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Australian Government

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Australian Synchrotron

Turning bright ideas into brilliant outcomes

BEAMLINES: DELIVERING REAL BENEFITS

‘THE USEFULNESS OF SYNCHROTRON LIGHT IS LIMITED ONLY BY OUR IMAGINATION’

– LIFE

PROFESSOR EMERITUS
SIR GUSTAV NOSSAL AC CBE FAA FRS

7 NEW BEAMLINES

ENABLING AUSTRALIAN AND NEW ZEALAND DISCOVERY AND INNOVATION INTO THE FUTURE

In its short lifetime, the Australian Synchrotron has become one of Australia's most important pieces of research infrastructure. The unique properties of synchrotron light provide academic researchers and industry with results that are greater in accuracy, clarity, specificity and timeliness than those that could be obtained using conventional laboratory equipment.

The Australian Synchrotron's ability to facilitate high quality research and to deliver real-life benefits is directly linked to the number of beamlines it hosts. With 38 ports available for experimental stations, the Australian Synchrotron has capacity for many more than the current 10 that are simultaneously supported; each of the 10 is oversubscribed and researchers require access to a broader suite of techniques than those currently available.

New beamlines will provide the tools needed for Australian and New Zealand industry and research communities to continue to compete on the world-stage with breakthrough research.

The areas of expansion build on existing facility strengths, meet future needs, match Australian and state government priorities in science and technology and, importantly, address growth areas in fundamental and applied science including in health and medical research, materials and textile science, manufacturing technology, and in engineering.

