MEASUREMENTS USING THE X-RAY AND OPTICAL DIAGNOSTIC BEAMLINES AT THE AUSTRALIAN SYNCHROTRON

M. J. Boland, J. Bergstrom, G. S. LeBlanc, Y.-R. E. Tan, R. Dowd and M. J. Spencer, Australian Synchrotron, Clayton, Victoria 3168, Australia.

D. J. Peake and R. P. Rassool, The University of Melbourne, Victoria 3010, Australia

Abstract

First Light has been achieved on the diagnostic beamlines at the Australian Synchrotron 3 GeV storage ring. The X-ray Diagnostic Beamline (XDB) has been used to measure the beam size, divergence and emittance, while the Optical Diagnostic Beamline (ODB) has been used the measure the bunch length and turn-by-turn stability. Both beamlines receive dipole radiation from a bend magnet and provide continuous diagnostic data to the control room. The beamlines compliment each other with the ODB providing mainly longitudinal (temporal) information, while the XDB measures predominantly transverse (spatial) information. A brief description is given of the equipment on each beamline and the commissioning results are presented.

X-RAY DIAGNOSTIC BEAMLINE

The x-ray diagnostic beamline provides mostly transverse beam information and is described in more detail in Ref [1]. Measurements made during the commissioning of the storage ring are presented here.

Image Array

A pinhole array generates 9 images of the bend magnet source point which is displayed in the control room via EPICS (see Fig. 1). The spots provide a qualitative as well as quantitative diagnostic of the status of the stored beam.

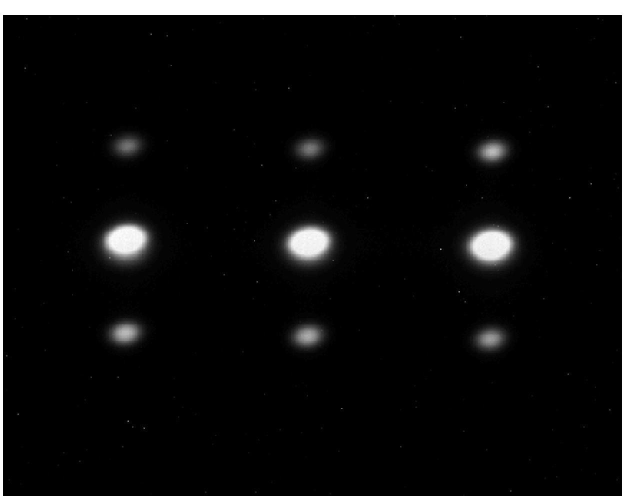

Figure 1: Array of beam spot images created by the x-ray pinhole array. The data is captured with a CCD camera viewing a YAG screen on the x-ray diagnostic beamline.

Beam Size and Emittance

The beam spot is measured from the YAG screen image and fitted with a Gaussian curve to obtain the horizontal and vertical beam sizes. The emittance was determined using the measured beam size and the beta-functions from the calibrated model that was fit using LOCO [2]. Fig. 2 shows the results of a measurement after the first correction to optics to remove beta-beating. The emittance of 17.5 nm is close to the design value of 15.8 nm for a lattice with zero dispersion in the straight sections.

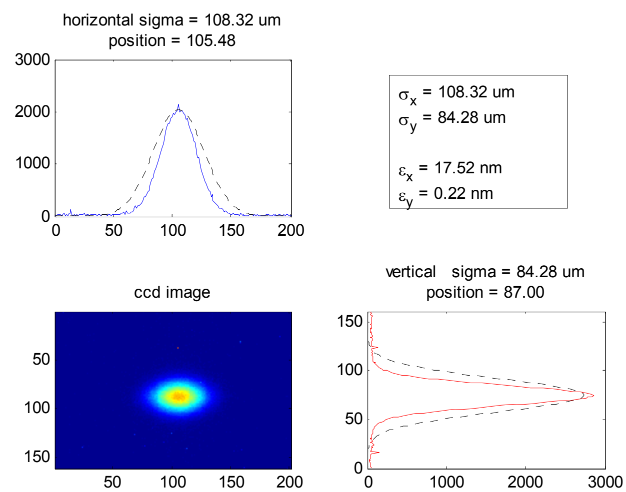

Figure 2: Emittance measurement from a single spot on the x-ray diagnostic beamline and beta-functions from a calibrated model.

Beam Stability

Using an EPICS driver to process the camera data from the Firewire CCD camera the x-ray beam centroid is monitored to track the beam stability. In order to get a good quality image the CCD integration time needs to be 50 ms or greater. With the CCD triggered at 1 Hz and a 50 ms integration time the beam stability is measured to be 2 μm rms.

