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# Australian Synchrotron Light Source – (Boomerang)

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**SUMMARY** The Australian National Synchrotron Light Source – (Boomerang) is to be installed at the Monash University in Victoria. This report provides some background to the proposed facility and discusses aspects of a prospective design. This design is a refinement of the design concept presented to the SRI –2000, Berlin (Boldeman , Einfeld et al), to the meeting of the 4th Asian Forum and the Preliminary Design Study presented to the Australian Synchrotron Research Program.

## 1 INTRODUCTION

A Feasibility Study (AUGUST 1997)[1] has recommended that the most appropriate synchrotron light facility for Australia would have

- an energy of 3 GeV,
- that it should be competitive in performance with other third generation compact facilities currently under construction and
- that it should have adequate beam line and experimental stations to satisfy 95% of the research requirements of an expected Australian community of 1200 different researchers
- and provide internationally competitive performance for essentially all Australian industry requirements.

Thus the minimum parameters of the recommended facility can be extended to include

- an emittance of better than 18 nmrad,
  - a beam current of at least 200 mA,
- at least 8 useable straight sections for insertion devices and
- a management policy which encouraged front line research and a strong industrial focus.

With such a facility, competitive synchrotron radiation could be delivered to the various experimental stations to almost 100 keV via appropriate insertion devices.

A proposal was submitted to the Federal Government in December 1999 to construct such a facility – the Boomerang Proposal Parts I – VII[2]. The Boomerang Proposal Parts II and III described an in-principle storage ring design which was based on an extended version of the ANKA facility at the Forchungszentrum Karlsruhe in Germany[3]. It was always intended that this in principle design would be refined.

More recently, significant effort was devoted to refining this in principle design and a lattice providing an emittance of 18 nm rad was obtained with a distributed dispersion $(n_x)$ in the straight sections of 0.29m. However it is now apparent that if some aspects of the design of the Canadian Light Source[4] are incorporated an even higher performance can be obtained with no additional cost.

The design goal of the desired storage ring has now been extended and the target parameters are listed below.

| | |
|---|---|
| Beam Energy | 3 GeV |
| Beam Current | at least 200 mA in Phase I |
| Emittance | better than 12 nm rad for a dispersion of less than 0.3 m |
| Long Straights | more than 9 |
| Life Time | greater than 20 hrs |
| Circumference | less than 200m |
| Instrument Stations | 9 in Phase I |

Exhaustive studies have been made of the economic benefits that would accrue to Australia following the installation of a facility with the design parameters listed above. In addition to the studies within the ASRP, the Victorian Industrial Synchrotron RoundTable evaluated economic opportunities from 1996 and funded several Workshops dealing with potential opportunities within areas such as the biotechnology industries and mining and mineral extraction. Three independent bodies were funded to evaluate the economic benefit. These comprised

- Centre for International Economics
- Centre for Strategic and Economic Studies
- PricewaterhouseCoopers.

Recently, the three Eastern Australian States submitted proposals to the Federal Government seeking funding to build a third generation light source in Australia. Subsequently the Victorian Government committed $100M towards the construction of the facility and has underwritten the balance. A site at Monash University has been selected. This report details the proposed design of the facility.

## 2. Lattice

A Double Bend Achromat (DBA) has been adopted, similar to the designs of the CLS and ANKA facilities and is a refinement of the design presented to SRI-2000 and the 2nd Asian Forum[5)]. Each cell comprises two dipoles, six quadrupoles (Q), and six sextupoles (S) separated by appropriate drift spaces (D). The chosen lattice differs from the ANKA facility in that all straight sections are of equal length. In addition, the dipoles have a gradient magnet field as in the CLS and thus function as quadrupole elements as well as bending the electron beam. The chosen facility differs from the Canadian lattice in that the gradient field of the dipole is more modest. Additional vertical focussing is provided by two small vertically focussing dipoles in each cell. The lattice also incorporates additional sextupoles to allow the lattice to operate at a higher distributed dispersion. The sextupoles can also be double function elements as they incorporate correctors thereby minimising space requirements.

