accelerating the future

a plan for australian synchrotron based science 2007–2017

accelerating the future

Australia is entering a new era of scientific research with unprecedented investment in landmark facilities. The Australian Synchrotron and the OPAL research reactor are world-class research facilities opening within months of each other. The new opportunities they bring to Australian and New Zealand science and innovation is hard to overestimate.

The Australian and New Zealand synchrotron user communities have collaborated to develop this plan for the coming decade.


what is synchrotron
science and why
australia needs to
invest in it

What is a synchrotron light source?

A synchrotron light source is a facility that accelerates electrons to very high speed. This process causes the electrons to emit extremely intense light that can be used for a massive array of scientific and technological applications. The utility of synchrotron facilities is such that essentially all advanced economies, and many not so advanced economies, have invested in them.

Why?

Xrays are incredibly useful in studying objects of all kinds, from the very large like engine components and broken bones, to the arrangement of atoms in materials (nano-scale structure), because the interaction of x-rays with matter is very well understood. The atomic structures of most materials, from diamond to very complex biological molecules, have been determined by x-ray diffraction techniques.

X-rays were applied to the study of materials immediately following their discovery by Wilhelm Röntgen just over 100 years ago. The last few decades have seen all facets of x-ray research revolutionised by the use of synchrotron light and the high brightness beams now available.

As scientific knowledge advances it has become clear that our world is governed by complex processes, which can only be fully understood by investigation at the atomic and molecular level. Thus protein crystallography, the measurement of the atomic structure of biological molecules, enables a fundamental understanding of disease and the design of more effective drugs with fewer side effects. Similarly, new materials with astounding properties —like high temperature superconductors and self assembling materials—can be developed from an understanding of atomic structure. Synchrotron x-rays are uniquely suited to these investigations, and this has led to the construction of synchrotron facilities in all advanced countries.

> Professor Jenny Martin, of the Institute for Molecular Biology, University of Queensland, who works as part of a team investigating proteins involved in chronic inflammation, is looking forward to using the protein crystallography beamlines at the Australian Synchrotron:
> *"Protein crystals are notoriously difficult to grow and very delicate. It can take months or even years to get a suitable crystal, and it is heartbreaking when these are lost, delayed or damaged in transit to an overseas synchrotron. Having a synchrotron on our doorstep means an end to these problems."*

synchrotron scientists around the world are:

- Discovering the fundamental processes of life and disease at the molecular level
- Developing new more effective drugs with fewer or no side effects
- Gaining new insights into our environment
- Remediating toxic pollutants in soils and aquifers
- Combating crop disease and boosting agricultural production
- Developing more efficient and environmentally friendly mineral processing strategies
- Discovering new materials with amazing properties
- Inventing and understanding new materials processes that mimic natural materials
- Imaging animals and insects with unprecedented speed and clarity
- Exploiting new forms of light to invent new types of airport security screening

Australian synchrotron scientists are at the forefront of many of these amazing developments, and the goal of the coming decade is to use the unprecedented new investment in the Australian Synchrotron and the new fourth generation sources being developed overseas to enhance and cement our leadership in these areas.

australian synchrotron science in 2017

In 2017, Australia will have taken its proper place among advanced nations as a front line and mature user of synchrotron techniques. Around 2,000 scientists will routinely use synchrotron facilities, but the number will still be growing. Industry will be deeply involved. The vast majority of users will be people who in 2007 would never have considered using such a facility.

These researchers will be recognised as being at the forefront of their field. They will be regarded as desirable partners for international collaborations.

The Australian Synchrotron will be a state-of-the-art facility. It will be regarded as a jewel in Australian and New Zealand science, for its contributions to research and the economy, including new industries not even conceived in 2007.

By 2017, the users will have contributed to important improvements in healthcare and produced exports of healthcare products around the world. Their research will have ensured ongoing competitiveness in our agricultural, minerals and manufacturing industries. Damage to the landscape will have been held back or remediated through innovations not foreseen in 2007. Through a better understanding of science at the atomic scale, new and innovative nanotechnological applications will be enabled.

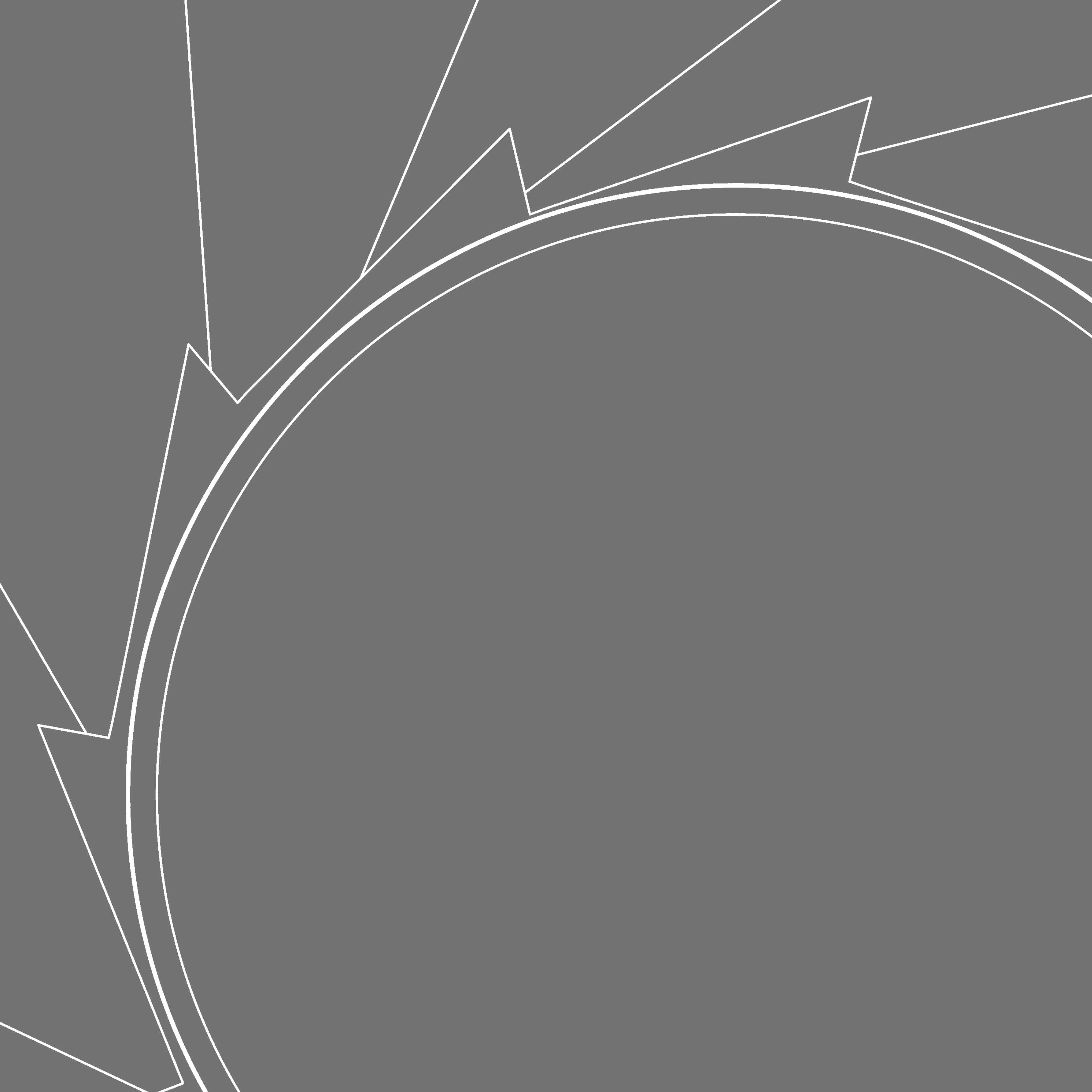
We will be one of the top three facilities in the world in medical imaging. The facility will be a major regional facility for structural biologists and materials scientists, and will be a central piece of infrastructure for the structural biology community and pharmaceutical industry.

