DIAGNOSTICS AND TIMING AT THE AUSTRALIAN SYNCHROTRON

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Abstract

The 3GeV Australian Synchrotron will begin operation in March 2007. This paper outlines the storage ring diagnostics systems and the injection timing system. The diagnostics system includes an optical beamline with streak camera, an X-ray beamline with pinhole array, a diagnostic straight with fast feedback kicker, stripline, direct current current transformer, and a four-fingered scraper. Over the 14 sectors there are 98 beam position monitors and 14 movable beam loss monitors. The timing system is based on a static injection system with the storage ring bucket to be filled targeted by delaying the firing of the electron gun.

INTRODUCTION

The ASP (Australian Synchrotron Project) [1] consists of a 3rd generation 3 GeV storage ring with 14 sectors and straights [2] fed by a full energy booster synchrotron [3] and 100 MeV LINAC [4].

The diagnostics systems of such a storage ring must allow for very accurate tuning and stabilisation of the beam. As such, a high degree of attention has been paid to the Beam Position Monitoring system and two diagnostic beamlines from which it is possible to derive much useful information.

The injection timing system should allow for top up mode in which a particular storage ring bucket can be targeted. It is intended that a bunch current measurement system will be used to take measurements of the bunch current profile and chose particular buckets to be ‘topped up’. The timing system must allow for this mode of operation.

STORAGE RING DIAGNOSTICS

Optical Diagnostic Beamline

The optical diagnostic beamline [5] utilises the synchrotron radiation from a dipole magnet. The radiation is passed through an optical chicane where the visible component of the radiation is allowed to pass through to a hutch containing an optical bench.

A streak camera is used to obtain images of the synchrotron light from individual bunches. The light may also be used to make measurements of the filled bucket profile in the storage ring,

X-ray Diagnostic Beamline

The X-ray diagnostic beamline [5] utilises the synchrotron radiation from a dipole magnet. The radiation is passed through a pinhole array and is converted to visible light using a YAG screen. A camera then views the image.

The pinhole array allows simultaneous measurements of beam divergence, size, and stability.

BPMs (Beam Position Monitors)

Each of the 14 sectors of the storage ring is fitted with 7 BPMs, totalling 98 BPMs. These are attached to I-Tech Libera Electron Beam Position Processors [6] that are capable of measuring first-turn, turn-by-turn, and average beam position data. The Libera units are controlled via EPICS (Experimental Physics and Industrial Control System) [7] and the data made available in the control room for use in Matlab using Middle Layer [8].

The BPMs have been used in the commissioning of the storage ring to monitor the sum signal strength to get first turn, and (by calculating the necessary offsets) the second and subsequent turns. The sum signal and transverse position are updated every second and it is possible to have a live plot of the sum signal as well as transverse positions. Figure 1 shows the first turn plot. Live plots of subsequent turns are also possible. This ability was useful in optimising the injection parameters to maximise the number of turns.

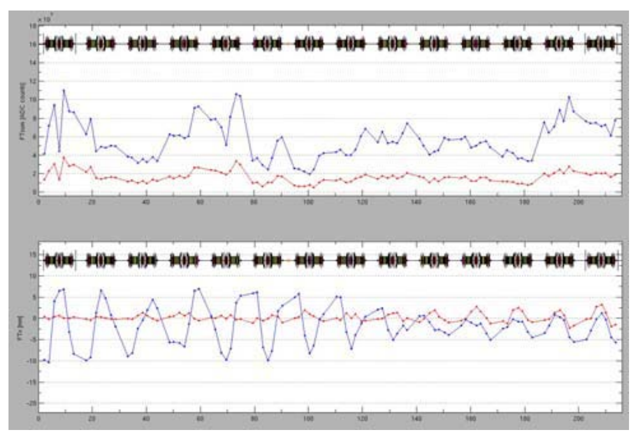

Figure 1: First turn without injection kickers. The horizontal axis is the s position of the BPM. Top: shows the sum signal, the variation in strength comes from cable attenuations. Bottom: first turn horizontal orbit.

By optimising the timing of the BPM trigger it is possible to capture the first 11 turns in total. By interpolating the data to make the distances uniform it is possible to estimate the tune using a simple FFT. This is shown in Figure 2.

