mean outcomes vary each year, as capabilities are developed, and new researchers become increasingly aware of applications.

Most synchrotron applications can be broadly summarised across two areas of impact:

Supporting Australian Health and Linking with Australian Industry

Scientific discovery is conducted at the frontier of our current knowledge, collecting new information to apply to various human endeavours. The Australian Synchrotron is positioned at the leading edge of this frontier – each investigation unlocks pathways to discovery and impact. Throughout the following case studies we have included an indication of the areas of scientific understanding to which they have contributed, and the relevant portfolios impacted by the practical outcomes. We have also provided an indication of the synchrotron technique used, by naming the beamline that supported the findings of the work.

Research areas:

LIFE — **Medical & Life Sciences**
Understanding disease, fighting bacteria and viruses, and food and agriculture.

MATERIALS — **Advanced Materials & Engineering Science**
Alternative energy and carbon dioxide, batteries and electronic devices, new materials with industrial applications.

CONVERGENCE — **Convergent Sciences**
An interdisciplinary approach to solving complex problems including environment, energy, geological processes, mineral exploration and mineralogy.

Portfolios:

AGRICULTURE

ARTS

COMMUNICATIONS

EDUCATION

ENVIRONMENT

HEALTH

INDUSTRY

Beamlines:

IMBL – IMBL – imaging and medical

IRM – IRM – infrared microspectroscopy

MX – MX1 and MX2 – macromolecular- and micro crystallography

PD – PD – powder diffraction

SAXS/WAXS – SAXS/WAXS – small- and wide-angle x-ray scattering

SXR – SXR – soft x-ray spectroscopy

THz/FAR-IR – THz/Far-IR – terahertz/far-infrared

XAS – XAS – x-ray absorption spectroscopy

XFM – XFM – x-ray fluorescence microspectroscopy

Supporting Australian Health and Wellbeing

The Australian Synchrotron is extremely proud of our role in supporting world-class research in the health sector by providing researchers with the ability to 'see the invisible', accelerating breakthroughs in medical treatment, diagnosis and research.

The Synchrotron's powerful light provides advanced data and imagery in unprecedented detail of the structure, composition and behaviour of proteins, viruses, disease and human tissue at the macro and nanoscale.

Such powerful knowledge bolsters Australia's strength in many areas of health, with outcomes such as:

1. Breakthroughs for high-quality Australian health research
2. Savings for the Health portfolio
3. Investigating diseases associated with Australia's ageing population
4. Enabling the growth of local pharmaceutical development
5. Supporting Australia's international standing in health

The Australian Synchrotron has continued to play a significant role in research that impacts wellbeing: the quality of life in our community. Research into societal wellbeing goes beyond physical health to include fields that contribute to society more broadly. At the Synchrotron, the same cutting-edge technology that is used to understand the structure and function of natural materials, can also be used to understand a broad range of man-made materials used throughout our history and their impact on our lives. For example, understanding our cultural heritage by revealing the origin and construction of an historical artefact, significant painting or rock art: using which materials; by whom; and over what period of time.

Frank Gagliardi is a Medical Physicist from the William Buckland Radiotherapy Centre at the Alfred Hospital and cancer researcher at RMIT University. Here on the Australian Synchrotron's Imaging and Medical Beamline (IMBL), he places a sample of radiosensitive human-tissue-equivalent plastic on the sample table. Frank is working with the IMBL team to understand the 3D dose distribution of x-ray microbeams, which will help develop new ways of treating cancer using synchrotron radiation.

MAITs – switching on our immune sentries

Scientists have identified the biochemical signal that wakes up a group of immune cells and sends them into action against invading bacteria and fungi.

An Australian-led international research team – involving the universities of Melbourne, Monash, Queensland and Cork – announced their discovery in the journal Nature on 3 April 2014.

Their findings will help researchers develop new ways of diagnosing and treating chronic inflammatory diseases such as tuberculosis, peptic ulcers, periodontal disease and inflammatory bowel disease, and may also assist the development of novel protective vaccines.

The work focuses on a group of immune cells called 'mucosal-associated invariant T-cells' (MAITs) found in our guts, lungs and mouths. MAITs make up about one in 10 of the body's T-cells and half of all T-cells in the liver.

The latest discovery narrows the biochemical trigger down to a small group of compounds produced by specific bacteria and fungi, which may be associated with several diseases.

MAITs detect when bacteria are making vitamin B2 (riboflavin) but don't detect vitamin B2 in our diet. This clever distinction provides valuable clues for new drug development strategies.

http://bit.ly/MAITSNature

HEALTH INDUSTRY LIFE

MX

X-ray insights sharpen Hospira's competitive edge

When a popular medicine goes 'off-patent' it allows other companies to legally make the product more competitively.

What is less well known is the amount of scientific research that must be done to produce a generic version of the drug.

While a generic drug is more affordable than the 'name' brand it must also be just as effective – and manufactured to the highest safety standards.

Hospira Australia Pty Ltd employs more than 650 people in Mulgrave, Victoria – a highly skilled workforce manufacturing high-quality generic injectable oncology medicines. They export more than $280 million worth of product from this site annually.

Hospira's access to the world-class instrumentation and expertise at the Australian Synchrotron is enhancing their ongoing industrial research – research that keeps them competitive on the world stage.

http://bit.ly/Hospira_edge

'For the Australian pharmaceutical and biotech industry broadly, the Synchrotron provides access to advanced technologies providing a competitive edge in drug discovery and production. For Hospira the benefits of having a Synchrotron locally, means improvements in process, a quick understanding of specific product issues, complements to our existing company expertise, and a competitive edge.'

Andrew Hodder,
Vice President Operations.
Hospira Australia Pty Ltd.

LIFE INDUSTRY HEALTH

XFM

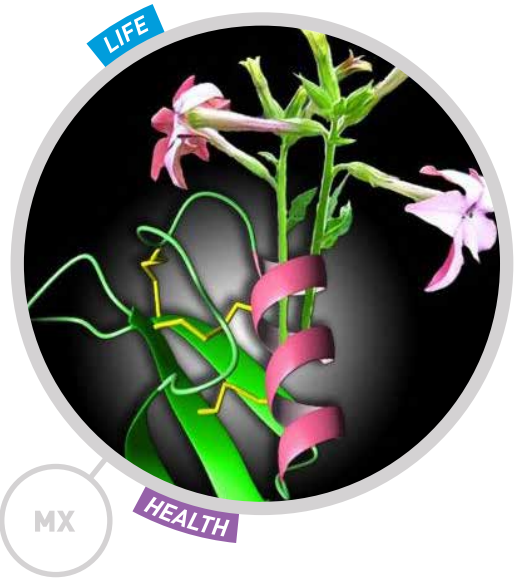
Nanoparticle study allays zinc oxide concerns

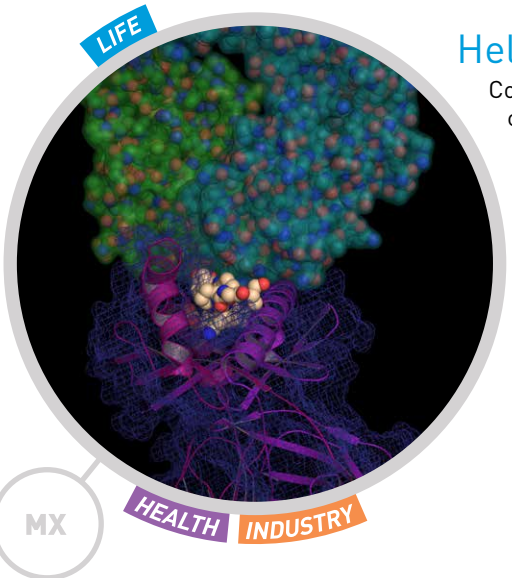
Ground-breaking x-ray techniques have provided further evidence that zinc oxide nanoparticles in sunscreen are unlikely to cause harm to beach-goers. Zinc oxide nanoparticles are popular in sunscreen because they are invisible to the eye, unlike larger white zinc oxide particles that remain on the skin. Researchers from the Australian Synchrotron, Melbourne Centre for Nanofabrication, CSIRO, RMIT University and Monash University used synchrotron x-ray fluorescence and specialised MCN capabilities to investigate what happens to zinc oxide nanoparticles when they interact with cells that are key components of our immune system. Their findings show that human macrophages would ingest and break down any zinc oxide nanoparticles that might enter the body. http://bit.ly/SimonSaysZnOnanoSafe

Tobacco plant could help treat cancer

A small peptide molecule that is found in the flowers of ornamental tobacco plants (*Nicotiana alata*) to fight off fungal and bacterial infections has the potential to treat cancer in humans, according to a new discovery by La Trobe University. Called NaD1, these peptide molecules work together to form a pincer-like structure that rips open the membrane of a fungal cell or a cancer cell, killing it. La Trobe University researchers used synchrotron x-ray diffraction to determine the structure of a complex of NaD1 peptides binding to lipid molecules found in the cell membranes of fungi and mammals.

http://bit.ly/cancerfightingtobacco





Help is on the way for coeliac sufferers

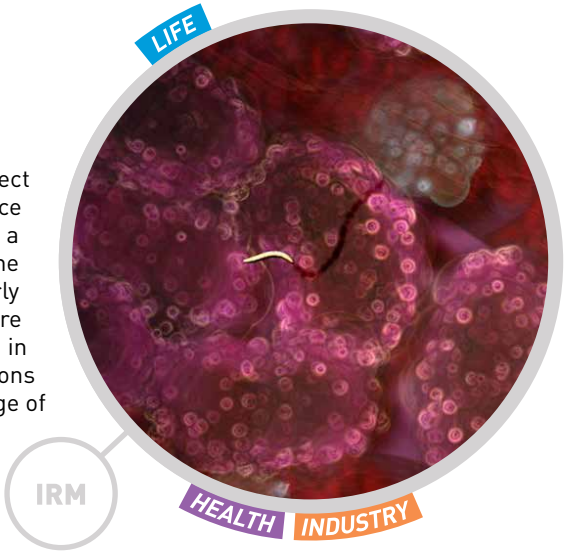
Coeliac disease affects one in 70 Australians. When coeliac sufferers eat foods containing wheat, rye, barley or oats, their immune system reacts against gluten, creating major discomfort. An international research team used synchrotron x-ray diffraction to discover the 'trigger' for coeliac disease. They obtained a detailed picture of how a component of gluten (gliadin) combines with a special protein inherited by most coeliac sufferers and then binds to T-cells, causing them to inflame the lining of the small intestine. Australian and Dutch researchers are working with United States biotechnology company ImmusanT to develop a therapeutic vaccine and a blood test to help 95 percent of coeliac sufferers.

