



Australian
Synchrotron
Turning bright ideas into brilliant outcomes



Introduction to the Australian Synchrotron

*Michael James
Head of Science*

Supported
by



Australian Government



What is the Australian Synchrotron?



The Facility...



A **3 GeV accelerator** that accelerates bunches of electrons to near the speed of light to generate **intense beams** of X-rays, visible and infrared light



The Capabilities...



Pharmaceuticals &
Health

Device Fabrication

Materials Development

Minerals &
Mining

**A suite of laboratories with a wide range of
unique analytic capabilities**

Agriculture

Medical Imaging
& Therapy

Polymers/Semicon/
Ceramics/Metals

Protein Structure

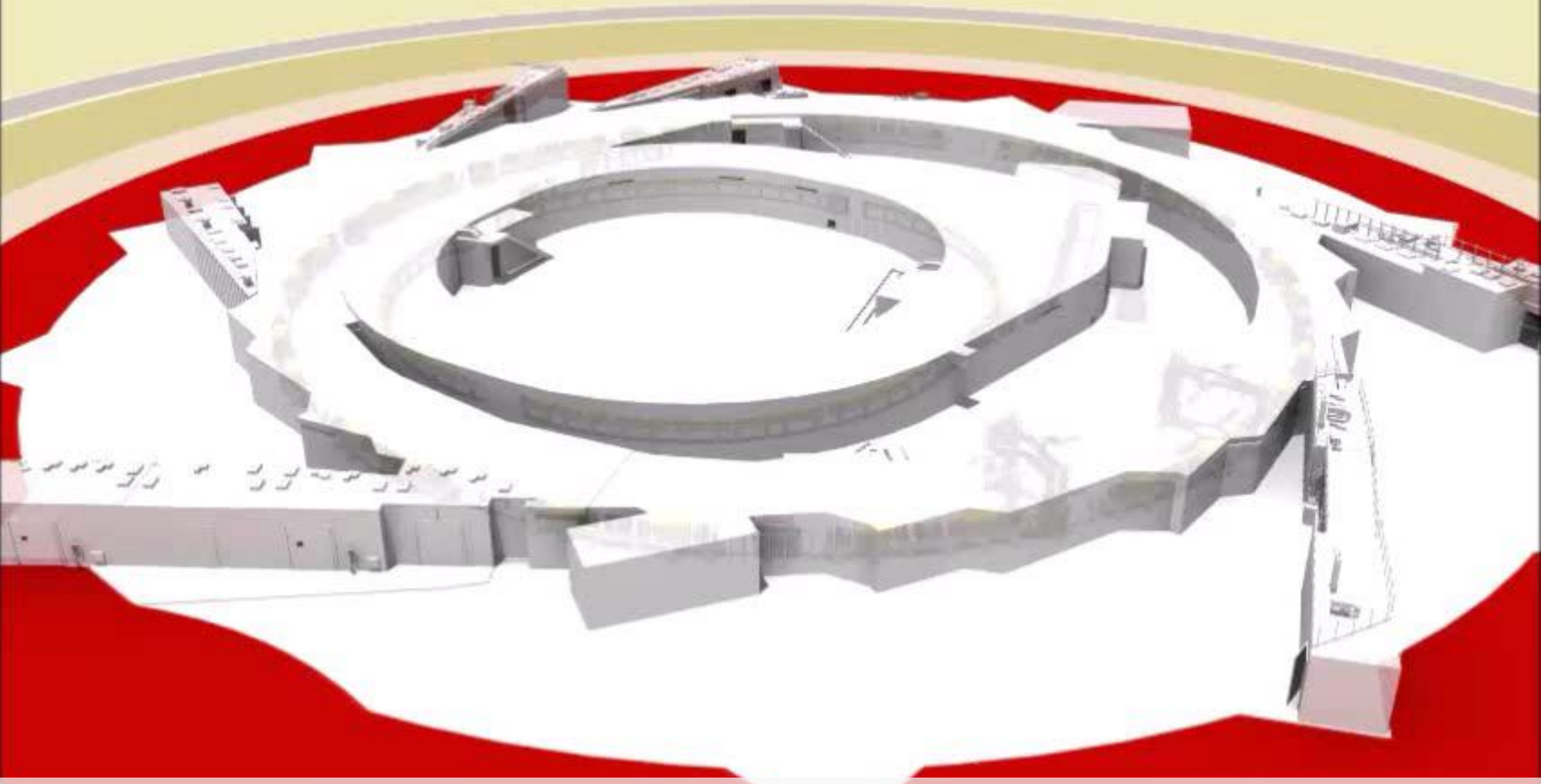
Surfaces
& Coatings



The Australian Synchrotron...

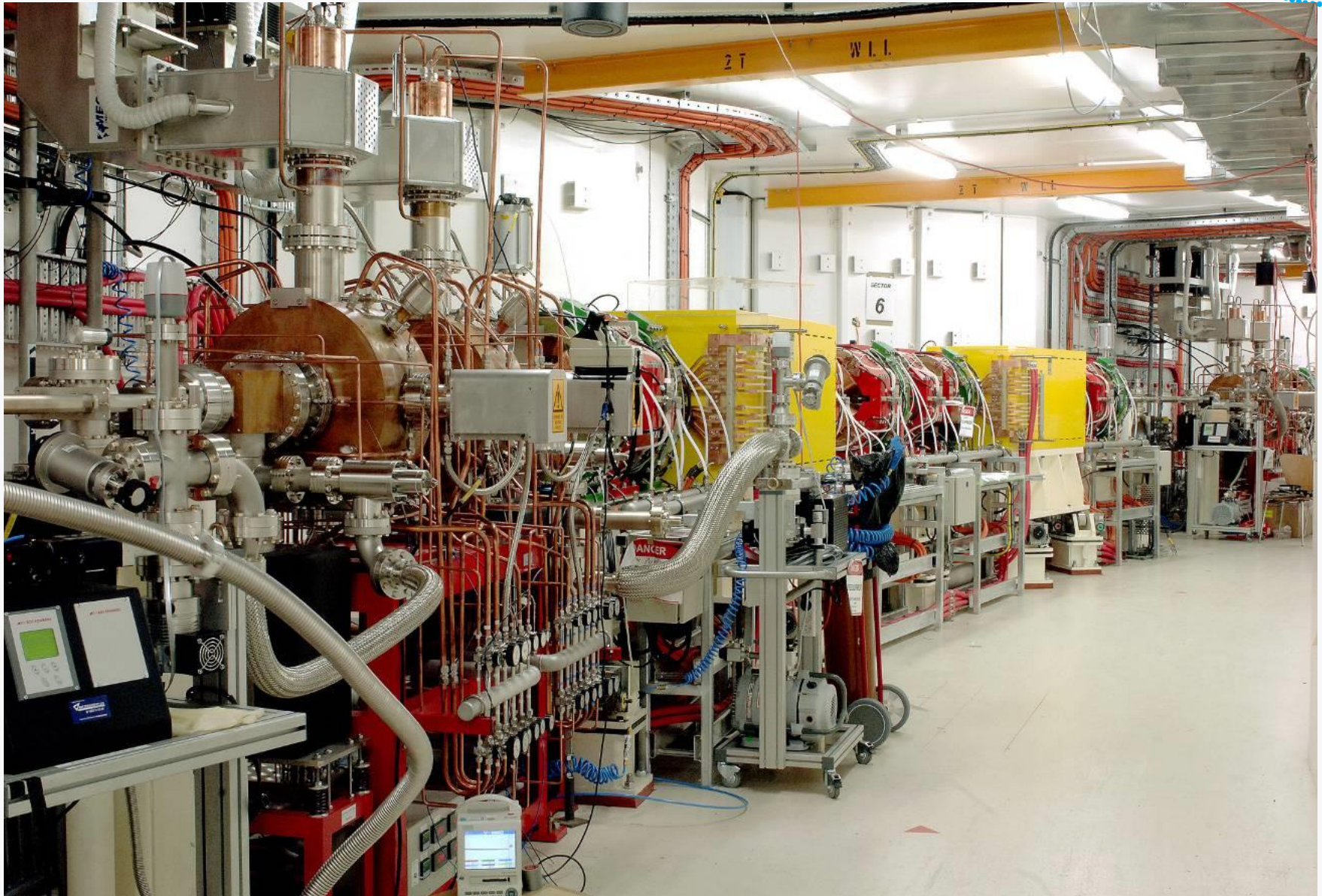


Is an electron accelerator...