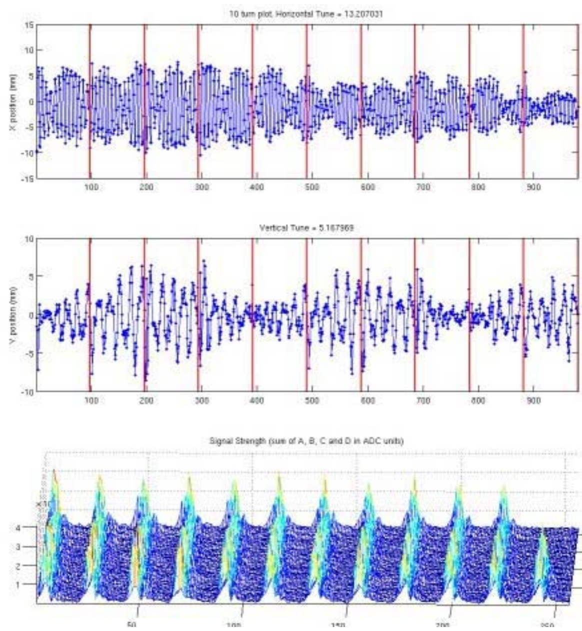

Figure 2: Multiple turns (>20) with injection kickers. The vertical lines in the plots above indicate a revolution. Top: Horizontal position (ν_x = 13.21). Middle: Vertical position (ν_y = 5.17). Bottom: sum signal where each line represents a turn.

Turn-by-turn data of up to 16000 turns as well as a 10 Hz data stream is also available but are as yet unused until RF becomes available. First turn data will continue to be used to optimise injection.

Diagnostic Oscilloscopes

The ASP uses 14 Bitscope diagnostic oscilloscopes with 4 channels each [9]. These oscilloscopes have a 40 MHz sample rate, but through random sampling, can achieve a 100 MHz bandwidth for repetitive harmonic signals.

These oscilloscopes are 'network' oscilloscopes and have no display of there own, instead they are viewable by any computer connected to the network.

In addition, a 4 GHz Tektronix Ethernet controllable oscilloscope is used where fast acquisition is required.

BLMs (Beam Loss Monitors)

The ASP is equipped with 14 BLMs, one for each sector of the storage ring. These BLMs are easily moveable around the storage ring. They might be evenly spread, or clustered in one area as required.

The BLMs used are Bergoz PIN-diode type [10]. These utilise two Siemens PIN diodes. When an ionising particle passes through both PIN diodes the BLM outputs a 50ns TTL pulse at a frequency up to 10 MHz. Since this signal is both too short and at too high a frequency to be directly input to an IOC, a secondary count acquisition system is utilised.

The BLM measurement system [11] (see figure 3) was developed by Cosylab in consultation with the ASP. The 14 pulse trains from the 14 BLMs spread around the storage ring are converted to 14 'count rates' available in our EPICS database. This is achieved using a single IOC (Input Output Controller) which communicates with the 14 counters via a daisy-chained twisted pair cable up to 200 m long. The IOC also powers the counters and BLMs via the same cable. The advantage of this system is that the counters are located close to the BLMs, thus reducing any interference with the count rate.

Figure 3: The BLM measurement system consists of an IOC and 14 counters each with 1 BLM.

Once the count rates are available to the EPICS database they can be displayed graphically (figure 4)

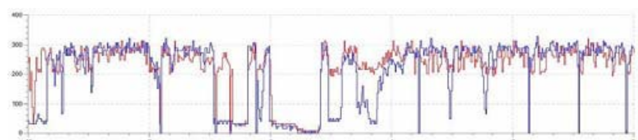

Figure 4: Count rates from 2 BLMs during storage ring commissioning activities.

Scraper

A scraper with 4 blades is included in the 'diagnostics straight' (figure 5). Each blade is water cooled along its length. This is especially important for the blade on the outer side of the vacuum chamber where it is liable to encounter a significant amount of synchrotron radiation.

The blades are designed flush with the chamber wall so as to avoid cavities which could create unwanted resonances.

