Australian Government

ansto

Nuclear-based science benefiting all Australians

OPEN POOL AUSTRALIAN LIGHT-WATER REACTOR

OPAL

FOREWORD

The construction of Australia's new world-class research reactor, OPAL, heralds the nation's determination to maintain its position at the frontiers of international science.

OPAL will become the centre-piece of the facilities we offer at ANSTO, where we apply our nuclear expertise to support health, environmental, industrial and national security objectives.

Since 1958, Australia has benefited from the nuclear capabilities of HIFAR, the High Flux Australian Reactor, and the nuclear-based science of ANSTO and its forebears.

We provide high-quality radiopharmaceuticals for nuclear medicine, irradiate silicon for advanced electronics applications and produce radioisotopes for environmental, medical and industrial uses including non-destructive testing methods.

Australian researchers and their counterparts from around the world use the unique insights afforded by neutron beam science to increase our fundamental scientific knowledge and assist our industries.

Our nuclear expertise also enables us to make an important international contribution through groups such as the Forum for Nuclear Cooperation in Asia, which promotes the safe and peaceful use of nuclear technology in the Asian region.

The OPAL reactor will outperform HIFAR in every aspect, making radiopharmaceutical and radioisotope production, irradiation services and neutron beam research quicker and more efficient. It can operate 340 days a year, a significant increase over the operating levels typically achieved by comparable overseas facilities.

The new reactor uses low enriched uranium fuel with around 20 per cent uranium-235. In terms of nuclear security and safeguards, this is a distinct advantage over earlier nuclear reactors, some of which required as much as 95 per cent enriched uranium. A state-of-the-art research reactor, OPAL uses heavy water to moderate the neutrons produced in its fuel assemblies and light water for cooling.

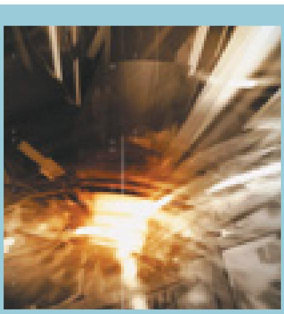
A 'cold' neutron source will produce neutrons with lower energy levels and longer wavelengths, significantly enhancing the versatility of the reactor's neutron beam scattering facilities. Neutron guides, which function rather like optical fibre, are used to transport the useful neutrons to experiments, thereby removing unwanted high-energy neutrons and gamma radiation.

To maximise scientific use of the OPAL reactor and to attract researchers who have not previously used neutron techniques, ANSTO has established the Bragg Institute as a regional centre of excellence in neutron science. The Bragg Institute is Australia's leading group in the use of neutron scattering and X-ray techniques to solve complex research and industrial problems. The Institute is named in honour of Australians William and Lawrence Bragg, who jointly won the 1915 Nobel Prize for Physics.

In recognition of the complementary nature of neutron and X-ray techniques, ANSTO has also invested $5 million in beamlines at the Australian Synchrotron being built in Melbourne by the Victorian Government.

This publication explains the capabilities of OPAL and some of the many ways in which it will bring benefits to Australia and our international relationships.

Dr Ian Smith
Executive Director, ANSTO



Bragg Institute

Established to maximise scientific use of the OPAL reactor, the Bragg Institute was named after Australian Nobel Prize winners William and Lawrence Bragg. The Institute leads Australia in the use of neutron scattering and X-ray techniques to solve a wide range of complex research and industrial problems. Under the direction of Dr Rob Robinson, the Institute is working to increase its partnerships with other leading research organisations in Australia and around the world. For more information on the Bragg Institute's activities see www.ansto.gov.au/ansto/bragg

Building for the next generation

Bragg Institute Head Rob Robinson says the new reactor is "the opportunity of a generation". With an impressive track record in condensed-matter physics in five countries, Dr. Robinson clearly relishes his role as one of the founders of a facility he says will "create an environment on which Australia can live for 20 years". His own research interests have been set aside while he concentrates on "building something big and useful" that will meet the needs of the future.