The Australian Synchrotron of 2017 will be immersed in a science park hosting a range of capabilities in addition to those based on the synchrotron itself. New beamlines, detectors and optics will have been added. About 23 beamlines will be operating, taking the synchrotron to more than two-thirds of its full capacity.

Many researchers will only rarely see the building because they will access beamlines and laboratories remotely. Enormous databases will also make the research data of others easily available.

Australia will be involved regionally and internationally as an equal partner in the global synchrotron science community. Significant numbers of overseas users will travel here to use the Australian Synchrotron; equally significant numbers of Australian scientists will use overseas facilities, and will have leading roles in the exploitation of the latest developments, known as fourth generation sources.

where are we now?



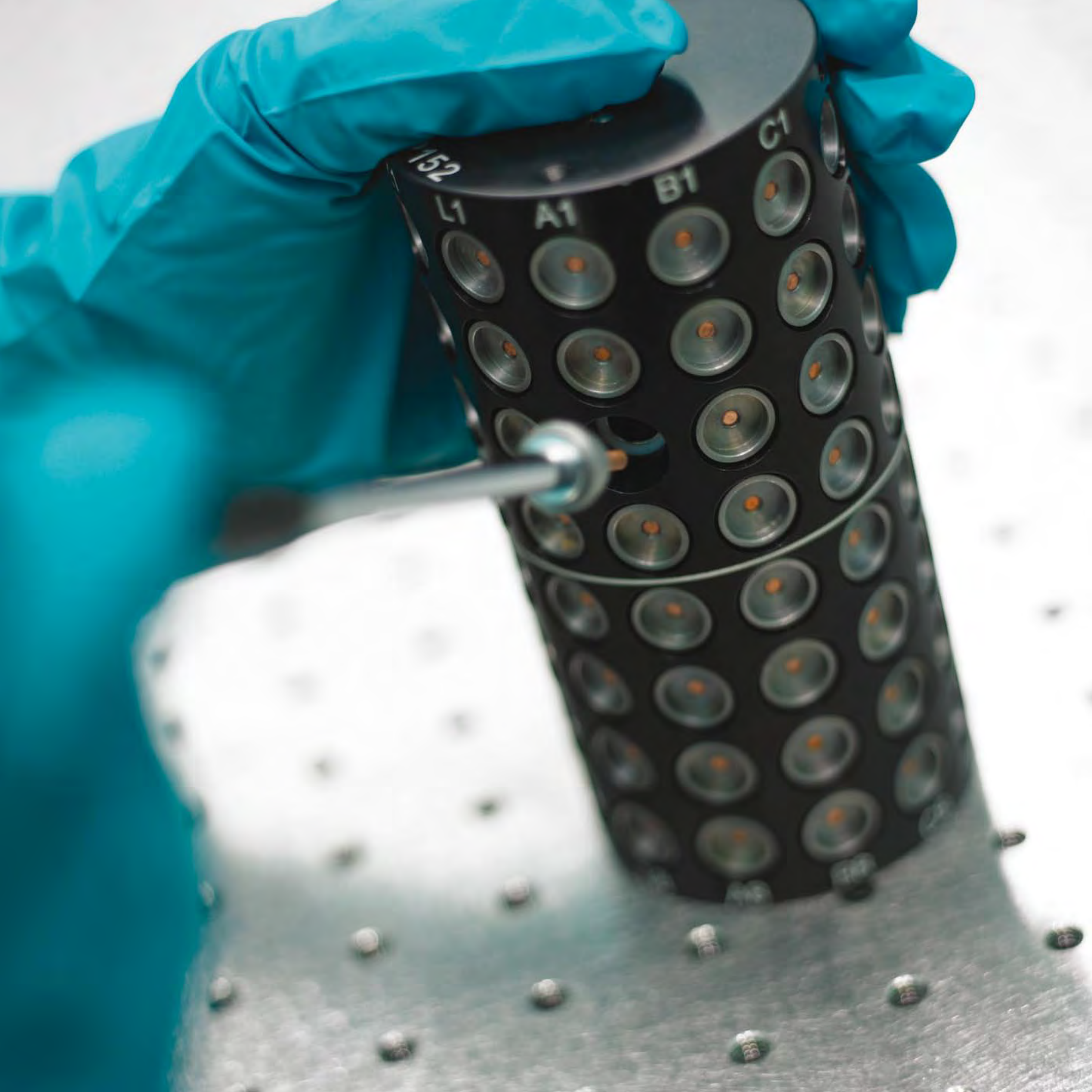
australia already has great synchrotron scientists

Professor Peter Colman FAA FTSE, Head of Structural Biology at the Walter and Eliza Hall Institute for Medical Research, has received high honours for his success in pioneering synchrotron x-ray crystallography to reveal the structure of a key protein in the influenza virus, which led to the development of anti-influenza drug Relenza™. He is continuing his synchrotron research into both cancers and infectious diseases. Professor Colman also works closely with Dr Jose Varghese, Head of CSIRO's Structural Biology Program, who says that "Finding cures is increasingly tied to working out the structure of proteins and how they act in the human body."

Professor Andrea Gerson, University of South Australia, works extensively in physical chemistry on applications affecting the petrochemical, mineral processing, manufacturing and pigment industries to understand structure and reaction mechanisms, improve mineral flotation, inhibit acid mine drainage, improve pigment performance and alby performance. Significant advances have been made in several areas. She is the Director of the Applied Centre for Structural and Synchrotron Studies at the University of South Australia. The Centre is self-supporting through industry and national competitive funding and utilises a wide range of synchrotron techniques.

Professor John W White CMG FAA FRS heads the Solid State Molecular Science Research Group at the Australian National University Research School of Chemistry. The White group has developed novel x-ray (small-angle scattering and reflectometry) instrumentation, and combines the powerful methods of neutron and x-ray scattering with computer simulation and chemical synthesis to study structure and dynamics at nanometre and picosecond space/time scales. Insights gained using these techniques are used to guide chemical synthesis in making new materials with interesting physicochemical properties.

Dr Steve Wilkins, a CSIRO Chief Research Scientist, has played a profound role in the development of instruments and methods for x-ray science. Together with his team, he has played a pioneering role in the development of the most practical and widely used method of x-ray phase-contrast imaging—a method that is implemented at virtually every major synchrotron in the world for biomedical, materials and industrial applications. The resulting intellectual property has led to technology that is now manufactured and sold by a major US company, via licences from the Victorian start-up company XRT Limited.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Professor Jenny Martin, Institute for Molecular Bioscience at The University of Queensland, is one of Australia's leading protein crystallographers. Professor Martin has made numerous important scientific contributions to biomedical science and uses protein structures in drug discovery research. She is now working on techniques to speed up drug discovery. Professor Martin is an NHMRC Fellow and was the President of the Society of Crystallographers in Australia and New Zealand 2003 – 2005.