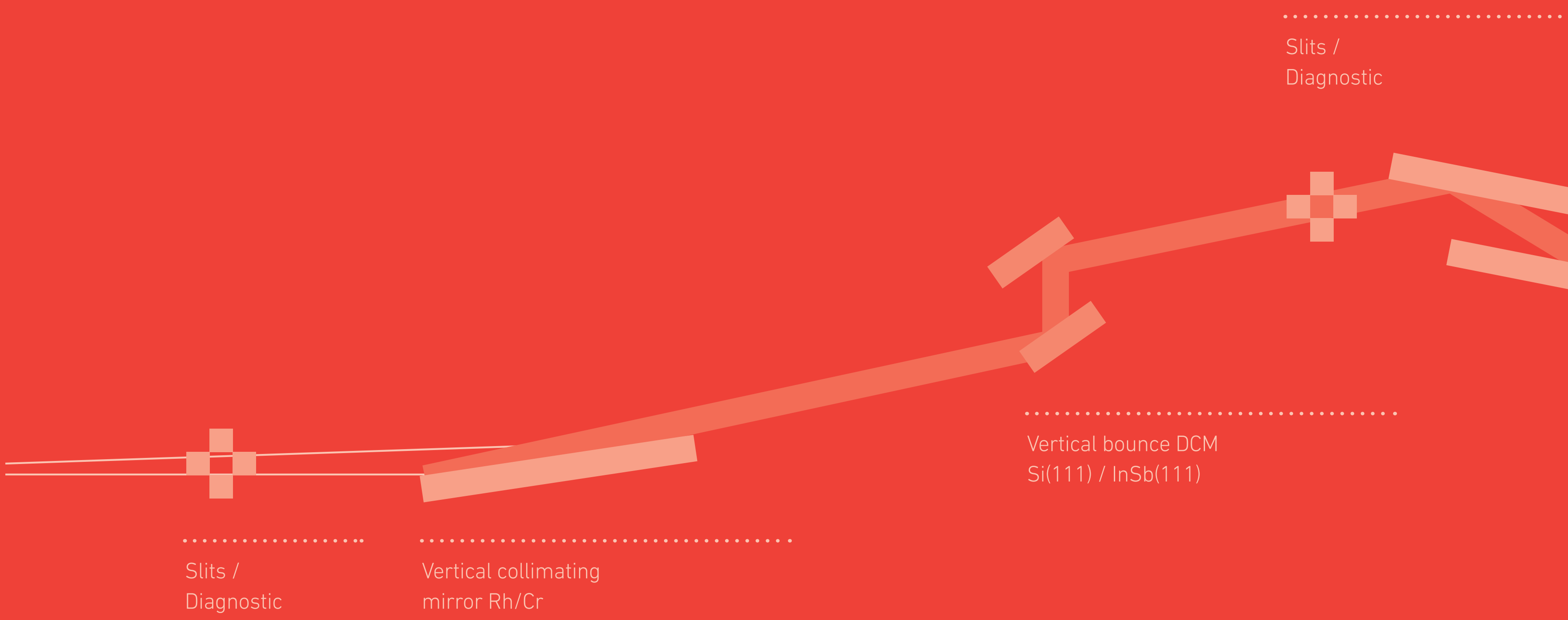
ALLEVIATE DEMAND ISSUES

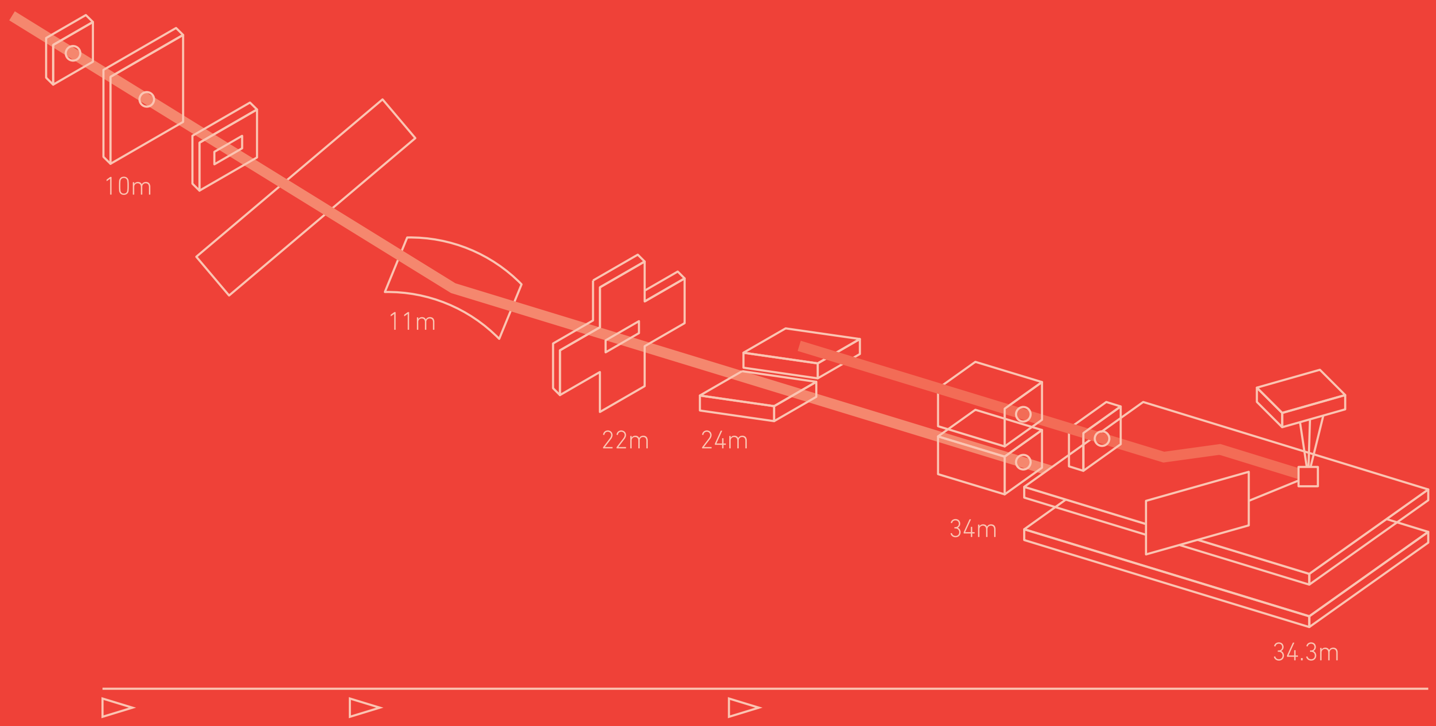
EXPAND CAPABILITY INTO AREAS OF WORLD-CLASS RESEARCH

THIS EXPANSION WILL GIVE AUSTRALIAN AND NEW ZEALAND INDUSTRY AND OUR BEST AND BRIGHTEST SCIENTIFIC MINDS ACCESS TO THE SPECIALISED TOOLS AND TECHNIQUES NEEDED FOR IMPORTANT RESEARCH, ENABLING THEM TO CONTINUE TO COMPETE ON THE WORLD-STAGE