http://bit.ly/CoeliacFinding

Rapid new test may dramatically reduce malaria deaths

A fast, accurate and inexpensive test that uses infrared light to detect malaria at a very early stage of its development, could dramatically reduce the number of people who die from the disease, estimated at 1.2 million a year. Researchers from Monash University and The University of Melbourne used synchrotron infrared microspectroscopy to detect the parasite's early life-cycle stages and determine the number of parasites in the blood before it matures and can hide in body tissues. This study was an integral part in developing their portable test which can provide results at remote locations within minutes, giving a clear indication of malaria at a much earlier stage of infection than currently available by other tests.

http://bit.ly/ASMalariaTest2013



How nature's anti-microbial works

Zinc is nature's anti-microbial, but how does it actually work? University of Adelaide researchers used the Synchrotron to find out how zinc affects *Streptococcus pneumoniae*, a bacterium that kills more than one million people a year by causing diseases such as pneumonia and meningitis. They found that zinc binds to a bacterial protein that transports essential manganese across cell membranes and into bacterial cells. The zinc binds so tightly that it blocks the transporter – and starves the bacteria of manganese. Human bodies don't have this particular transporter protein, so it could be a valuable target for new anti-bacterial drugs.

http://bit.ly/ZincBacteriaKill2014

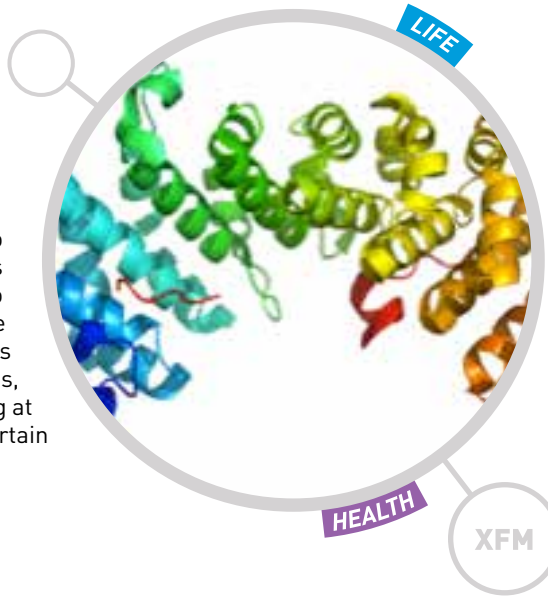
Towards better radiation therapy methods

Synchrotron microbeam radiation therapy (MRT) is an experimental form of radiotherapy that uses an array of synchrotron-generated x-ray microbeams tens of micrometres wide (a fraction of the width of a human hair) separated by hundreds of micrometres. MRT has the potential to deliver better outcomes than conventional broadbeam radiation therapy, but the reasons are not currently well understood. Australian and international researchers used the Synchrotron's imaging and medical beamline (IMBL) to identify MRT doses that give similar outcomes to broadbeam treatments. Their results will be used to select safe but effective MRT doses for future veterinary and clinical trials. DOI: 10.1371/journal.pone.0100547

Understanding how protein transport can lead to disease

University of Queensland researchers used the Australian Synchrotron to reveal new information about key proteins involved in trafficking other proteins between different parts of the cell. Problems with this process can lead to diseases such as cancers. Controlled movement of key proteins between the nucleus and the rest of the cell (the cytoplasm) is essential. These proteins carry 'targeting signals' that are recognised by 'transport factor' proteins, which then carry them across cell membranes. The researchers were looking at some proteins with unusual targeting signals, providing insight into why certain cancers might develop.

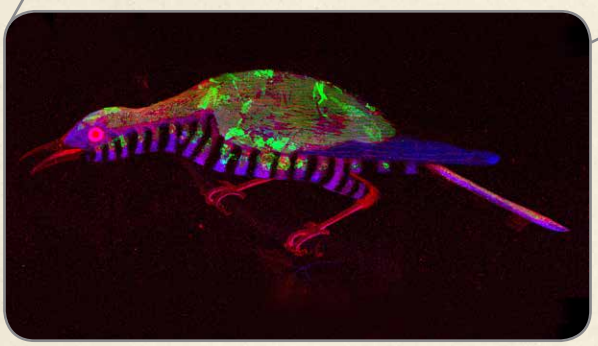
http://bit.ly/UQ_cellproteins_2013



'Jekyll and hyde' protein may hold key to diabetes

Researchers are a step closer to establishing the link between a protein with a split personality and type 1 diabetes. The discovery that a protein called GAD65 changes shape depending on whether it is active or not – and is then treated differently by the body's immune system – could speed up the development of better vaccines to potentially treat and prevent type 1 diabetes. The Australian-led international research team used the Australian Synchrotron to produce highly detailed pictures of the protein in its active and inactive states.

http://bit.ly/JekyllHydeprotein_diabetes



Drawings from first fleet era reveal their provenance

Some of Australia's earliest scientific drawings are giving up their secrets under the watchful eyes of Australian Synchrotron scientists and State Library of New South Wales (SLNSW) conservators. The exquisite bird and flower drawings are too delicate to be touched, so the Synchrotron is the only way to examine their very fine detail. Synchrotron data is being used to verify their provenance, help identify the artists, add to the unfolding story of how the First Fleet colonists made artwork, provide the basis for a pigment composition database, and validate other laboratory-based methods for assessing other works in the SLNSW collection.

http://bit.ly/FirstFleetBirds

ARTS EDUCATION CONVERGENCE

XFM

Better knowledge and preservation of rock art

The Synchrotron is helping to improve knowledge of the cultural context of rock art production by enabling researchers to closely examine individual layers of mineral pigments from rock art sites using just a few milligrams of material. The results are increasing our knowledge of the provenance of rock art pigments, the relationship of Aboriginal people to their land through time, the impact on rock art of local manifestations of climate change, and how environmental degradation processes might affect long-term conservation and management of rock art.

An example of work in this area: http://bit.ly/RockArtKimberleyPD

CONVERGENCE EDUCATION ARTS

PD IRM

Learning how to preserve appearances

Paintings conservators from Australia and the United States studied the composition and degradation of a particular brand of enamel house-paint (Ripolin) from the studio of the well-known Australian artist Sidney Nolan pictured below. They used synchrotron infrared spectroscopy to investigate deterioration of zinc oxide pigments combined with oil in sealed and still-liquid paint. Zinc oxide deterioration can cause lumps and cracks in 20th century oil paintings. *Journal of the American Institute for Conservation 2013, Vol. 52 No. 4, 213–226*

CONVERGENCE EDUCATION ARTS

IRM

Linking with Australian Industry

The Australian Synchrotron is proud of our role in supporting the nation's industrial sector – from small to medium-sized enterprises (SMEs) to large global entities – and providing significant contributions to the agricultural sector.

The Synchrotron is accelerating breakthroughs that enable industry to: reduce costs; increase productivity and global competitiveness; attract investment; maintain highly-skilled workforces; mitigate environmental impacts; and develop new products, processes, materials and markets.

For instance, agricultural work done at the Australian Synchrotron is high-quality, targeted research done by scientists with agribusiness experience and connections. This research is usually conducted through third-party providers such as Australian universities, CSIRO and state-based agriculture departments that provide a well-established pipeline of knowledge transfer from research findings to on-farm adoption. Examples include results in soil acidity, disease resistance in plants, and improving consumable such as milk, meat, grain and wine.

Demand from industry for synchrotron-based research capabilities is growing year-on-year. In October 2013, the facility established an industry scientific support team (pictured below) to bolster the efficiency and efficacy of our direct industry engagement links and activities, and to facilitate access for SMEs.

Clients this year include: Hospira – the world's leading provider of injectable drugs and infusion technologies; and Aqua Diagnostic Pty Ltd – an SME about to venture into the global market; and BHP Billiton Worsley Alumina.

The Australian Synchrotron contributes significant outcomes to industry across broad areas including:

1. Mineral exploration, processing and mining site remediation
2. Innovation in SMEs
3. Pharmaceuticals and medical devices
4. Agribusiness enterprises
5. Alternative energy production and storage for transport applications

The Australian Synchrotron contributes significant outcomes to agriculture including:

1. Providing valuable insights across agricultural sectors important to Australia
2. Adding benefits and profits along the farm-to-consumer value chain
3. Improving and developing consumer products
4. Validating new plant varieties for improved nutrition, yield and market value

Helping SMEs innovate

Aqua Diagnostic Pty Ltd, a Melbourne SME producing advanced water quality monitoring equipment and consumables for measuring chemical oxygen demand (COD), used the Australian Synchrotron to enhance the quality of its proprietary nanotechnology PeCOD® sensors through increased understanding of its manufacturing process.

The Synchrotron findings have assisted the company's plans to scale up to higher volumes in response to expected global demand as it expands its share of the international COD measurement market valued at more than $100 million.

http://bit.ly/AS_Case_SMEInnovation

MATERIALS ENVIRONMENT INDUSTRY

SAXS/ WAXS

Helping Australia tackle global malnutrition

Melbourne and Adelaide researchers are helping solve iron and other nutrition deficiencies affecting more than two billion people. Using the Australian Synchrotron, they're able to create highly detailed quantitative images of the distribution of iron, magnesium, zinc and calcium throughout grains. Synchrotron images such as the one shown here, have confirmed that newly developed strains of rice have retained nutrients in the centre of the grain, essential to avoiding loss during the de-husking process. This has great potential for addressing global malnutrition, including in Australia.

The project is funding by the Gates Foundation (HarvestPlus Challenge Program), ARC and in kind support from World Vision. Trials of the biofortified material started in June, in collaboration with the Australian Centre for Plant Functional Genomics, with a goal to distribute the rice and wheat material to farmers in developing countries.

http://bit.ly/Graintotrial_June

LIFE AGRICULTURE HEALTH INDUSTRY

XFM

A false-colour image from the Synchrotron shows potassium (red), manganese (green) and iron (blue) distribution in a longitudinal section of wheat. Image produced on the XFM beamline by users Alex Johnson (University of Melbourne) and Enzo Lombi (University of South Australia).

Worsley seeks high resolution

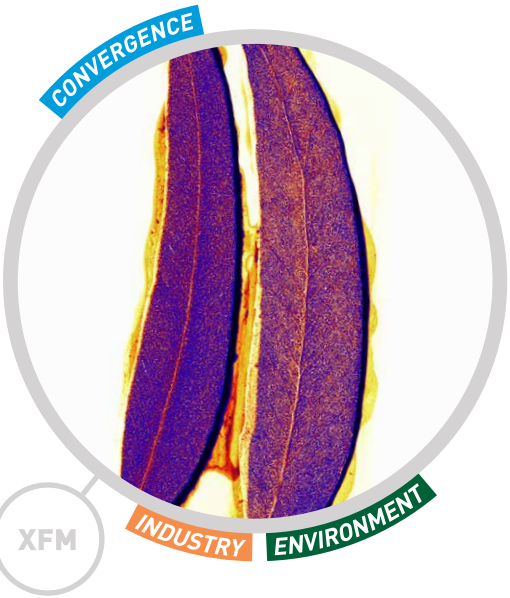
BHP Billiton Worsley Alumina (Worsley) has been mining bauxite and refining alumina in Western Australia for more than 30 years.