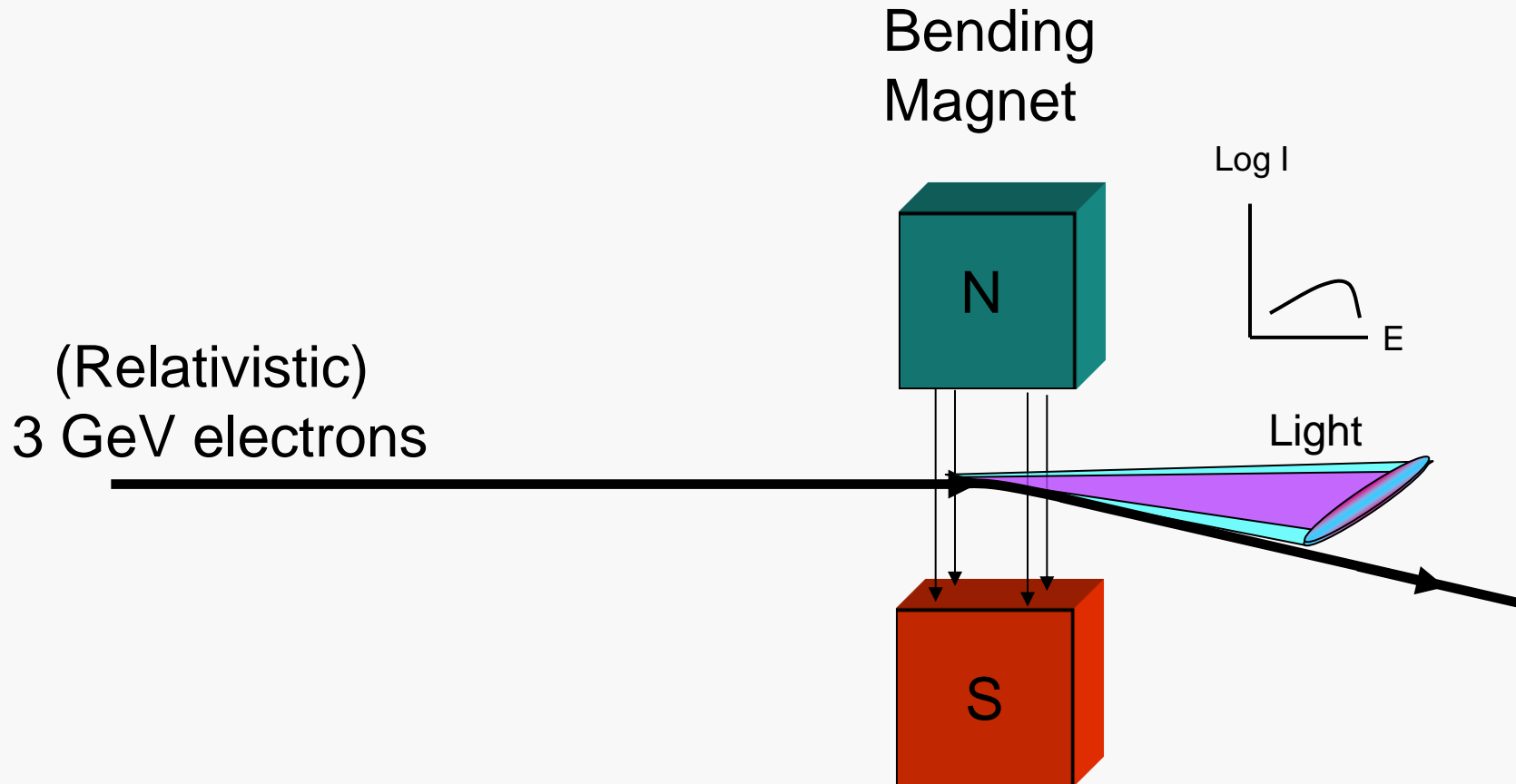


When electrons travel through magnetic fields at relativistic speeds they generate intense beams of synchrotron light (Infrared, visible and X-rays)

The Accelerator & Storage Ring...



How is light produced in a Synchrotron?

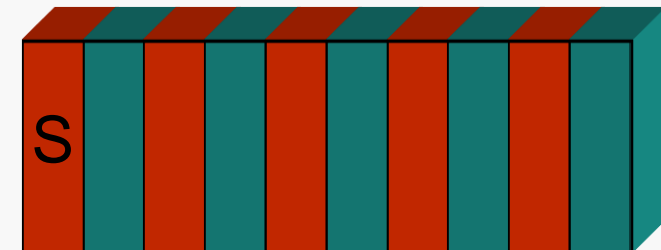
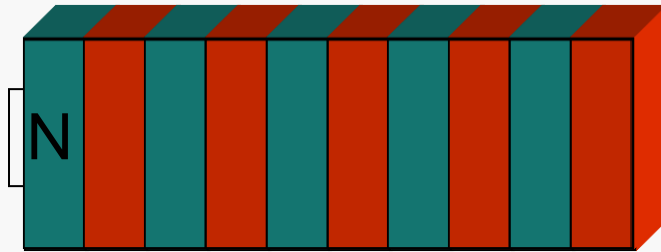


Synchrotron light produced by bending magnet sources is collimated, tunable, polarised and up to a **million** of times brighter than the sun.

How is light produced in a Synchrotron?



Undulator

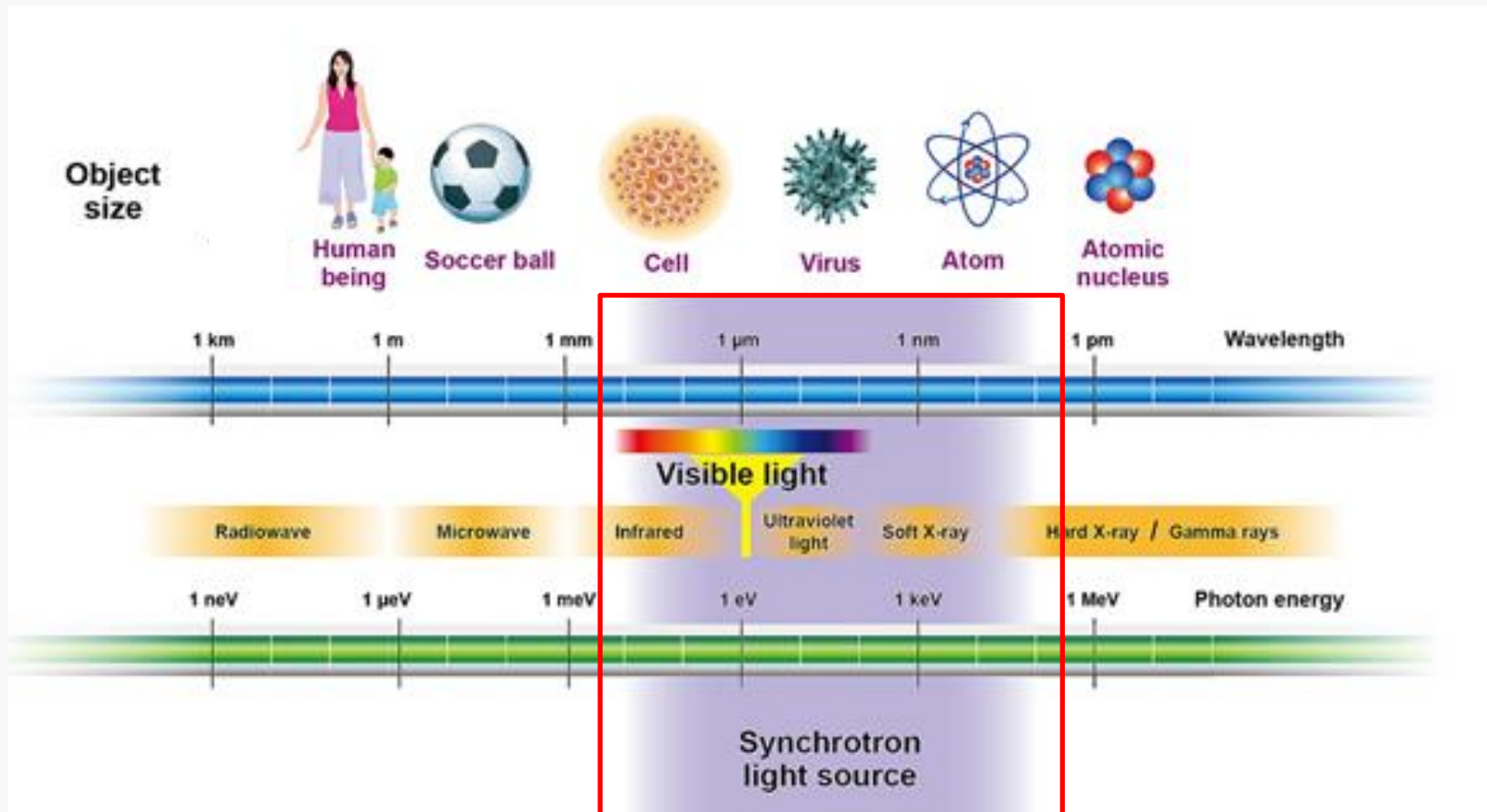


Log I

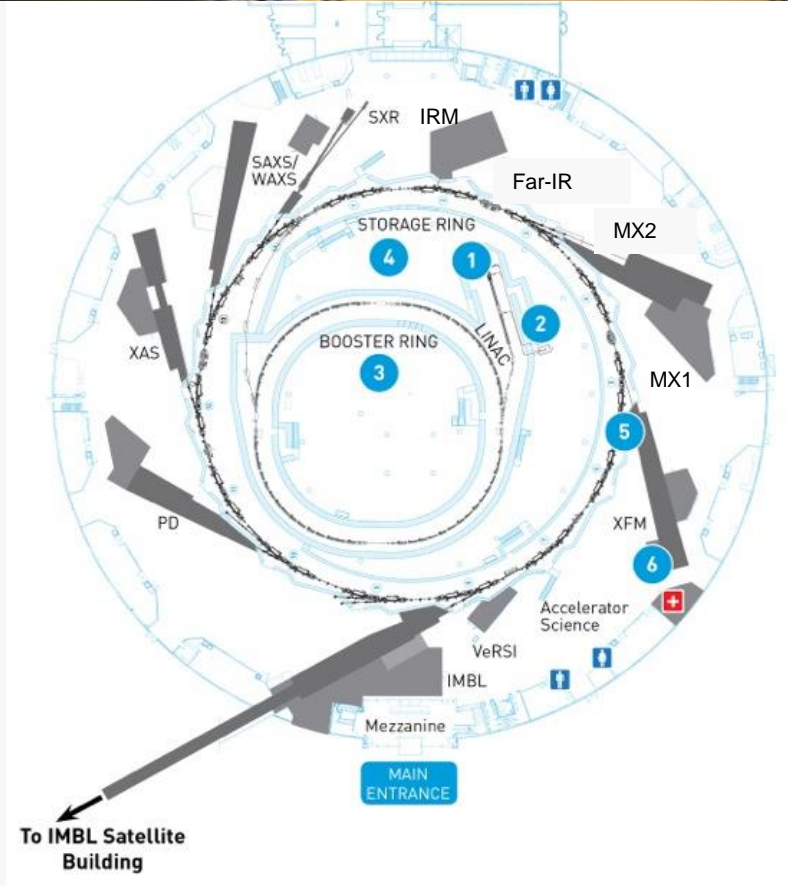


Light produced by the Australian Synchrotron can be **billions** of times brighter than light from the sun.