The Boomerang lattice is shown in Figure 1. To calculate the performance of the selected storage ring, three different codes have been used. These are

1. Beta Code developed at the ESRF
2. WinAgile from CERN
3. Beam Optics from Stanford.

All three codes provided similar performance (i.e. optical functions and emittance) for very similar design parameters and unchanged lattice dimensions if account is taken of the different units for the specified parameters. This was important as each of the codes has some aspects which makes their use more convenient that that of others. For example the dynamic aperture is more conveniently calculated in the Beta Code while for tune variations the WinAgile Code is more appropriate. The WinAgile Code is particularly useful for orbit correction schemes.

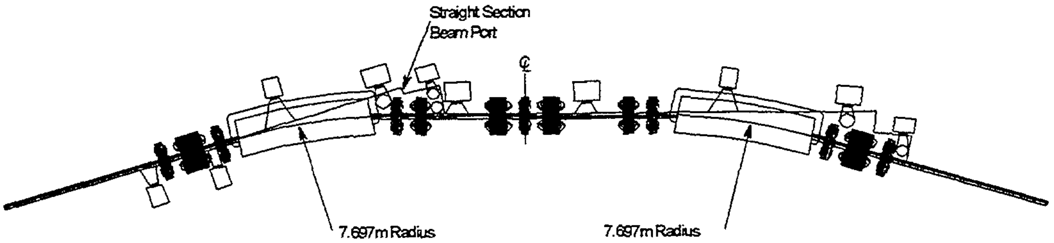

Figure 1. Proposed lattice

## 3. Distributed Dispersion

The minimum value for the emittance and maximum brightness is achieved with distributed dispersion. The performance and parameters associated with the lattice have been calculated allowing a maximum of approximately 0.29m dispersion in the straight sections.

### Beta Code – Distributed Dispersion

The optical functions calculated using the Beta code are shown for one cell for distributed dispersion in Figure 2. The emittance under these conditions is 11.7 nm rad.

The lattice functions calculated with the Beta Code for distributed dispersion are shown in Figure 2.

Table 1 presents a comparison of the settings of the various magnets as derived in the three programs.

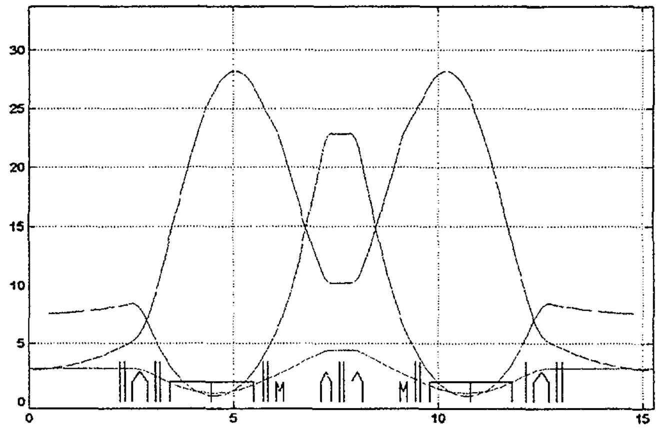

Figure 2. Lattice functions – Beta Code

Table 1. Comparison of the Magnet Settings

| Parameter | Beta Code | WinAgile Code | Beam Optics |
|---|---|---|---|
| Q1 | 1.724 | -1.7240 | 1.724 |
| Q2 | -0.9083 | 0.9083 | -0.9083 |
| Q3 | 1.5726 | -1.5726 | 1.5726 |
| S1 | 24.5 | -51.70 | 24.00 |
| S2 | -25.0 | 51.7 | -25.02 |
| SV | -5.27 | 12.53 | -10.18 |
| SH | 6.28 | -9.03 | 7.10 |