Some of its processes involve extensive materials research, in particular the use of an x-ray based technique called 'powder diffraction'.

To leverage the maximum value from its own data, the Worsley research team has applied very high resolution data measured at the Australian Synchrotron.

Worsley's own research and the advanced capabilities of the Australian Synchrotron are helping Worsley to become a more efficient and sustainable business.

http://bit.ly/BHPseekshighres



Gold grows on trees

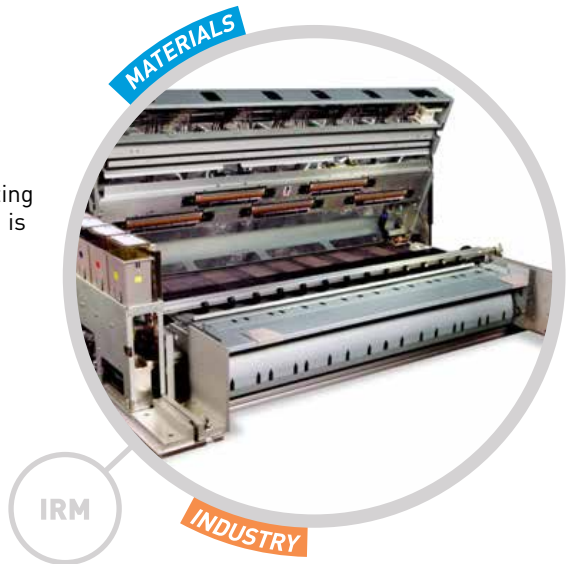
CSIRO researchers have worked with the Australian Synchrotron to reveal micro-nuggets of gold collecting in eucalyptus leaves in Western Australia. The presence of gold in the leaves is indicative of larger deposits below, drawn up through the tree's water source. The finding will help develop new exploration techniques with reduced costs and environmental impact.

http://bit.ly/Goldgrowsontrees

World's first wireless tracking system for healthcare sector

Melbourne-based, ASX-listed bluechiip® Limited has developed a wireless sample tracking system for the healthcare and life sciences sector that also has applications in security, defence, manufacturing and aviation. The technology was developed with the assistance of the Australian Synchrotron.

http://bit.ly/bluechiipMR

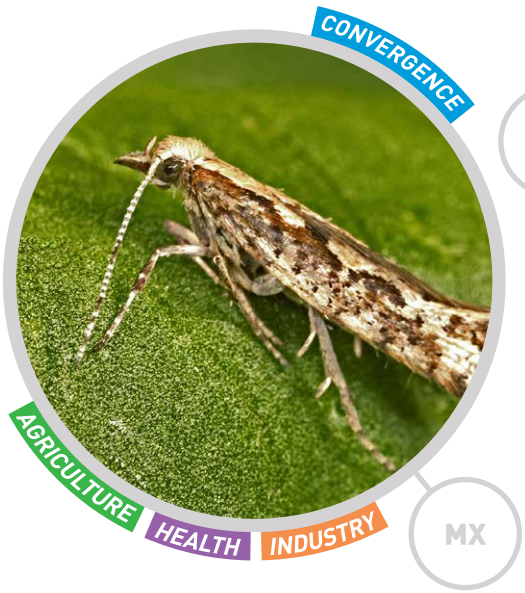


Memjet quality control uses Synchrotron

Sydney-based Memjet Australia produces and exports a unique printing head capable of extremely high throughput. The Australian Synchrotron is assisting with quality control, product design and fabrication.

http://bit.ly/Memjetcasestudy

Potential new weapon against agricultural pests



A giant, hollow, protein shell manufactured by some bacteria and used to contain toxins that kill insects could lead to new bio-insecticides for controlling crop pests. Australian and New Zealand researchers used the Australian Synchrotron to discover the structure of a protein 'canister' that protects an insect-killing bacteria from its own toxins and keeps them safe until environmental conditions are right. Other bacteria and animals produce similar canisters, but the contents can vary widely. The discovery has implications for research into human disease as well as pesticides.

http://bit.ly/Bio-insecticideCannister

Plant defences point the way to stronger crops

New insights into the way plants such as potatoes and tomatoes defend themselves against potentially lethal bacterial invaders will assist development of crop plants that are less susceptible to pre-harvest diseases, which can account for up to 15 per cent of crop losses in a single season.

An international team led by the University of Queensland used a combination of Australian Synchrotron techniques to reveal precise details of the mechanism some plants use to activate their immune responses to bacterial invaders. Such important insight about key biological mechanisms leads to big benefits for agriculture and human health.

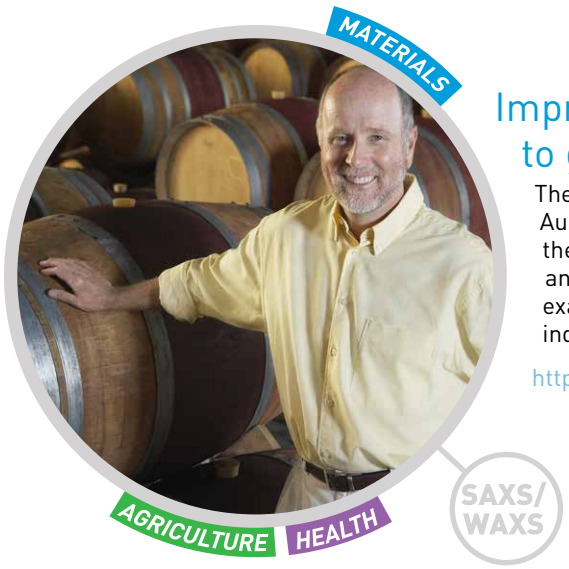
http://bit.ly/PlantsFightBack

Milk fat structure findings to lead to new products

The Synchrotron has enabled researchers from The Monash Institute of Pharmaceutical Sciences to discover that milk is highly geometrically ordered and structured at the nanoscale while it's being digested. This fresh insight into the digestion of milk, will lead to new products such as easy-to-digest milks for premature babies and milk-intolerant individuals, products that help dieters to feel full for longer and eat less, and better orally-administered drugs.

http://bit.ly/MilkFatStructure

Improved understanding of tannins may lead to global edge for Australian wine industry



The Department of Primary Industries (Mildura) is working with the Australian Synchrotron to determine the exact influence of tannins, on the taste and ageing qualities of wine. Tannins have a large size variation and while it's known that they affect ageing and taste, understanding exactly how, will provide globally competitive insights for the Australian industry.

http://bit.ly/ASwinetime

Test for meat tenderness and juiciness in development

In collaboration with the Australian Meat Processing Association, universities and state agriculture departments in Victoria and New South Wales are using Australian Synchrotron technology to validate and understand tests for meat tenderness and juiciness (as perceived by consumers) and correlating these with feed, season and region.

Valuable insights to aid fish stock management

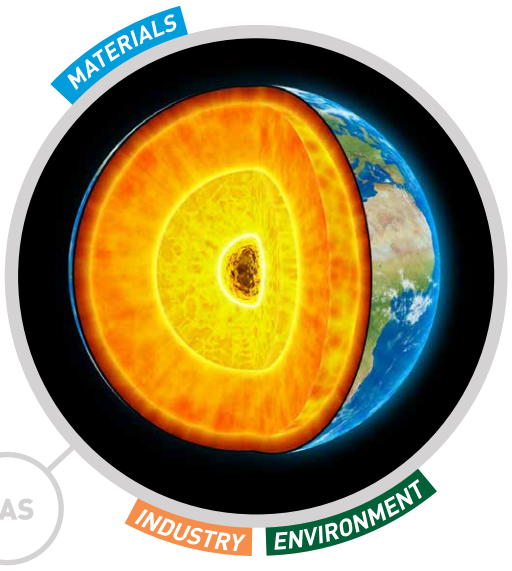
Fish ear bones or otoliths provide important information to support sustainable management of commercial fish stocks and the survival of threatened fish species. Otolith chemistry yields valuable insights into fish dispersal, migration, population and habitat usage. Researchers from the University of Adelaide used the Australian Synchrotron to study the atomic-level structure of otoliths, and for the first time validated the long-held assumption that strontium randomly replaced calcium atoms in the carbonate material that makes up the bones. If their results had disproved this assumption, this could have been a significant setback, forcing fish scientists to re-evaluate their earlier interpretations of otolith chemistry data.

http://bit.ly/FishEars

Deriving energy from alcohol and gold

Gold nanoparticles could hold the key to the development of highly-efficient fuel cells that convert alcohol into energy. Glycerol (a kind of alcohol) is a very attractive potential energy source: renewable, non-toxic, energy-dense and much safer than hydrogen or fossil fuels. The challenge is to find a faster way to produce energy by burning (oxidising) the glycerol. Scientists from the University of Canterbury New Zealand used the Synchrotron to investigate the size and properties of the gold nanoparticles that catalyse the energy production process. Their findings will enable them to develop better, more-stable catalysts.

http://bit.ly/AlcoholicEnergy



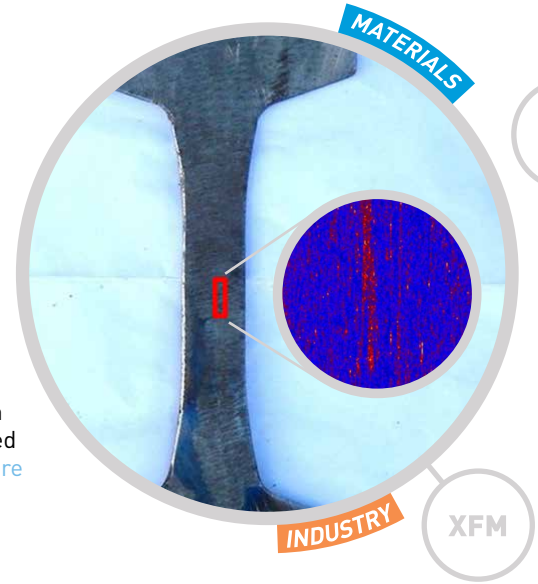
Ground work for mineral processing improvements and safer, more efficient and cost-effective operations for geothermal energy