Synchrotron Light Covers a Wide Range of Energies



10 Beamlines with Capacity for ~30+...



Infrared Microscope

Terrahertz / Far-IR Spectroscopy

Soft X-ray Spectroscopy (90-2500 eV)

Soft X-ray Imaging (La Trobe Uni.)

X-ray Absorption Spectroscopy (4-50 keV)

Powder Diffraction (4 –37 keV)

SAXS / WAXS (6–20 keV)

Macromolecular Crystallography (MX1)

Micro-focused Crystallography (MX2)

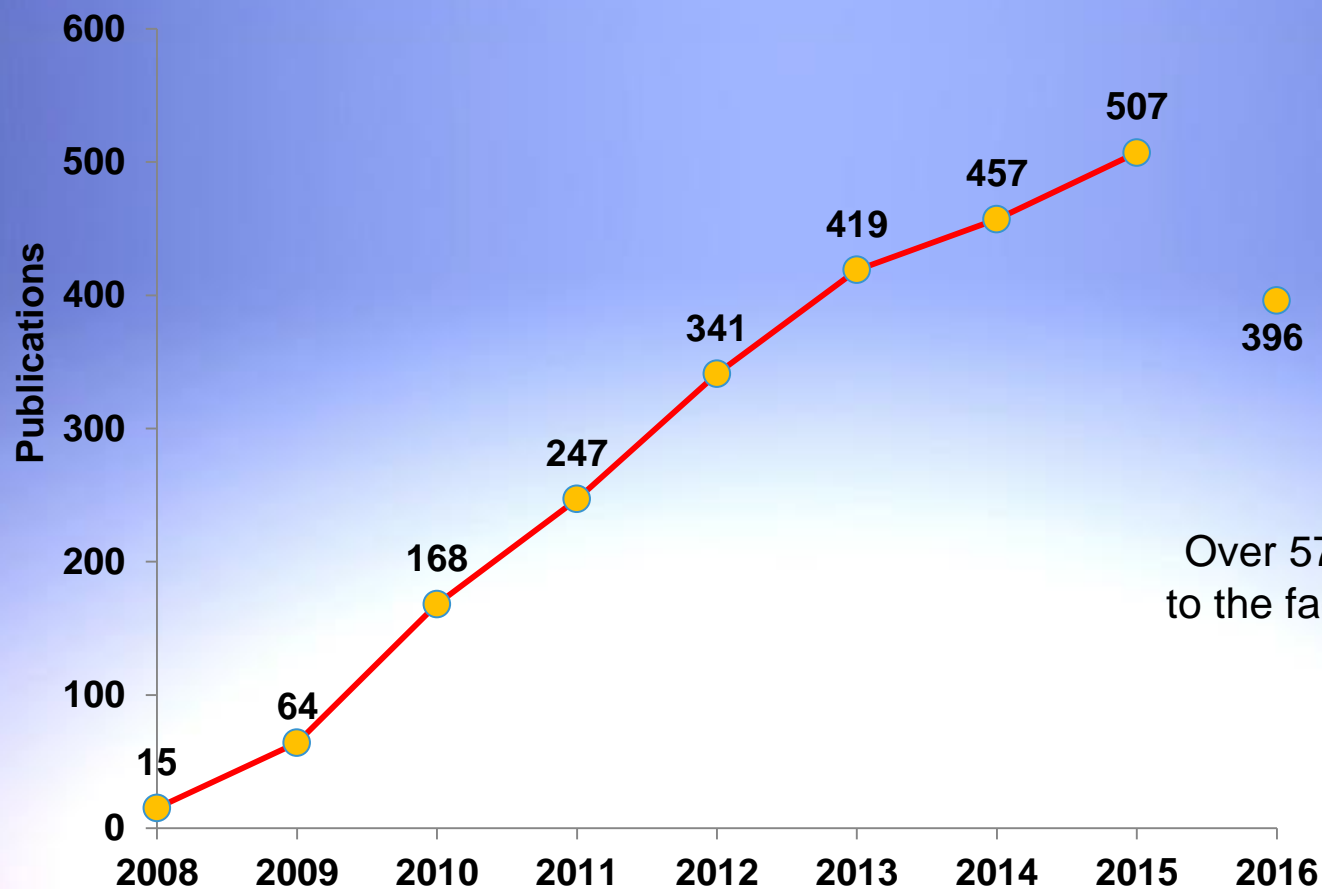
X-ray Fluorescence Microscopy (4–25 keV)

Imaging and Medical Beamline (30–120 keV)

Our User Community & Our Science.



Scientific Output From AS Beamlines



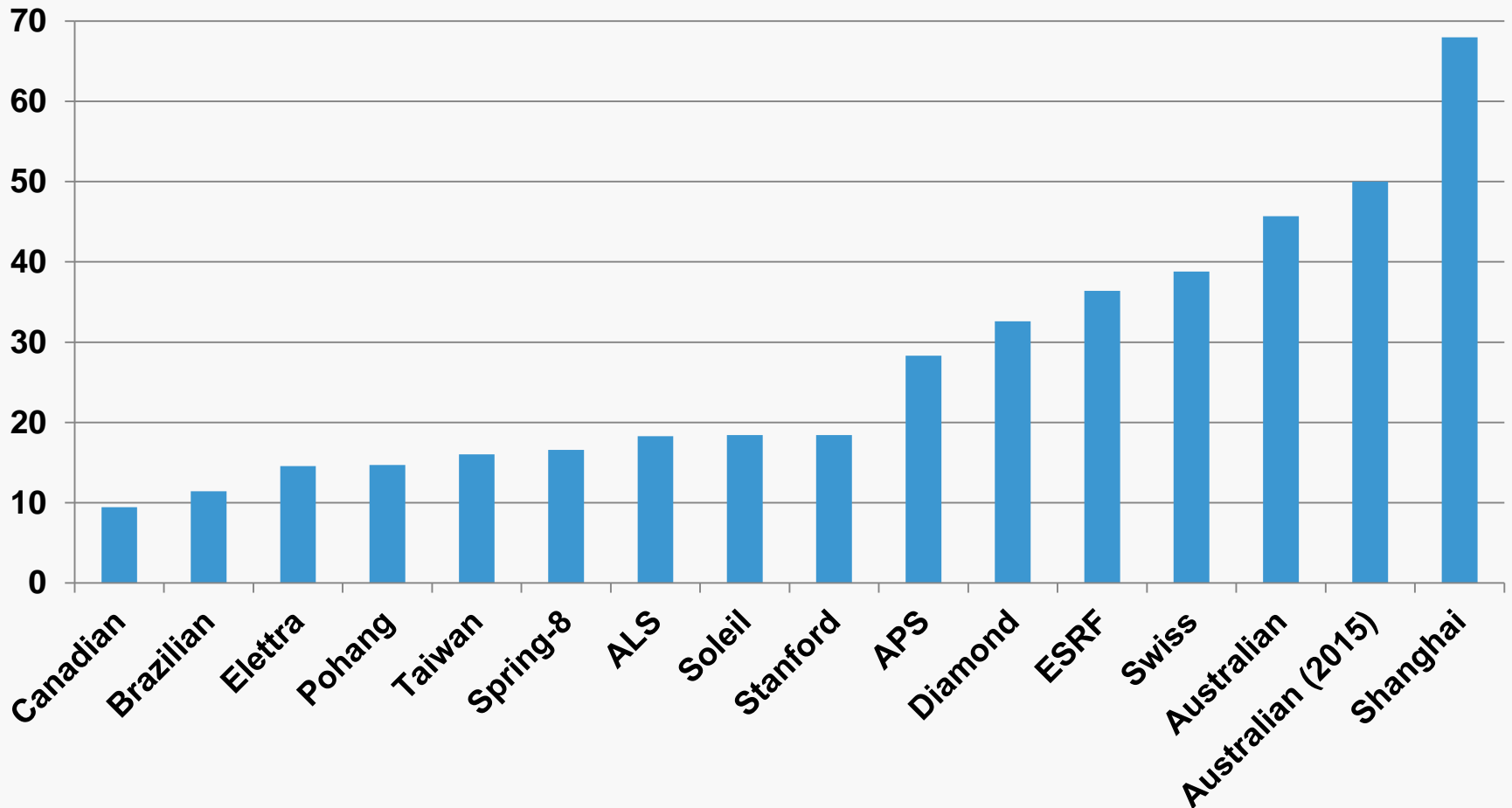
Over 5700 User visits
to the facility each year.



How Do We Stack-up Against Our Peers?...



No. of Peer-Reviewed Publications per Operational Beamline (2014)



Mineralogy on Micro-Crystals

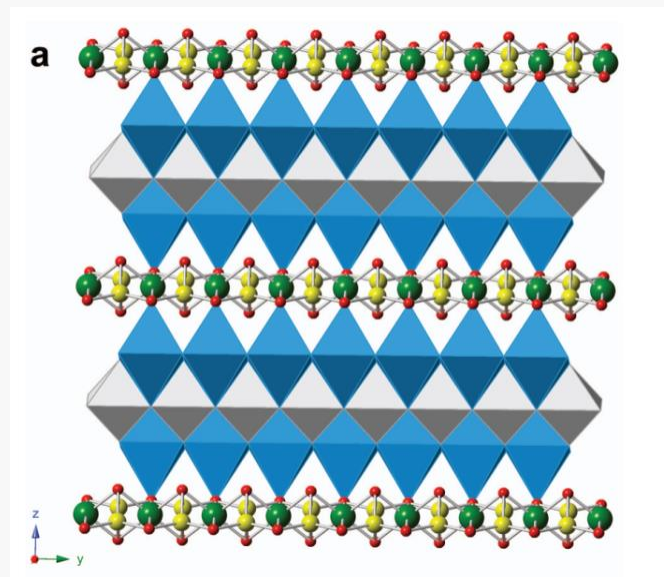


World's rarest minerals reveal Earth's uniqueness

About 120 new minerals are found every year, roughly double that of two decades ago - and they shed light on Earth's evolution.

