THE AUSTRALIAN SYNCHROTRON PROJECT STORAGE RING AND INJECTION SYSTEM OVERIVEW

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Abstract

This paper will give an overview of the Australian Synchrotron Project (ASP) storage ring and injection system [1]. The ASP storage ring is a 3 GeV machine with 14 identical cells and a circumference of 216 m. The unit cell is based on a Double Bend Achromat (DBA) structure. The present design of the magnet lattice and the results of simulations pertaining to the storage ring performance are presented. The facility is expected to be in operation by March 2007 [2].

STORAGE RING

A single cell of the ASP lattice is shown below in Figure 1. The two bending magnets are identical and are gradient dipoles with a focusing strength of $k = -0.335$ m^{-2}. There are three families of quadrupoles and four families of sextupoles. Horizontal and vertical corrector coils are wound into the sextupole magnets to make the lattice more compact [3]. The design of the vacuum system is detailed in Ref. [4].

The nominal lattice tunes are $\nu_x = 13.3$ and $\nu_y = 5.2$, but the machine can be tuned over a large range by using the outer two of the quadrupole families. The inner quadrupoles are used to distribute the dispersion to allow it to leak into the straight sections. Two of the straight sections are used for RF cavities, one for the injection septum and the remaining eleven will be available for insertion devices. The machine functions for one cell in the lattice are shown in Figure 2 and the design specifications are shown in Table 1.

The natural chromaticities of the lattice are $\xi_x = -28$ and $\xi_y = -27$ and using the inner two sextupole families these values can be set to be slightly positive. When the sextupoles are turned off the dynamic aperture is significantly larger than the physical beam pipe cross section. Setting the chromaticity to zero reduces the dynamic aperture, but it still remains comparable to the physical beam pipe.

Table 1. ASP storage ring specifications.

Energy	3	[Gev]
Circumference	216	[m]
RF Frequency	499.654	[MHz]
Harmonic Number	360	
Peak RF Voltage	3.0	[MV]
Current	200	[mA]
Critical Photon Energy	7.8	[keV]
Betatron Tune (h/v)	13.3/5.2	
Momentum Compaction	0.002	
Natural Chromaticity (h/v)	-28/-27	
Radiation Damping (h/v/l)	3/5/3	[ms]
Energy Spread	0.1	[%]
Radiation Loss	932	[keV]
Horizontal Emittance	16	[nm·rad]

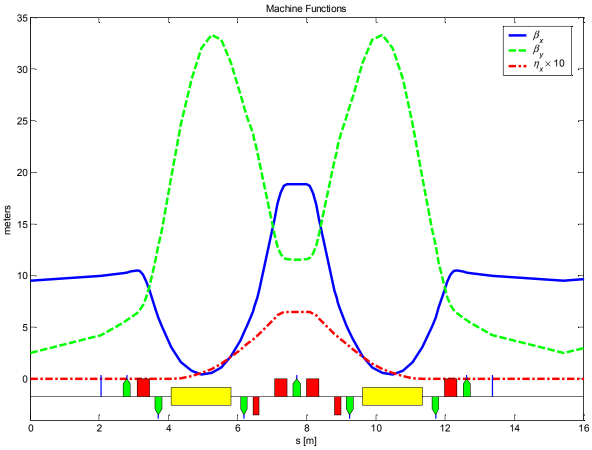

Figure 2. Machine functions for one cell of the ASP storage ring with zero dispersion in the straight sections.

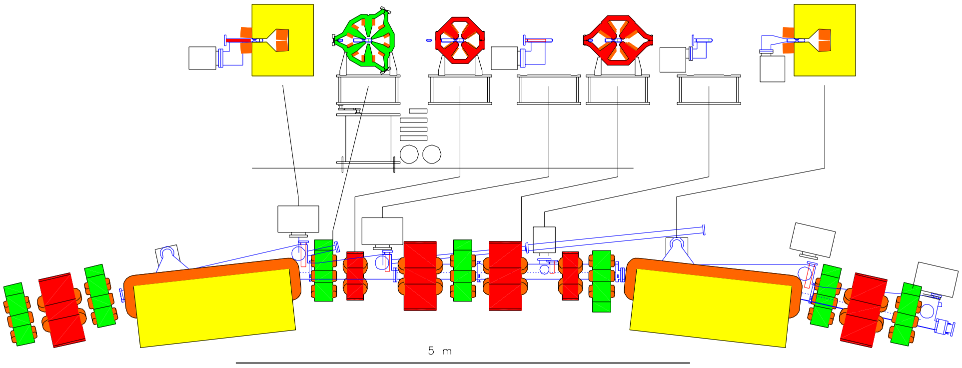

Figure 1. A unit cell of the 14 cell double bend achromat ASP storage ring lattice.