Professor Keith Nugent FAA, a Federation Fellow, has made many significant contributions to x-ray optics and imaging. His pioneering work with quantitative phase imaging—using a mathematical formula to measure light refraction—provides images of tissues and other objects not available from conventional imaging techniques, such as the density of cell walls and the concentration of protein. Professor Nugent's methods have been adopted around the world and applied to areas as diverse as materials science and biomedical research and have led to the formation of the publicly listed company IATIA Limited.

Professor Peter Lay FAA, Professor Trevor Hambley and collaborators at The University of Sydney have combined the unique ability of synchrotron techniques to study atomic structure of drugs in solution, biological tissues and formulations and to image their distribution and chemical action inside cells to facilitate the design of new anti-inflammatory and anti-cancer drugs and their formulations. The drugs, copper-indomethacin-based compounds, offer much reduced side effects over currently used pharmaceuticals. This is another example of synchrotron techniques being used to design and characterise new drugs that combine high effectiveness with much reduced side effects. Initially developed for veterinary use, the new drugs are expected to enter human clinical trials in 2007. The trials will be funded by a new Australian pharmaceutical company, Medical Therapies Limited, that owns the IP.

Across the Tasman

Professor Ted Baker, Auckland University and the Maurice Wilkins Centre for Molecular Biodiscovery, a New Zealand Centre of Research Excellence in Biomedicine and Biotechnology, is a leading New Zealand protein crystallographer at the forefront in using synchrotron science. His research into the structure and function of proteins has spanned investigations into kiwifruit enzymes, milk proteins and proteins involved in infectious disease—including the streptococcal "flesh-eating" enzyme and proteins from the tuberculosis (TB) bacterium. Professor Baker and his team recently identified a protein essential to the bacterium that causes TB, one of humanity's oldest and most intractable diseases:

"Determination of the protein structure might normally have taken many months, if not years. X-ray data were collected at the Stanford synchrotron in less than one day, and the structure was solved in a few weeks, using methods that are only possible with synchrotron data."

australia's synchrotron scientists already have great ideas

Australians are valued collaborators at overseas synchrotron light sources. Via the Australian Synchrotron Research Program, Australia has built an enviable reputation for innovative and productive users at front line facilities such as the Advanced Photon Source in the USA. Australian synchrotron science has forged numerous strong international links: the Australian Synchrotron has collaborative agreements with all leading facilities, and Australia is a founding member of the newly formed Asia–Oceania Forum for Synchrotron Radiation Research which will promote and enhance regional collaboration.

New Drugs

In 2006, a CSIRO team led by Dr Mike Lawrence and Dr Colin Ward solved the atomic structure of the insulin receptor protein, an extremely complicated biological molecule containing over 50,000 atoms. This structure is the culmination of two decades of work by the team and its structure was solved using synchrotron x-ray protein crystallography. The insulin receptor is a vitally important drug target due to its role in major diseases such as diabetes, dementia and cancer. With the protein structure now known, work on designing drugs specifically to combat these diseases can begin.

New Medical Treatments

New drugs utilising copper and zinc are emerging from collaborative research undertaken by Professors Peter Lay and Trevor Hambley and Associate Professor Brendan Kennedy. Medical Therapies Limited was established to take these drugs into the human markets for the treatment of inflammation, pain and cancer.

Professor Veronica James has been working for a decade exploring simple synchrotron-based diagnostic tests for breast cancer. Her technology is being commercialised by the listed company Fermiscan Limited.

New Technologies

Synchrotron-based research by Professor Keith Nugent, ARC Federation Fellow in the School of Physics at the University of Melbourne, is the basis for a Victorian company, IATIA, which is now traded on the Australian Stock Exchange and contributed to Professor Nugent being awarded the 2004 Victoria Prize.

A CSIRO team led by Dr Steve Wilkins has been involved in pioneering the development of important new methods and instruments for x-ray phase-contrast imaging and microscopy that have benefited greatly from synchrotron-based experiments and are currently being commercialised internationally.

New Ways of Seeing

Synchrotron medical imaging and detector development work by Professor Rob Lewis and colleagues of Monash University has attracted US technology giants to invest in and share their technologies with the Cooperative Research Centre for Biomedical Imaging Development.

New Products

A new silk-like fibre made from wool, called Optim™, resulted from more than 10 years of development by CSIRO and the Woolmark Company using synchrotron analysis. Optim is arguably the most significant breakthrough in wool technology since the 1960s.

New Materials

Associate Professors Ian Gentle of the University of Queensland and Mark Ridgway of the Australian National University are examining new routes toward the production of metallic nanowires. These materials exhibit unique properties and have potential application to devices such as new generation optical filters.


synchrotron science
is exciting science

Synchrotron science is making wide-ranging contributions to modern society, from creating new technologies for industry through to research at the cutting edge of human knowledge.

Examples include the probing of the atomic structure of single molecules, a project being pursued by the Australian Research Council Centre of Excellence for Coherent X-ray Science, through to imaging live cells with unprecedented resolution and probing chemical reactions with exquisite precision in space and time.

Australia's participation in this frontier science requires an ongoing investment in both national infrastructure and capability, while also ensuring that Australia's scientists continue to have access to the best facilities in the world, wherever they are.

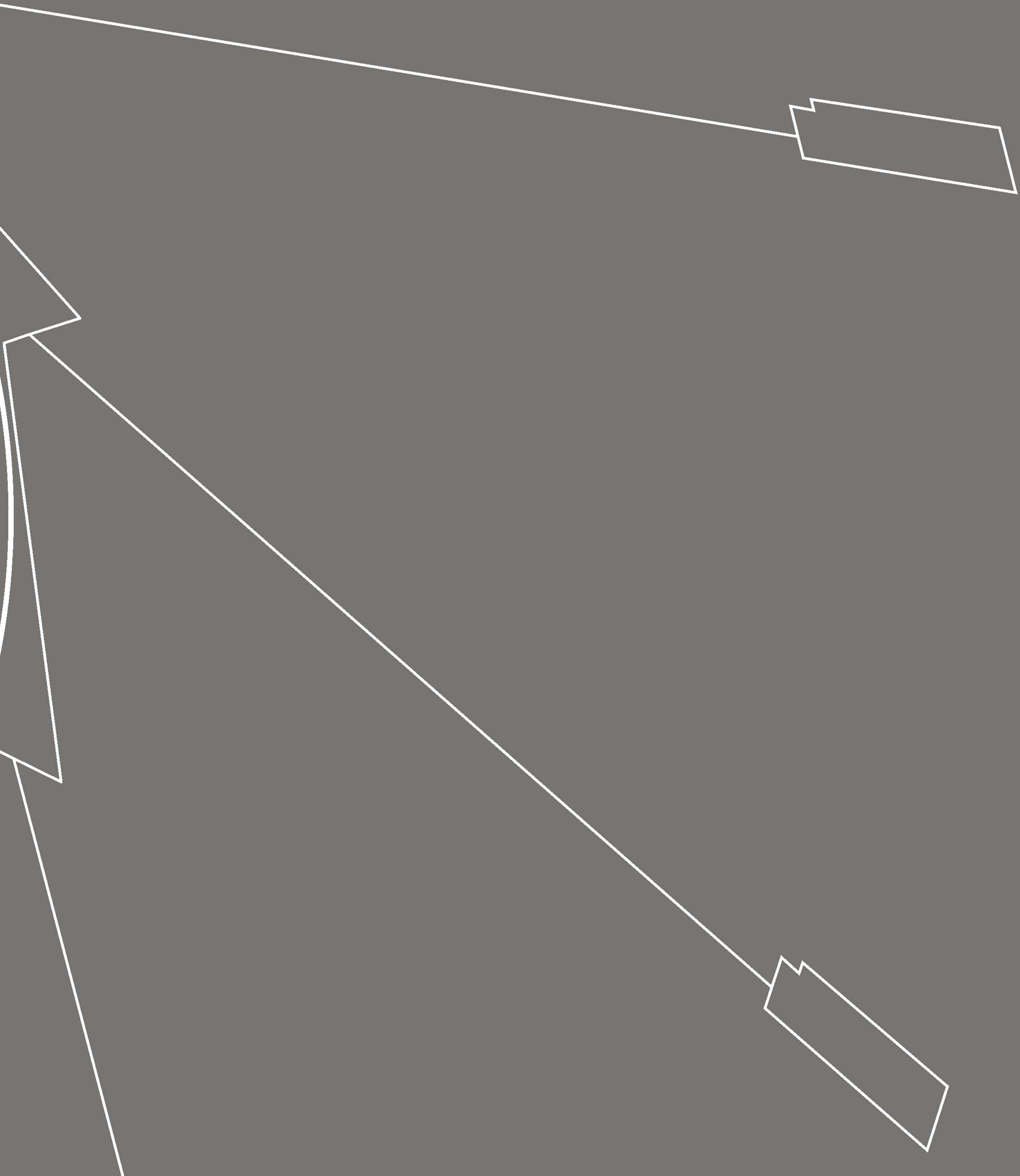
australia has a great synchrotron facility

