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AUSTRALIAN SYNCHROTRON BPM ELECTRONICS UPGRADE

Y.-R. E. Tan*, R. Hogan, Australian Synchrotron - ANSTO, Clayton, Australia

Abstract

The storage ring at the Australian Synchrotron (AS) had been originally equipped with 98 Libera Electrons. In late 2017 the all 98 of the BPM electronics has been upgraded to Libera Brilliance+. This report will outline plans that were put in place for the transition and the results from commissioning the new system.

INTRODUCTION

The Australian Synchrotron (AS) is a 3rd generation light source that was commissioned in 2006. The storage ring is a Chassman-Green lattice with 14 sectors each equipped with 7 Beam Position Monitors (BPMs) connected to Instrumentation Technology's Libera Electrons (98 Electrons) [1–3]. The booster ring is a FODO lattice with 4 sectors each equipped with 8 BPMs connected to Bergoz MX processors that is then digitized by NI DAQ cards [4]. Since an upgrade to the booster BPM system in 2010 increasing hardware problems has resulted in a continuous decline in the number of usable BPMs. Simultaneously, between 2013 and 2016 the Libera Electrons in the storage ring began to display an increasing number of hardware problems. In 2016 the decision was made to replace the storage ring Libera Electrons with Brilliance+ electronics [5] and to re-purpose the Libera Electrons in the booster ring.

Additional improvements to the system has also been the integration of the Brilliance+ directly into the Micro-Research Timing Event system with the EVR module and the option to increase the fast acquisition (FA) data rate from 10 kHz to 30 kHz. The increase in the FA data rate was added to push the performance of our Fast Orbit Feedback System (FOFB) [6] by reducing the group delay of the FA data.

PERFORMANCE MEASUREMENTS

To get the Libera Brilliance+ units ready for installation and to confirm that the performance met the requirements a initial configuration script and acceptance testing script were used. The configuration script configured the Linux subsystem to use some of the standards at the AS. The acceptance test script confirmed that the basic functionality was working such as locking to the machine clock and the unit was correctly reading the event data stream. The script would sweep the input power to each of the BPM cards in the Brilliance+ unit from −2 dB to −63 dB (Instrumentation Technology RF clock generator and power splitter) and log the position data at Turn-by-Turn (TbT; 1.389 MHz) and FA data rates (10 kHz) at different power levels. The average and spread of $\sigma_{x,y}$ across 110 cards is shown in Fig. 1.

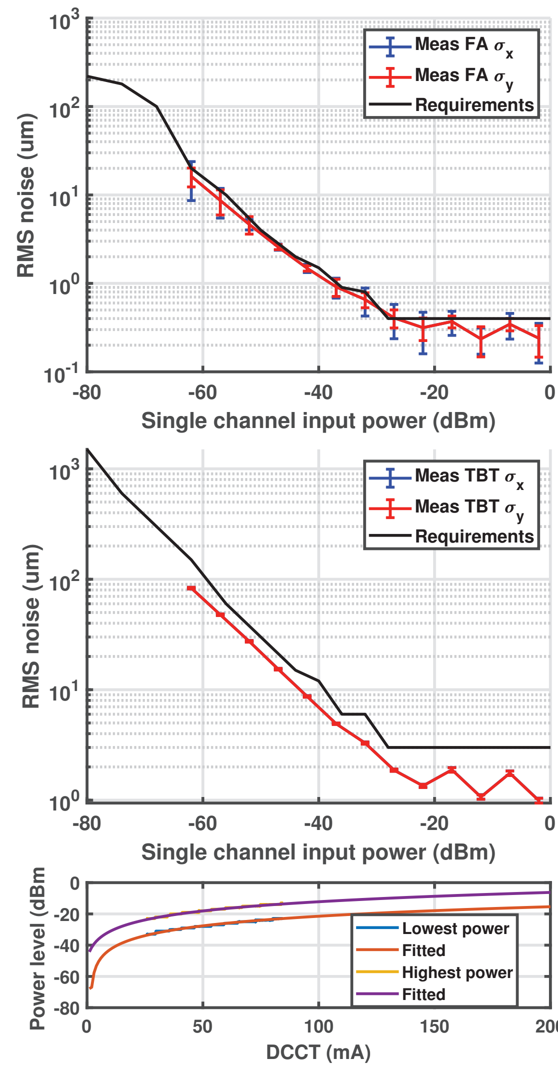

Figure 1: The average and spread of $\sigma_{x,y}$ across 110 BPM modules measured at TbT (1.389 MHz) and FA (10 kHz) data rates. The spread of the FA data rate is higher than expected where there was not enough time allowed for the digital signal conditioning learning cycle to complete before taking measurements. The corresponding input power graphs shows that below 30 mA the position resolution starts to increase.