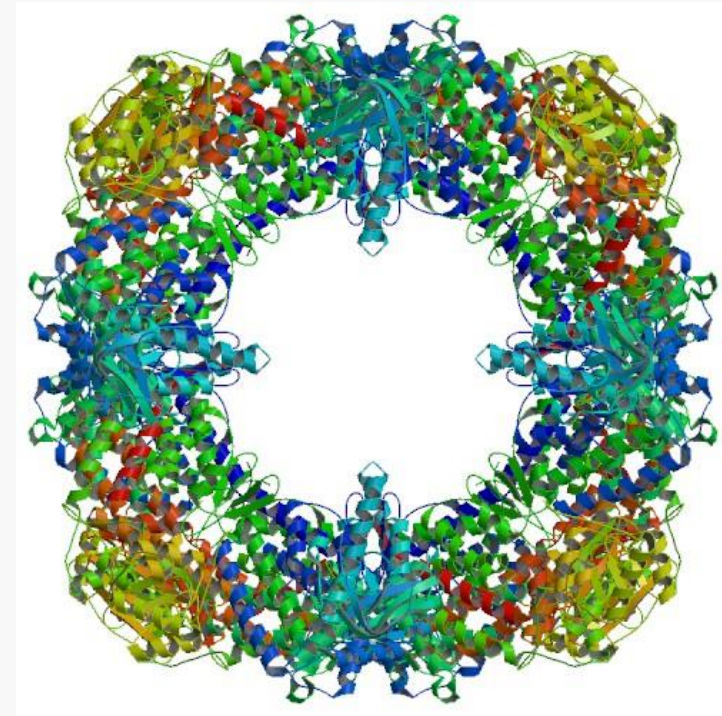
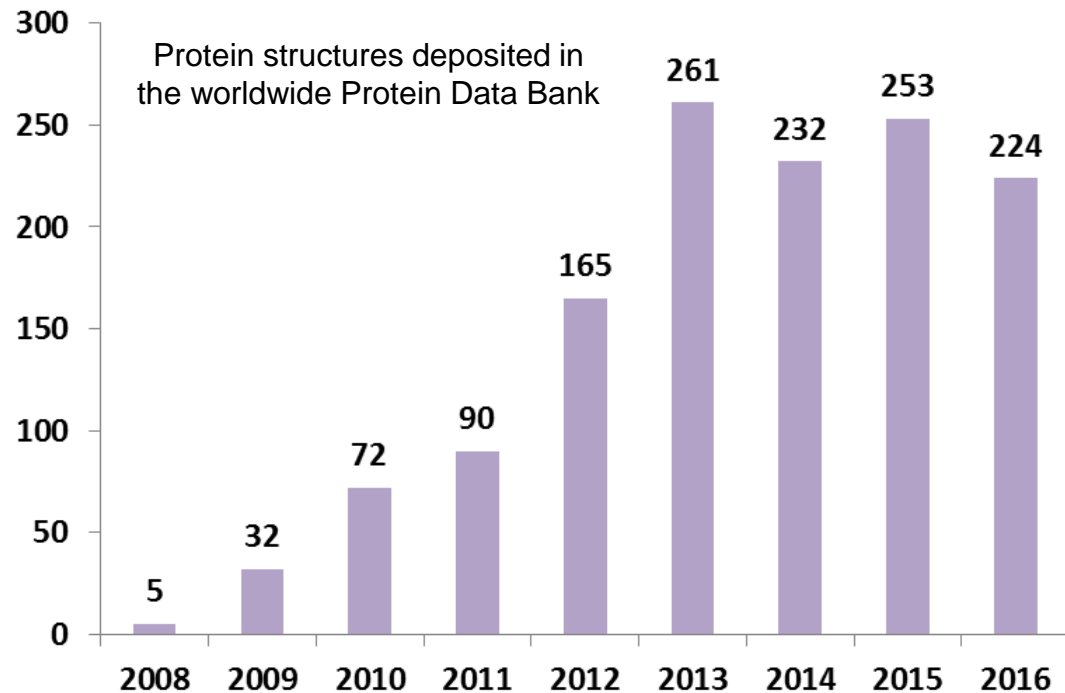
THE  AGE

February 15, 2016.



S. J. Mills, *et al.*, *Min. Mag.*, **78**, 1527 (2014).

1300+ Structures in the Worldwide Protein Data Bank From the MX1 and MX2 Beamlines



A vast array of macromolecular structures are solved using the MX1 and MX2 beamlines for the study of life sciences, biology, disease processes and pharmaceutical research.

J. J. Chaston, *et al.*,
Structure **24**, 364 (2016).

From Macromolecular Crystallography to Therapies...



Several drugs have been developed following structural studies and target screening at the AS and are now under clinical trials

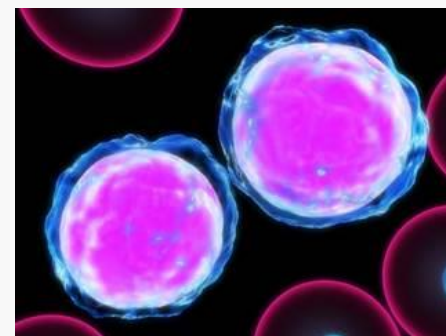
CSL362, (developed by St Vincent's Institute of Medical Research & CSL) is currently under clinical trials to treat *Acute Myeloid Leukaemia* cancer cells.

Venetoclax (developed by WEHI, Genentech & Abbott) is being used to treat *Chronic Lymphocytic Leukaemia* in Phase III clinical trials.

Momelotinib (Gilead Sciences) Phase III clinical trials for *Myelofibrosis* and *Pancreatic Cancer*.

Nexvax2 (Developed by WEHI, Monash University and ImmunsanT) Phase II clinical trials for *Celiac Disease*.

Solanezumab (St Vincent's Institute) for *Alzheimer's disease*.



From PDBs to Therapies...



A promising new cancer drug, developed in Australia by the Cancer Therapeutics CRC (CTx), has been licensed to US pharmaceutical company Merck in a deal worth \$730 million.



**Australian cancer drug
licensed in \$730m deal**

The Diamond Age: Soft X-ray Spectroscopy



Diamond films are very attractive for new electronics devices.

- Great thermal conductor.
- Optically transparent.
- Chemically stable, acid resistant.
- Radiation hardened.
- Can be grown as a film on almost any surface.

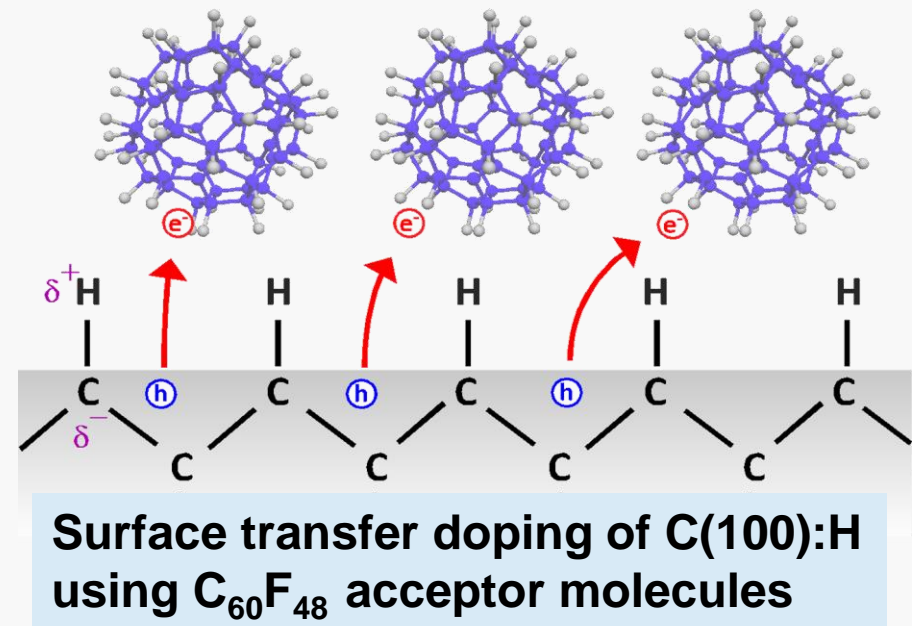


The only problems is that diamond is *terrible* electronic conductor

Surface Transfer Doping of Diamond



Introduction of charge carriers on hydrogen-terminated diamond surface due to charge transfer from atoms or molecular acceptors



Langley *et al*, *Appl. Phys. Lett.* **100**, 032103 (2012).

O'Donnell, *et al*, *Adv. Funct. Mater.*, **23**, 5608 (2013).

Stacey, *et al.*, *Adv. Mater. Interfaces*, **2**, 1500079 (2015).

Kane O'Donnell, *et al.*, *Physical Review B*, **92**, 035303 (2015).

Schenk, *at al.*, *Nanotechnology*, **27**, 275201 (2016).

