

Physics at the Australian Nuclear Science and Technology Organisation

ROBERT A. ROBINSON, MIHAIL IONESCU AND MARK REINHARD
AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION

INTRODUCTION

The Australian Nuclear Science and Technology Organisation is Australia's nuclear national laboratory and is the prime repository of nuclear expertise in the country. It plays a key role in research, operation of major facilities, isotope production and advice to Government. It was founded in 1987, as the successor to the Australian Atomic Energy Commission, which had existed from 1952. For almost 50 years, from 1958 until 2006, the AAEC and ANSTO operated the HIFAR heavy-water reactor, the second research reactor to be established in Asia, the first after India. Initially the AAEC's focus was on nuclear power and nuclear fuel cycle issues, but in the ANSTO era, the focus has shifted towards the technological use of nuclear methods in medicine, the environment and science more generally.

ANSTO was significantly re-energised in 1997, by the Australian Government's decision to construct a new research reactor to replace HIFAR, with an increased ambition to supply nuclear medicines, particularly ^{99m}Tc , neutron transmutation doped silicon for the global semiconductor industry, and neutron scattering for the national and international research community. This is described in the next section.

In addition to reactors, the AAEC and ANSTO have a long tradition in electrostatic accelerators, initially for nuclear physics studies, but more recently for a range of applied-physics activities, as well as cyclotrons for proton-rich radioisotope production and related medical research.

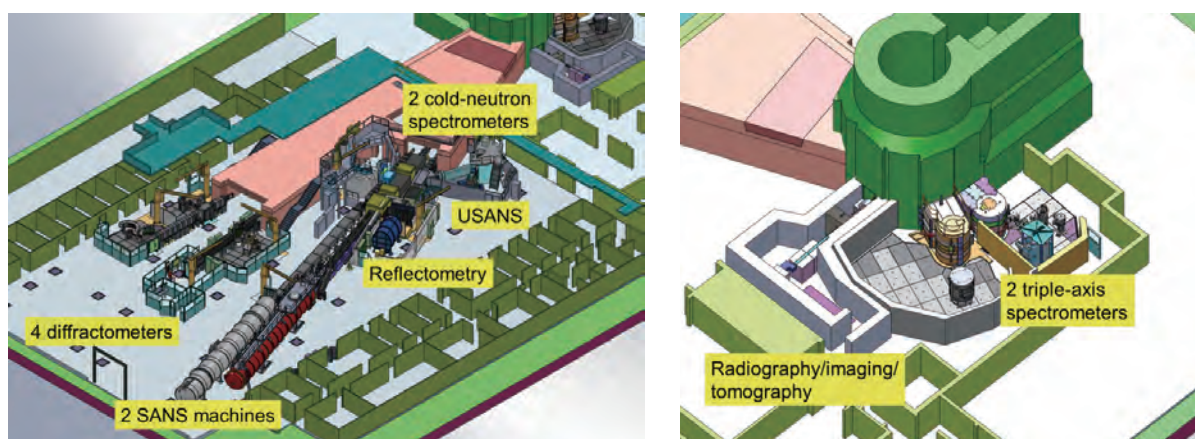


Fig. 1: OPAL's neutron beam instruments in the Neutron Guide Hall (left) and Reactor Beam Hall (right): the 4 diffractometers, radiography and one 3-axis spectrometer view the room-temperature heavy-water reflector, while 3 small-angle neutron scattering instruments, reflectometer and 3 other spectrometers view OPAL's liquid-deuterium cold source.

Instrument [Reference]	Type	Scientists	Status (first data)
1. ECHIDNA [1]	Powder Diffraction	M. Avdeev, J. Hester, A. Studer, V. Peterson, H. Maynard Casely, C.-W. Wang	Operating (2006)
2. WOMBAT [2]	Powder Diffraction		Operating (2007)
3. KOALA [3]	Laue Diffraction	R. Piltz, A. Edwards	Operating (2008)
4. KOWARI [4]	Strain Scanner	V. Luzin, M. Reid	Operating (2008)
5. PLATYPUS [5]	Reflectometer	A. Nelson, S. Holt F. Klose	Operating (2008)
6. QUOKKA [6]	SANS	E. Gilbert, K. Wood, C. Garvey, J. Mata	Operating (2009)
7. TAIPAN [7] (+ Be-filter option)	Thermal 3-Axis Spectrometer	S. Danilkin, A. Stampfl, K. Rule	Operating (2010)
8. PELICAN [9]	Cold Time-of-Flight Spectrometer	D. Yu, R. Mole	Operating (2013)
9. SIKA	Cold 3-Axis Spectrometer	C. Wu, G. Deng, S. Yano	Commissioning (2014)
10. KOOKABURRA [9]	USANS	C. Rehm, L. de Campo	Operating (2013)
11. DINGO	Radiography	U. Garbe, K.-D. Liss, F. Salvemini, J. Bevvit	Operating (2013)
12. EMU	Backscattering Spectrometer	N. de Souza, A. Klapproth G. Iles	Commissioning (2015)
13. BILBY	Time-of-Flight SANS	A. Sokolova, L. de Campo, A. Whitten	Commissioning (2014)

For much of its history, the physics activities were focussed in a “Physics Division”, but with the preparation for the start-up of the OPAL Reactor in 2006, ANSTO dispersed its physics activities into multidisciplinary “Institutes” focussed on neutron scattering (the Bragg Institute), environmental research, materials science and so on.

ANSTO operates on a number of sites, beyond its New South Wales home at Lucas Heights, most notably in its role as operator of the Australian Synchrotron in Melbourne. This 3-GeV light source, came on line in 2007, and will feature separately in a future article for the AAPPS Bulletin.

