BOOMERANG - The Australian light source

J.W. Boldeman and R.L. Garrett
Australian Nuclear Science and Technology Organisation,
PMB 1, Menai, NSW 2234

1. Introduction

A proposal has been prepared for the installation in Australia of a national high performance synchrotron light facility called **Boomerang**. The Boomerang proposal had its origin in the establishment of the Australian Synchrotron Research Program (ASRP) which was one of the seven Major National Research Facilities announced by the Federal Government in December 1995. The ASRP provides the opportunity and funding for Australian researchers to access international synchrotron facilities, specifically two consortia at the Advanced Photon Source (APS) at the Argonne National Laboratory, USA and continued interaction with the Photon Factory at the KEK Laboratory in Japan. The ASRP was the successor to the Australian National Beamline Facility project (ANBF) which began in 1991 following the ASTEC inquiry titled "Small Country - Big Science".

The Federal Government also provided funding for a Feasibility Study to determine the value of establishing an Australian-based synchrotron radiation facility. The Feasibility Study was completed in August 1998 and endorsed by the institutional members of the ASRP and the research community in general. The study concluded that, on the data available in Australia, there was a strong case for the installation of an Australian-based facility. The study considered several options for an Australian-based facility and recommended that these options and the data supporting the general conclusions receive further investigation. A mission was arranged to a select group of overseas laboratories to explore these questions in detail. The review team included a mix of scientific and industrial experience and also represented the interests of the ASRP and an Industrial Synchrotron Consortium based in Victoria. Based on the conclusions of the overseas mission and incorporating the advice of all international specialists in the design and use of synchrotron facilities consulted during the mission, the most cost-effective option was an extended version of 'ANKA', a synchrotron facility that is currently under construction at Karlsruhe, Germany.

2. Specifications for Boomerang

The lattice of the parent ANKA facility, currently under construction, comprises four cells each having a dual Double Bend Achromat giving a total of 16 dipoles in the ring. The extended version of ANKA, Boomerang, has six cells and thus 24 dipole magnets in the storage ring. As for the ANKA storage ring, the spacing between the six cells in the proposed facility is different from the internal spacing between the DBAs in each cell, thereby reducing the overall size of the lattice without any compromise in performance. The configuration of Boomerang is shown in Figure 1. The injector and booster are identical to those on ANKA and the RF system is also the same. However, the positioning of the two RF sections has been changed for more efficient operation. Although the extension of the original ANKA design leads to a modest increase in cost, the overall cost of the facility remains attractive because of the use of many of the components from the ANKA facility. The principal specifications of Boomerang are also shown in Figure 1.

The extension of the design has a number of consequences:

- The number of long straight sections is increased to 6 allowing up to 6 insertion devices of traditional design;
- the number of available short sections is increased to 3;

- the circumference of the ring is now 163.8 m;
- with the same magnet field strength of 1.5 T for the dipoles, the energy of the ring increases to 3 GeV making the facility very competitive with other third generation storage rings under construction;
- the emittance of the ring with distributed dispersion is reduced to 16 nm rad which will produce very high brilliance beams.
- Beam current is maintained at 300mA.