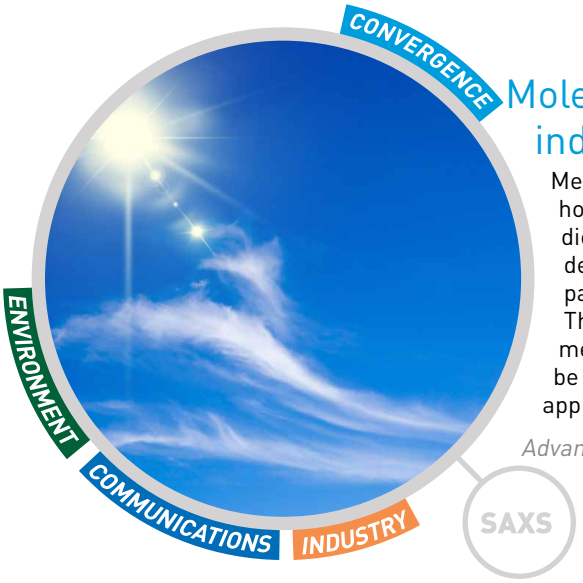
The Australian Synchrotron is helping scientists create 'hellish' conditions – around 600 degrees and 600 times atmospheric pressure – to observe metal speciation and chemistry in hydrothermal fluids under these 'deep earth' conditions. The work of scientists, from the University of Adelaide, Monash University and CSIRO, will contribute to improved predictive mineral exploration strategies, more efficient mineral and metallurgical processing techniques; and better modelling of geothermal energy and geo-sequestration strategies, leading to safer, more efficient and cost-effective operations.

http://bit.ly/ASHellish

Preventing heavy rail failure

The overwhelming majority of iron ore and coal for export is transported on heavy haul rail systems. New steel alloys for both rails and wheels are being developed to allow for even higher loads to improve the network efficiency and the bottom line of these operations. However, the higher alloy content in these steels can lead to issues with welding of the rails, and pose a substantial safety risk. A derailment can cost tens of millions of dollars in lost production. The Institute for Rail Technology at Monash University, which has BHP Billiton, Rio Tinto, FMG and Vale (four of the largest iron ore producers) as clients, is investigating with the Australian Synchrotron, how the uneven distribution of elements such as manganese affects the reliability of welded rails, enabling better prediction of failure. http://bit.ly/AS_Case_RailFailure





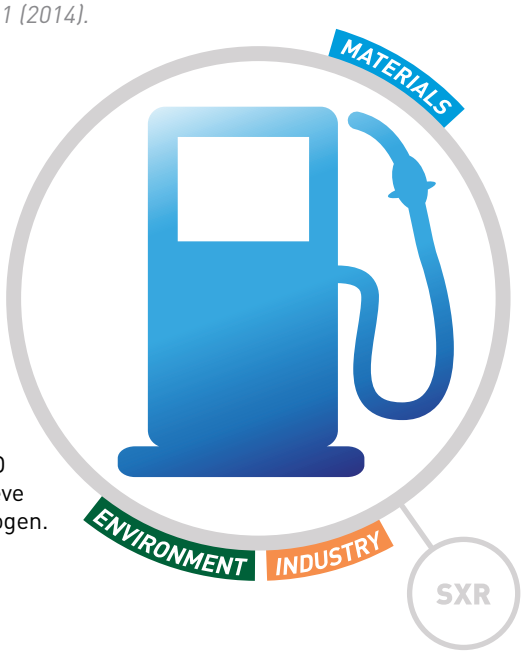
Molecular device coating using sunlight – high industrial capability potential

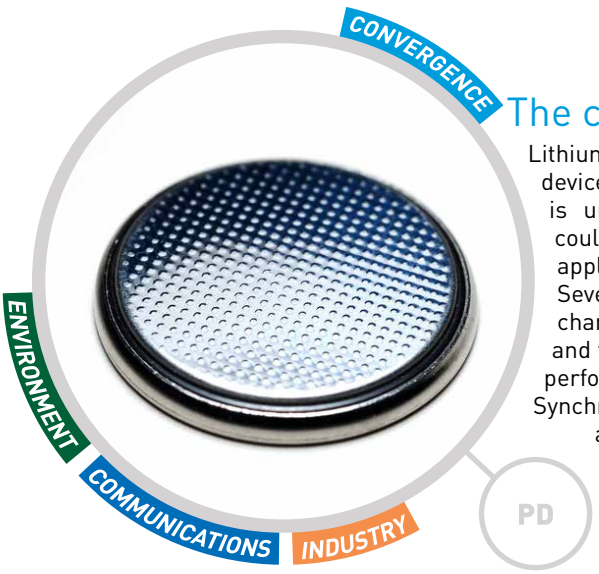
Metal-organic framework (MOF) materials – the Tardis of molecules - can hold amazing amounts of gases such as hydrogen, methane and carbon dioxide. An Australian-Japanese collaboration used the Synchrotron to demonstrate a fast, inexpensive, room-temperature process for coating a particular kind of MOF onto copper metal plates, 3D objects and meshes. The process uses copper hydroxide nanotubes prepared from copper metal, and can be applied to any copper metal object. The MOF coatings can be readily patterned using sunlight, making it ideal for exploring industrial applications of MOF capabilities.

Advanced Functional Materials, 24, 1961 (2014).

Hydrogen from water without the precious metal price tag

It could provide a sustainable energy supply for the future, but a process called 'electrocatalytic reduction' that produces molecular hydrogen from water currently relies on expensive platinum catalysts – and the cost is hampering commercial applications. An international research team including several Australian universities, is using the Synchrotron to develop a metal-free electrocatalyst that can produce similar amounts of hydrogen to some of the well-developed metallic alternatives to platinum catalysts. The catalyst combines graphitic-carbon nitride with nitrogen-doped graphene, both of which form regular 2D structures that can be stacked or joined to make larger arrays. The researchers believe this is the world's first metal-free hybrid catalyst for electrocatalytic evolution of hydrogen.
Nature Communications, 5, 3783 (2014).





The charge for better batteries

Lithium-ion batteries are used worldwide to power portable electronic devices. The technology has many benefits and considerable research is underway to further improve performance. Sodium-ion batteries could offer a more economical alternative, particularly for stationary applications, because sodium is more abundant in nature than lithium. Several research teams are using the Synchrotron to investigate charging and discharging processes at battery electrodes in real time and their results are accelerating the discovery and development of high-performance electrode materials. A number of organisations are using the Synchrotron in this area of study including several Australian universities, and ANSTO.

Some relevant publications in this area of work:
Sodium ion batteries: DOI: 10.1021/cm5005104
Lithium-ion batteries: http://bit.ly/AS_Lithium_batt_group

Science Overview

The Australian Synchrotron's scientific output for this year can be summarised as 'full steam ahead'. While there have been considerable developments to improve the facility's performance and capabilities, this hasn't hindered the breadth, quality and volume of research produced by Synchrotron users and staff. Along with maintaining traditional research strengths in medical and life sciences, advanced materials, agriculture, energy, environmental and geosciences, our scientists, engineers and collaborators have developed new capabilities in the radiotherapy treatment of cancers, biomedical and nanoscale imaging, and studies of the electronic properties of materials.

The year-on-year increase in output from the Australian Synchrotron reflects not only the expertise and effort of our research community and scientific staff but also, importantly, that of our engineering, computing and other staff in providing the advanced investigative capabilities of this research facility. In practical terms the past 12 months have delivered: better beam quality; improvements in beamline optics, detectors and sample environments; advances in data analysis tools and high-performance computing; along with an expanding and highly skilled synchrotron research community. In May 2014, the Australian Synchrotron supported the 20,000th user visit to the facility, from research institutions and industries around the country, reflecting its role as a landmark national research facility. The continued featuring of research from the facility in the world's best scientific journals and mainstream media has been testament to not only its quality but also its applicability and benefit to society.

Facility performance

Excellence and breadth

The excellence and breadth of research supported by the facility has again been exceptional.

This year, Australian Synchrotron research was published in all three of the world's highest ranking multi-disciplinary scientific journals: *Nature*, *Science*, and *Nature Communications*. Synchrotron research was also published in a wide array of other very high-quality journals including *Accounts* of *Chemical Research*, *Immunity*, *Angewandte Chemie*, *ACS Nano*, *Nature Immunology*, *Advanced Materials*, *Trends in Plant Science*, *Journal of the American Chemical Society*, *Physical Review Letters and Proceedings of the National Academy of Sciences of the United States of America*.

The quality of publications – determined by the publishing journal's global citation rates or 'impact factor' – for Australian Synchrotron affiliated publications was again very high. Of the year's publications, 15 per cent achieved a high or very high impact factor (of seven or more). The average impact factor was an impressive 4.88.

Excellence at the Australian Synchrotron is not only a product of this world-class scientific facility and the efforts of Australia's scientific community, it is also facilitated by the merit-based allocation of access to the Synchrotron. Researchers' proposals for access, or beamtime, are reviewed by local and international experts for their potential impact, research team track record, and need for synchrotron radiation. With the strong demand experienced at the facility, selection for excellence is achieved by this process.

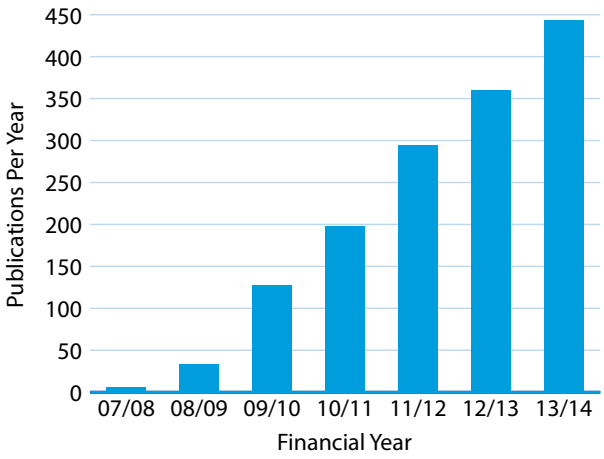
Productivity

Productivity at the Australian Synchrotron is measured by not only the number of experiments carried-out and researcher visits supported, but also by the number of research papers that have been published containing data from the facility. Research output from the facility has again been outstanding, with the publication of 443 peer-reviewed scientific articles – an increase of more than 20 per cent on the previous year. In June the facility had its 1,500th peer-reviewed paper published – a considerable achievement given that the 1,000th publication milestone was reached just over a year ago.

One of the major activities of the Australian Synchrotron is the determination of protein structures which, using techniques at the macromolecular and micro crystallography beamlines (MX1 and MX2), can now take researchers minutes to achieve; something that used to take a lifetime. In this, the International Year of Crystallography, we are proud to report that depositions of protein structures in the worldwide Protein Data Bank, determined using data from the Australian Synchrotron, have exceeded 750, more than doubling the regional deposition rate achieved prior to the advent of the facility.

This level of output earns the Australian Synchrotron user community the recognition of being one of the most productive in the world. To put this productivity into context, this success has been achieved with only 10 operational beamlines, whereas comparable international synchrotron facilities may host 30, 40 or more.

A further 73 publications were produced by Synchrotron staff or other Australian researchers accessing international synchrotron facilities, supported by funding administered by the Australian Synchrotron. This demand for access to international facilities is further evidence of the sophistication of the Australian user community and provides a way to grow expertise and demonstrate need for instrumentation that is yet to be developed at the Australian Synchrotron.