Robinson believes ANSTO has the right culture to place the new reactor and its neutron beam instrumentation among the world's top three such facilities. "And in some areas, such as time-resolved powder diffraction and small-molecule crystallography, we will be the world's best."

WHY USE NEUTRONS?

Electrons and protons, which carry electric charges, were discovered in 1897 and 1911 respectively. Neutrons were discovered in 1932 by British scientist James Chadwick. Several years later, while using neutrons to split atoms and create new radioactive elements, Italian scientist Enrico Fermi discovered that slowing down the neutrons made them more effective at splitting atoms. Chadwick and Fermi both received Nobel Prizes in Physics for their work.

Realising that neutron beams had the potential to reveal much about the structure of solids and liquids, American and Canadian scientists began to use the neutrons produced by the first generation of nuclear facilities soon after the Second World War. Major advances in scientific knowledge and techniques quickly followed and continue to the present day. Clifford Shull and Bertram Brockhouse received the 1994 Nobel Prize in Physics for some of these developments.

Fermi produced his neutrons by bombarding beryllium atoms with alpha particles from radium. Nuclear reactors produce a continuous stream of neutrons through chain reactions involving the fission of uranium-235. Spallation sources produce neutrons in short pulses by bombarding a heavy element like tungsten with high-energy protons from an accelerator. Neutron beams from nuclear reactors and spallation sources have different characteristics.

Properties

Neutrons have many properties that make them useful for studying atomic and molecular structures ranging in size from a tenth of a nanometre up to several hundred nanometres. They can be considered as particles or waves, with wavelengths comparable to the interatomic distances found in solids and liquids. Their energies are of similar magnitude to those associated with molecular vibrations.

Neutrons have some advantages over X-rays as tools for determining the structure of molecules and solids, although the two techniques are often complementary.

Because neutrons have no electric charge, they are not deflected by the electron clouds around an atomic nucleus. This means that they can reveal the position of the nucleus itself. X-rays are scattered by electrons and reveal the position of the electron clouds.

X-rays cannot be used to determine the positions of hydrogen atoms or of light atoms in close proximity to heavy atoms—but neutrons can. Different isotopes (atoms of the same element with different numbers of neutrons) such as hydrogen and deuterium can also readily be distinguished by neutron scattering but not by X-rays.

Because neutrons scatter from nuclei and not electrons, they are highly penetrating. This makes it possible to study samples deep inside large pieces of equipment and to investigate large industrial components and structures.

Neutrons are also tiny magnets and can therefore be used to investigate the magnetic properties of materials such as superconductors and computer memories.


Australia's new reactor, OPAL.

ABOUT ANSTO

The Australian Nuclear Science and Technology Organisation (ANSTO) is the centre of Australian nuclear expertise.

Since 1958, ANSTO and its forebears have maintained a wide range of nuclear facilities—including the HIgh Flux Australian Reactor (HIFAR) and the National Medical Cyclotron—to benefit Australia's health, economy, environment and international relationships.

ANSTO provides the Australian Government with expert scientific and technical advice in support of national strategic and nuclear policy objectives and the safe international use of nuclear technologies.

We supply high-quality nuclear-based services and products to industry and research organisations. Our product range includes radiopharmaceuticals for nuclear medicine, radioisotopes for environmental and industrial uses including non-destructive testing methods, and irradiated silicon for advanced electronics applications.

We undertake research and development activities in our own right and in association with other Australian and international agencies on specific aspects of nuclear science, the nuclear fuel cycle and related technologies. We also help to train postgraduate students.

Our research results and expertise are applied to increase the competitiveness of Australian industry and improve quality of life for all Australians. Major contributions include the development of advanced materials, processes and equipment for aerospace, mining, mineral processing, power generation, oil exploration, agriculture, food processing, manufacturing, engineering and plastics industry applications.

We study the impact of human activity on climate change and long-term environmental stability and monitor the dispersion of airborne pollutants and the movement of sediments, pollutants and sewage in harbours, rivers and oceans. We help communities and industries to make sustainable use of underground water resources. We also contribute to international efforts to detect clandestine nuclear weapons programs.