Soft X-ray Studies of DNA Nucleobase Absorption onto Graphene



Combined photoemission and *in situ* electrical measurements of the adsorption of DNA nucleobases

Each molecule exhibited a characteristic response on the graphene

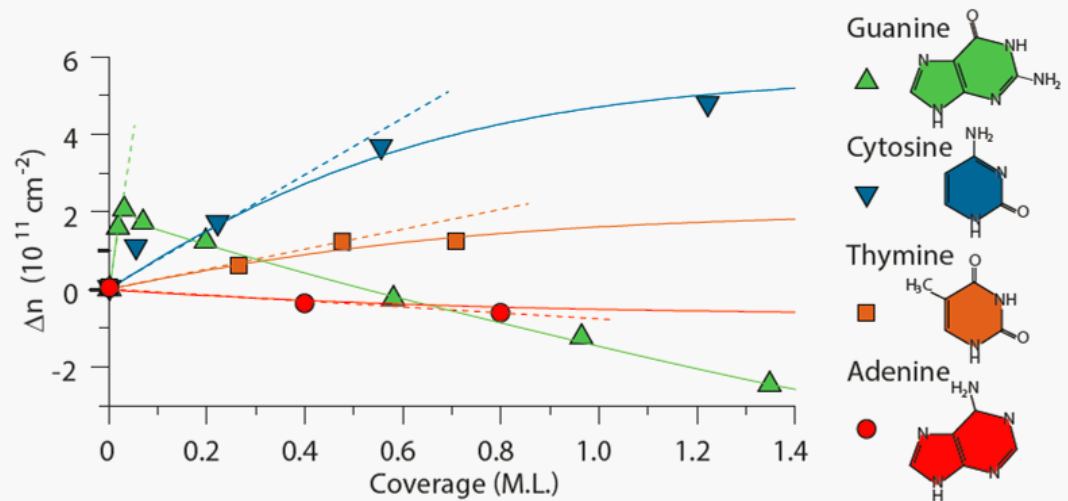
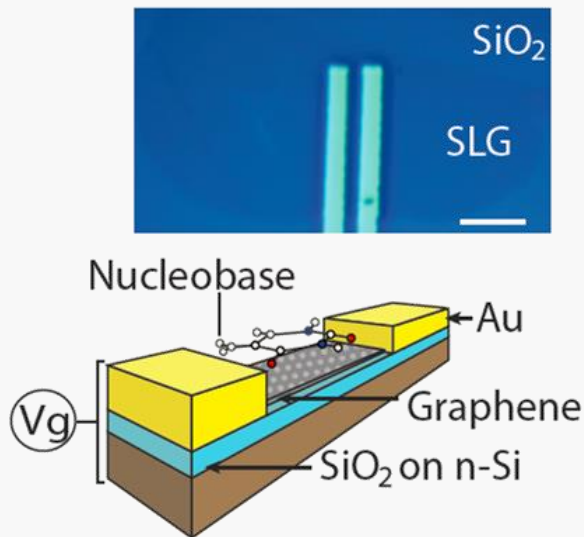
nature COMMUNICATIONS

ARTICLE

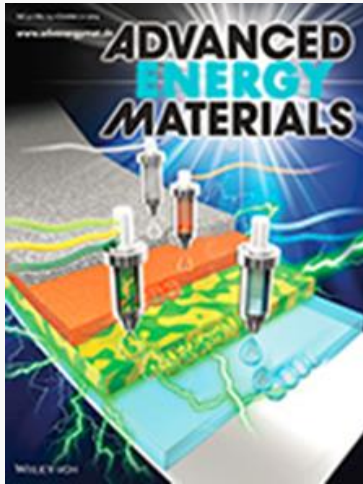
Received 9 Sep 2014 | Accepted 9 Feb 2015 | Published 24 Mar 2015 DOI: 10.1038/ncomms7563

A graphene field-effect transistor as a molecule-specific probe of DNA nucleobases

Nikolai Dontschuk¹, Alastair Stacey¹, Anton Tadić^{2,3}, Kevin J. Rietwyk^{3,†}, Alex Schenk³, Mark T. Edmonds^{3,†}, Olga Shimon^{1,†}, Chris I. Pakes³, Steven Praver¹ & Jiri Cervenka¹



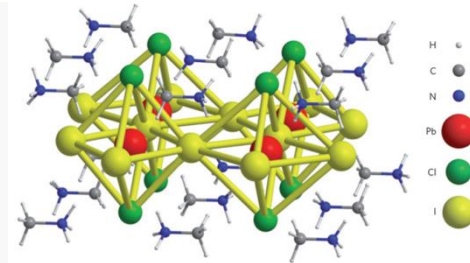
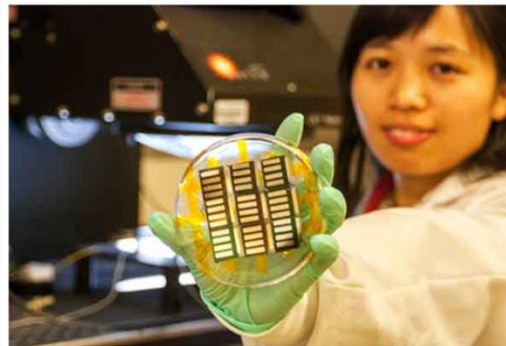
Nanoscale Semiconducting Polymer Solar Cells



Fabrication of inkjet-printed, air-processed organic solar cells is reported for the first time.

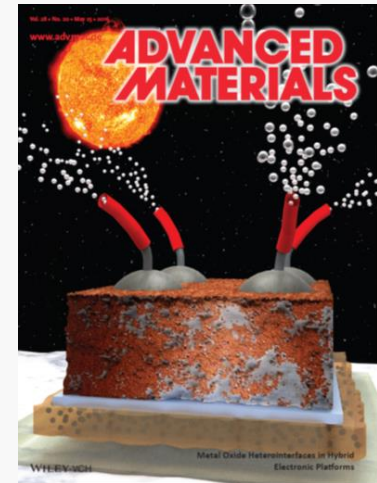
Sungjune Jung *et al.*,
Advanced Energy Materials
4, 1400432 (2014).

Molecular and crystalline orientation in solution-processed perovskite photovoltaics



Efficiencies over 20%

Wenchao Huang *et al.*,
Advanced Functional Materials
25, 5529 (2015).



Interfacial characteristics of efficient bulk heterojunction solar cells on molybdenum oxide anode interlayers

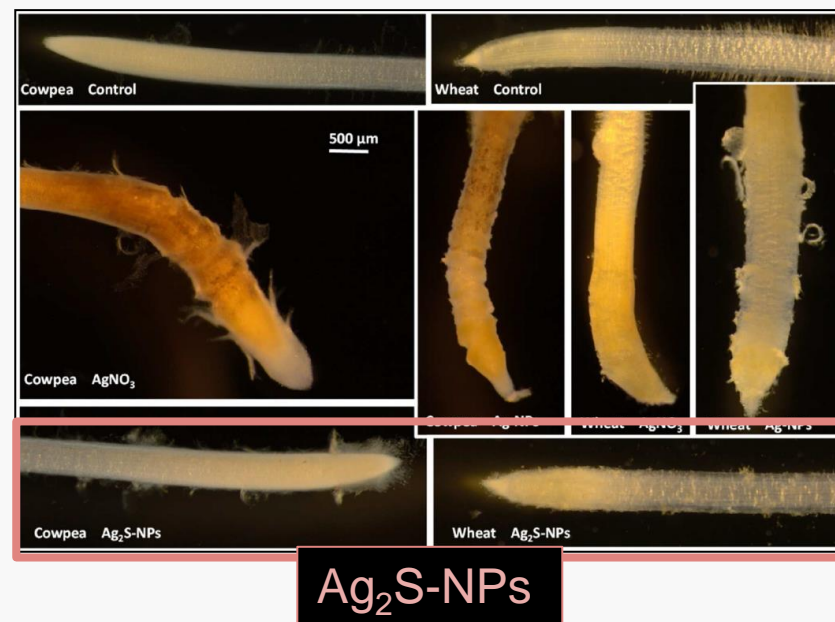
Jacek J. Jasieniak *et al.*,
Advanced Materials
28, 3944 (2016).

XAS for Plant Physiology and Metal Toxicity



Silver nanoparticles are pervasive in consumer products which enter waste streams as biosolids that can be used in agriculture.

Plant toxicity and crop quality can be correlated with longevity & chemistry of nanoparticles using X-ray Absorption Spectroscopy.



Peng Wang, *et al.*,
Nanotoxicology **9**, 1014 (2015).
Environ. Sci. & Tech., **50**, 8274 (2016).

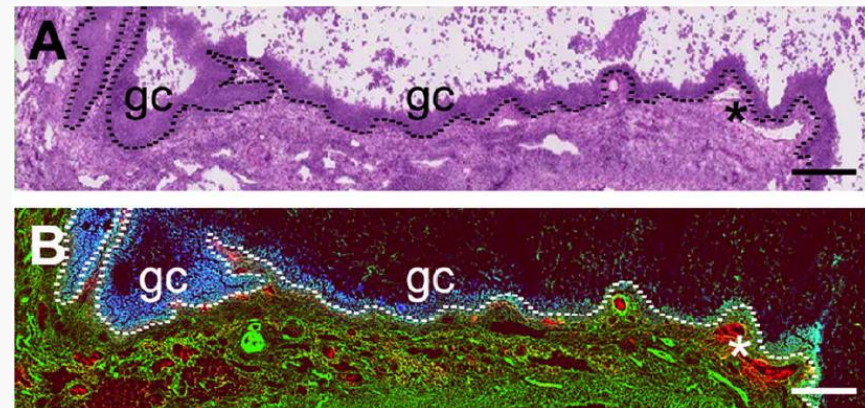
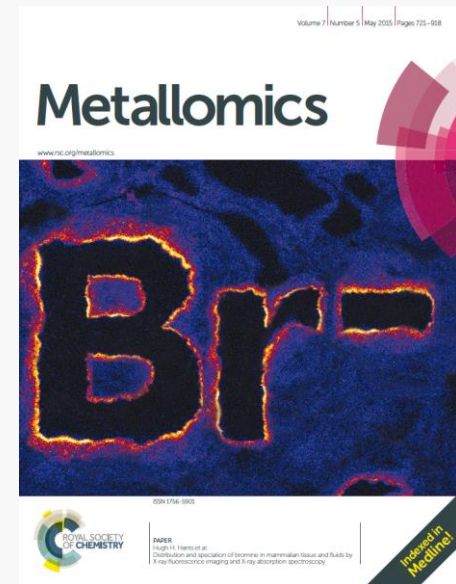
Elemental Mapping and Speciation in Tissues for Studies of Fertility – XAS and XFM



X-ray Absorption Spectroscopy and X-ray Fluorescence Microscopy can be used to identify the *in situ* speciation and distribution of trace elements in tissues.

