1.5 GeV LOW ENERGY MODE FOR THE AUSTRALIAN SYNCHROTRON

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Abstract

The Australian Synchrotron injection system and storage ring have been retuned to 1.5 GeV for use in special operations and machine development modes. The systems were designed for 3 GeV user operations but for certain research a lower energy of 1.5 GeV is advantageous. A description of how the new low energy mode was achieved is given, including extraction on the fly from the booster synchrotron and scaling of the storage ring lattice.

INTRODUCTION

The storage ring light source of the Australian Synchrotron provides a 3 GeV electron beam at 200 mA current for users of bending magnet and insertion device photon beamlines. The accelerator physics and operations group has identified that operation of the storage ring at a beam energy of 1.5 GeV could benefit several user groups.

The soft X–ray beamline [1] is an undulator beamline, providing photons over a wide energy range of 90-2500 eV. With the undulator closed to minimum gap, the fundamental photon energy is 90 eV. Australian user groups of soft X–ray techniques such as angle-resolved photoemission spectroscopy (ARPES) would benefit from access to photons at energy ranges of approximately 30 eV [2]. With a beam energy of 1.5 GeV, we could lower the photon energy of the first undulator harmonic to approximately 23 eV.

Synchrotron light sources are one of comparatively few useful sources of radiation in THz frequencies ($\lambda > 0.5$ mm) [3]. By configuring the storage ring lattice in a low–alpha mode, the equilibrium bunch length can be reduced to produce coherent synchrotron radiation (CSR) [4]. Initial studies demonstrate the useful production of CSR at beam energies of 3 GeV, but the bunch length can be further reduced by increasing the overvoltage factor. Without adding new accelerating RF cavities to the storage ring, the overvoltage can be increased by reducing the stored beam energy.

As an environmental and cost-saving initiative, various approaches to reduce the facility power demand have been investigated. This year we have reduced our storage ring gap voltage from 3 MV to 2 MV by operating with only three of our four RF cavities. Operating the storage ring at a reduced beam energy of 1.5 GeV significantly reduces the magnet electricity and RF power needed to store the beam.

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METHOD

Changing the Booster Ring Magnet Ramp Curves

The Australian Synchrotron injection system consists of a linac which accelerates an electron beam to 100 MeV, a booster ring which accelerates the beam from 100 MeV to 3 GeV and a storage ring where the beam is typically stored at 3 GeV. The booster ring accelerates the beam by increasing the strength of the bending and focussing magnets and the voltage to a RF cavity according to ramp curves illustrated in Figure 1.

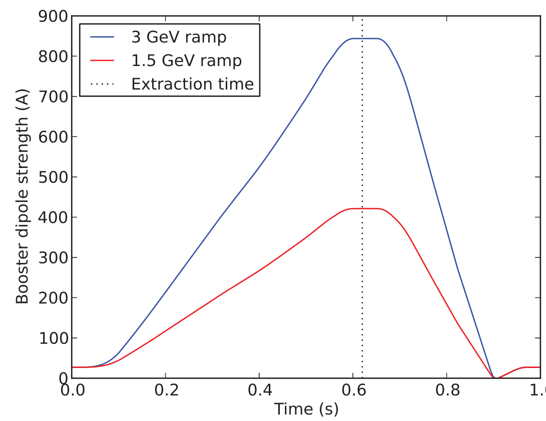

Figure 1: Booster bending magnet strength ramp curve. Extraction was attempted by reducing the height of the ramp curve.

We initially intended to extract the beam at 1.5 GeV by altering the booster ramp curves so that the dipole magnets increase to 50% of the current needed for 3 GeV (421.9 A instead of 843.8 A). However we have found that the betatron tunes in the booster ring are very sensitive to the ratios of magnet strengths [5], making it difficult to maintain beam stability. Generating new ramp curves for different extraction energies would be a significant challenge so a different approach was needed.

Extraction on the Fly

Rather than ramping the booster to a lower extraction energy we decided to leave the booster magnet ramps unchanged and adjust the time that the beam is extracted from the booster. The extraction is achieved by firing a series of pulsed magnets to divert the beam down a booster–to–storage ring transfer line (BTS). To trigger the magnets at the precise times required for a clean extraction, an Event Generator–Event Receiver system is used [6].