In addition to our contributions to diagnostic and therapeutic technologies in nuclear medicine, we are helping to shed new light on important biological molecules such as those found in human blood and on processes such as those involved in muscle movement.

Groups that have used our facilities and expertise include business enterprises, university departments, hospitals, government agencies and cooperative research centres.

Consultancy services

The materials and engineering science skills used in designing the new reactor are available to commercial clients. ANSTO staff have substantial expertise in assessing the working life and integrity of a wide range of industrial components and large structures such as coal-fired power stations. Their expertise is supported by one of Australia's most comprehensive materials testing and characterisation facilities.

PROFILE: Paul Metcalf

Science and engineering graduate Paul Metcalf says being trained as a reactor engineer has put him on a steeper learning curve than any he experienced at university—and he loves the challenge. Metcalf is one of the new graduates ANSTO is training to be part of the team that is responsible for the safe commissioning and operation of the OPAL reactor, and will help to supervise a control and monitoring system that handles data from around 5 000 sensors. With a training program that has included hands-on experience at a pool-type training reactor in Argentina, Metcalf says he has particularly enjoyed learning about the philosophy that underlies the new reactor design.

A NEW RESEARCH REACTOR FOR AUSTRALIA

Decision to build a new reactor

In 1997, the Australian Government announced that it would fund the construction of a research reactor to replace Australia's first nuclear reactor, HIFAR. Built in the 1950s, HIFAR has an excellent safety record but cannot match the performance of modern research reactors.

The new OPAL reactor will significantly increase Australia's nuclear science and technology capabilities. It will outperform HIFAR in every aspect, making radiopharmaceutical and radioisotope production, irradiation services and neutron beam research quicker, safer and more efficient.

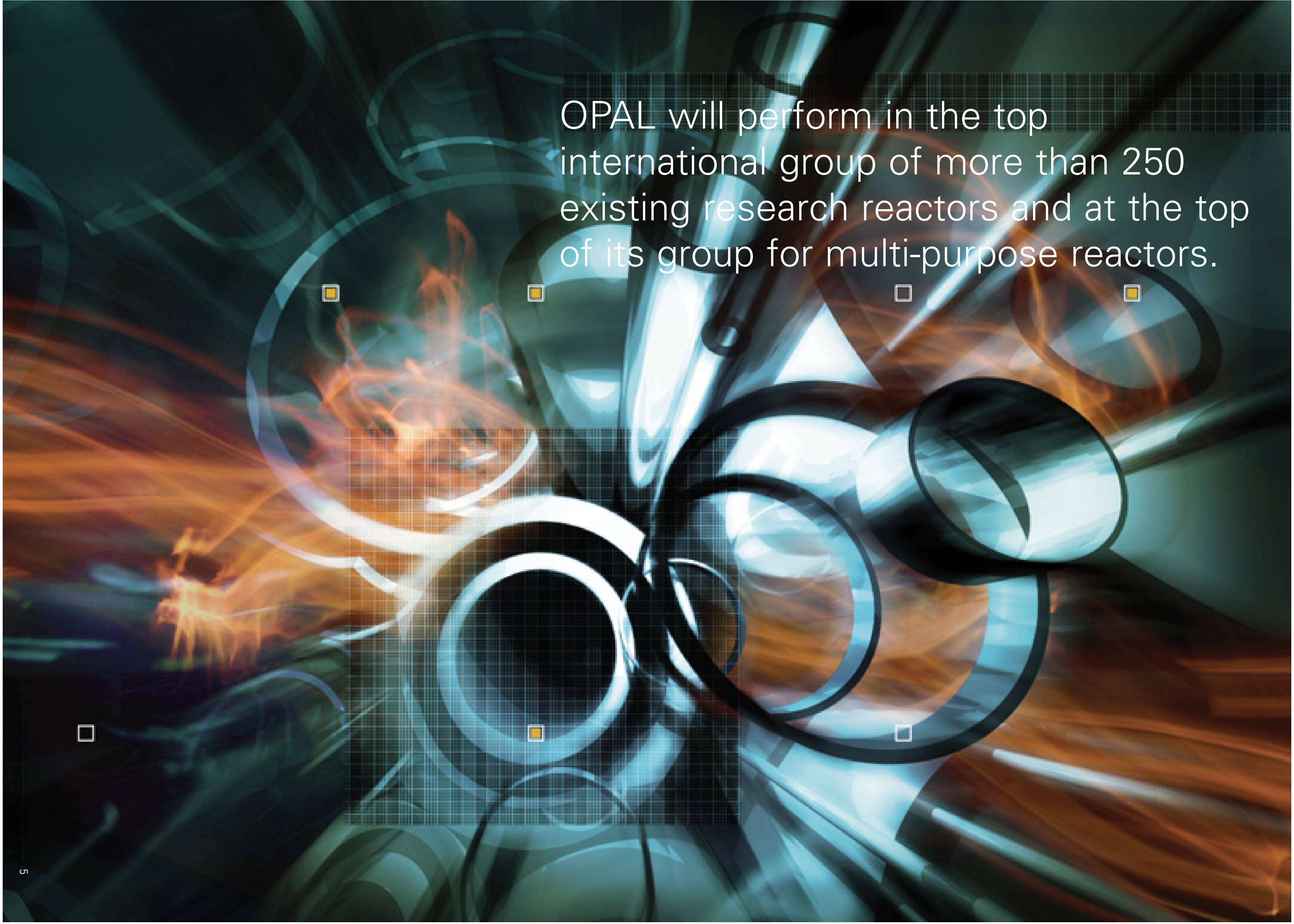
OPAL will perform in the top five per cent of more than 250 existing international research reactors, and at a similarly high level in its group of multi-purpose reactors. It can operate 340 days a year, a significant increase over the operating levels typically achieved by comparable overseas facilities.