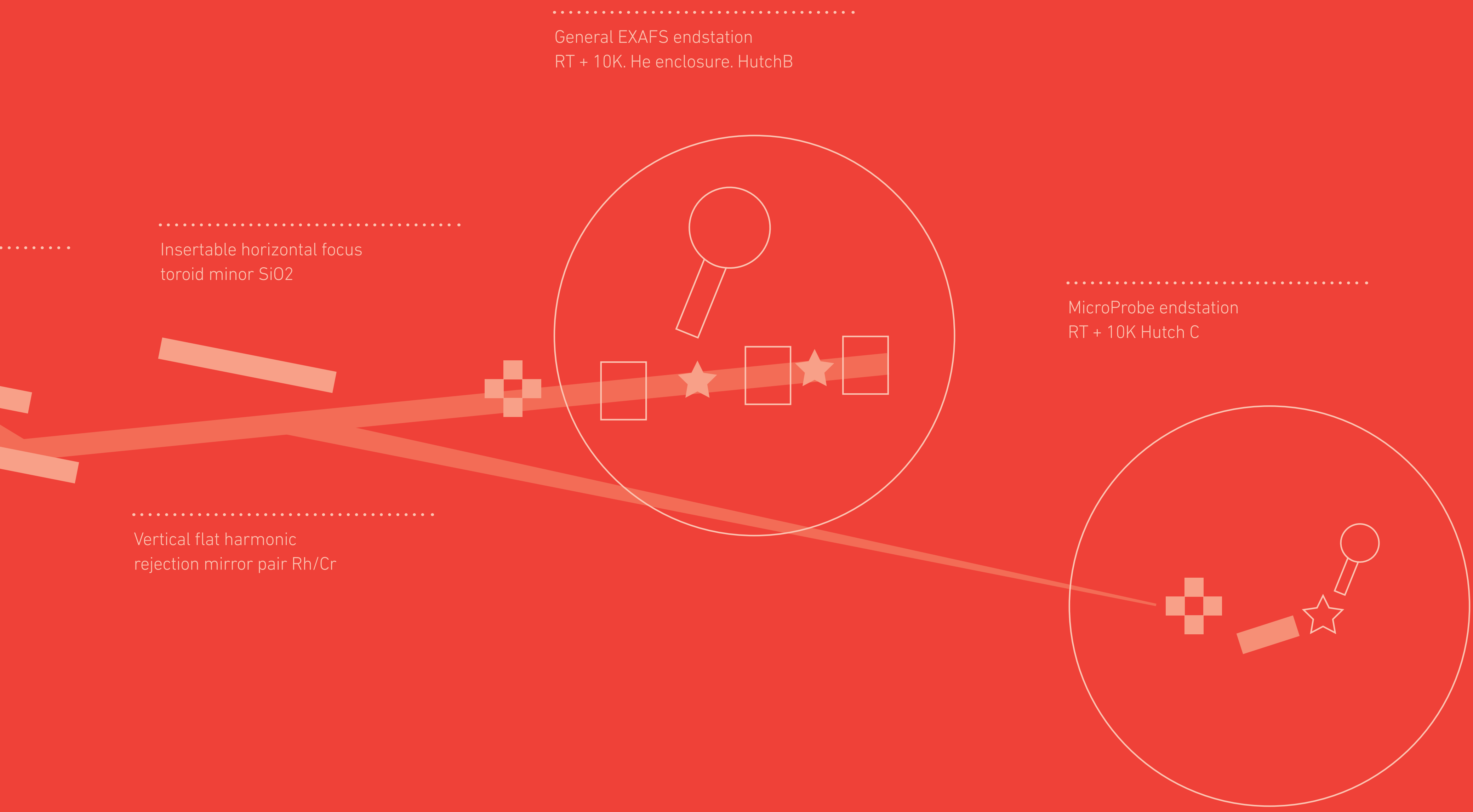
PROFESSOR ANDREW PEELE, DIRECTOR
AUSTRALIAN SYNCHROTRON

THE NEW BEAM


Slits /
Diagnostic
Vertical bounce DCM
Si(111) / InSb(111)
Slits /
Diagnostic
Vertical collimating
mirror Rh/Cr


10m
11m
22m
24m
34m
34.3m

–LINES


General EXAFS endstation
RT + 10K. He enclosure. HutchB
Insertable horizontal focus
toroid minor SiO2
MicroProbe endstation
RT + 10K Hutch C
Vertical flat harmonic
rejection mirror pair Rh/Cr

PRIORITY NO.1

ADVANCED DIFFRACTION & SCATTERING (ADS) BEAMLINE

High energy diffraction, pair distribution function analysis, laue diffraction, energy dispersive diffraction imaging, time-resolved and extreme environment powder diffraction.