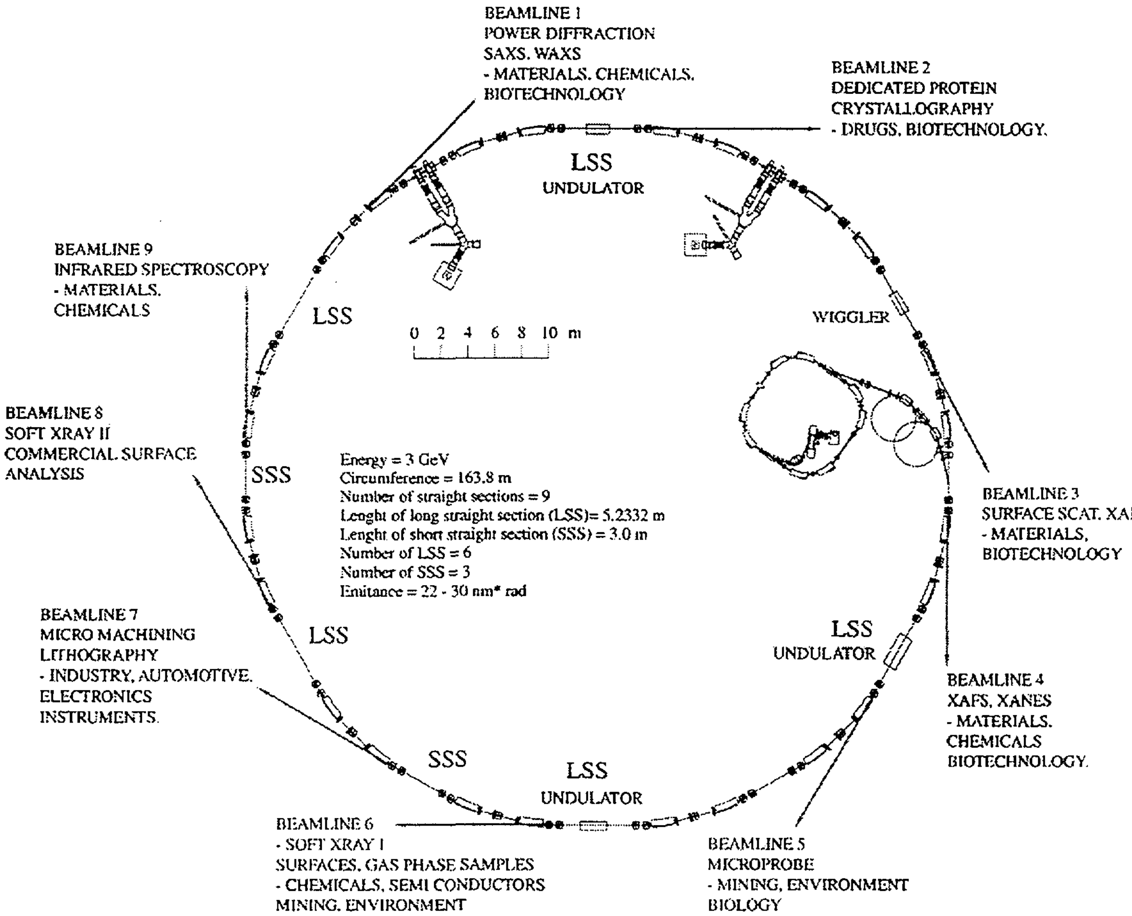

Figure 1 - Configuration of Boomerang

2.1 Beam Optics Calculations

The optics of the proposed lattice have been evaluated using the MAD program, developed at CERN, and the program DIMET, developed by the Stanford Synchrotron Radiation Laboratory. The optics of strong focussing storage rings is now a mature science and the optics calculations provide a very accurate evaluation of an actual storage ring particularly in the hands of experienced designers. Figure 2 shows the optical functions for non zero dispersion in the straight sections. When Boomerang is operated in this fashion, the performance is very competitive with that of other facilities currently in operation. Figure 3 compares the brightness from the Boomerang dipoles with that from the dipoles of the APS and the Photon Factory.