Design and construction

OPAL is being built within the existing 1.6 kilometre buffer zone that surrounds HIFAR. This will maximise use of existing infrastructure and expertise and maintain uninterrupted production of essential but short-lived medical and industrial isotopes. Expert geologists have confirmed that the site is geologically stable.

ANSTO has managed the design and construction of the reactor facility in a manner that meets all applicable health, safety, security, safeguards, environmental and quality standards, and relevant international obligations. The development process included a comprehensive environmental assessment and public consultations on safety issues. Every aspect of reactor siting design and construction has been overseen by the Australian Radiation Protection and Nuclear Safety Agency.

The OPAL reactor and the building that houses it have been designed to withstand major earthquakes and the impact of large aircraft. Its automated and highly sophisticated safety features include two independent safety control systems to quickly shut down the reactor and cool the reactor core in the case of an emergency.



OPAL will perform in the top international group of more than 250 existing research reactors and at the top of its group for multi-purpose reactors.

New hope for liver cancer

Worldwide, more than 800 000 new cases of primary or secondary liver cancer are diagnosed each year, with life expectancies varying from months to years. Australian company SIRTeX Medical has developed a biocompatible radioactive micro-sphere treatment that offers new hope to many liver cancer sufferers, with fewer side-effects than alternative treatments such as chemotherapy. The SIR-Spheres®, which contain yttrium-90 from ANSTO, are injected into the bloodstream and travel to the liver, where they selectively irradiate the tumours. SIRTeX operations manager David James says the micro-spheres have received regulatory approval in the US, European Union, Australia, New Zealand, Hong Kong, Malaysia, Singapore and Thailand.

PROFILE: Andrew Katsifis

Andrew Katsifis is one of the driving forces behind Australia's world-class radiopharmaceutical research activities. A senior research manager at both the ANSTO Radiopharmaceutical Research Institute and the newly-formed Cooperative Research Centre for Biomedical Imaging, Katsifis has worked on the development of molecular radiopharmaceuticals in Australia, France and Germany.