The ADS beamline will be optimised for a range of leading-edge diffraction and scattering techniques including: studies of mineral formation and recovery under extreme conditions of temperature and pressure; non-destructive detection of cracking, fractures, textures, strains and deformations in large manufactured objects across the energy, automotive, transport, defence and aerospace sectors; maintenance and component failure studies of engineering infrastructure; and studies of corrosion and cracking in aluminium alloys used in aircraft and marine platforms.

THE ADS BEAMLINE WILL PROVIDE CAPABILITIES PREVIOUSLY UNAVAILABLE IN AUSTRALIA AND WILL REMOVE BARRIERS TO WORLD-CLASS SCIENCE CONDUCTED LOCALLY

Source	Super Conducting Multi-pole Wiggler
Energy range	30-120 keV
Energy resolution	Monochromatic, pink and white beam
Beam size at sample	Variable – 10μm-1mm
Experimental stations	Main at 60m, side station at 40m – simultaneous operation
Major research fields	Materials science and engineering; earth science; chemistry
Time to construct & commission	Four years

The main experimental station of the ADS beamline is outside the synchrotron building at a distance of 60m from the source point.

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

ADS *complements*

Existing beamline

POWDER DIFFRACTION (PD) BEAMLINE

BIOLOGICAL SMALL ANGLE SCATTERING (BIOSAXS) BEAMLINE

Small angle scattering structural characterisation of biomolecules (proteins, protein assemblies, viruses and hormones) using dedicated supporting infrastructure for high-throughput sampling.

The BioSAXS beamline will be optimised for measuring small angle scattering of proteins and other biological macromolecules. It will combine a state-of-the-art small angle scattering beamline with specialised on-line protein purification and preparation techniques for high-throughput protein analysis. This technique will complement the existing small and wide angle scattering beamlines, as well as the macro-molecular crystallography beamlines without relying on large quantities or crystallised forms of purified biomolecules. The BioSAXS beamline will accommodate the rapidly growing demand for small angle X-ray scattering investigations of biological macro-molecules.

Applications include a great impact in the study of the structure of larger biomedical molecules involved in the critical functions of human cells, such as proteins and the nucleic acids that compose the genetic material within cells, and the study of interactions between biological molecules and new drugs.

THE BIOSAXS BEAMLINE WILL BE SPECIFICALLY DESIGNED FOR STRUCTURAL BIOLOGY AND WILL HAVE EQUAL OR BETTER SPECIFICATIONS THAN THE CURRENT SMALL ANGLE X-RAY SCATTERING BEAMLINE, COMBINED WITH SPECIALISED FACILITIES FOR PROTEIN WORK, GIVING SCIENTISTS AND INDUSTRY UNPRECEDENTED ACCESS TO THE MOST SOPHISTICATED TOOLS AVAILABLE

Source	In-vacuum undulator
Energy range	Nominally 8-15 keV; optimised for 12 keV operation
Beam size at sample	Variable – 0.2-0.5mm
Q-range	0.005-0.5 $Å^{-1}$
Experimental stations	Single station – highly automated; high throughput mode
Major research fields	Structural biology
Time to construct & commission	Three years

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

BIOSAXS *complements*

Existing beamline

SMALL ANGLE X-RAY SCATTERING (SAXS) BEAMLINE

MACROMOLECULAR AND MICRO CRYSTALLOGRAPHY (MX1 AND MX2) BEAMLINE

PRIORITY NO.2

MICRO-COMPUTED TOMOGRAPHY (MCT) BEAMLINE

High-resolution 3D imaging with applications in the biosciences, geomaterials, palaeontology and materials science.