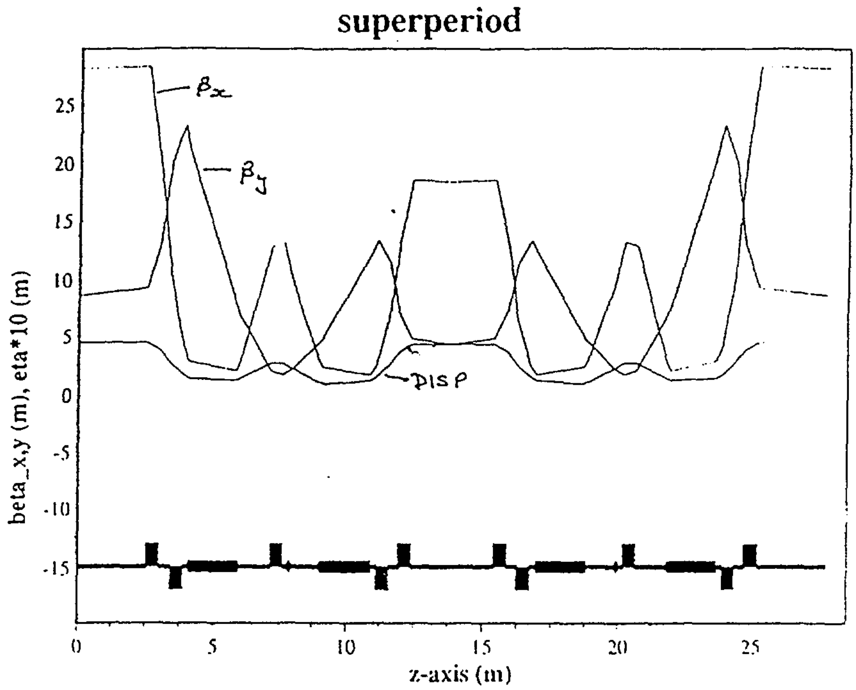

Figure 2 - Variation of the Machine Optics Parameters with Non Zero Dispersion

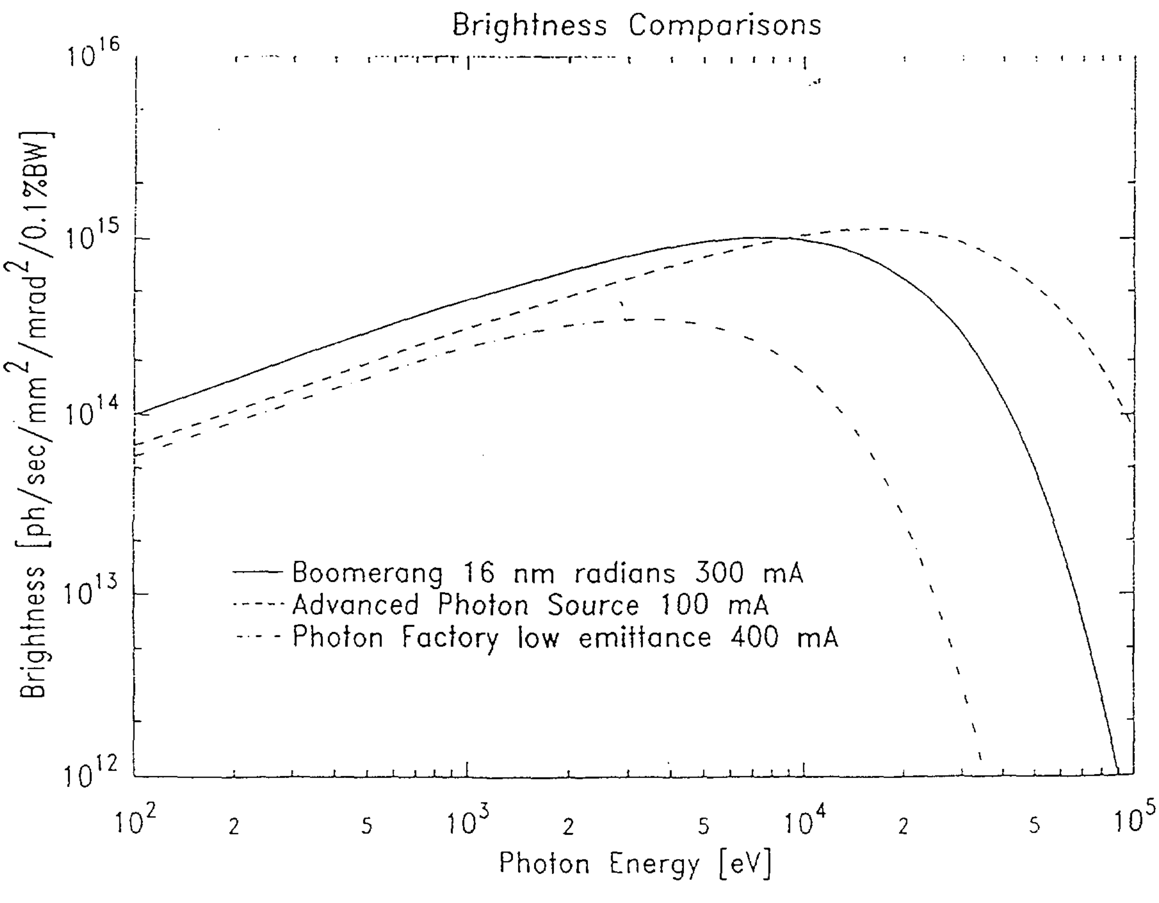

Figure 3. - Brightness Comparisons

2.2 Beamlines and Experimental Stations

Boomerang is capable of supporting as many as 60 experimental stations with perhaps 15 stations on insertion devices. It has therefore been designed to cater for the long term development of the applications of synchrotron radiation in Australia. However the cost per instrument station is approximately $2-4M and ultimately the major investment on the facility will be in associated equipment. A preliminary survey of current users in Australia has suggested that the limited instrument station package shown in Table 1 will cater for approximately 95% of the present and anticipated Australian usage in the first 5 years of operation. The package includes three undulator insertion devices plus a wiggler. The insertion devices and the bend magnets will provide photons to 9 experiment stations.