Molecular radiopharmaceuticals consist of radiolabels attached to biological molecules such as small proteins that can travel through the body and attach to diseased or abnormal cells. Non-invasive imaging techniques are then used to identify the location of the radiolabels and therefore the diseased cells.

Katsifis says the full potential of the new OPAL reactor in radiopharmaceutical research can only be realised by maintaining close working relationships with the medical and scientific communities.

Going live

When the OPAL reactor reaches full operating status HIFAR will be decommissioned.

To ensure that OPAL is safely and effectively managed throughout its intended 40-year lifetime, a system of technical and administrative controls will address all safety, regulatory, operational, quality, training, environmental and commercial objectives.

Inside the OPAL reactor

The heart of the new reactor is a compact core of 16 radioactive fuel assemblies interspersed with control rods. In a process known as nuclear fission, the uranium-235 in the fuel splits into smaller atoms that emit neutrons. The OPAL reactor uses low enriched uranium fuel with around 20 per cent uranium-235. In terms of security and nuclear safeguards, this is a distinct advantage over earlier nuclear reactors, some of which required as much as 95 per cent enriched uranium.

The fuel assemblies are cooled by demineralised light water (ordinary water or H_2O) and surrounded by heavy water (deuterium oxide or D_2O) in a zirconium alloy 'reflector' vessel at the bottom of a 13-metre-deep open pool of light water. The sides of the pool are lined to help absorb unwanted radiation. A separate vessel uses liquid deuterium, at very low temperature, to produce 'cold' neutrons with lower energies and longer wavelengths.

The open pool design makes it easy to see and manipulate items inside the reactor. The depth of the light water helps ensure effective radiation shielding of staff working in the area above.

Items can be irradiated in various locations inside the reflector vessel. These materials can be manually or pneumatically manipulated and transported to a nearby building for further processing.

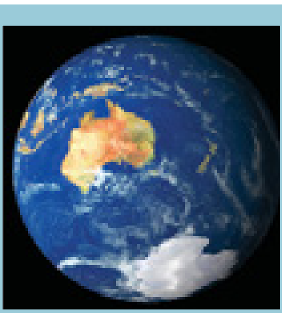
Neutrons are produced in the heavy water reflector and travel down neutron guides to scientific instruments located outside the reactor containment area. High-energy neutrons and gamma rays pass through the 'supermirror' lining of the guides and are absorbed in shielding. Neutrons with the right energy levels bounce off the supermirror sides and continue down the guide channels to the scientific instruments.

SPECIFICATIONS:

Reactor type:	open pool, low enriched uranium, water-cooled
Thermal power:	20 megawatts
Peak thermal neutron flux:	3×10^{14} neutrons per square cm per second in the reflector vessel
Installations:	cold neutron source (20 litres of liquid deuterium at 20K)
	thermal neutron source
	capacity for hot neutron source (graphite at 2 000K)
	irradiation facilities
	silicon transmutation facilities
	guide hall (35 x 65 sq. m)
	up to 18 neutron instruments
Operational:	340 days per year

SCHEDULE:

Mid 2000	neutron beam instruments project commenced
Mid 2005	guide hall and reactor hall ready
Mid 2005	neutron beam operations project commenced
Late 2005	OPAL cold commissioning begins
Early 2006	Bragg Institute building ready
Early 2006	first fuel in OPAL reactor
Late 2006	OPAL reactor and instruments commissioned
Early 2007	HIFAR shut down



Supplying a global market

ANSTO's biggest radiopharmaceuticals customer, Global Medical Solutions, provides a wide range of radiopharmaceuticals and associated products and services for nuclear medicine applications that include diagnosing heart disease, treating thyroid conditions and detecting tumours. The company has clients in Australia, Brazil, China, Hong Kong, New Zealand and the Philippines and an international turnover of US$35 million a year. In Australia, raw materials account for over half the company's costs, with ANSTO the major supplier of these materials. GMS Managing Director, John Hodder, says he would like ANSTO to supply even more of its "very high quality" products and is interested in undertaking joint research into new products as well.