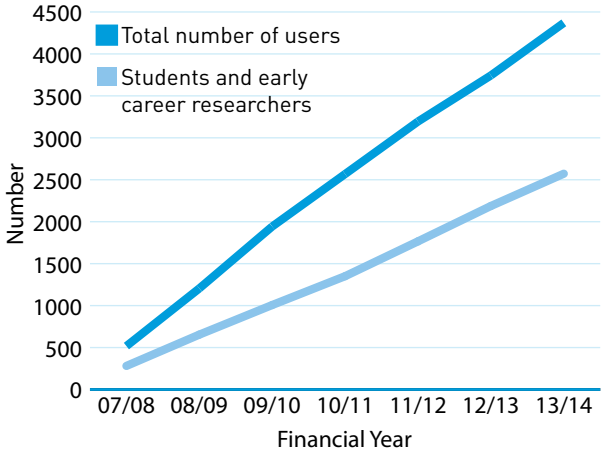
Publications per year from Australian Synchrotron instruments

User community

Australian Synchrotron Users

Registered and new users

The number of registered users of the Australian Synchrotron, has climbed to 4,370 since opening in 2007. Students and early-career researchers (ECR) represent half of the total number of users. Year-on-year, the number of new users to the facility remains consistent, with 628 researchers registering this year; demonstrating the continuing engagement of the regional research community.



Number of Australian Synchrotron users and students/ ECRs

Access to beamtime

This year saw the full implementation of the Juste Retour system under which our funding partners access 'merit' beamtime. This year, 826 experiments were approved for access to beamtime, leading to a total of 4347 user visits by 1594 individual researchers.

A new mode of access to the macromolecular and micro- crystallography beamlines (MX1 and MX2) was also introduced this year. The Collaborative Access Program (CAP) allows researchers from different groups and institutions to work together to maximise outcomes from the limited beamtime available. On opening the program, 23 CAPs consisting of around 125 Principal Investigators submitted research proposals to cover access for one year. Researchers are able to share shipping costs, acquire data via remote access systems, and optimise experimental outcomes for CAP members.

Industrial usage

Many of the scientific research teams that use the Synchrotron already collaborate with industry. Historically, more than 10 per cent of all successful merit-based proposals consistently have researchers self-reporting interactions with industry.

An industry support group was established in September, to better facilitate direct engagement with Australian and international businesses, ranging from small to medium-sized enterprises (SMEs) to multinational corporations, many of which are unfamiliar with synchrotron applications.

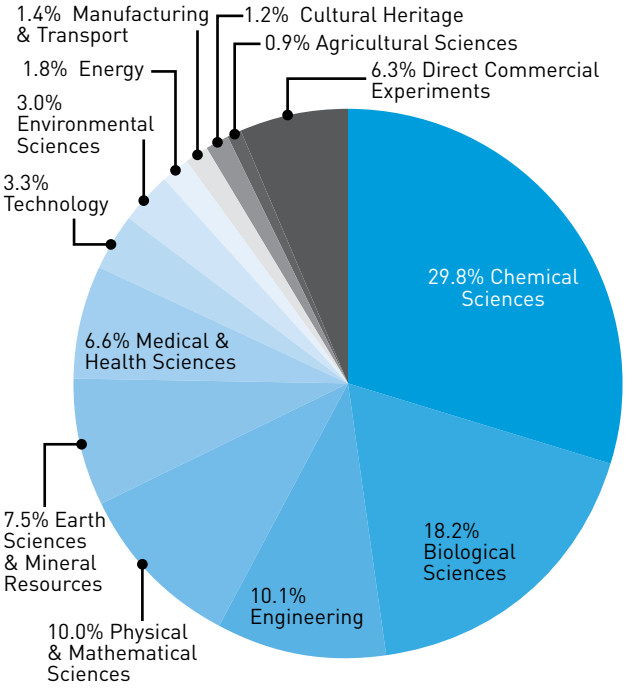
A NSW Government-funded program for direct industry access was successfully implemented this year and facilitated Synchrotron access and expertise for a range of projects. The work included applications as diverse as lamb meat tenderness (Australian Meat Processing Association), state-of-the-art printer heads (Memjet) and conservation studies of an Egyptian Mummy, a valuable asset acquired by the Australian Museum in 1912.

Following the establishment of our dedicated industry support team, and efforts to penetrate the service crystallography market, direct industry engagement has increased dramatically with a rise of direct and indirect industry proposals to around 19 per cent of all experiments. This impressive growth has also been assisted from direct industry interactions driven, to a large extent, by the NSW Government's industry access scheme.

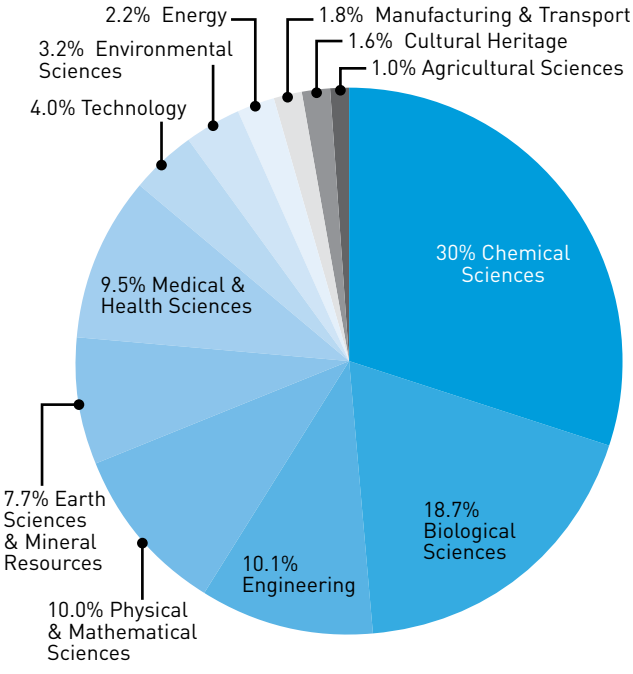
Experiments by field of research

The figure below indicates fields of research for this year's outputs. These Australian Bureau of Statistics classifications plus a direct commercial experiments category, clearly demonstrate the broad applications of synchrotron-related research to critical sectors including: health, pharmaceutical, mineral exploration and mining, manufacturing and engineering, agriculture, energy, the environment, and the arts.

Merit and Commercial Access



Commercial Access

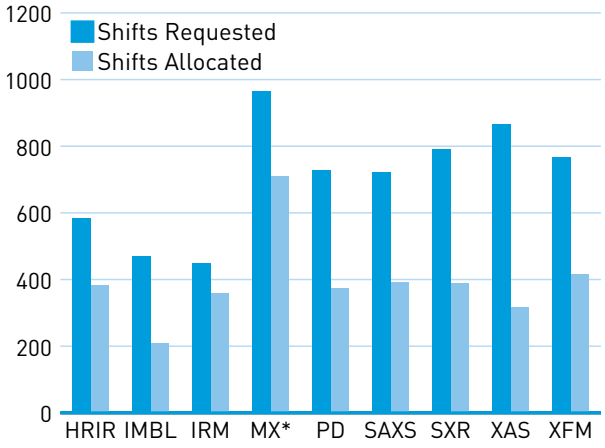


Australian Synchrotron experiments by Field of Research categories.

Subscription rates by beamline

Subscription rates reflect the balance of demand and supply of access to beamlines at the Australian Synchrotron. Subscription across the facility remains consistently high with the number of eight-hour access shifts requested at 1.8 times that available. This is indicative of the constant influx of new uses, and continuing demand from current users.

The majority of beamlines (imaging and medical (IMBL), powder diffraction (PD), small angle x-ray scattering (SAXS), soft x-ray spectroscopy (SXR), x-ray fluorescence micro-spectroscopy (XFM) and x-ray absorption spectroscopy (XAS)) showed subscription rates approaching or exceeding 200 per cent, demonstrating strong and consistent demand, and a need to further develop instrumentation as well as new beamline capabilities at the Australian Synchrotron.



Subscription rates per beamline

Research trends by beamline

Of the facility-supported 443 publications this year, 32 contained data from more than one instrument, with the most common pairings between the MX and SAXS beamlines, and the PD and SXR beamlines. The MX/SAXS combination allows researchers to examine protein structure with atomic resolution when packed into crystals, while scattering provides an understanding of their native conformation in solution. The PD/SXR combination allows researchers to examine both the long-range atomic structure of advanced crystalline materials, as well as the nature of local charge ordering due to variation in elemental oxidation states.

Twenty-eight publications also contained neutron scattering data from ANSTO's OPAL Research Reactor in Sydney. Increasingly we are seeing Australian researchers turn to these complementary techniques in order to solve sophisticated problems or better understand the nature of complex materials, especially in relation to powder diffraction where 22 per cent of all publications from the PD beamline used both x-ray and neutron techniques.

Imaging and Medical Beamline (IMBL)

Around half of IMBL beamtime has been allocated to merit-based preclinical research programs. The remainder has been used to develop and commission new beamline capabilities. Major advances in x-ray computed tomography (CT) and phase-contrast imaging of biomaterials and animals have been achieved this year, to support studies of disease progression and treatment in the lungs, heart, brain and kidney. In addition, developments in preclinical microbeam radiation therapy (MRT) studies led to a better understanding of dose and impact on tissue and cellular systems, particularly for applications in treating osteosarcomas (bone cancers).

Infrared Microspectroscopy (IRM)

IRM was used this year to characterise a very wide range of materials with a focus on organic and biological systems. Materials and areas of interest include: DNA, stem cells, microorganisms and other cellular systems (21 per cent of publications); polymers (25 per cent); forensic studies of fingerprints and automotive paints (13 per cent); Southern Ocean diatoms; and studies of nanoscale structures of insect wings and antimicrobial coatings.

Macromolecular and Micro-crystallography (MX1 and MX2)

Around 70 per cent of work from the MX beamlines related to biomolecular structure and function, including many high-profile publications on the functioning of the immune system, and a substantial number of studies on bacterial infections and related diseases, such as tuberculosis and meningitis. Slightly less than 30 per cent of MX publications related to the structure of organic or organometallic complexes, including metal clusters, coordination polymers and metal-organic frameworks with a range of optical, magnetic, gas separation and catalytic properties.

Powder Diffraction (PD)

The most prolific of the beamlines this year, with 99 publications, powder diffraction was used to study the structure-function relationships for numerous advanced materials. Approximately 20 per cent of materials studied were transition metal oxides with novel magnetic or electronic properties. Hydrogen storage and battery systems each accounted for 10 per cent of publications. In-situ studies of the above materials, as well as gas capture and mineral processing systems continue to be a feature of the PD beamline.