The Australian Synchrotron

The Australian Synchrotron is a state-of-the-art facility that is the equal of any other similar facility in the world. Its design and construction have taken full advantage of 40 years of development of accelerator and beamline technologies to deliver a world-class facility. It will dramatically improve access to techniques essential for globally competitive science supporting the enabling sciences and key technologies of the future.

The Australian Synchrotron will deliver better results faster, across the spectrum of Australian research. Structural and cellular biology, biosystems, nanotechnology and advanced materials as well as the environmental sciences and geology—and their innovative applications in many areas of national and global significance—will benefit from this new landmark science facility.

where are we going?




with synchrotron science
we will see new things
EALING

Synchrotron techniques are attractive for imaging as they offer greatly enhanced and more informative images than can be obtained with current methods.

Australian groups are at the forefront of new imaging techniques such as phase contrast and coherence-based methods.

Current fields of great interest in Australia include neonatal lung imaging, examining the deformation of teeth, and imaging airway surfaces for assessment of cystic fibrosis.

The secrets of lung development are being revealed using three-dimensional synchrotron images. A pioneering study, led by Dr Jane Whitley of the Department of Primary Industries, Victoria and Professor Rob Lewis of the Centre for Synchrotron Science, Monash University, examines the pattern of lung development in young wallabies, as each stage of development is triggered by proteins in the mother's milk. This information could lead to the isolation of proteins for use in the treatment of poor lung development in premature infants and in the treatment of lung and respiratory diseases.

Additional synchrotron images of the uptake of air in the lungs of new-born rabbit pups as they take their first breath of life will help neonatal intensive care units improve the breathing and lung development of very premature infants.

The important problem of hydrogen storage is being studied by Professor Evan Gray of Griffith University who is imaging structural changes in novel metal alloys as hydrogen is stored and released.

Food science, also, will benefit as it will be possible to follow food processing in real time, and to improve identification of toxins in food. A recent example of this in the New Zealand food industry involved the successful identification of a fine crystalline material related to cheese contamination, using synchrotron analysis conducted by Dr Graeme Gainsford from Industrial Research Limited, New Zealand.

with synchrotron
science we will invent
new technologies

Advanced materials and the engineering of these materials are expected to change significantly in the coming decade. Identifying new pathways to novel advanced materials is a hot area of science with considerable worldwide momentum. Success will rely heavily on a sophisticated understanding of the electronic, chemical, structural and physical properties of these materials, at atomic, nano-, micro- and macro-scales.

New Coatings

Professor Rob Lamb at the University of Melbourne specialises in surface and materials science. He is particularly interested in fabricating molecular thin films, measuring their nano-scale properties, and developing new applications. Professor Lamb and his colleagues have developed environmentally protective non-stick coatings and thin-film photonics devices.

New Textiles

A new silk-like fibre made from wool is the culmination of more than 10 years of product development by CSIRO and The Woolmark Company, in which synchrotron analysis played a significant role. “We were looking to challenge the conservative view of wool, and apply innovative technology to create new kinds of wool textiles,” said Dr David Phillips, who led CSIRO’s research team. “We found we could stretch and set wool to create a new fibre that has a silk-like and soft touch, distinctive sheen and subtle lustre, and retains the moisture sorption and comfort properties of wool. We needed to know exactly what was happening at the molecular level, so we used synchrotron x-ray diffraction analysis. These synchrotron results gave us the confidence we needed to commercialise the product”. Commercial manufacture of the new fibre started in 2000 in Melbourne and it is now retailed worldwide in high-value garments as an alternative to silk, mohair and cashmere.

New Manufacturing

Synchrotron techniques have been used to study materials such as electrodes used in battery manufacture and aluminium smelting, catalysts, solar cells and photonic materials.

In New Zealand, for example, synchrotron research has led directly into new designs for lithium ion batteries.

with synchrotron
science we will break
new boundaries

Genome Exploration

The Australian Synchrotron provides an opportunity to explore genomes of particular value to our national and economic interests, such as those involving diseases and agricultural pests.

X-ray Vision

Synchrotron phase contrast imaging and 3-D tomography are enabling researchers to see, non-destructively and with extraordinary clarity and definition, tiny insects trapped inside opaque amber beads, minute fossils hidden within ‘solid’ rocks, ancient texts written on parchment but subsequently scraped off and painted over, individual air-sacs as lungs expand when a newborn takes its first breath and the exact location and size of tumours in soft tissue or bone.

The commercial applications of synchrotron phase-contrast imaging have been captured by Australian companies that have transferred ideas developed from synchrotron science and applied them to biotechnology.

Solving Long-held Mysteries

Using synchrotron light, a single hair from the preserved hide of ‘Phar Lap’, Australia’s most famous race horse, indicated he ingested a large dose of arsenic some hours before death.

Scientists used a few strands of carefully preserved hair from Beethoven’s head to reveal he suffered and died from acute, chronic lead poisoning.

Analysis of pigments from Egyptian sarcophagi reveal how the ancient Egyptians created and blended colours thousands of years ago.

with synchrotron science we will solve national problems

Australian science is experiencing expanding demand for synchrotron techniques to solve problems in environmental areas such as soil science, water and energy research, minerals processing, and metals in the environment.

Environment

Problems in environmental science, including bio-remediation, climate change, soil degradation and salinity, will require synchrotron techniques for their solution.

The Australian Synchrotron will enable the identification of very small concentrations of minerals, pollutants, waste matter and toxins in soils, streams, seawater and the atmosphere.