Divergence

The multiple images from the pinhole array allows for divergence of the beam to be measured by fitting a Gaussian to the intensity distribution of the vertical beam spots. Fig. 3 shows the vertical profile and the Gaussian fit to the intensity distribution of the beam spot peaks.

The measurement is close to the $1/\gamma$ opening angle of 0.17 mrad.

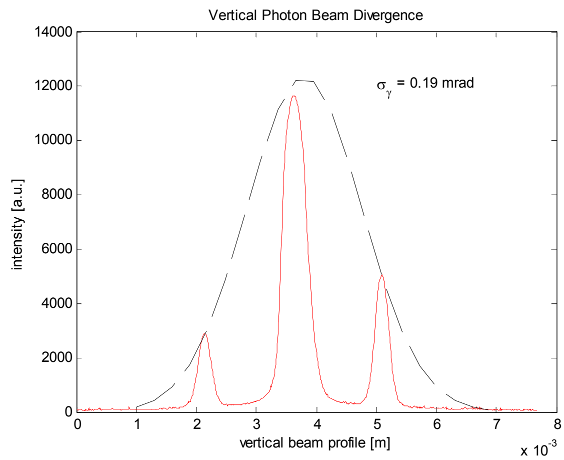

Figure 3: Vertical beam divergence measured by the x-ray pinhole array.

OPTICAL DIAGNOSTIC BEAMLINE

The optical diagnostic beamline provides mostly longitudinal beam information and is described in more detail in Ref. [1]. Results of the commissioning some of the optical instruments is presented here.

Dual Sweep Streak Camera

During the storage ring RF commissioning, the dual sweep streak camera was used to monitor the amplitude of the synchrotron oscillations while detuning the cavities. Fig. 4 shows the fast sweep on the vertical axis and the secondary sweep on the horizontal axis and the large amplitude synchrotron oscillation prior to detuning. After detuning the cavities there was no measurable amplitude modulation on the streak camera images.

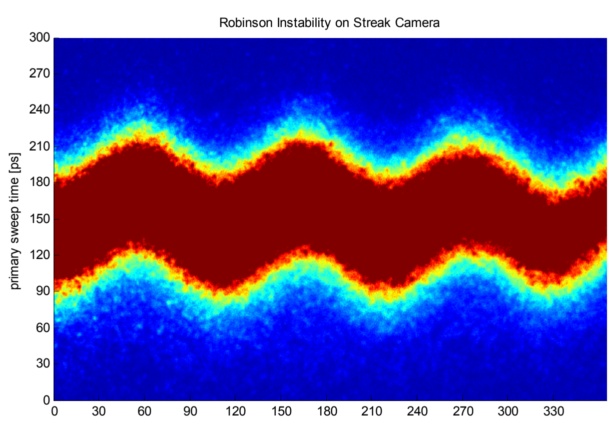

Figure 4: Dual Sweep Streak Camera image of a 9.19 kHz Robinson Instability during tuning of the storage ring RF cavities.

Beam Stability

A Position Sensitive Detector has been installed to measure the beam motion using visible light. A Hamamatsu S1300 2D photodiode connected to a C4757 controller board produces output voltages proportional to the horizontal and vertical beam position. The diode is biased by a PS2127 power supply from Oxford Electrical Products and has a stability of 1 mV RMS. The absolute position readout has not been calibrated since the beam is arbitrarily focused to as small a spot size as possible, but the frequency of the signal can be used to analyse the beam motion.

The voltage from the controller board it digitised using a Nation Instruments USB-6251 digitiser and LabView to EPICS software. Two different operational modes are used: slow and fast acquisition mode. In slow mode the systems outputs an average beam position at 1 Hz using a configurable number of samples and sample rate. This mode is used to monitor the long term stability of the beam. Using fast mode the system can output 1.4 MS/s with 16 bit resolution for up to 1.4 s to do more detailed analysis of transient beam motion.

Fig. 5 shows the beam motion during the RF commissioning when there was a large synchrotron oscillation due to the Robinson instability. The three plots of horizontal beam motion show some of the different ranges of data sampling that is possible with the system.