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An Event Generator (EVG) distributes events to Event Receiver cards (EVRs) which in turn output triggers based on these events. Such output triggers are used to fire the pulsed magnet power supplies. The input event from the EVG can be selected independently for each output channel, and a delay added before sending the trigger signal. Two EVG events have been designated "injection trigger" and "extraction trigger" and the time delay between these events can be adjusted. We placed all the pulsed magnets that need to be fired to extract the beam on the extraction trigger. By reducing the extraction delay we could shift the extraction of the beam from the booster to an earlier point in the ramp and hence extract a lower energy beam (Figure 2).

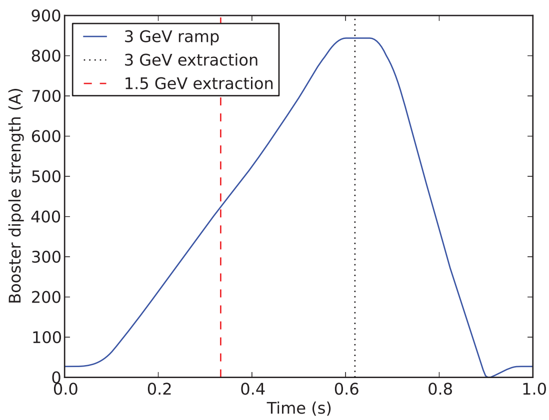

Figure 2: Extraction on the fly was achieved by changing the time of extraction from the booster.

We determined the extraction trigger delay that would extract the beam at 1.5 GeV by calculating where on the booster ramp the dipole magnets would be at half the strength of the 3 GeV extraction point. We then halved the strength of the pulsed extraction magnets and the magnets in the BTS.

It could be seen on a current transformer in the booster ring that the beam was being extracted at the correct time, but was not visible on fast current transformers or screens in the BTS. By tweaking BTS steering magnets we were able to observe the beam on a screen at the start of the BTS. The beam was centred on the screen and quadrupole magnets were used to focus it. We were then able to thread the beam down the BTS by tweaking the corrector and quadrupole magnets so the beam was visible on successive screens.

Capture in the Storage Ring

To capture the beam we needed to lower the storage ring magnet strengths. Due to saturation effects of some families of quadrupoles, linearly scaling all of the storage ring magnets does not work practically. To scale down the magnets we stored a 3 GeV beam in the storage ring and gradually lowered the magnet currents by 0.4% at a time. This allowed us to preserve the storage ring optics by correcting the betatron tunes at each step.

Once the storage ring dipole power supply was at 50% of the 3 GeV current, we halved the voltage to the four pulsed kicker magnets. These were triggered off the extraction trigger so the timing was already correct. We injected a 1.5 GeV beam through the BTS and observed turn–by–turn data from the storage ring beam position monitors (BPMs). By looking at the sum signal from the BPMs we could determine how many revolutions of the storage ring the injected beam would make before being lost. By tweaking the corrector magnets and quadrupoles at the end of the BTS we were able to increase the number of turns the beam would stay in the storage ring and eventually capture the injected beam. We could then inject to a high enough beam current to calibrate and optimise the lattice.

With 50 mA in the storage ring, an orbit response matrix was measured and analysed using the LOCO method [7]. The results of the analysis gave new quadrupole settings to correct the betatron functions.

Impact on Power Consumption

The power consumption of the injection system and storage ring was measured at the power nodes when the storage ring was at 3 GeV and 1.5 GeV. The power consumption to different subsystems is given in Table 1. It can be seen that the only significant reduction was for the storage ring magnet power supplies (MPS) where power was reduced by 69%. As the power supplies are a major component of the total power consumption of the injection system, this would have a significant impact on the economic and environmental cost of running the accelerators. At a lower beam energy the storage ring could also run with fewer RF cavities, which would further reduce the power consumption.

Table 1: Power Consumption by Accelerator Subsystem

Subsystem	**3 GeV (kW)**	**1.5 GeV (kW)**
Plant	226	224
Linac	32	32
Booster Ring	12	12
Storage Ring RF	834	824
Storage Ring MPS	1015	318
Total	2119	1410

CONCLUSION

A technique was developed for extracting the beam from the Australian Synchrotron booster ring at 1.5 GeV. As this was done by extracting the beam midway up the booster ramp, the booster magnet ramp tables did not need to be modified. This avoided the issue of beam instabilities due to the sensitivity of the betatron tunes to booster magnet ramps.

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