PROFILE: Peter Lam

As one of three quality control supervisors that ensures ANSTO radiopharmaceuticals meet strict quality standards, approved by Australian and international agencies, Peter Lam is a busy man.

With qualifications in chemistry and information technology, and sound project management skills, Lam supervises the day-to-day, quality-control operations of ANSTO's radiopharmaceutical manufacturing facilities and contributes to continuous improvement of procedures and processes. Lam and his team work six days a week testing and releasing a wide range of radiopharmaceuticals.

"Our products have relatively short half-lives, so it's a constant challenge to make sure they are tested quickly and accurately to meet tight delivery schedules," Lam says.

RADIOISOTOPE PRODUCTION AND APPLICATIONS

ANSTO has more than 40 years experience in the production and development of radioisotopes for medical, industrial and environmental applications. The new reactor will enable ANSTO to significantly increase the quality, quantity and range of its radioisotope products and services.

ANSTO Radiopharmaceuticals and Industrials supplies most of Australia's nuclear medicine, as well as that of a number of overseas countries, especially in the Asia-Pacific region. It also meets Australian industrial needs for radioisotopes, with clients operating in sectors such as transport, construction and energy.

Radiopharmaceuticals

Radiopharmaceuticals contain radioisotopes that spontaneously produce specific amounts of radiation which can safely be used to diagnose and treat a wide range of human diseases and injuries. For example, hospitals use technetium-99m to diagnose various heart, kidney, lung, liver and thyroid conditions and some bone cancers. Phosphorus-32 is used to treat blood disorders. Samarium-153, the radioisotope in Quadramet, can alleviate pain associated with advanced bone cancer.

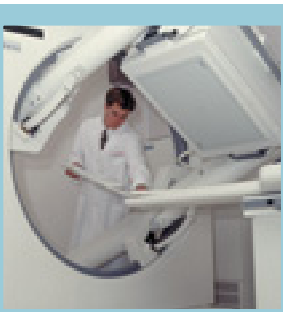
Most radiopharmaceuticals are produced by irradiating particular elements with neutrons in a nuclear reactor. ANSTO also makes some radiopharmaceuticals in a medical cyclotron, which uses high-energy protons rather than neutrons.

Radiopharmaceuticals have a limited shelf life (based on the radioisotope 'half-life', which is the time it takes for the radiation that is produced to fall to half its original value). To be effective, they must therefore be produced close to where they are used and transported without delay. Some radiopharmaceuticals have very short half-lives, in some cases just a few hours, so Australia must produce its own.

It is expected that OPAL will satisfy virtually all the radiopharmaceutical requirements of Australian medical professionals and ANSTO's overseas customers for the next 40 years. Its product range will include radioisotopes of chromium, cobalt, copper, dysprosium, gold, holmium, iodine, iridium, phosphorus, samarium, molybdenum (the precursor of technetium-99m), xenon, lutetium and yttrium.

The world radioisotope market is worth around $A900 million a year.

OPAL will significantly increase the quality, quantity and range of ANSTO' radioisotope products services.



How to gauge success

Running an efficient mineral processing operation requires real-time knowledge of the density of the material being processed. Adelaide-based Thermo Gamma-Metrics manufactures a range of devices that use caesium-137 and cobalt-60 from ANSTO to gauge the percentage of solid material at various stages in the processing of copper, nickel, alumina, zinc sulphides, mineral sands and iron ore. The company's 60 to 70 per cent of the Australian market for these gamma-radiation devices is worth around $1.5 million a year. Thermo Gamma-Metrics senior physicist Kevin Gardner says ANSTO is a reliable supplier and the company is keen to obtain an expanded range of sources from ANSTO rather than importing these from overseas.

PROFILE: Tatiana Karma

Tatiana Karma is the face behind ANSTO's multi-million dollar silicon irradiation business, with customers in Europe and Asia. A Russian-born nuclear engineer, Karma thoroughly enjoys the challenges of the job, including the important task of maintaining good long-term business relationships with international customers.