Key:

Red – Quadrupole

Green – Sextupole

Yellow – Dipole

INJECTION SYSTEM

The storage ring will be injected at full energy from a 0.1 GeV linac that feeds a 0.1−3 GeV booster ring. The booster consists of a combined function FODO lattice and will inject at a 1 Hz repetition rate. Table 2 shows the specifications of the injector system and Figure 3 shows the floor plan of the accelerator systems.

Injection into the storage ring will be achieved by first bumping the stored charge using four kicker magnets, and then the injected charge is delivered from the booster transfer line using a thin horizontal septum. The injection system has been designed to operate in top-up mode in the future.

Table 2. ASP injection booster specifications.

LINAC		
Energy	0.1	[GeV]
RF Frequency	2997.92	[MHz]
Sub-harmonic Pre-buncher	499.654	[MHz]
Repetition rate	1-5	[Hz]
Normalised Emittance	<50π	[mm·mrad]
End charge (single/multi)	>0.31/>3.1	[nC]
BOOSTER		
Energy	0.1 → 3.0	[GeV]
Circumference	130.2	[m]
RF Frequency	499.654	[MHz]
Harmonic Number	217	
Single Bunch Current	>0.5	[mA]
Multi-bunch Train	>5.0	[mA]
Betatron Tune (h/v)	9.2/3.25	
Natural Chrom. (h/v)	-8.8/-11.5	
Energy Spread (3GeV)	0.094	[%]
Horizontal Emittance	33	[nm·rad]

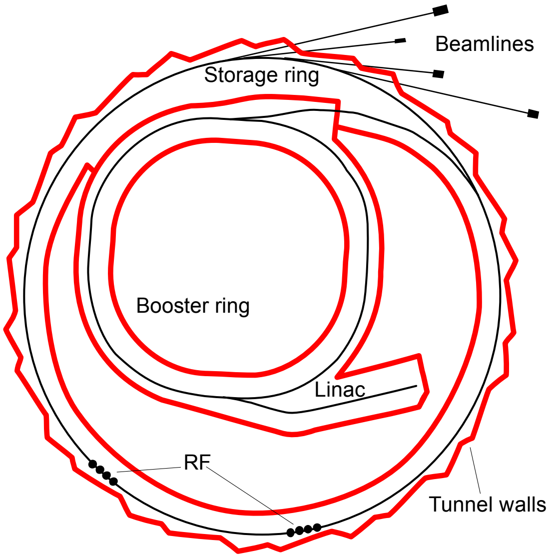

Figure 3. Storage ring and injector floor plan.

BEAMLINES

Diagnostic Beamlines

There are plans for two diagnostic beamlines to monitor the synchrotron light from dipoles in the storage ring; one for X-rays and one for optical light. The X-ray beamline has been designed to fit entirely within the shielding walls of the storage ring to simplify the design and remove the need for a hutch. An X-ray pinhole camera, a YAG screen and a CCD camera will be used to measure the beam size from a dipole source to determine the beam stability and the emittance.

An optical diagnostic beamline has also been planned in order to measure the bunch length and longitudinal beam dynamics. This design will consist of an optical chicane to bring the light out through the shielding wall and to absorb the unwanted X-rays. A hutch containing an optical bench will house a streak camera and a high speed CCD to measure the longitudinal beam characteristics.

Experimental Beamlines

An initial suite of nine beamlines is included in the design of the ASP. Four of these are expected to be under commissioning at the completion of the storage ring in 2007. Two beamlines will be from bend magnet sources and two from insertion devices [2].

STORAGE RING STUDIES

Beam Sizes

The electron beam sizes in the dipole at the photon source points have been calculated at the nominal tune with zero dispersion in the straight sections and are shown in Table 3. Analysis has shown that the beam size decreases by ~20% with a dispersion of 0.1 m in the straights, so that will most likely become the normal operating mode. Figure 4 shows the photon flux spectrum from a dipole in the storage ring at the design current of 200 mA and has a critical energy of 7.8 keV (λ = 0.16 nm).

Table 3. Calculated beam sizes in the ASP storage ring with zero dispersion in the straight sections.