The beam current/input power dependence was measured at the FA data rate and shown to be less than 1 µm from −60 dBm to −5 dBm which covers the range from 5 mA up to 200 mA in the storage ring.

The temperature dependence was measured by restricting the air flow to the crate, causing a 10 degree change in temperature. Using the internal airflow temperature sensors the temperature dependence was found to be an average of 0.8 µm/°C (switching enabled) and 0.4 µm/°C (switching

* eugene.tan@ansto.gov.au

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disabled) on one of the crates tested. This was higher than the stated performance but was still within our requirements.

MACHINE MEASUREMENTS

Transverse Coupling and RF Cable Attenuation

One of the known issues with the Libera Electrons was a insufficient isolation between the four RF channels that resulted in an effective transverse coupling of ∼ 2 % [3]. The new Brillinace+ has a significantly improved channel to channel isolation and the transverse coupling has been practically removed as shown in Fig. 2. The remaining variation in the coupling has been confirmed to come from the small differences in the attenuation (∼ 0.5 dB) of the RF cables [3].

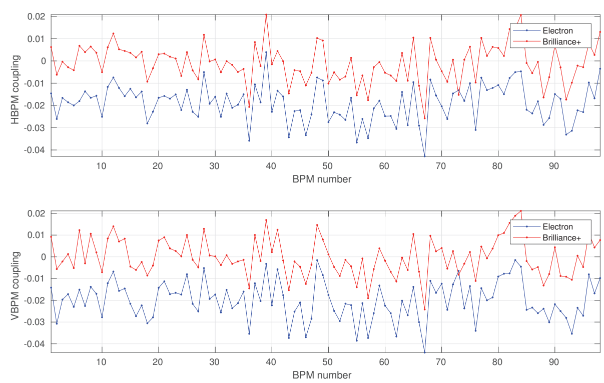

Figure 2: Improvement in the systematic transverse coupling on all BPMs. With the Electron the measured transverse coupling was 2% between planes and this has been reduced to < 0.2% in the Brilliance+. The variation across BPMs is a result of differences in the attenuation of the four RF cables (∼ 0.5 dB). BPM coupling calculated with Linear Optics from Closed Orbit method (LOCO).

In the transition a patch panel was installed and all connections were re-measured, see Fig. 3. A few years ago the cables were re-terminated to phase match the 4 BPM cable to less than 10 degrees at 500 MHz in an attempt to improve the beam current dependence, however the results have been inconclusive. A consequence of the phase matching has been an increase in the attenuation between the four RF cables. is The largest impact may be the effective coupling created due to the differences in the cable attenuation. One proposed method to minimise this effect is to include a calibration factor for each of the four RF inputs.

FA Data Noise Floor

Figure 4 compares the beam motion spectrum measured just before and after the installation of the Brilliance+. The figure shows an improvement in the noise floor of the FA data from 9 (H) and 13 (V) nm/$\sqrt{\text{Hz}}$ to 6 (H) and 7 (V) nm/$\sqrt{\text{Hz}}$ at 1 kHz.

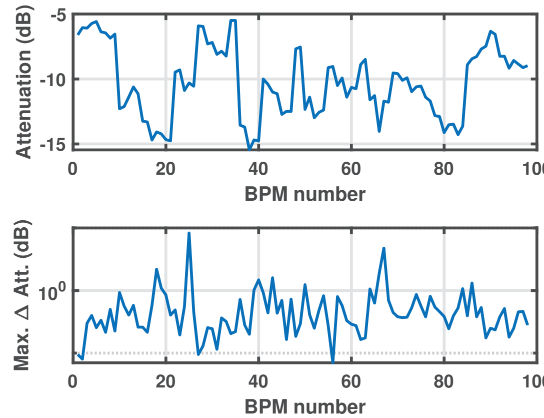

Figure 3: RF cable attenuation and input power for the BPM modules. Attenuation differences greater than 2 dB were the result of faulty connectors that have since been fixed.

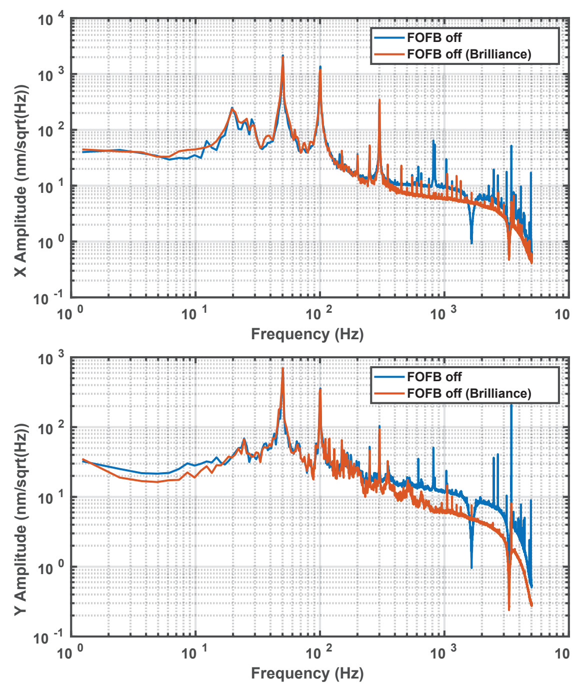

Figure 4: Comparison of the beam spectrum of the electron beam before and after the installation of the Brilliance+. The improvement in the noise floor is notable in the FA data ($K_x = K_y = 15 \times 10^6$).