Small- and Wide-angle X-ray Scattering (SAXS/WAXS)

Another highly productive beamline with 90 publications, the SAXS/WAXS beamline also generated outcomes across a diverse range of topics. Traditional areas of study featured highly and included biomolecular structure (25 per cent of publications), and liquid crystal mesophases for drug delivery applications (20 per cent). The nanoscale structure of polymer-based systems (11 per cent) and materials modified by radiation damage (11 per cent) were also of significant interest.

Soft X-ray Spectroscopy and Imaging (SXR)

Beamtime over the past year has been shared between the Soft X-ray Spectroscopy (SXRs) user program and commissioning experiments on the Soft X-ray Imaging (SXRi) branchline (operated by staff from La Trobe University). The Soft X-ray spectroscopy beamline had a very productive year, with 46 publications across a range of fields from studies of surface electronics (22 per cent), conducting polymer devices (18 per cent), nanomaterials and nanodevices (18 per cent) and characterisation of local chemistry in bulk electronic materials (15 per cent).

Terahertz / Far-Infrared (THz-FarIR)

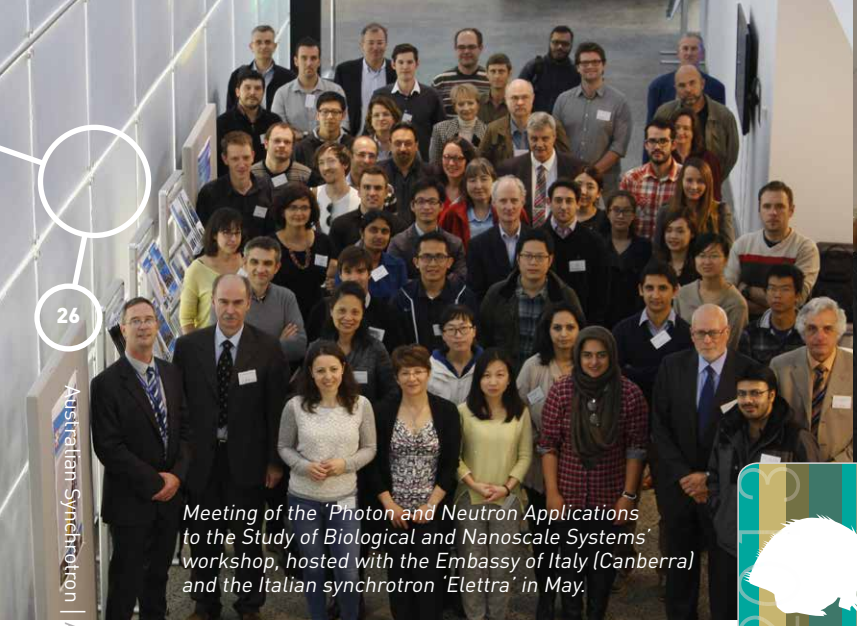
The second of the two infrared beamlines, THz-FarIR ran experiments this year on a range of gaseous and condensed phase systems, with publications in the fields of metallic clusters, nanocomposites, corrosion studies and characterisation of greenhouse gases.

X-ray Absorption Spectroscopy (XAS)

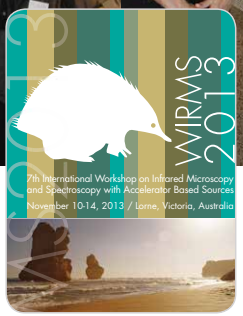
The main areas of research that used XAS, related to environmental science either from the perspective of toxic metal contamination and speciation in the environment, or retention of metal contaminants in various bio-solids. In a related field, XAS was also used (often in concert with the XFM beamline) to investigate the uptake and form of metals and nanoparticles in plants. Nanocomposite systems and mineral processing were the other main fields of interest.

X-ray Fluorescence Microspectroscopy (XFM)

A number of studies carried out using the XFM beamline, featured in mainstream media this year, with the 'Gold grows on trees' story in particular being picked up all around the world. The characterisation of artworks of international significance continued to feature, highlighted by the imaging of a 16th century portrait of Henry VIII. Published studies covered the mapping of micronutrients and toxic metals in plants, grains and environmental samples (52 per cent), cellular uptake and distribution of metals, imaging agents and nanoparticles (24 per cent) geobiology and mineral formation (17 per cent).



Meeting of the 'Photon and Neutron Applications to the Study of Biological and Nanoscale Systems' workshop, hosted with the Embassy of Italy (Canberra) and the Italian synchrotron 'Elettra' in May.



The Australian Synchrotron hosted the 7th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator based Sources (WIRMS 2013) in Lorne. The highly successful event was chaired by Dr Mark Tobin, Principal Scientist of the Infrared Microspectroscopy beamline.

(L – R): Dr Anita Hill (CSIRO), Dr Stephen Dubsky (winner of the inaugural Stephen Wilkins Thesis Medal), and Prof Andrew Peele, Director, Australian Synchrotron.

User engagement

Engagement with researches is an important part of the facility's contribution to the community. This year's activities included hosting a successful annual User Meeting with over 200 delegates; beamline workshops attracting international delegates from industry and other synchrotrons; the 7th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator Based Sources (WIRMS); and a collaborative neutron and x-ray (Free Electron Laser) workshop with ANSTO, the Italian synchrotron 'Elettra' and supported by the Italian Embassy in Australia.

User services

The administrative backbone for any synchrotron is its User Office, and the central tool for the Australian Synchrotron user office is the user portal. The Australian Synchrotron User Portal was developed by our scientific computing team in collaboration with the user office, beamline staff and safety team. From the submission of proposals through to the scheduling of experiments, the Portal must be user-friendly, and reliably track and report almost 1,600 users, 4,300 visits and well over 400 publications and rising, each year. Advances this year have seen the development of on-line safety approval and experimental authorisation systems.

Corresponding to the high volume of researcher visits, the Australian Synchrotron Guesthouse, operated by the User Office, has over the past year been very busy with 72 per cent of all bookings at the Guesthouse for users of beamtime with the remainder of guests attending onsite meetings, conferences and workshops. The Guesthouse and the User Office have received excellent reviews from guests who are happy to be looked after so well when on site.

Machine updates

Upgrades

Upgrades to the synchrotron machine are constantly being planned and implemented. Projects recently completed or currently in hand include:

- A feedback system to improve beam stability in the range of 0 to 300 Hz
- A modification of the cooling water system allowing a reduction in power consumption
- A feedback system to combat electron bunch instabilities.

A reduction in reliability is inevitable as the machine ages without intervention, and this is being addressed by the use of predictive tools that allow possible failures to be identified and mitigating actions to be prioritised and implemented.

Machine reliability

The machine's reliability continues to be outstanding, with availability well above the target figure of 97 per cent at 99.5 per cent. A small number of failures that could have adversely affected machine availability were successfully addressed by the facility's specialist teams. Most notable among these was an unexpected failure of the linear accelerator which was repaired during a planned maintenance shutdown in January.

Beamline developments

Beamline developments over the past year have focused on improvements to reliability, the speed of operation, the quality of data acquired, and the implementation of capabilities to reach new areas of scientific impact. Despite improvements in efficiency, demand for beamtime at the Australian Synchrotron outstrips supply, on some beamlines by almost 300 per cent, which also reflects the continued expansion of our researcher community. Work has continued this year to realise the next generation of synchrotron beamlines at the facility. There exists a great need to expand the range of techniques beyond our initial suite to cover those which Australian researchers currently access at overseas facilities, and additionally to meet the over-subscription demands of the domestic community.

A well-developed case for new beamlines exists [http://bit.ly/ASDevelopmentPlan] and it is expected that as long-term funding for the facility is clarified the business case for investment in new beamlines will be strengthened.

Imaging and Medical Beamline (IMBL)

The IMBL can now perform some experiments that previously required travel overseas. Researchers demonstrated this by conducting key radiography experiments involving high-accuracy lung and cerebral vasculature imaging of anaesthetised rabbits.

Beamline staff commissioned a wide detector system that allows 3D imaging of large palaeontological specimens (up to $1m^2$). All detector systems are now controlled with a unified, user-friendly graphical user interface (GUI).

The beamline is close to providing clinically-accurate measurements of absorbed radiation (i.e. dosimetry studies), thanks to a fine-resolution X-Tream silicon dosimeter from the University of Wollongong and a graphite calorimeter for high dose rate dosimetry on loan from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

Substantial progress was made in the development of the high-power x-ray filter system. Graphene sheets are being used as a stable low-energy filter to avoid the risk of filter materials failing as a result of the large heat load from the source.

Infrared Microspectroscopy (IRM)

The IRM beamline has had another successful year, hosting many unique experiments from a diverse community, while developing the technical capabilities of staff and the beamline. Upgrades to the computer system will allow use of the latest Bruker software. Hardware upgrades of note include: the new ultra-stable 3-axis piezo-controlled condenser mount; and a Bruker macro-ATR (attenuated total reflection) accessory, to allow faster sample mapping at higher spatial resolutions. Staff attended the Advanced Light Source (ALS), in the United States, to test the newly developed near-field IRM capabilities at that facility, in anticipation of potentially developing this novel method.

The IRM beamline teams, also successfully hosted the 7th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator Based Sources (WIRMS), in November 2013, in Lorne, Victoria. The conference was attended by 95 delegates and included for the first time representatives from Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), Jordan; Indus, India; and the Brazilian Synchrotron Light Laboratory (LNLS), Brazil.

Macromolecular and Micro-crystallography Beamlines (MX1 and MX2)

The MX1 and MX2 beamlines have a large user base of 124 principal investigators with 517 instrument users. This community produced 158 peer-reviewed papers over the past 12 months. The beamlines support users from biological and chemical crystallography communities.

The MX beamlines support academic and commercial users, including remote access experiments for domestic and international groups. Automated data processing gives users near real time feedback on data quality.

Beamline development is ongoing with recent upgrades of sample loading robots, filter wheels and beam steering system, and the installation of a UV laser. The Australian structural biology community regularly produces internationally leading research using crystal structures from data produced at the MX beamlines.

Recent highlights include insights into the mechanisms of immunity in humans and plants, development of potential vaccine for coeliac disease, new catalysts, a protein from tobacco that kills cancer cells and much more.

Powder Diffraction (PD)

The Powder Diffraction (PD) beamline team have contributed to a variety of in situ powder diffraction experiments that have led to some fantastic outcomes. Behind the scenes, several upgrade programs designed to improve the performance of the beamline and maintain its high reliability record are underway. The Mythen microstrip II detector hardware and software upgrade programme began late in 2013. Valuable assistance from the Detector group at the Paul Scherrer Institute (PSI) along with the Australian Synchrotron's Controls group led to its rapid introduction in early 2014.

Construction of a new capillary sample alignment spinner is now complete with testing of the control system to begin shortly. The new equipment will align capillaries in seconds rather than minutes meaning that sample throughput will be significantly enhanced. The new alignment system will also be capable of being fully integrated into the planned automated robotic sample loading system.