The values for the three quadrupole families are exactly identical as expected. The values for the sextupoles are similar after allowance is made for the difference in the units. For example the values for the Beta Code need to be multiplied by a factor of 2 for comparison with the values for the WinAgile code. The optimisation of the sextupole settings proceeded as follows. Within the Beta Code, an iterative scan was made of the S1 and S2 sextupoles settings to maximise the dynamic aperture while maintaining a slightly positive value for the chromaticity. (These calculations were performed by M.Abo-Bakr using a routine developed at BESSY II). Within the WinAgile Code particles were followed for 4000 revolutions of the full lattice to determine the best values for the Dynamic aperture. As before the chromaticities were maintained slightly positive. The dynamic aperture calculated with the Beta Code is shown in Figure 3.

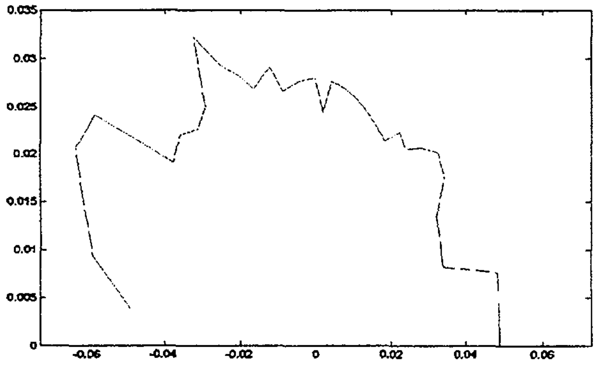

Fig.3 Dynamic Aperture calculated with the Beta Code for an ideal lattice

Table 2 presents a comparison of synchrotron data calculated with the three codes. Data from the CLS are presented for comparison.

Table 2. Comparison of the Calculated Synchrotron Data

| Parameter | Beta Code | WinAgile | Beam Optics | CLS |
|---|---|---|---|---|
| | | | | |
| Energy | 3 GeV | 3 GeV | 3 GeV | 2.9 GeV |
| Circumference | 184.07 m | 184.07 m | 184.07 m | 170.88 m |
| Periodicity | 12 | 12 | 12 | 12 |
| Emittance | 11.7 nmrad | 11.5 nmrad | 11.5 nmrad | 18.1 nmrad |
| Current | 200 mA | 200 mA | 200 mA | 500 mA |
| Horizontal Tune | 11.11 | 11.11 | 11.11 | 10.22 |
| Vertical Tune | 4.18 | 4.18 | 4.18 | 3.26 |
| Hor Nat Chrom | | -23.3 | -23.6 | -13.9 |
| Vert Nat Chrom | | -17.7 | -15.8 | -17.7 |
| Corrected Chrom H | 0.072 | 0.1 | 0.1 | |
| Corrected Chrom V | 0.160 | 0.1 | 0.1 | |
| Momentum Com | 0.0034 | 0.0034 | 0.0034 | 0.0038 |
| Length Straight | 4.57 m | 4.57 m | 4.57 m | 5.2 m |
| Beta x | 7.5 m | 7.43 m | 7.50 m | 8.5 m |
| Beta y | 2.85 m | 2.84 m | 2.84 m | 4.6 m |
| Dispersion | 0.285 m | 0.285 m | 0.285 m | 0.15 m |
| Dipole Field | 1.3 T | 1.3 T | 1.3 T | 1.354 T |
| Damping Time x | 2.84 ms | 2.84 ms | 2.85 ms | 2.4 ms |
| Damping Time y | 3.85 ms | 3.95 ms | 3.95 ms | 3.8 ms |
| Damping Time E | 2.35 ms | 2.46 ms | 2.45 ms | 2.7 ms |
| Energy Loss/turn | 931 keV | 931 keV | 931 keV | 876 keV |
| Total Rad Power | 186 kW | 186 kW | 186 kW | 438 kW |
| Energy Spread % | 0.103 % | 0.103 % | 0.103 % | 0.111 % |
| Energy Acceptance | ±6 % | ±5% | ±5% | 1.54% |
| Full Bunch Length | | | 9.84 mm | 54 ps |
| Dynamic Aperture H | ± 50 mm | ± 36 mm | ± 33 mm | ± 29 mm |
| Dynamic Aperture V | 27 mm | 14 mm | 18 mm | 21 mm |