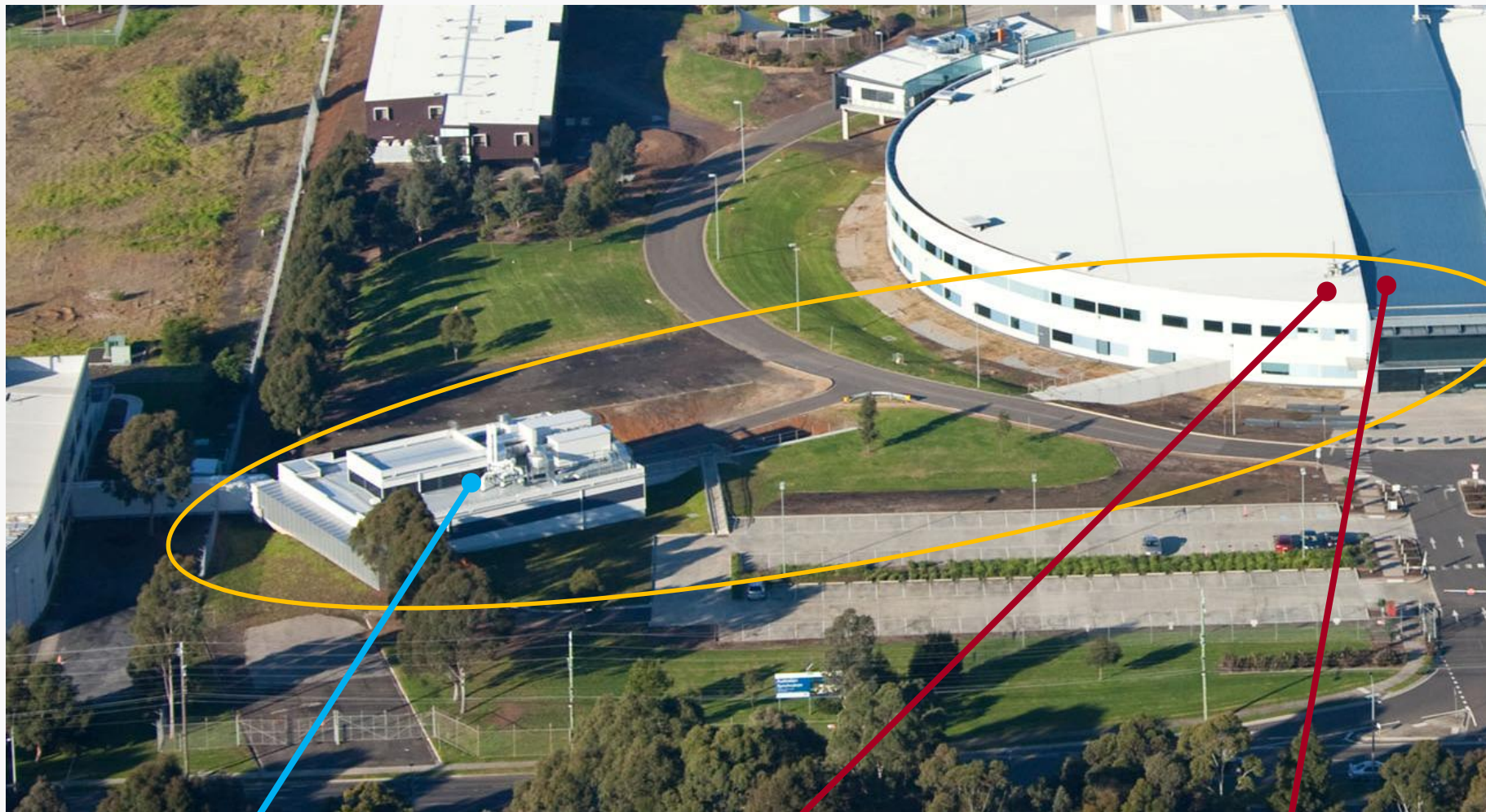
Recent studies of bovine ovaries have examined the distribution of Fe, Se, Zn and Br and their roles reproduction and fertility.

Melanie J. Ceko, *et al.*,
Metallomics **7**, 66 (2015).
Metallomics **7**, 756 (2015).
Biology of Reproduction, **94**, 86 (2016).



Zn, Fe, Se

Imaging and Medical Beamline (IMBL)