Parameter	Insertion Device	Dipole 1	Dipole 2
β_x [m]	9.469	0.386	0.386
β_y [m]	2.462	32.507	32.464
$(\beta_x\varepsilon_x)^{1/2}$ [μm]	387	78	78
$\eta_x\sigma_\varepsilon$ [μm]	0	60	59
σ_x [μm]	387	99	98
σ_x'[μrad]	41	240	241
σ_y [μm] (1% Coupling)	20	72	72
σ_y'[μrad]	8	7	7

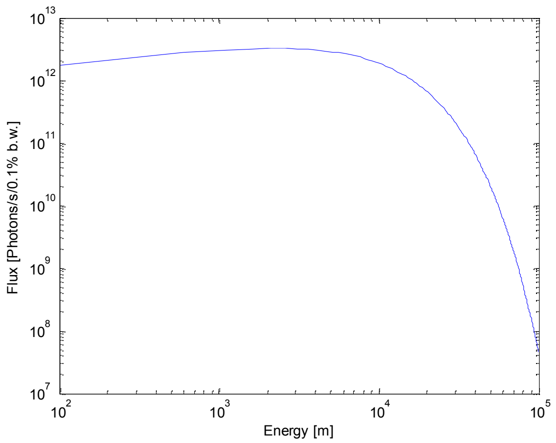

Figure 4. Synchrotron light spectrum from the ASP storage ring bend magnet.

Model Server

In order to facilitate a smooth transition from the design phase to the commissioning phase, a *model server* of the storage ring has been implemented [5]. The server, written in Matlab, uses the Accelerator Toolbox (AT) [6] to model the storage ring, while other modules were written to simulate the vacuum system and other hardware. Results of the calculations are sent to the ASP Development Control System via Channel Access over the network to an IOC running EPICS. In principle the simulator can be replaced by the real machine enabling a rapid deployment of the Control System during commissioning.

Frequency Maps

The technique of Frequency Map Analysis (FMA) has recently been used for dynamics optimisation in third generation synchrotron light sources such as SOLEIL, ESRF and ALS [7]. This technique has been implemented here at the ASP and has been used to identify the resonances that affect the global dynamics. The frequency map shown in Figure 5 was calculated at the nominal tune for the ideal lattice with zero chromaticities in both planes and zero dispersion in the straight sections.

The method involves tracking on-momentum particles launched at different horizontal and vertical amplitudes with zero angles using Matlab AT. These particles are tracked for 1000 turns before calculating the first set of tunes followed by a further 1000 turns for the second set using a modified Fourier technique [8]. A measure of the stability of the orbit is given by a diffusion index which is defined as the RMS difference of the tunes and is used to colour code the plots in Figure 5.

The frequency map in Figure 5 indicate that the dynamics is strongly affected by the 7th order resonance, $5\nu_x - 2\nu_y = 4 \times 14$ and consequently the working point may have to be moved. Further work will involve finding the best quadrupole and sextupole strengths to optimise the dynamics.

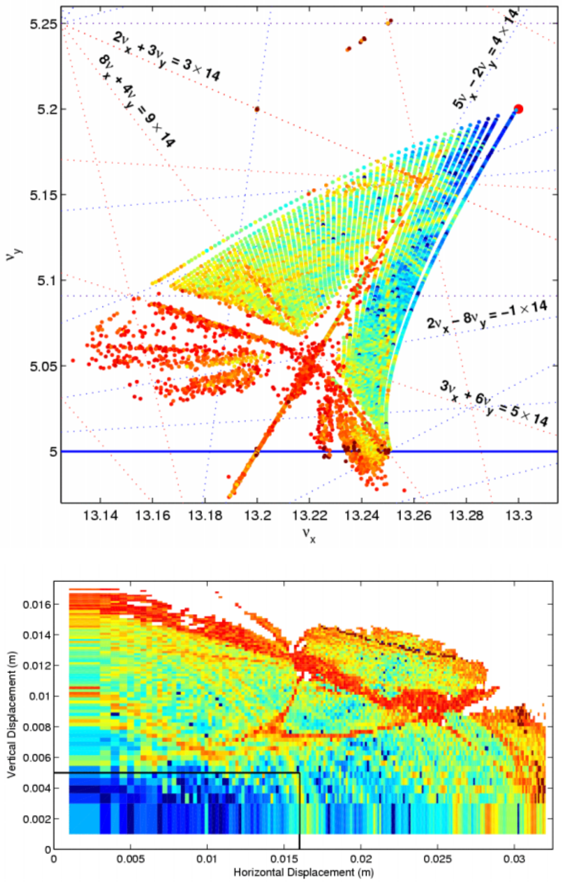

Figure 5. Frequency map (top) and dynamic aperture (bottom) are plotted where the log of the diffusion index has been colour coded such that blue denotes stable orbits and red, unstable orbits. The dotted lines (top) are the resonances plotted up to 12th order. The square box (bottom) shows the physical aperture as defined by the injection septum and ID vacuum chambers.

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