30 kHz FA Data

One of the improvements that was commissioned was an attempt to improve the performance of the FOFB system by reducing the latency of the FA data. Aside from the limitations of the vacuum chamber, the BPM processing latency was the second largest contributor to the overall latency of the feedback system. The FA data stream comprised of a CIC (decimation factor of 3) + Polyphase FIR filter to reduce the data rate from 1.388 MHz to 10 kHz. Instrumentation Technology was able to reduce the group delay to < 150 µs by removing the initial CIC decimation

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filter. The simulated step response of the initial design of $\tau_s^{10\text{kHz}} = 227\,\mu\text{s}$ and a bandwidth of 2 kHz was reduced to $\tau_s^{30\text{kHz}} = 55\,\mu\text{s}$ and a bandwidth of 5 kHz. The initial test of the increased data rate FA data measured a decrease of the step response from $\tau_{\text{meas}}^{10\text{kHz}} = 200\,\mu\text{s}$ and a bandwidth of 2.0 kHz, to $\tau_{\text{meas}}^{30\text{kHz}} = 40\,\mu\text{s}$ and a bandwidth of 5.8 kHz. The measurement results are shown in Figs. 5 and 6.

The increased FA data rate is not currently used as the effects of switching noise and the optimisation of the notch filter has yet to be evaluated.

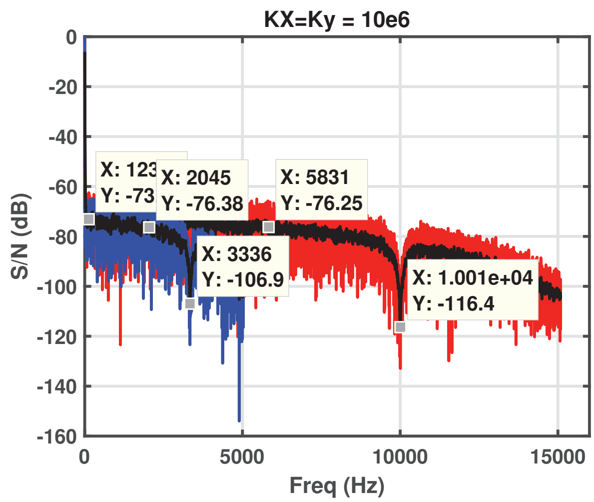

Figure 5: The integrated FA data noise increases from $\sigma_x^{10\text{kHz}} = 203$ nm to $\sigma_x^{30\text{kHz}} = 346$ nm from the wider bandwidth of 5.8 kHz.

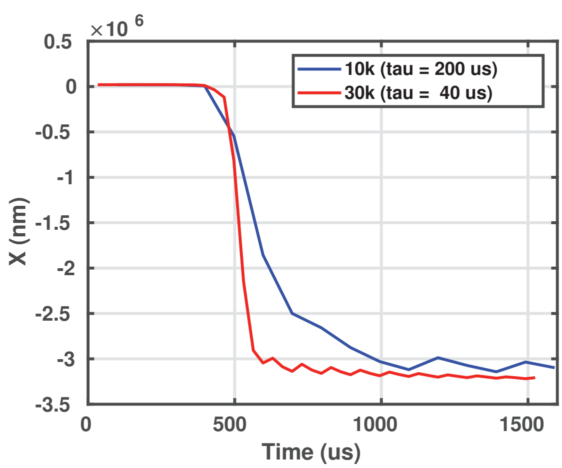

Figure 6: The improvement in the response time however can improve the performance of the FOFB system and has been shown to have reduced from $\tau = 200\,\mu\text{s}$ at 10 kHz to $\tau = 40\,\mu\text{s}$ at 30 kHz. Simulations predicted a reduction from $\tau = 230\,\mu\text{s}$ to $\tau = 55\,\mu\text{s}$.

CONCLUSION

Aside from some firmware bugs the installation and commissioning of the Brilliance+ system was smooth. The new system has removed the systematic coupling of 2% of the Electron and reduced the beam current dependence from $\sim 10\,\mu\text{m}$ to $1\,\mu\text{m}$. Initial measurements of the 30 kHz FA data has confirmed the predicted improvement in the response time. Further work is still needed to quantify the effect of the wider bandwith before it is used in the FOFB system.

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