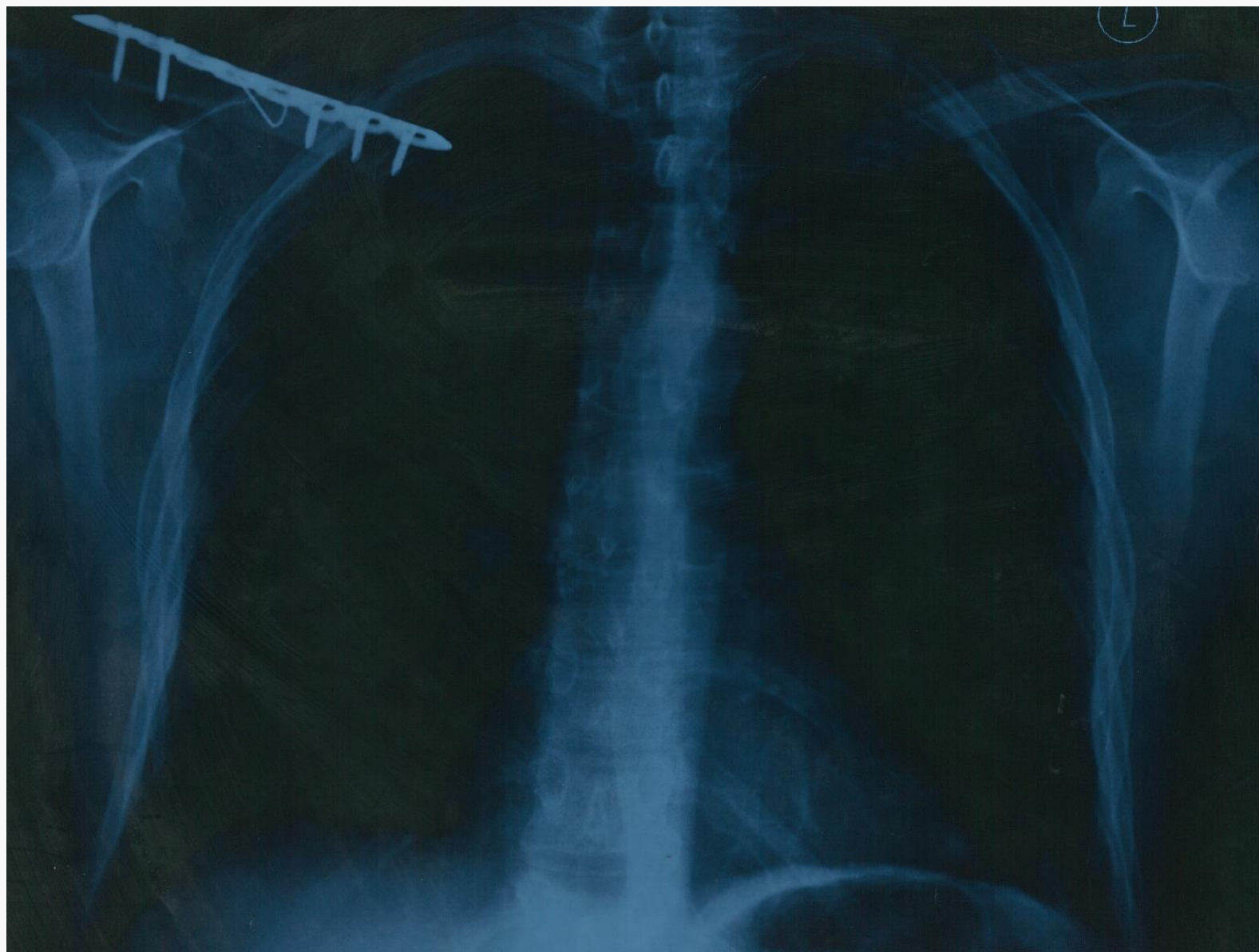


138m - High Resolution Phase Contrast Imaging

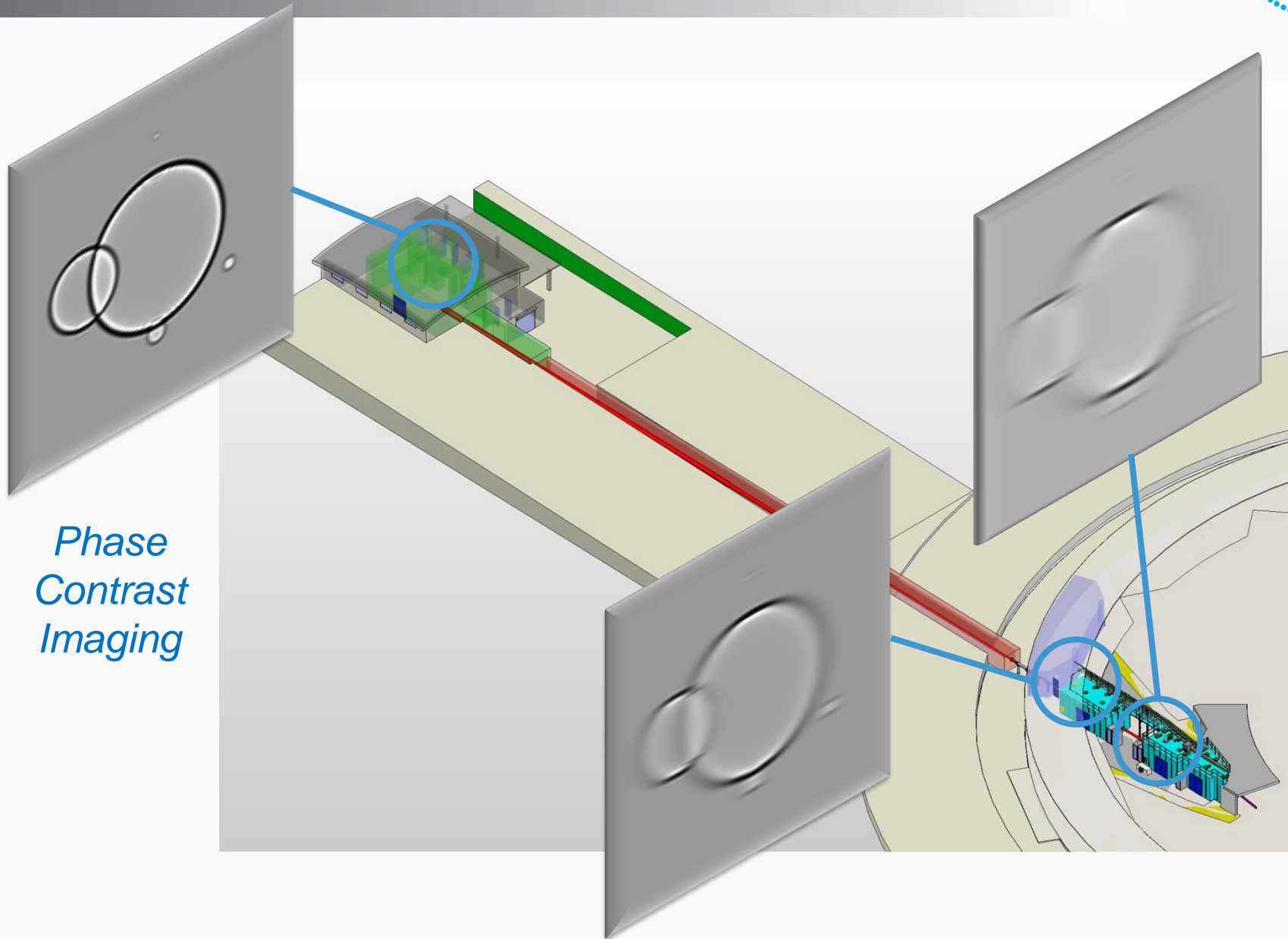
34m – Fast Imaging and Computed Tomography (CT)

22m - High Dose Irradiation, MRT

Conventional X-ray Lung Imaging



Why is the IMBL so Long?



*Phase
Contrast
Imaging*

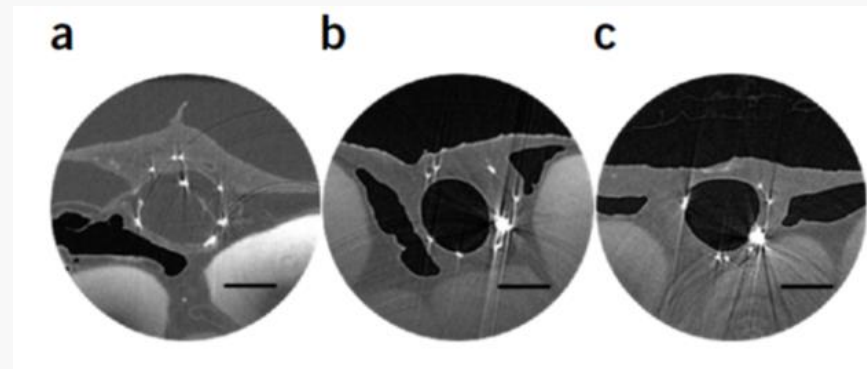
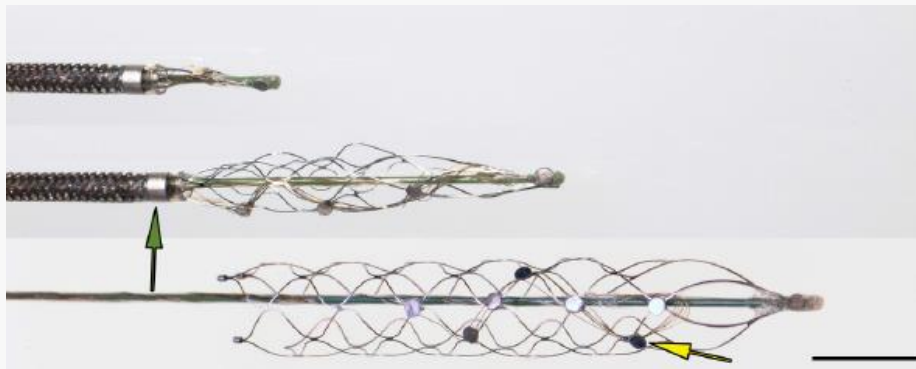
It's Not Brain Surgery...



HOME » NEWS » WORLD NEWS » AUSTRALIA AND THE PACIFIC » AUSTRALIA

Australia scientists develop 'bionic spine' which could help paralysed patients walk

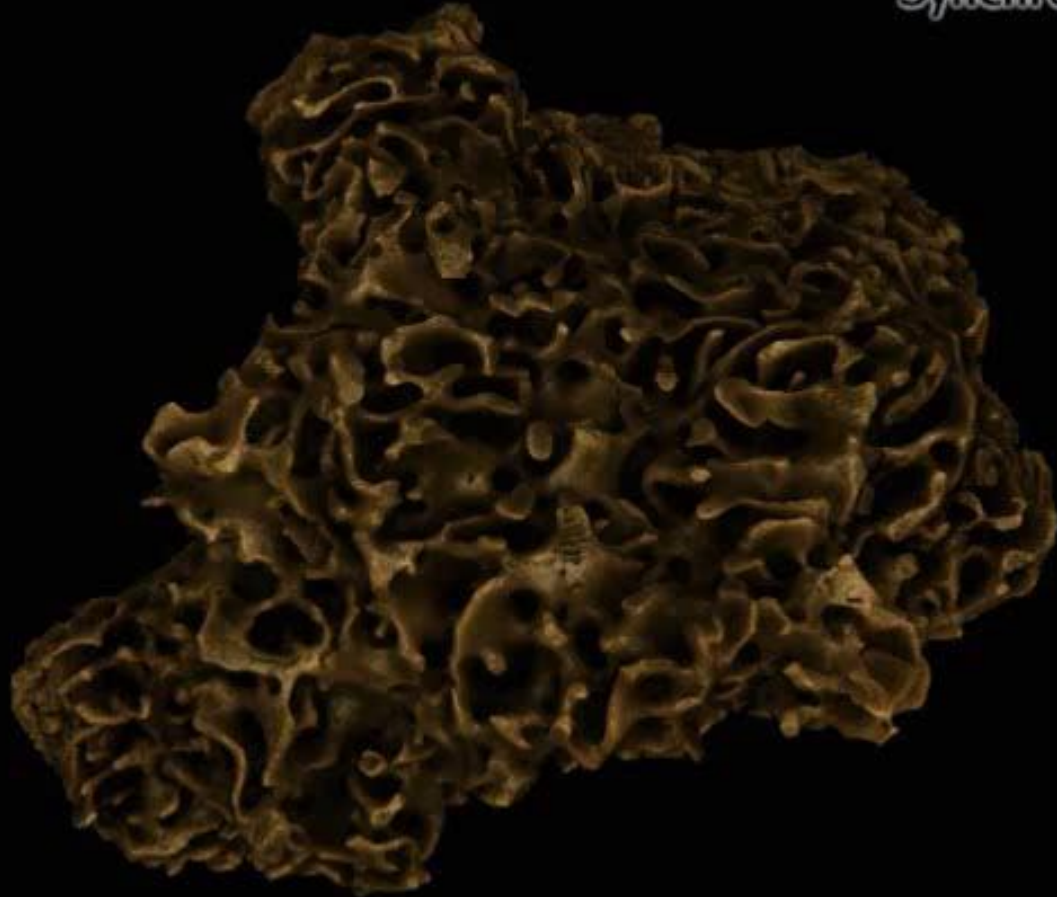
Device can be inserted in the brain – without brain surgery – and could allow paralysed patients to operate robotic limbs “using thought alone”



nature
biotechnology

Thomas J. Oxley, et al. (2016).

Engineers Take Lessons from Nature



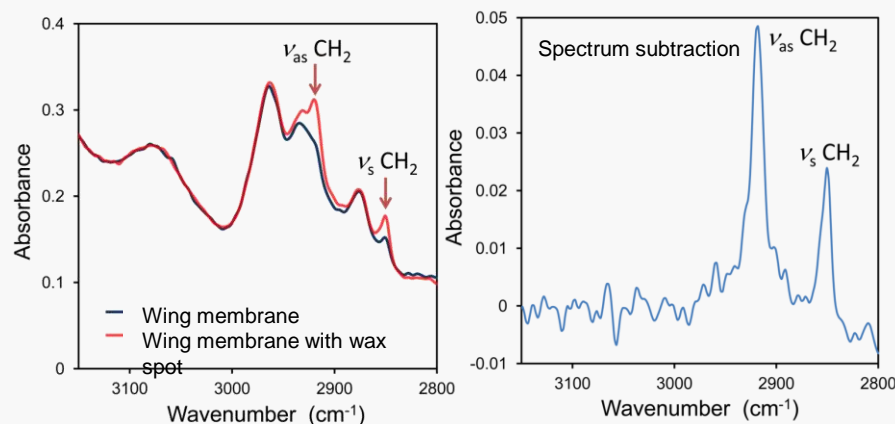
Surface Chemistry and Nanoscale Structures of Insect Wings: Infrared Microscopy