Synchrotron light allows us to identify sources of airborne pollutants with unprecedented accuracy.

Synchrotron light is also used to help clean up contaminated sites, including the site of the September 11 terrorist attacks on New York. It is also used to help with the management and remediation of mine tailings, and polluted industrial sites.

Synchrotron techniques advance our understanding of the environmental behaviour of contaminants. The outcomes will be seen in risk assessment protocols, management options and land-use policies.

Energy Research

Synchrotrons can combine some of the most rapidly advancing areas in science, such as nanotechnology and synthetic biology, in the race to create new technologies that produce carbon-neutral energy. Examples include the development of better fuel cells, solar panels, and catalytic converters, as well as cleaner diesel engines, the development of membranes for gas separation, geothermal energy and clean coal technologies.

Global Warming

Synchrotron light is used to understand atmospheric science including ozone depletion and global warming. Synchrotron light is also used to unlock climate and environmental information stored in plants, ice cores, corals and marine animals.

Water Research

Synchrotron techniques are ideal for researching contaminants in water, their concentration, location and removal options, including desalination.

By improving our understanding of the environment, synchrotron light will contribute to our understanding of water and to the international search to save, renew and locate water.

Australian scientists are developing clever ideas to save and recycle water, and are working on membranes that will purify recycled wastewater and techniques to cut water usage in mining and manufacturing operations.

with synchrotron
science we will build
the nation's wealth

The synchrotron community is seeking to establish what science needs to be done in our national interest, where our national strengths lie and the important international trends. It is only by being continually aware of international trends and developments that synchrotron users are able to remain at the forefront of research.

A revolution is under way in biology and biotechnology that will escalate in coming years. Physical and life sciences are converging. Major advances are appearing in materials science. Traditional industries such as agriculture and mining continue to innovate to maintain their competitive advantages.

Internationally synchrotron science continues to grow rapidly, including in the size of user communities, the number of facilities and developments of new methods. Australian synchrotron science will be at the leading edge of such developments.

There have been and will be numerous problem-solving applications that translate to improvements in businesses. Breakthrough opportunities must also be sought, both from existing areas (for example, rational drug design) and from new areas at the interfaces of the traditional science and technology disciplines.

A characteristic feature of the Australian Synchrotron will be that leading scientists and technologists will be working together in the same place. A well-delivered industry program will make the Australian Synchrotron a national focal point for innovation leading to industry benefits.

Value capture of synchrotron-related activities will include assistance in developing pathways into industry for synchrotron-related technologies, rather than simply bringing industry applications to the facility.

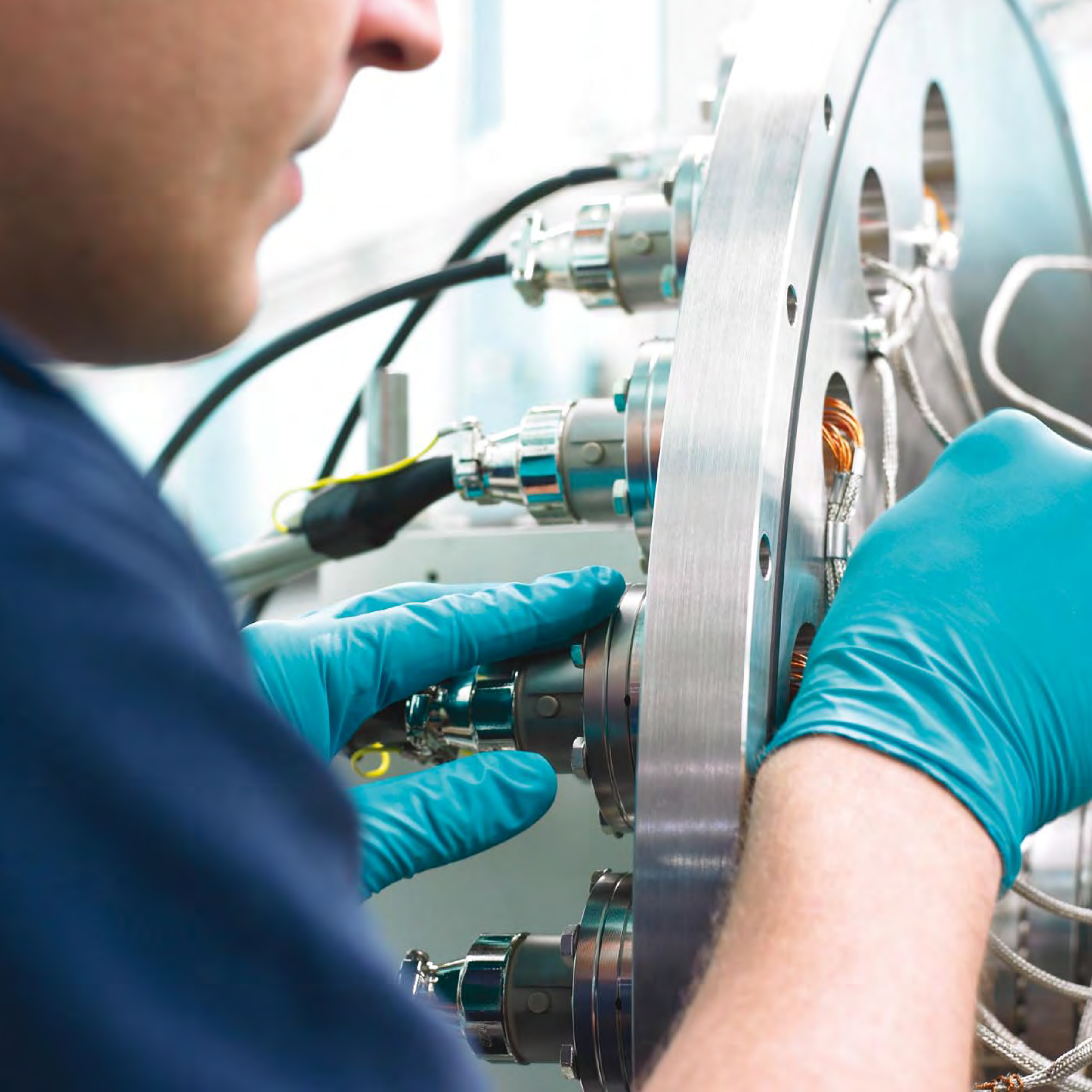
Earth Resources

Mineral exploration is critical to Australia's future and will be driven by sophisticated models based on synchrotron data that provide a detailed understanding of ore forming processes through a molecular understanding of the behaviour of metals in the environment.

Synchrotron-based techniques provide valuable information on the structural, dynamic, electronic and magnetic properties of materials under previously unexplored conditions. Experiments at extreme temperatures, pressures and magnetic fields, such as found at the Earth's centre, are now within reach.

The generation of accurate, predictive models of the Earth is the aim of the next generation of mineral exploration. Information obtained using synchrotron light is having a major impact in this field.

Synchrotron light is having a similar impact on the optimisation of minerals processing from ore. Even relatively minor improvements in processing efficiency can have a major impact on the economic returns.



Biotechnology and Medicine

Synchrotron-based research plays a major role in the design, development and safety of drugs, and Australia is a world leader in this area.

The Australian Synchrotron will give Australia high-throughput methods for drug discovery and increase our capabilities in drug design. Veterinary pharmaceuticals are a particularly large market for Australian and New Zealand industry.