Micro-computed tomography opens a window on the micron-scale 3D structure of a wide range of samples relevant to many areas of science including life sciences, materials engineering, anthropology, palaeontology and geology. The MCT beamline will enable high-throughput and dynamic micro-CT down to submicron resolution. A key feature will be speed of data collection, focusing both on applications where many samples are imaged and experiments where a single specimen is imaged many times to observe dynamic responses to temperature, pressure, strain or other changing environmental conditions. The high brightness and high intensity monochromatic X-ray beam produced by the MCT beamline will provide significant advantages in spatial resolution, speed and contrast compared to conventional laboratory micro-CT instruments, including capabilities such as phase contrast, which can be implemented using synchrotron sources.

Applications include: studies of fabricated, structured, encapsulated or porous materials; studies of the structure and well-being of bone and teeth; and palaeontology and studies of encapsulated or amber-based fossils.

SYNCHROTRON MICRO-CT HAS THE POTENTIAL TO IMPACT ON SCIENTIFIC ENDEAVOUR IN A WIDE VARIETY OF FIELDS

Source	Bending magnet
Energy range	8-40 keV
Energy resolution	Variable – up to 4cm horizontal and 6mm vertical
Spatial resolution	Normal mode 1-10 μm; high resolution mode ~200 nm
Experimental stations	Two – standard CT and phase contrast station
Major research fields	Biology, health, food, archaeology, palaeontology, geology
Time to construct & commission	Three years

The MCT beamline will be constructed next to the existing Imaging and Medical beamline.

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

MCT *complements* — *Existing beamline*: IMAGING AND MEDICAL (IM) BEAMLINE

MEDIUM ENERGY XAS (MEX) BEAMLINE

Tender to hard X-ray absorption spectroscopy and microspectroscopy.

The MEX beamline will provide medium energy absorption spectroscopy on a bending magnet, optimised for cutting-edge applications in biological, agricultural and environmental science. It will cover an energy range not currently available to Australian and New Zealand researchers, allowing X-ray absorption spectroscopy measurements of a group of very important elements such as sulphur, phosphorus, silicon and chlorine. Focusing optics will add microprobe capabilities to this energy range. The MEX beamline will be highly complementary to both the existing X-ray Absorption Spectroscopy beamline and the X-ray Fluorescence Microscopy beamline at the Australian Synchrotron.

Applications include environmental studies of inorganic, organophosphate and organochlorine pollutants, water pollution, plant growth, micro-nutrient transport and soil salinity, as well as studies of biomineralisation.

THIS BEAMLINE WILL ENABLE THE CONTINUATION OF RESULTS OF THE HIGHEST QUALITY, IN ENERGY RANGES NOT CURRENTLY AVAILABLE AT THE AUSTRALIAN SYNCHROTRON, WITH THE ADDED CAPABILITY OF MICRO-FOCUS

Source	Bending magnet
Energy range	1.8-14 keV
Beam size at sample	2x10mm standard XAS; <5 μm micro-focus
Experimental stations	Two – standard XAS station; micro-focus station
Major research fields	Biology, agriculture, environmental and soil science
Time to construct & commission	Three years

The MEX beamline will include two experimental stations with micro-focus optics close to the sample.

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

MEX *complements* — *Existing beamline*: X-RAY ABSORPTION SPECTROSCOPY (XAS) BEAMLINE; X-RAY FLUROESCENCE MICROSCOPY (XFM) BEAMLINE

PRIORITY NO.2

HIGH PERFORMANCE MACROMOLECULAR CRYSTALLOGRAPHY (HMX) BEAMLINE

Micro-focus macromolecular crystallography for small and/or poorly diffracting samples.

The most important targets for the design of novel drugs include difficult large assemblies, which rarely produce crystals of sufficient size for analysis using traditional macro or micro-molecular crystallography beamlines. The HMX beamline will enable the study of sub-5μm crystals, providing a state-of-the-art high-throughput facility for researchers to study very small, weakly diffracting crystals of protein fragments and solution studies of protein fragments. Researchers working on medically-relevant projects for which only small, weakly diffracting crystals are achievable must currently travel to overseas facilities to collect data.

Applications include: in membrane proteins and receptors; virology; and materials science. The beamline will take advantage of the latest developments in high-throughput crystallography, including robot handling of 96-well crystallisation plates.