Advantageous properties of Cicada wings

- Superhydrophobic
- Self cleaning
- Antireflective
- Antibacterial

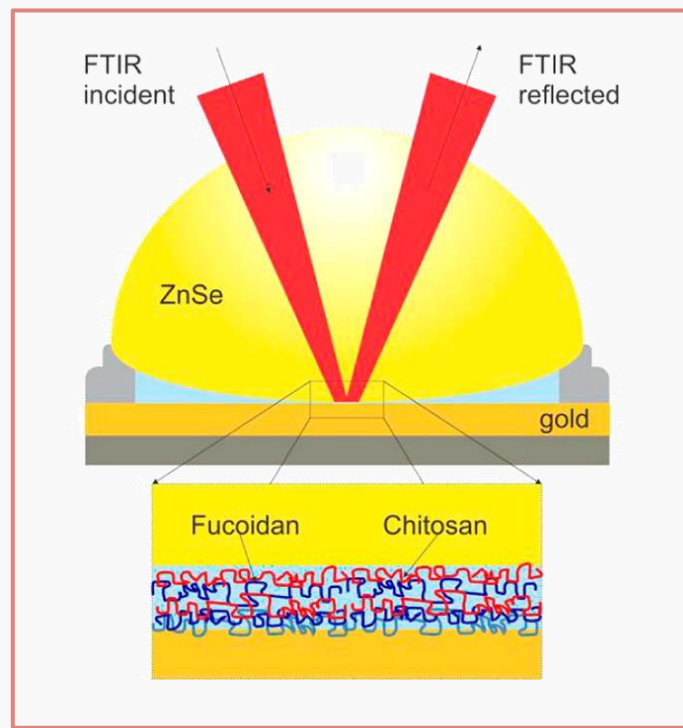
Mark J. Tobin, *et al.*,
Spectroscopy Europe,
27, 15 (2015).



Taking the Soft Approach... Single Contact ATR



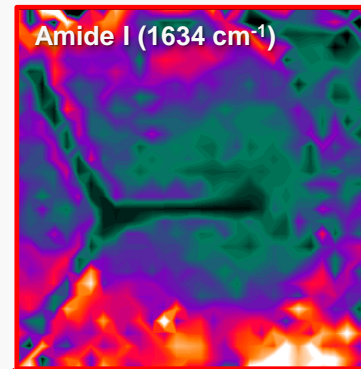
The **Infrared Microscopy** beamline has developed a new single contact **Attenuated Total Reflectance** cell that has proved ideal for a wide range of soft materials.



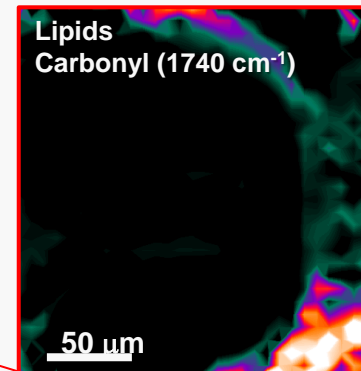
Taking the Soft Approach... Single Contact ATR



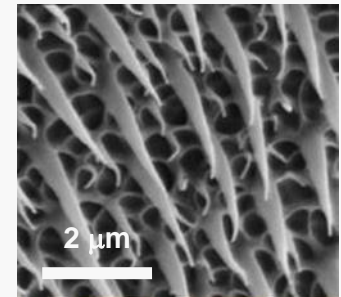
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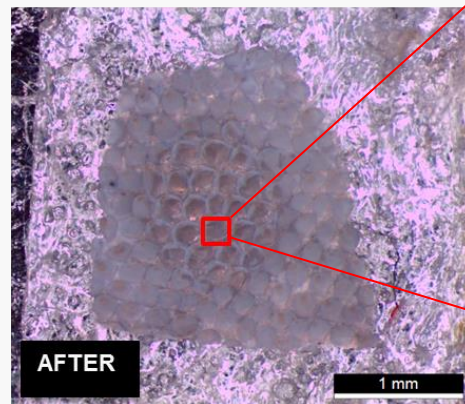
Proteins



Lipids

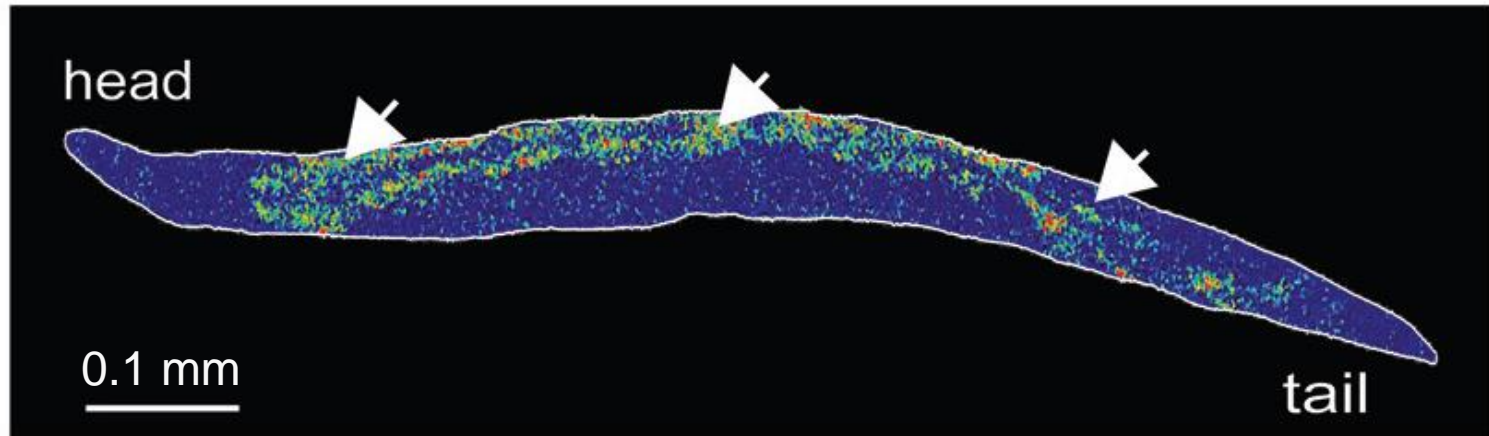
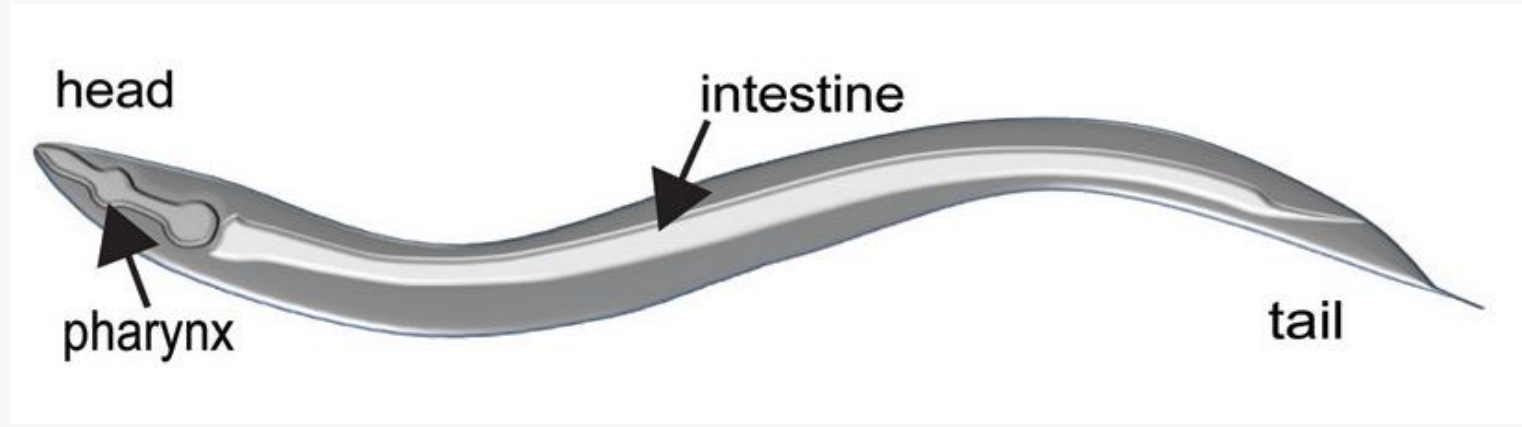


Surface properties
of gecko skin



Dr Greg Watson,
(U. Sunshine Coast)

X-ray Fluorescence Microscopy



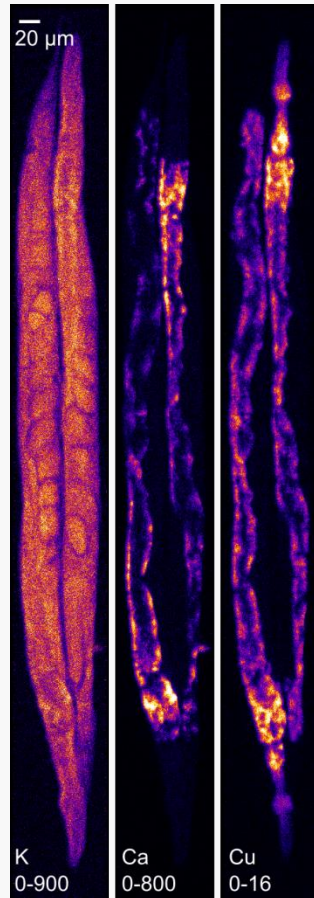
Elemental mapping of *C. elegans* allows the role of metals in disease to be studied

Multimodal Whole “Animal” Imaging



The X-ray Fluorescence Microprobe reveals elemental composition within *C. elegans* @ 2 μm resolution using a Maia Detector

(2200 Files = 180 GB)



Super-resolution
(~50 nm)
X-ray
Diffraction
Microscopy

Phase
+
Fluorescence
(Cu)

Multimodal Whole “Animal” Imaging



2 μm resolution elemental mapping
with
50 nm resolution structural mapping

500,000 diffraction patterns in a single “fly scan” in 3 hours
(A year ago a similar “step scan” would have taken 30 hours)

(3.8 Million Image Files = 2.3 TB)

Our Staff.



Any Questions? - See me at Morning Tea...