Small and Wide Angle X-ray Scattering Beamline (SAXS)

The past year has seen further refinement of capabilities to better accommodate an increasingly diverse range of applications on the high-performance small and wide angle x-ray scattering (SAXS/WAXS) beamline. Software upgrades have addressed highly-automated data acquisition, processing and presentation; many systems now run within web browsers. New capabilities include x-ray reflectivity for investigating surface layers at air-solid and liquid-solid interfaces, and a spin-off method for high-accuracy Grazing Incidence WAXS (GIWAXS) sample alignment using an analyser-crystal. GIWAXS is used to study thin films. The sample stage and space envelope around the beam position have been duplicated in the user cabin, enabling users to set up their experiments ahead of time, save valuable beamtime and more efficiently use complex and multiple setups during single experiments.

Since 2009, users have published over 275 research papers in wide-ranging areas that include drug delivery applications, polymers, proteins across many biological and biomedical areas, and materials science. Food and agricultural applications also featured this year.

Soft X ray Spectroscopy beamline (SXR)

This year SXR has focussed on upgrading our capabilities for measuring the electrical properties of samples in situ. In particular, we can now measure the electron transport characteristics of surface materials, or 'surface work function', using a non-contact vibrating Kelvin probe and a four point electric probe. Both techniques are used regularly in user's laboratories but not under the clean, ultra-high vacuum environment we have to have at the Synchrotron. Several user groups are working with diamond, graphene and fullerenes and depositing other materials on to them to vary their electronic properties. The use of low-energy, or soft x-rays, can reveal the energy and arrangement of electron energy levels that directly give rise to these properties. Linking our unique measurements directly to the simpler laboratory measurements can better help guide researchers' preparations to make materials that can have technological impacts, and with their subsequent visits to the SXR beamline.

Terahertz/Far-Infrared Beamline (THz/Far-IR)

This year the THz/Far-IR beamline has witnessed a considerable increase in the number of proposals submitted both in condensed and gas-phase applications, including an international applicant funded by NASA. Two new scientific apparatus have been rolled out to the condensed-phase community: a closed-loop pulse tube offering users access to temperatures down to 10 K for transmission studies, and a near-normal incidence transmission reflection optical system to study the optical properties of materials. In addition, we are developing three techniques that will further increase activity at the beamline: laser photolysis primarily for the gas-phase community, and high-temperature near-normal reflection/transmission, and a low-temperature reflection for the condensed-phase community. The beamline staff have been complemented by the arrival of a postdoctoral fellow, in addition to two PhD candidates who are co-supervised by the beamline staff.

X-ray Absorption Spectroscopy Beamline (XAS)

The XAS beamline continued to enable research activities for a broad community. Significant outcomes included journal articles on plant and crop toxicology upon uptake of metals such as selenium, on chemical forms of lead in residential areas of Sydney, and on strontium structure in fish ear bones to further manage commercial fish populations.

Technical beamline remediation activities progressed strongly. Activities included implementation of a low-vibration sample cryostat, installation of a low-noise robust monochromator piezo actuator, and improvement of motion controls systems. Development work has commenced to further improve user beam quality, critical for enabling studies of highly dilute systems such as trace metals in plant tissues, cells and the environment, or metal clusters implanted in semiconductors.

Improved beam quality will also be important for investigating changing systems in-situ. In a joint project with Monash University, a post-doctoral fellow joined the XAS team to drive high-temperature in-situ studies of geochemical systems. Activities led by a team from Macquarie University are hosted to commission a large-scale, roll-in-roll-out high-pressure sample environment to study geological processes.

X-ray Fluorescence Microspectroscopy Beamline (XFM)

Improvements on the XFM beamline this year include an ultra-stable, high-load capacity table carved from solid granite to support the XFM microprobe. The table has fine-tilt control to optimise tomographic scanning, and can carry heavy equipment such as a cryostream cooling system and secondary detectors.

Users can now scan large artworks without interruption, thanks to milliprobe stages that accommodate scans up to 1.2 x 0.6 m. Designed, constructed and installed by Australian Synchrotron Engineering and XFM staff, the milliprobe stages will eventually also allow for parallel scanning of samples such as protein gels with routine microprobe scans.

The purchase of a second Maia detector has expanded the XFM beamline's capabilities to enable measurement of biologically important light elements such as phosphorus and sulfur. The second Maia detector is a third-generation model with extended low-energy range and improved energy resolution. XFM will ultimately be able to run two Maia detectors in parallel.

Our People

The Australian Synchrotron provides users from research and commercial backgrounds with a uniquely powerful combination of cutting-edge technology and internationally renowned expertise.

At our facility, it is the commitment passion and expertise of all of our staff that enables the maximum possible productivity from highly specialised equipment. Our people are a diverse group who represent a wealth of expert skills in such diverse areas as science and research, electrical and mechanical engineering, computing, software, control systems, user liaison, occupational health and safety, business development, finance, accounting, human resource management, public affairs, communication, education, and event management.

Specialist teams

Science, User Office and Computing

All research undertaken at the Australian Synchrotron is underpinned by dedicated beamline scientific teams, who each year develop beamline capabilities, provide practical user support, and collaborate on research.

The User Office team implemented a Collaborative Access Program for macromolecular crystallography beamline (MX1 and MX2) users, allocating beamtime to groups of users who coordinate themselves to make maximum use of their beamtime.

The IT and Scientific Computing group worked with User Office staff this year to develop an online experiment authorisation process that will replace the current paper-based system. They also upgraded core facilities to ensure the accelerator and instruments remain operational and data are not lost in the event of equipment or network failure.

Accelerator Science & Operations

The Accelerator Science and Operations group maintained machine availability above the target of 97 per cent for the full year, and dealt with 860 beamline support calls to the control room, only 28 of which required the beamline scientist to return to the facility. The operators are working on many projects such as a dedicated wireless network in the accelerator tunnels to improve field diagnostics capabilities.

Principal Accelerator Physicist Mark Boland has been appointed Honorary Associate Professor with the Faculty of Science at The University of Melbourne, strengthening ties with one of our most productive collaborative partners. Mark also received a Fulbright Professional Scholarship (see page 31).

The group is developing feedback systems to further improve accelerator performance, and working with a local company to develop power supplies that will suppress residual electron beam motion.

Engineering

A major area of ongoing effort of the Engineering group is the Imaging and Medical Beamline, where staff from all areas are working with the beamline team, to meet a target date of July 2015 for completing the current phase of the project. The teams are currently designing, building, installing and commissioning a range of equipment and associated control systems – and are well on the way to achieving their goals.

Two new principal engineers have been appointed from within the existing 13-member Controls Engineering group, the facility's largest team, which deals with all aspects of controls software and hardware from experimental and machine controls to safety systems. The group now has four principal engineers leading teams within the larger group and providing a focal point for ideas and decisions that affect the entire facility.

Corporate Services

The Synchrotron retained its international quality standard ISO9001 and national safety system standard AS4801 accreditations. We also achieved accreditation to international environmental management system standard ISO14001, demonstrating our commitment to environmental sustainability.

In the area of human resources, staff delivered a succession planning exercise, a new salary banding and classification system, an all-staff employee survey, updated performance planning and promotion systems, a full learning and development program and a postdoctoral recruitment program.

On the financial management front, organisational expenditure was kept within budget and revenue exceeded target levels. The finance team developed a fixed asset register and upgraded the financial management system TechOne to include asset management capabilities.

The External Relations group activities included our best-attended Open Day in October, hosting and planning for major international conferences, initiating a number of high-profile media stories including several biomedical breakthroughs, and our popular education programs and VIP visits.

Beamline scientists, Australian Synchrotron

Dr Mark Boland (Australian Synchrotron) in the Large Hadron Collider (LHC) tunnel at CERN, Switzerland

Staff awards

Australian Synchrotron staff consistently demonstrate excellence in supporting the needs of Australia's leading industrial and scientific researchers using the Synchrotron. Many Synchrotron researchers have received awards and other recognition through the use of the facility. Here we celebrate some of the similar successes enjoyed by Australian Synchrotron staff.

1. Fulbright award for Synchrotron physicist

Australian researchers may soon be able to examine the intimate details of chemical reactions and biological processes by collecting information billions of times faster than the blink of an eye. Australian Synchrotron Principal Accelerator Physicist Dr Mark Boland will use his prestigious 2014 Fulbright Professional Scholarship in Nuclear Science and Technology to study at the SLAC National Accelerator Laboratory at Stanford University, California. Mark's aim is to extend the Australian Synchrotron's capabilities so it can collect real-time information about processes at the level of trillionths of a second. This will enable Australian scientists to examine chemical processes with thousands of times more detail than currently possible.

http://bit.ly/BlinkofAnEye

As a member of the Synchrotron's accelerator science team, Mark contributes to the ongoing development of the Large Hadron Collider, where the 2012 discovery of evidence for the Higgs boson led to the 2013 Nobel Prize for Physics being awarded to François Englert and Peter Higgs.

http://bit.ly/ASHiggsNobelContribution

2. Awards for early-career researchers

Three early-career synchrotron researchers were awarded Victorian fellowships in October 2013. Drs Simon James (Australian Synchrotron) and Nishar Hameed (Deakin University) received Victoria Fellowships. Dr Wye Khay Fong (Monash University) received a Victorian Postdoctoral Research Fellowship. Simon will use his Fellowship to develop new knowledge and skills for using the Synchrotron to understand how the damaging build-up of the amyloid beta peptide in the brains of Alzheimer's sufferers is influenced by the peptide's ability to interact with essential biological co-factors such as copper and zinc ions.

http://bit.ly/VicFellowshipJames2013

3. Award for jarosite paper

Useful in some mineral processes but a major problem in others, jarosite may also be the key to unlocking the geological history and environmental context of water on Mars. In January 2014, a jarosite research paper by synchrotron employee Dr Helen Brand was judged "equal-best paper by an early career researcher" in an award issued by CSIRO Process Science and Engineering. The paper describes how scientists used the Synchrotron to discover a new structural type of jarosite and identify a potential method for promoting or suppressing jarosite formation as required. Their results also help narrow down the environmental conditions that must have been present for jarosite formation on Mars.

http://bit.ly/JarositeHeroVillain

4. Australian Innovation Challenge

In October, Australian Synchrotron physicist Dr Martin de Jonge and his CSIRO and Synchrotron collaborators were shortlisted for the Australian Innovation Challenge awards in recognition of their work in designing and building the Synchrotron's world-class x-ray fluorescence microprobe. Run by The Australian newspaper in association with Shell, the awards are supported by Innovation Australia. The microprobe enables scientists to produce high-sensitivity maps of the distribution of trace elements such as iron, zinc and copper in plants, and could potentially answer some big questions about agriculture and food security.

http://bit.ly/InnovationChallengeNomination2013

Governance

Australian Synchrotron

'Australian Synchrotron' is the trading name of Synchrotron Light Source Australia Pty Ltd (SLSA), which assumed operations of the facility on 1 January 2013 from the previous operator Australian Synchrotron Company (ASCo).