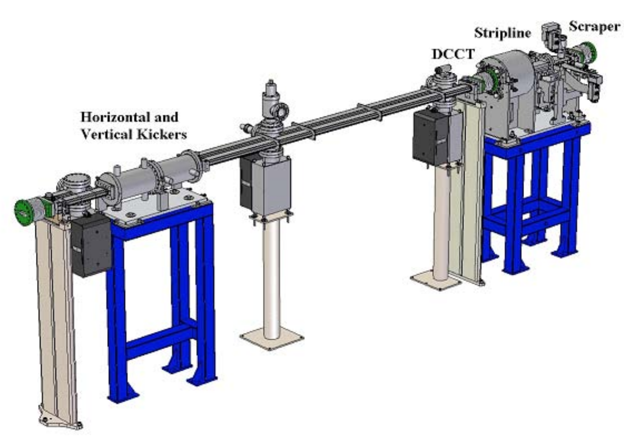

Figure 5: The diagnostic straight includes the kickers, DCCT, stripline and scraper.

DCCT (Direct Current Current Transformer)

A DCCT provided by Bergoz and mounted by FMB is included in the diagnostic straight (figure 5). The output is monitored by an analogue input channel on an IOC.

The beam current output from the DCCT is smoothed using a Kalman filtering algorithm called alpha-beta smoothing. Alpha-beta smoothing was chosen over a running average algorithm because alpha-beta smoothing does not require allocation of space for an array as a running average does. In addition, a running average will be vertically displaced from the real current if the beam current is increasing or decreasing, whereas this is not the case for alpha-beta smoothing.

Stripline and Kickers

A stripline and horizontal/vertical kickers are included in the diagnostic straight (figure 5). The stripline is used in conjunction with the kickers to make tune measurements using an Ethernet controllable spectrum analyser with a power amplifier.

In the future, the kickers will also be used with a power amplifier to make beam energy measurements using resonant de-polarisation. The kickers may also be utilised in a fast feedback system.

TIMING

Static Injection

The system used to target a specific storage ring bucket is referred to as 'static injection'. Instead of delaying extraction of the beam from the booster when there is a co-incidence with the correct storage ring bucket, the entire booster system is delayed. Only the initial trigger is varied, not the timings between events in the injection system, hence, a static injection system.

Timing Hardware

The timing system is based on a custom timing board from Micro-Research Finland [12] which derives an injection trigger timing signal from the Master Oscillator. This signal is pulsed once each second and is phased to both the mains and the booster-ring/storage-ring coincidence clock. The trigger is further delayed by an integer number of 2 ns RF buckets to target a particular bucket in the storage ring. This delay can be adjusted every second, ready for the next injection cycle.

The injection trigger is fed to a 'tree' of Stanford Instruments delay generators [13] which provide all of the triggers for injection and diagnostics. Although the jitter is low when the delay generators are used in parallel, it becomes larger when the delay generators are used in series. This deficiency will soon be rectified by updating the system with an event receiver and fibre-optic transmission for the electron gun.

REFERENCES

[1] D. Morris (ASP), "When Less is More – Construction of the Australian Synchrotron", these proceedings.

[2] J. W. Boldeman, D. Einfeld, 2004 Nucl. Instr. And Meth. A **521**, 306.

[3] S. Friis-Nielsen et al, "Commissioning Results from the Injection System for the Australian Synchrotron Project", these proceedings.

[4] C. Piel, K. et al. "Commissioning of the Australian Synchrotron Injector RF Systems", these proceedings.

[5] M. J. Boland et al, "X-ray and Optical Diagnostic Beamlines at the Australian Synchrotron Storage Ring", these proceedings.

[6] http://www.i-tech.si/products-libera.html

[7] R. Bartolini et al, "Turn-by-turn Data Acquisition and Post-processing for the Diamond Booster and Storage Ring", these proceedings.

[8] J. Corbett et al, "Accelerator Control Middle Layer", PAC, 2003.

[9] http://www.bergoz.com/products/BLM/BLM.html

[10] http://www.microioc.com/blm.htm

[11] http://www.bitscope.com/product/BS442/

[12] http://www.mrf.fi/

[13] http://www.thinksrs.com/products/DG535.htm