Karma says the new reactor will be able to handle silicon crystals up to 200 millimetres in diameter. It will produce irradiated silicon with uniform phosphorus distribution and a wide range of resistivities (20 to 5000 ohm cm) to meet customer specifications.

Industrial products

The neutrons and gamma radiation produced by certain radioisotopes play important roles in non-destructive testing for the petrochemical, aerospace, power, rail and nuclear industries, and in process control in the minerals industry. Over the last three years, ANSTO's sales of radioisotopes for non-destructive 'imaging' methods have tripled.

ANSTO produces a range of radioisotopes and non-destructive testing equipment for industrial customers around the world. These radioactive sources can be used somewhat like a more powerful form of X-rays to safely and reliably test the integrity of power station turbine blades, pipeline welds, aerospace structural components, railway tracks, bridges and heavy mining equipment. Other uses include checking the density of the rock on which bridges and roads are to be built, measuring the extent of subterranean oil resources, gauging refinery tank levels and assessing mineral flow on conveyor belts.

In addition to improving the quality and quantity of these products, the new reactor will enable ANSTO to expand into new market sectors that require higher levels of radioactivity.

Irradiation services

ANSTO provides a customised irradiation service to clients in university departments and commercial enterprises. One important use of this service is in fission track analysis, which measures the uranium content of rock samples to determine the range of temperatures and geological processes a sample has experienced. This information can help to identify promising areas to drill for oil.

Silicon irradiation

ANSTO is one of the world's leading providers of irradiated silicon ingots of electronic grade for advanced electronic devices, integrated circuits and many other industrial applications. The new reactor will enable ANSTO to significantly increase its silicon irradiation capacity and produce a wide range of irradiated material of the highest quality.

In its pure natural state, silicon is an insulating material, so it does not conduct electricity. With the introduction of small amounts of impurities such as phosphorus atoms, silicon becomes a better conductor of electricity. The best way to 'add' phosphorus atoms is by 'neutron transmutation doping' of large single crystals of pure silicon. Inside a neutron source such as a nuclear reactor, silicon-30 atoms are transformed into unstable silicon-31 atoms, which quickly decay to stable phosphorus atoms. This creates a much more even distribution of phosphorus than alternative methods such as diffusion of phosphorous into the ingot.

Silicon semiconductors are an essential part of many sophisticated control, switching and sensing devices. These devices are used for a wide range of applications in the power transmission, manufacturing, automotive, transport, military and space industries and in scientific research. Closer to home, devices manufactured from irradiated silicon can be used in appliances such as air conditioners, fridges and microwaves.

Silicon semiconductors are used for power transmission, manufacturing, automotive, transport, military and space industries and in scientific research.

How to find out more about ANSTO

ANSTO is happy to provide further information on its wide range of products, services, publications and research and business development activities.

Enquiries
Telephone +61 2 9717 3111
Email enquiries@ansto.gov.au
Website www.ansto.gov.au

Postal address
PMB 1, Menai NSW 2234 Australia

Location
New Illawarra Road, Lucas Heights
New South Wales 2234 Australia

For advice on car, train and bus travel to ANSTO's Lucas Heights site, visit the ANSTO website www.ansto.gov.au/ansto/dir.html or contact ANSTO reception.

ANSTO Representative Offices

Canberra
ANSTO Representative
Department of Education, Science and Training
Level 1, 17 Mort Street
Canberra ACT 2600
Australia
Telephone +61 2 6240 5017

Vienna
Counsellor (Nuclear)
Australian Embassy
Mattiellistrasse 2-4
A-1040 Vienna
Austria
Telephone +43 1 5067 4119

Washington
Counsellor (Nuclear)
Australian Embassy
1601 Massachusetts Ave, NW
Washington DC 20036
United States of America
Telephone +1 202 797 3042

ENQUIRIES:

Printed on recycled paper - June 2005

Australian Government

Nuclear-based science benefiting all Australians