Structural biology seeks to understand living systems at the level of the single molecule using the method known as protein crystallography. Internationally competitive protein crystallography depends on easy access to a synchrotron. The Australian Synchrotron provides an opportunity to explore genomes particularly relevant to our national economic interests, such as in medicine or agriculture.

Manufacturing and Materials

An integration of the Australian Synchrotron with Australian manufacturing industry is of key importance. Synchrotrons will support developments in advanced materials, engineering materials, nanotechnology as well as production methods.

Success in the development of new types of advanced materials for manufacturing relies on understanding the electronic, chemical, structural and physical properties of these materials at very small scales. Efforts in nanotechnology will develop biocomposites and bionanocomposites from renewable resources to achieve sustainability in industrial applications.

The analysis of magnetic materials is an important branch of materials science for the development of computer memory technology. The OPAL research reactor and the Australian Synchrotron will stimulate increased activity in this area.

Synchrotron techniques play a significant role in fundamental fibre research as well as in extending our understanding of the effects of both chemical and physical processing of textile fibres. Surface treatments with synchrotrons can be a highly cost-effective means of specifically modifying the surface properties of materials to create new textiles.

with synchrotron science we will serve our national research priorities

For both Australia and New Zealand, the pursuit of research excellence is a top scientific priority and synchrotron science is a key element of this strategy.

Maintaining a competitive edge internationally also requires a balance of research, covering pure, basic research, strategic research programs, tactical research, experimental development and short-term problem-solving.

Synchrotron technology contributes to all four of Australia's national research priorities, namely:

- An environmentally sustainable Australia
- Promoting and maintaining good health
- Frontier technologies for building and transforming Australian industries
- Safeguarding Australia

For the New Zealand Government, a top priority is research in population health, especially in diseases such as diabetes and cancer. Biotechnology is also a high priority, informing areas such as food and beverages, pharmaceuticals, neutraceuticals and biosecurity. The synchrotron feeds other priority areas such as nanotechnology, energy, climate change, oceanographic research, sustainable development and biodiversity.

with synchrotron science we will build national skills and expertise

Synchrotron facilities will increasingly be used by non-experts. Consequently, facilities will experience an increasing need for scientific and technical expertise. This trend provides significant stimulus for universities and training institutions to provide appropriate courses and training for the next generation of experts. The Australian Research Council recognised the importance of training in its funding of the Molecular and Materials Structure Network, which, with the Australian Synchrotron Research Program and Australian National University summer schools, provided training courses in a range of synchrotron techniques. Australia should continue such collaborations to address major skills shortages.

The synchrotron user community recognises an important need for training of more beamline scientists and technicians. It sees value in postdoctoral fellowships being established at the Australian Synchrotron, joint appointments between universities and the Australian Synchrotron, support for postgraduate researchers and forums such as summer schools for early career researchers.

The Australian Synchrotron Research Program Fellowship scheme has been a major success, with many of its 'graduates' taking up positions at the Australian Synchrotron. Scientists of this calibre must continue to be attracted, trained and retained, especially to give them expertise in the right range of disciplines. This is only possible if continued attention is paid to the development of interdisciplinary science.

The continuation of overseas access will provide a mechanism to enable skills to be developed at other synchrotrons before it is decided whether to introduce similar capabilities at the Australian Synchrotron.

There are growing opportunities for international collaboration in holding training schools and workshops. Within our region the newly formed Asia–Oceania Forum for Synchrotron Radiation Research is taking a leading role in delivering coordinated international and synchrotron schools.

what do we need to do?

australia must keep investing in synchrotron-based science

Developments in synchrotron science have been driven by improvements in the source, beamline optics and detectors.

Accelerator Development

The next decade will see significant developments in accelerator technology. Decreasing the length of the pulse of x-rays from the synchrotron will allow experiments to probe ultra-short timescales, opening up exciting new areas of science.

The Australian Synchrotron's accelerators will be subject to ongoing development and upgrades. There will be opportunities to increase the brilliance of the synchrotron by modifying its overall architecture.

Fourth generation sources are rapidly emerging and will enable scientists to probe structures on unprecedented timescales and to image with unprecedented resolution. There are potential niches for Australia, such as an ultra-short pulse source using superconducting accelerator technology. This would enable probing of protein function and it could be accommodated on the Australian Synchrotron site.

Optics

Optics developments over the preceding decade have encompassed both improved performance from existing optics, and the development of new x-ray optical elements, and this trend is forecast to continue over the coming decade.
Key drivers are:

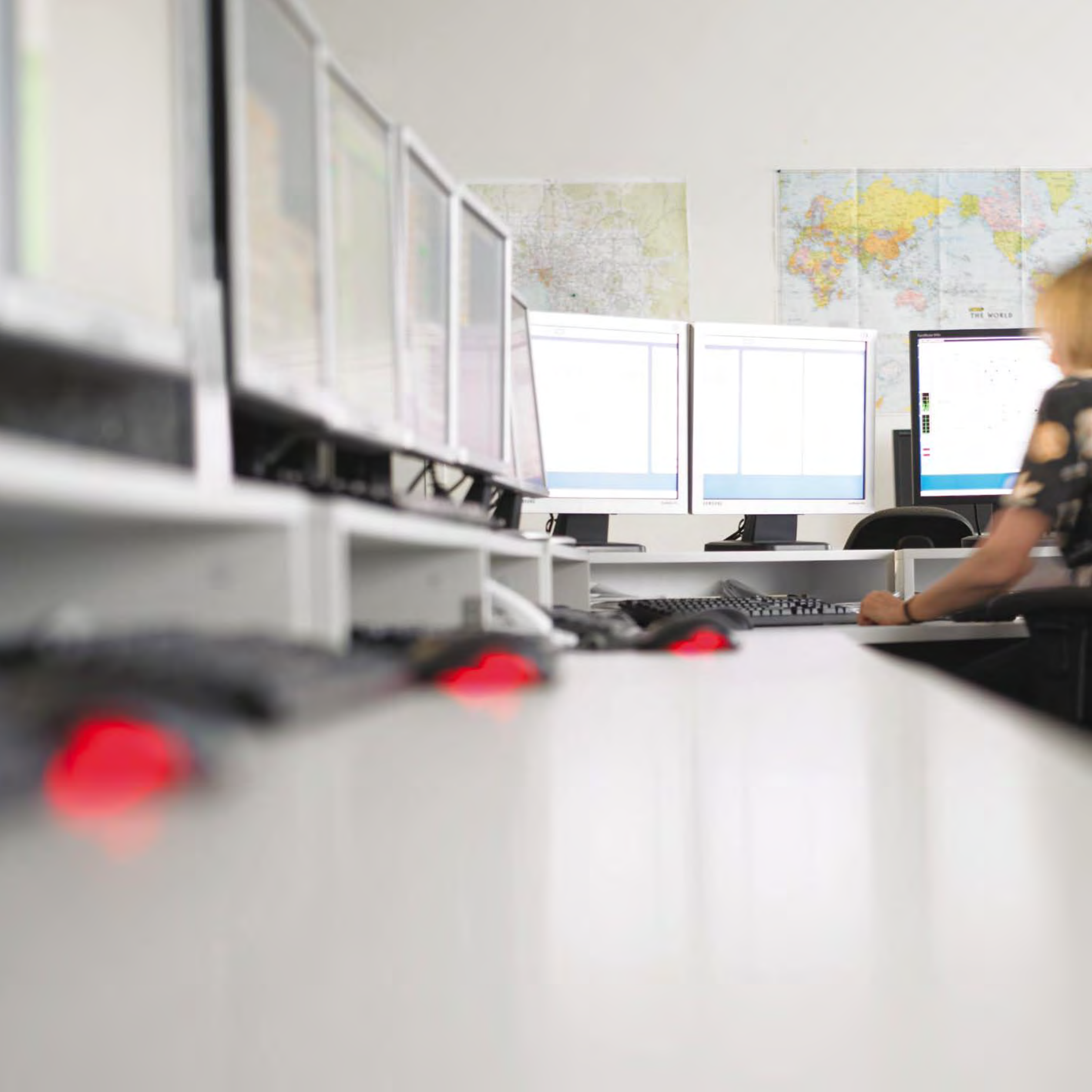
- the push for seeing smaller things
- the need to conserve the beam quality of the sources
- the advent of better and more powerful sources.