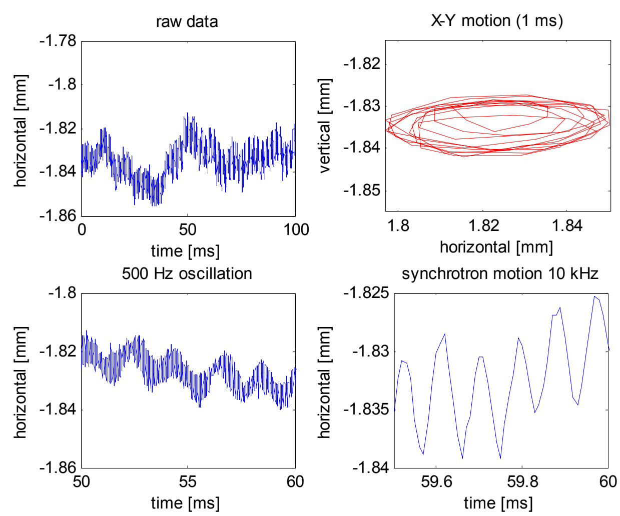

Figure 5: Beam stability measurements during RF cavity commissioning with a 2D position sensitive detector. At the maximum digitisation rate the synchrotron tune can be observed at approximately 10 kHz.

Bunch Length

During commissioning of the RF cavities, with only three of the four in operation, the storage ring was tested in single bunch mode. Using the streak camera the bunch length was measured while increasing the current in a single RF bucket. When the measurement was taken the cavities were still being conditioned and could not operate at full voltage. The theoretical bunch length at the design voltage is 22 ps, but with the commissioning settings a minimum bunch length of only 40 ps could be achieved.

Fig. 6 shows the bunch lengthening with increasing single bunch current as expected. The total current in one bunch was limited to 5 mA in this measurement as a precaution, but currents of up to 25 mA should be achievable in the future. More detailed studies will be conducted to determine the impedance of the vacuum chamber from the single bunch length, once the RF is fully operational.

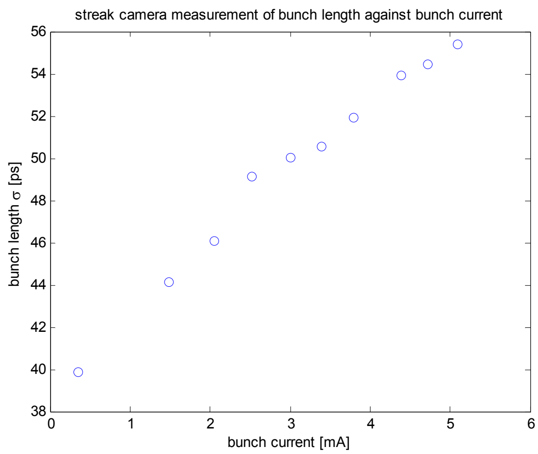

Figure 6: Bunch length measured by a streak camera for a range of single bunch currents.

Fill Pattern Monitor (FPM)

The electron bunch fill pattern in the storage ring is measured using an optical photodiode. The diode output is digitised and made available in EPICS. Fig. 7 shows a comparison between the FPM and a conventional measurement of the fill pattern using the signal from a stripline pickup on an oscilloscope. The measurements are in good agreement and the FPM is now in routine operation for controlling the filling of the storage ring.

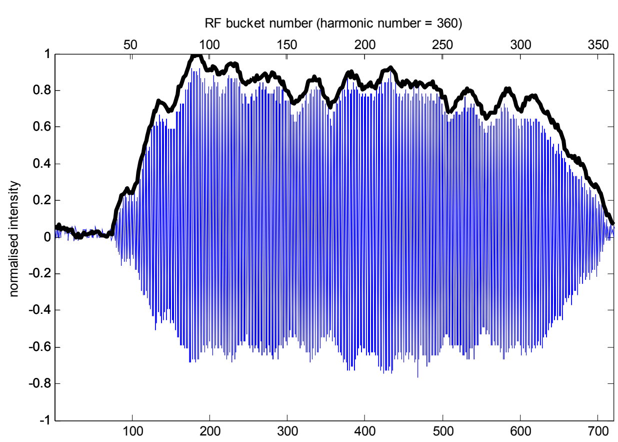

Figure 7: Comparison of the fill pattern measured on the optical monitor (thick black) and the stripline response on an oscilloscope (blue).

The system was sensitive down to less than 0.05 mA total current in the storage ring. Tests were also done with single bunch injection and the fill pattern was able to be flattened out and squared off. The fill pattern measurement was stable to less than 1 % of the maximum bunch current in an even fill, thus providing a reliable signal for injection efficiency and feedback systems. A system is under development using the FPM to provide automatic arbitrary pattern filling and can be used in a feedback loop for top up mode in the future.

SUMMARY

The diagnostic beamlines have been successfully commissioned and most of the instrumentation is now in routine operation. The x-ray diagnostic beamline has been providing stable and useful information from the first moment of stored beam in the storage ring. The optical diagnostic beamline has a powerful set of tools that have been used to tune the machine during commissioning and will be vital in the fine tuning required as we move into user operations in March 2007.

REFERENCES

[1] M. J. Boland et. al., EPAC 2006, Edinburgh, UK.
[2] J. Safranek et. al., EPAC 2002, Paris, France.