ASCo was formally wound up as a company on 12 April 2013.

The ownership entity for the facility is Australian Synchrotron Holding Company Pty Ltd (ASHCo), which owns the relevant assets.

SLSA is a wholly-owned subsidiary of the Australian Nuclear Science and Technology Organisation (ANSTO), and operates the Synchrotron under an operations services agreement with ASHCo.

SLSA Board of Directors

The members of the Board of Directors for SLSA as at 30 June 2014 are listed below.

Further details of the Directors and activities of SLSA are contained in the Australian Synchrotron Financial Reports, 30 June 2014.

Further details of each of the SLSA Board members, can be found at: http://bit.ly/SLSABoard2014

SLSA Board of Directors membership

Dr Greg Storr (Chair)
Group Executive, ANSTO

Mr Peter Arambatzis
Chief Financial Officer, ANSTO

Ms Nadia Levin
General Manager, Government, International and External Relations, ANSTO

Professor Liz Sonenberg
Pro Vice-Chancellor (Research Collaboration)
The University of Melbourne

Professor Jill Trewhella
Deputy Vice-Chancellor (Research)
The University of Sydney

Funders' Committee

The Funders' Committee is a representative committee of the Funding Parties (see Funding Framework). It has an oversight role on operations of the facility and its endorsement is required before certain matters, such as the operating plan and budget for SLSA can be approved.

Committees

Several bodies continue to support the development and effective operation of the Australian Synchrotron:

- Scientific Advisory Committee (SAC)
- Animal Ethics Committee
- Industry Advisory Committee (IAC)
- International Program Advisory Committee (IPAC)
- Machine Advisory Group (MAG)
- National Science Colloquium (NSC)
- Program Advisory Committees (PAC)
- User Advisory Committee (UAC)

Funding Framework

In March 2012, Commonwealth and Victorian Government parties signed a Memorandum of Understanding that provided a framework to deliver $100 million to support operating and research costs at the Australian Synchrotron for the four years to 30 June 2016.

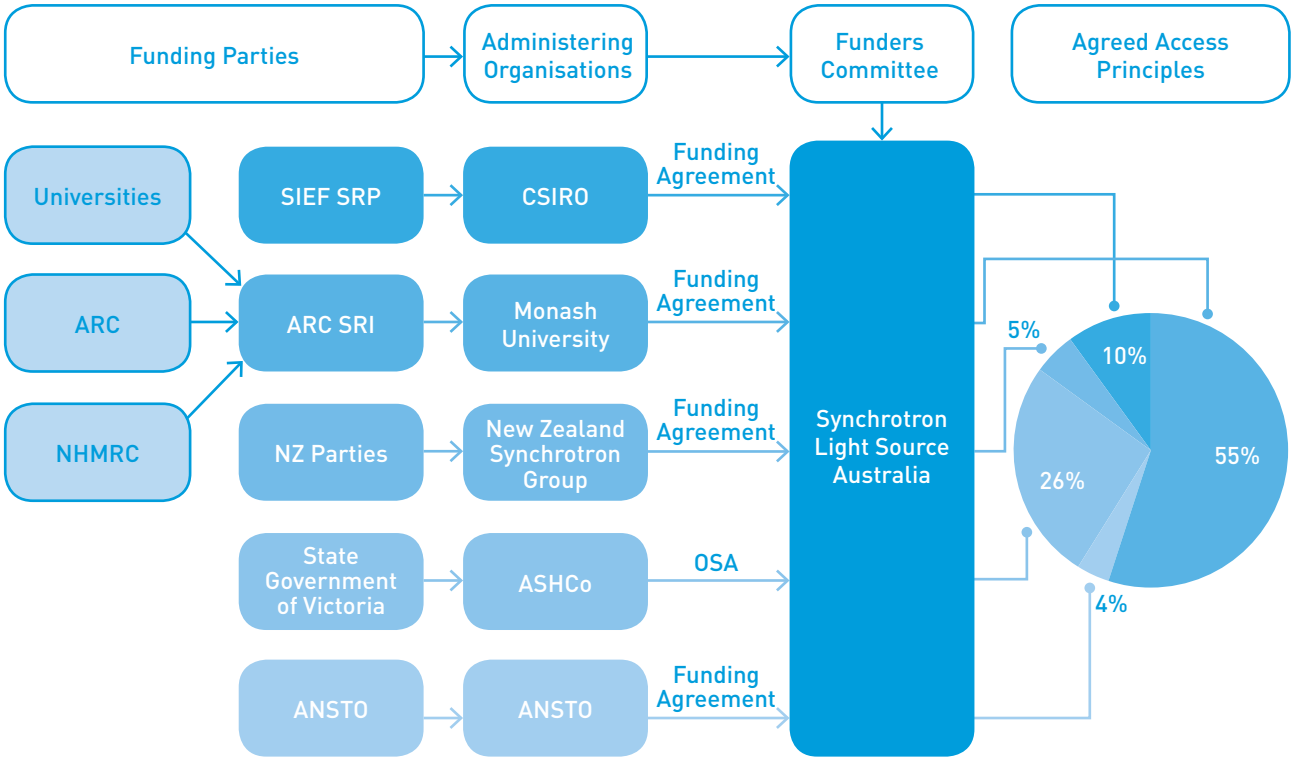
The funding parties and relevant funding schemes are:

- Australian Research Council Strategic Research Initiative (ARC SRI), National Health and Medical Research Council (NHMRC), and Australian universities, $55M
- State Government of Victoria (managed through the Department State Development, Business and Innovation), $26M
- Science and Industry Endowment Fund Special Research Program (SIEF SRP), $10M
- The New Zealand Synchrotron Group Ltd representing a consortium of the federal government, universities and research institutes, $5M
- ANSTO, $4M

August 2013 saw the end of the Foundation Investor arrangement that played a critical role in the first years of the facility's development. We sincerely thank our Foundation Investors – AAMRI, ANSTO, CSIRO, Monash University, The University of Melbourne, New Zealand Synchrotron Group Limited, State Government of Victoria and the four consortia representing AUSyn14, Queensland, South Australia/La Trobe University, and Western Australia – for their additional investment and support, without which the Australian Synchrotron would not have thrived as it has.

The funding parties are granted synchrotron beamtime in proportion to their funding contributions (outlined below), an access model that replaces the previous system which gave beamtime entitlements to the Foundation Investors.

The relationship between the funding parties, their administering organisations, the Funders Commitee and the share of beamtime is set out below.



Financial Statements

The Australian Synchrotron continued to deliver strong scientific achievements to Foundation Investors, funding parties and the wider scientific and commercial communities during the 2013-14 financial year.

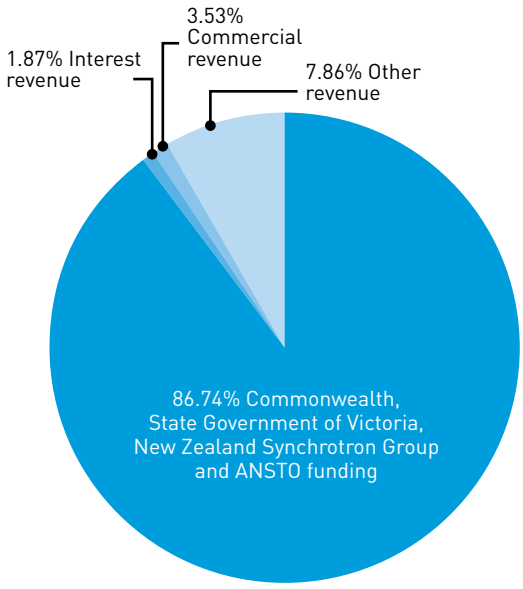
The year saw an increase in other revenue above budget of $1.004 million and an underspend in operating expenditure of $164, 000. With an offset of $173, 000 due to certain grant revenue having been received and recognised in the previous year, this meant that an additional $0.995 million is available for operations in the 2014-15 and 2015-16 financial years.

This year's result is on total revenue of $26,156,570 and total expenditure of $26,329,570, which includes $1,395,455 of assets transferred to Australian Synchrotron Holding Company Proprietary Limited (ASHCo) for zero consideration.

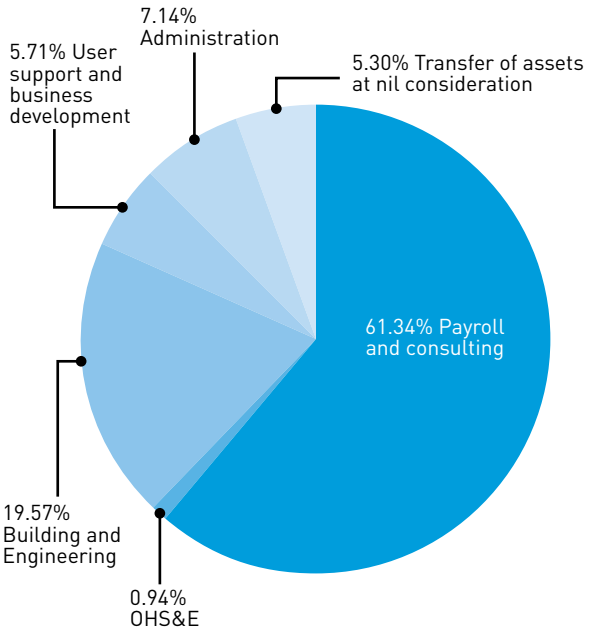
The main source of revenue was from the funding parties (see page 33) comprising $22,687,398. In addition $13,948,069 of revenue was also received in advance and allocated into the statement of financial position as a contribution in advance. Commercial revenue of $922,120 includes $456,521 for NSW Government-funded beamline access. Other revenue of $2,057,024 mainly consists of $1,007,877 from surplus funds transferred from Australian Synchrotron Holding Proprietary Limited (ASHCo), grant funding towards International Synchrotron Access Program (ISAP), NeCTAR grant funding, guesthouse revenue, conference and workshop registrations and postdoctoral contributions.

Operating expenditure during the year was made up of $16,149,797 for salaries and employee benefits and $246,627 for occupational, health and safety expenditure. The amount of $5,153,270 was spent on operating and maintaining the facility at a world-class standard, including $2,792,894 for building and technical expenditure, and $1,395,455 on essential operating upgrades and spare parts. An additional $1,503,827 was committed to support local and international user access, scientific development, external relations activity and business development. Administrative costs of the facility were $1,880,594 including staff travel, information technology and general administration.

Further financial information is available in the 2014 annual financial statements for Synchrotron Light Source Australia (SLSA), available on request.



Income



Expenditure

This report is a public document and can be downloaded here:
http://www.synchrotron.org.au/news/publications/annual-report