Much of the manufacture of optics is dominated by a few specialist companies. Australia has a good track record in conceiving and developing novel optics, for example the "Lobster Eye" micro-machined optics, and very high energy resolution crystal optics. Both of these projects were developed by Melbourne-based groups, so an opportunity exists to combine with the Australian Synchrotron staff and the increasing Australian activities in coherence-based research to work on niche novel optics development.

Detectors

There are large gains in capability to be had from new detector developments. Improvements are needed, and are being realised, in all key performance attributes of x-ray detectors.

Detectors have long been the 'weak link' in the synchrotron experimental chain. The development of detectors has lagged behind the development of other aspects of synchrotron-related technologies. However, a number of new collaborations, including CSIRO, the CRC for Biomedical Imaging Development and the University of Melbourne, are intending to inject significant impetus into this area. Monash University has attracted a very strong research team, many from the distinguished Daresbury Laboratory in the UK. Developments are progressing in both advanced imaging and spectroscopic detectors that are tailored for the needs of the Australian Synchrotron.


THE WORLD

Methods

As the technology of synchrotron facilities improves, new experimental methodologies are continually developed.

Phase-contrast imaging is emerging as a critically important imaging method using synchrotrons, and Australia has world-leading expertise in this area.

We must ensure that the Australian Synchrotron uses its expertise to implement world-leading phase-contrast imaging facilities. Many, if not most, molecules of biological interest are not amenable to imaging by conventional crystallographic methods. One potential solution to this problem is to use diffraction from fourth-generation sources. Australia must have access to these facilities if our scientists and industries are to benefit from the information yielded by these techniques.

Access

To maintain equality between geographically widespread Australian and New Zealand researchers, mechanisms to facilitate travel and access to the Australian Synchrotron must be developed.

eResearch has emerged as an increasingly important trend across all research areas in recent years, and will become an intrinsic aspect of research over the coming decade. It will enhance and stimulate collaborative research and will be indispensable for cost-effective access to major facilities. Elements such as virtual laboratories and other collaboration environments, high capacity and high performance networks, databases and database services, remote access to synchrotron beamlines, high performance computing and grid computing (for automated structure determination) and mass data storage will be required in the near future for scientific experimentation and communication.

International collaboration is continuing to grow in volume and importance. This often involves Australian and New Zealander researchers travelling to other facilities to work with collaborators there, reinforcing the need for programs to support travel and access to overseas facilities.

an investment plan for synchrotron-based science until 2017

The top priority for the Australian Synchrotron community is completion of the initial suite of beamlines to world-class standard.

Access to the Australian Synchrotron and complementary techniques at international facilities will best be provided within a single framework. Funding will always be critical to support travel and subsistence as part of access to such facilities.

The Australian Synchrotron has the capacity to host more than 30 beamlines. A plan for evolution at the Australian Synchrotron has been developed, based on user demand, scientific excellence, national priorities, economic impact and instrument excellence. This will demand regular review and refinement.

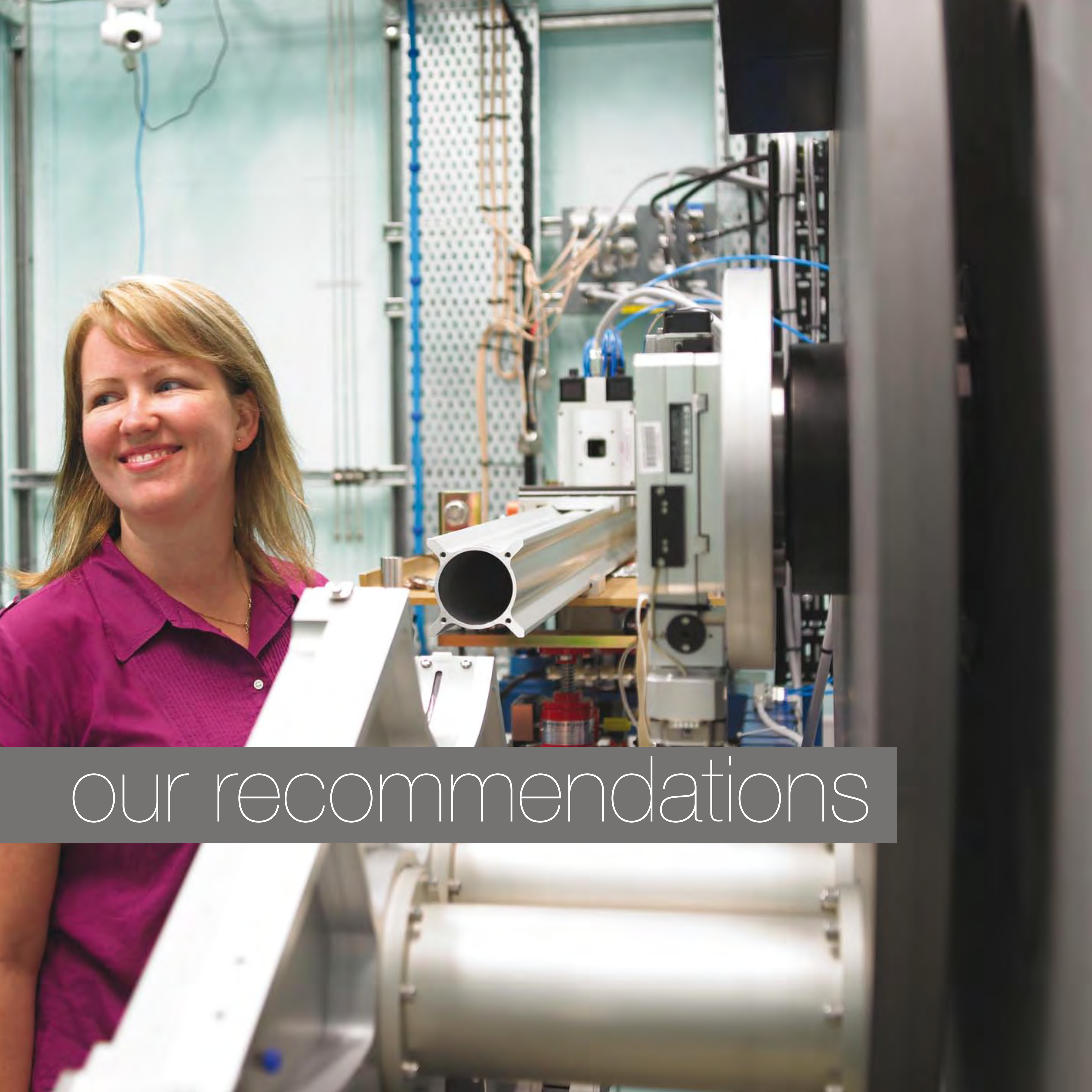
This resulted in three proposed phases of enhancement:

1. In the near term, circular dichroism, combined micro x-ray diffraction and fluorescence, extended-capability hard x-ray biomedical imaging and extended capability x-ray absorption spectroscopy.