FLAGSHIP CRYSTALLOGRAPHY ENVIRONMENT SERVING AUSTRALASIAN BIOTECHNOLOGY AND SMART MATERIALS RESEARCH FOR THE NEXT DECADE, THE HMX BEAMLINE WILL PLACE AUSTRALIA'S AND NEW ZEALAND'S INTEGRATED STRUCTURAL BIOLOGY CAPABILITY AT THE FOREFRONT OF WORLD SCIENCE

Source	In-vacuum undulator
Energy range	6-18 keV
Beam size at sample	25 × 25 μm
Beam intensity at sample	>4e12 ph/s
Experimental stations	Single station – high throughput automated crystallography
Major research fields	Structural biology
Time to construct & commission	Three years

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

HMX *complements* — *Existing beamline* MACROMOLECULAR AND MICRO CRYSTALLOGRAPHY (MX1 AND MX2) BEAMLINE

HIGH COHERENCE NANOPROBE (HCN) BEAMLINE

High-resolution X-ray microspectroscopy and elemental mapping, coherent diffraction imaging.

The HCN beamline will provide a unique facility capable of spectroscopic and full-field imaging at sub-30nm resolution. This beamline will complement the X-ray Fluorescence Microscopy beamline at the Australian Synchrotron and offer increased sensitivity for high resolution imaging, as well as extended capability for full-field and phase imaging. With a cryogenic sample mount, the system will also provide the ability to probe frozen hydrated biological samples, imaging and identifying cellular substructures that are critical components in biological machinery, but are far smaller than what current beam spots can resolve. The HCN beamline will use an undulator source and a very long beamline, in the order of 100m, to deliver the highest brightness X-rays possible to an experiment.

Capable of accessing the K-edges of elements from phosphorous to silver, the HCN beamline will suit applications in chemistry, biological sciences, condensed matter physics, nanotechnology, environmental sciences and geology. The high coherence properties of the beamline will make it suitable for the development of new techniques in coherent X-ray science – an area that has been undergoing tremendous growth across the globe.

THE HIGH COHERENCE NANOPROBE BEAMLINE PROVIDES THE CAPABILITY TO PERFORM CUTTING-EDGE SCIENCE ACROSS A BROAD RANGE OF DISCIPLINES

Source	In-vacuum undulator
Energy range	2-20 keV
Beam size at sample	50-500 nm
Imaging resolution	5-10 nm (CDI)
Experimental stations	Single station – imaging station at ~100m from source
Major research fields	Biology, nano-materials, environment, fundamental physics
Time to construct & commission	Four years

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

HCN *complements* — *Existing beamline* X-RAY FLUORESCENCE MICROSCOPY (XFM) BEAMLINE

PRIORITY NO.2

MICRO MATERIALS CHARACTERISATION (MMC) BEAMLINE

Microdiffraction (mono and polychromatic), 3D phase and strain mapping.

Polycrystallinity, strain, grain orientation, defect structure, migration and organisation are fundamental to understanding the properties of materials. The MMC beamline will enable these properties to be measured in 3D at sub-micron scale and will be only the second 3D diffraction facility in the world. The MMC beamline will offer multiple micro-focus analysis techniques for materials science – monochromatic and Laue diffraction, X-ray fluorescence microscopy and selected area X-ray absorption spectroscopy.

Applications of this technique extend across a wide range of fields, including: solar cells; high-temperature and nuclear energy materials; pollutants; mining and mineral recovery processes; and biological materials.

THE ANALYTICAL STRENGTHS OF THE MMC BEAMLINE WILL FEED DIRECTLY INTO AREAS OF AUSTRALIAN RESEARCH STRENGTH, PROMOTING WORLD-CLASS RESEARCH ACROSS A WIDE RANGE OF DISCIPLINES

Source	Wiggler or wavelength shifter
Energy range	5-60 keV
Bandpass	Selectable white beam; 10% bandpass; 10^{-4}
Beam size at sample	1-5 µm
Experimental stations	Single station – multiple techniques
Major research fields	Materials science and engineering; geology; environmental science
Time to construct & commission	Three years

EXPANDING CAPABILITY AND SUPPORTING DEMAND:

MMC *complements* — *Existing beamline*: POWDER DIFFRACTION (PD) BEAMLINE, X-RAY FLUORESCENCE MICROSCOPY (XFM) BEAMLINE

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