PHYSICS AT THE OPAL RESEARCH REACTOR

These days, the strongest physics effort, and it is mainly in condensed-matter physics and chemical physics, is based at the new 20-MW OPAL Research Reactor, which was constructed between 2000 and 2005 and which went critical in August 2006. OPAL features a large (20-litre) liquid-deuterium cold neutron source and large curved supermirror guides, to carry the neutrons

out into a large (35 × 65 m²) guide hall. As presently configured, the facility has a capacity to accommodate up to 18 instruments on up to 6 guides, half of which view the cold source and half of which view the normal room-temperature heavy water reflector. At present, the facility hosts a total of 13 instruments, in 4 broad classes: diffraction and crystallography, inelastic neutron scattering, nanoscience and imaging, as listed in Table 1. One of these instruments, the SIKA cold-neutron 3-axis spectrometer, was constructed by the National Central University (in Taiwan) and is operated by the National Synchrotron Radiation Research Centre.

To date, specific research highlights have included studies of:

- Magnetism in technetium compounds [10]
- Adsorption of gases into Metal-Organic Frameworks [11]
- In-operando* studies of Li-ion batteries [12]
- Organic Light-Emitting Diodes and Photovoltaics [13]
- The microstructure of starch [14]
- Thin-film and multilayer magnetism [15]

PHYSICS USING ANSTO’S ACCELERATORS

ANSTO currently operates two ion-beam accelerators, with a further two about to enter user service:

Accelerator	Operating since	Voltage	Energy (MeV)	Ions	Main function
ANTARES	1991	10 MV	5 - 100	Almost all ions	Ion Beam Analysis and Accelerator Mass Spectrometry, materials analysis, radiation damage, micro-beam, basic nuclear physics
STAR	2005	2 MV	~0.3 - 4	¹⁴ C, wide range of light and medium-weight ions	Ion Beam Analysis and Accelerator Mass Spectrometry, materials analysis, biological and environmental studies, radiation damage
VEGA	2014	1 MV		¹⁴ C and actinides	High-efficiency, high-precision ¹⁴ C and actinide mass spectrometry
SIRIUS	2015	6 MV		¹⁴ C, ¹⁰ Be, ²⁷ Al, ³⁶ Cl, ⁴⁰ Ca, and almost all other ions	Ion Beam Analysis and Accelerator Mass Spectrometry, materials modification and characterisation, confocal micro-beam, basic nuclear physics



Fig. 2: ANSTO’s new 6 MV SIRIUS accelerator and its associated ion-beam analysis and accelerator mass spectrometry beamlines.

In support of these accelerators, ANSTO operates chemistry laboratory facilities for preparation of samples prior to applying high sensitivity accelerator-based analysis techniques and state of the art uranium series laboratory facilities for ultra-sensitive isotopic analyses. This science platform is at the forefront of ion beam analysis, accelerator mass spectrometry and accelerator instrumentation, and caters for a wide range of research applications, from archaeology, climate change and energy materials, to radiation detectors, nuclear safeguards and zoology. It is used by internal, domestic and overseas researchers, with approximately 40% of running time used for ANSTO internal research and 60% for externally driven research and commercial activities.

These facilities position ANSTO as a significant international player on the accelerator applications landscape

and provide a good basis for many decades into the future. They also build on nationally and internationally recognised ANSTO strengths in ion-beam analysis and accelerator mass spectrometry applied to:

studies of energy materials[16], paleo-climate studies[17], water resource management[18], fine particle air pollution characterisation[19], radiation detector optimisations[20], bio-imaging[21], soil erosion[22], ion implantation[23], ion micro-spectroscopy[24], micro-dosimetry[25] and archaeology[26].

OTHER PHYSICS ACTIVITIES AT ANSTO

ANSTO hosts a number of other physics-related activities, including a detector research laboratory which specialises in innovative ionising radiation technologies, radionuclide metrology which maintains the Becquerel radioactivity standard for Australia, and a nuclear analysis group which performs all manner of radiation, criticality, shielding and other calculations mainly in support the OPAL reactor and its programs. Examples of recent work include:

- 1) Licensing of patented X-ray test-piece technology for quality assurance of large container X-ray scanners; [27]
- 2) Work on microdosimetry with collaborators at the University of Wollongong, that is contributing towards a possible future Australian Hadron Therapy Treatment and Research Facility; [28]

3) Development of algorithm technology (patented) to reduce false alarms and improve threat detection in radiation portal monitors. [29]

4) the national launch in 2014 of the Australian Nuclear Medicine Traceability Program which provides direct traceability for measurements of quantities of nuclear medicines within nuclear medicine departments to the Australian Standard maintained by ANSTO.

Overall, ANSTO also plays a significant role in education and training of students and researchers from Australia and overseas, in collaboration with other national laboratories, universities and the International Atomic Energy Agency.

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Robert A. Robinson received a PhD in experimental physics from Cambridge University in 1982. He has been a fellow of the American Physical Society since 1998. In December 1999 he moved to ANSTO to become leader of the Neutron Scattering and Synchrotron Radiation Group, and he is also an Adjunct Professor in both the School of Physics at the University of New South Wales and the Faculty of Science at Sydney University. He is Immediate Past President and a fellow of the Australian Institute of Physics. He has been Head of the Bragg Institute, since its inception in December 2002. Rob's main research activities have been in condensed-matter physics. His current research interests include strongly correlated f-electron systems magnetism in uranium intermetallics, molecular magnets, the dynamics of amorphous materials and neutron-scattering instrumentation.