## 4 Zero Dispersion

The parameters of the lattice for each of the three codes have been calculated for zero dispersion in the straight sections. This can be accomplished simply by increasing the value of the central quadrupoles from 1.5726 to 1.5938. The optical functions calculated with the BeamOptics Codes are shown in Figure 4.

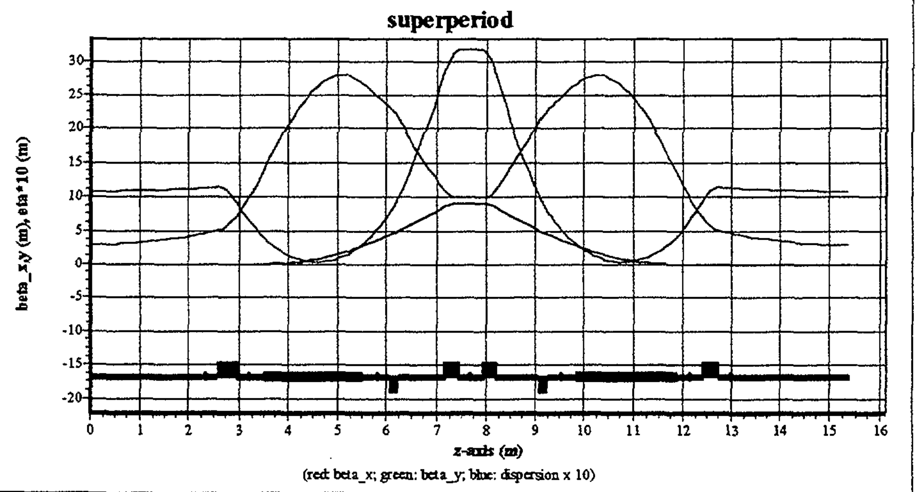

Fig 4. Lattice parameters – zero dispersion – Beam Optics Code

## 5. Other Details

A comprehensive study has been made of magnet alignment errors etc and a preliminary diagnostic and beam orbit correction scheme has been derived. This is not shown here. It is intended to operate with full energy injection. Since the proposed facility has many similarities to the CLS it is intended to use a full energy booster synchrotron not too different from that employed there. A decision on the injector whether a microtron or a linac has yet to be made. The choice for the RF system between a conventional and super conducting system has also not been made. The control system is likely to be EPICS. A final decision is also not expected on the initial complement of Beamline and instrument stations. Table 3 lists the preliminary package of instrument stations from the Boomerang Proposal that was used to evaluate facility costs.

Table 3. Preliminary Beamline and Instrument Stations

| Beamline* | 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 |

* There is no priority attached to the beamline number.

## 6. Status

The present schedule for the construction of the facility has a completion date of December 2005. At this time a preliminary management structure has been put in place and several international and national advisory groups are being formed. The site has been selected – Monash University in Victoria. Recruitment of the senior personnel to manage the project has begun. The selection of the Project Management team is under consideration. A preliminary design for the buildings is presented on the poster at this meeting.

## 7. References

(1) J. W. Boldeman "Feasibility Study for an Australian Synchrotron" ASRP Document (1997)
(2) J.W. Boldeman "The Boomerang Proposal - Parts I - VI" ASRP Document (1999)
(3) D. Einfeld, "ANKA"
(4) L. Dallin, "CLS"
(5) J. W. Boldeman, R. F. Garrett, D. Einfeld, E. Huttel et al "Boomerang: The Australian Light Source" 7th International Conference on Synchrotron Radiation Instrumentation, Berlin 2000 and 4th Asian Forum on Synchrotron Radiation Sources, Hiroshima.