Table 11 - Beamlines and Instrument Stations

	Source	Capabilities
Beamline 1	Bending Magnet	Powder Diffraction, SAXS, WAXS
Beamline 2	Undulator	Protein Crystallography
Beamline 3	Wiggler	Surface Scattering/Dilute XAS
Beamline 4	Bending Magnet	General X-ray Absorption Spectroscopy
Beamline 5	Undulator	Fluorescence Microprobe/Coherence
Beamline 6	Undulator	Soft X-ray I
Beamline 7	Bending Magnet	Micro-machining & Lithography
Beamline 8	Bending Magnet	Soft X-ray II
Beamline 9	Bending Magnet	Infra Red

2.3 Site, Staff and Total Cost

The Boomerang storage ring and associated beamlines will be housed in a large warehouse type structure, 75m by 85m in size. An associated office and laboratory complex will be constructed adjacent to the warehouse building. Office accommodation will include 40 rooms, each with an area of $20m^2$. Five specialist laboratories, $40m^2$, will also be included. The storage ring itself will be enclosed in an airconditioned concrete tunnel. The Boomerang Complex includes a dormitory with 30 double rooms and associated conference and parking facilities. The approximate dimensions of the site are 110m by 220m.

It is proposed that the facility be constructed by Australian staff supported by 7 specialist synchrotron designers from the FZK laboratory. A project engineer will be appointed. The Australian staff, recruited during the construction stage, will become the operational staff of the facility. To operate, promote and fully exploit the capability of the facility will require approximately 52 staff members.

The facility will be operated as a national facility with scientific access following peer review. A strong emphasis will be given to industrial use. The estimated cost over the first 10 years of the facility, including the construction period of 4 years, is $160M. At this time no site has been selected. The philosophy is to submit this proposal to the Federal Government as a national facility and recommend to the government that they seek expressions of interest to house the facility.

3. *Summary of the Scientific and Economic Consequences*

A comprehensive analysis has been made of the scientific and economic benefits that should arise from the installation of Boomerang. Some of the relevant benefits are as follows:

Synchrotron radiation research has evolved from an esoteric endeavour practiced by a small number of scientists primarily from the fields of solid state physics and surface science to a mainstream activity which provides essential information in the materials and chemical sciences, the life sciences, molecular environmental science, the geosciences, nascent technology and defence related research among many fields.

Based on the experience in OECD countries, the Australian scientific community involved in the applications of synchrotron radiation could be expected to reach 1200 registered users by the year 2010 if Boomerang is installed.

Boomerang would become the premier research tool in Australia for the training of a scientifically advanced community.

Synchrotron facilities are the most versatile of all major research facilities and therefore the installation of Boomerang would allow Australian researchers to participate in many emerging technologies.

Boomerang is expected to become a major Pacific Rim research facility and could attract investment from neighbouring nations such as New Zealand, South Africa, Malaysia and perhaps Indonesia.

Australian science with a rapidly growing community of internationally respected protein crystallographers would be extremely well placed to capture the benefits in biological science following the installation of a synchrotron facility. The installation of Boomerang would provide the opportunity for Australia to compete on a level playing field as a pharmaceutical supplier in the next century. It could be expected that products based on the generation of Intellectual Property by Australian researchers at Boomerang could generate annual revenue of as much as $2B. Appropriate investment could capture much of this revenue for Australian based companies.

The installation of Boomerang could supplement existing capabilities for the manufacture of microstructure products. The potential annual revenue from the provision of comprehensive capabilities in this industrial activity could be up to $60-120M based on an expected world market of more than $60B in the early part of the next century.

It is expected that synchrotron radiation will play an important role in diagnostic and perhaps therapeutic medicine in the 21st century. It is also apparent that Australian scientists have the tradition and expertise to exploit these opportunities when they arise. For any application in medicine it is not conceivable to consider the use of international facilities.

Boomerang should assist the Australian mining and exploration industry by providing state of the art analytical X-ray capabilities. At a time when the decline in commodity prices is placing pressure on this major Australian industry, it would be a wise strategic decision to have access to state of the art analytical facilities available at short notice to protect these industries.

Internationally with more than 80 facilities planned or operational, Australia is by far the largest trading nation without a home based facility.