2. In the second phase, high energy x-ray diffraction, high-throughput micro computed tomography, a long, high coherence beamline, quick-scanning x-ray absorption spectroscopy and time-resolved reflectometry.

3. Finally, areas that require scoping or are currently emerging are micro lithography, nano lithography, photoemission electron microscopy, resonant inelastic x-ray scattering, small molecule crystallography, a tera hertz beamline, another protein crystallography beamline, a vacuum ultraviolet beamline and x-ray microscopy / scanning transmission x-ray microscopy.

Developments in accelerators, detectors, robotics for remote access and x-ray optics should also be introduced in collaboration with research partners, and further skills development undertaken.



our recommendations

Developments across synchrotron-based science will be monitored and this plan amended accordingly in coming years. In addition to our detailed recommendations, we regard investment in eResearch modes as essential in the near future for scientific experimentation and communication.

1. The initial suite of beamlines should be completed to world-class standards.

2. Resources should be made available for Australian researchers to continue to access overseas synchrotrons until beamlines are available locally, and for capabilities not available at the Australian Synchrotron, including access to fourth generation sources. Resources should also be provided for travel and subsistence costs associated with users accessing the Australian Synchrotron.

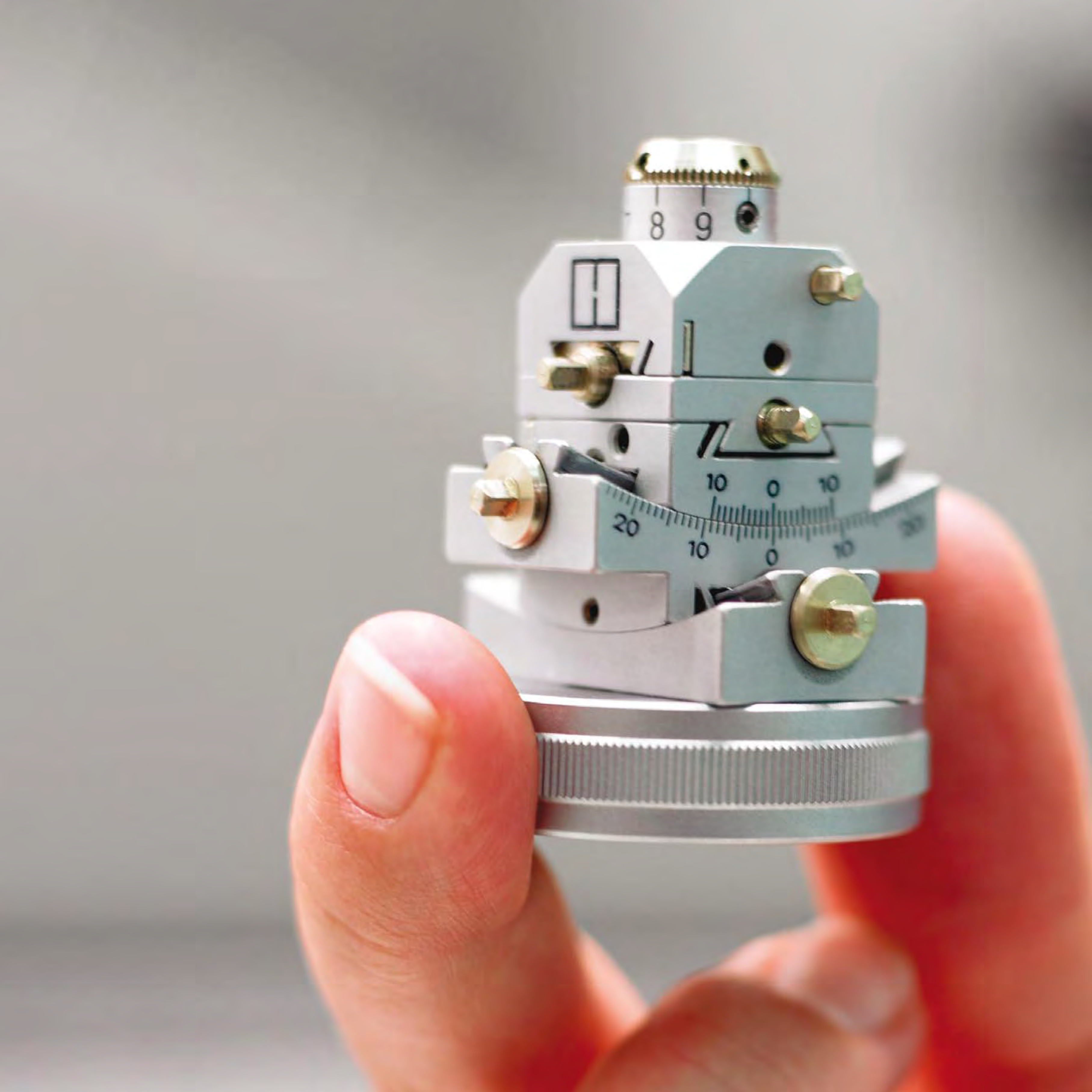
3. Access will best be provided under a single framework that includes the allocation of access to the Australian Synchrotron as well as international access.

4. The Australian Synchrotron should be continually upgraded and evolve in its capabilities.

In the near term this would be with the addition of circular dichroism, combined micro x-ray diffraction and fluorescence, medical imaging and extended-capability x-ray absorption spectroscopy.

High energy x-ray diffraction, high-throughput micro computed tomography, a long, high coherence beamline, quick-scanning x-ray absorption spectroscopy and time-resolved reflectometry would be subsequently introduced.

Areas that require scoping or are emerging are micro lithography, nano lithography, photoemission electron microscopy, resonant inelastic x-ray scattering, small molecule crystallography, a tera hertz (THz) beamline, a protein crystallography beamline that would be the third at the Australian Synchrotron, a vacuum ultraviolet beamline and x-ray microscopy / scanning transmission x-ray microscopy.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5. Suitable convenient accommodation should be provided for scientists visiting the Australian Synchrotron.

6. Developments in accelerators, detectors, robotics for remote access and x-ray optics should also be introduced in collaboration with research partners. Ongoing funding for the Australian Synchrotron should include a commitment to new instrumentation and refurbishments.

7. Australia's x-ray optics and detector development communities should be nurtured.

8. The capabilities proposed in this strategic plan should be accompanied by complementary development of skills among users, training of additional beamline scientists and technicians and development of the absorptive capacity required for future enhancement of the Australian Synchrotron.

9. The synchrotron community should actively engage with governments, the broader scientific community and the wider public.

10. Industry-related programs should include a demonstration project program, further development of capabilities attractive to industry, rapid and timely access, appropriate intellectual property protocols, quality assurance, integrated safety practices and technical consulting and support. A successor to the National Industry Advisory Committee should be established.

expert subcommittee on decadal planning

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