COMPARISON OF RF BPM RECEIVERS FOR NSLS-II PROJECT*

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Abstract

The NSLS-II Light Source being built at Brookhaven National Laboratory requires submicron stability of the electron orbit in the storage ring in order to utilize fully the very small emittances and electron beam sizes. This sets high stability requirements for beam position monitors (BPMs) and a program has been initiated for the purpose of characterizing RF BPM receivers in use at other light sources. Present state-of-the-art performance will be contrasted with more recently available technologies.

INTRODUCTION

The comparative tests of different BPM receivers were performed at APS. The Libera Brilliance receiver was connected to the S36A:P0 BPM station in the diagnostics straight. An in-house built APS FPGA-based BPM receiver was connected to the S35B:P0 BPM station. Both stations use 4-mm diameter pick-up electrodes mounted on an 8-mm high vacuum chamber of diagnostics undulator. Horizontal separation of the buttons is 9.6 mm center-to-center. Separation between 35B:P0 and 36A:P0 is about 4 meters. Bergoz electronics was used for S35B:P1 and S36A:P1 equipped with 10-mm buttons mounted on the approximately 4x8 cm elliptical vacuum chamber.

OBSERVING NOISE SPECTRUM OF CIRCULATING BEAM

During studies the Libera Brilliance signal level was manually set and direct measurement (no switching) was selected. The APS FPGA based BPM receivers were in routine configuration. 262144 data points at a revolution frequency of 271.6 kHz were collected for both devices and the observed horizontal beam motion spectra are shown in Fig. 1.

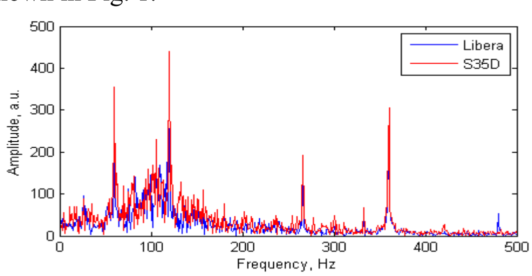

Figure 1: Overlaid spectra of beam motion in the horizontal plane. The data are from both Libera Brilliance and FPGA based receiver.

An APS FPGA-based BPM receiver had incorrect calibration. To get proper position readback its readings were multiplied by 1.36. Excellent agreement of two sets of data was found. The finest details are in perfect fit (see Fig. 2-4).

As it can be seen from the Figures 3 and 4 Libera Brilliance has less noise than the APS FPGA-based receiver.

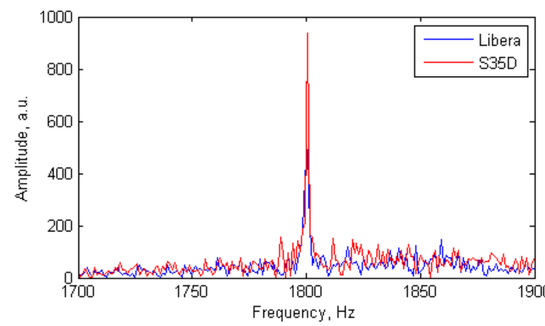

Figure 2: Synchrotron motion line observed by two BPM receivers (Libera Brilliance and FPGA based receiver).

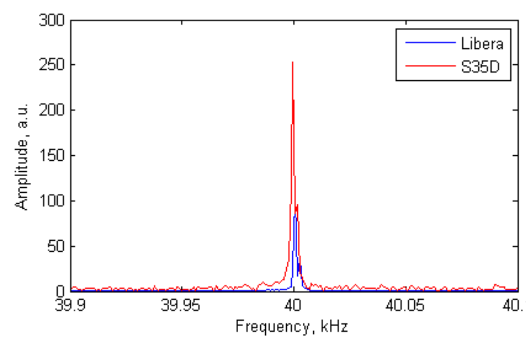

Figure 3: Quadrupole power supplies noise line observed by two BPM receivers (Libera Brilliance and FPGA based receiver).

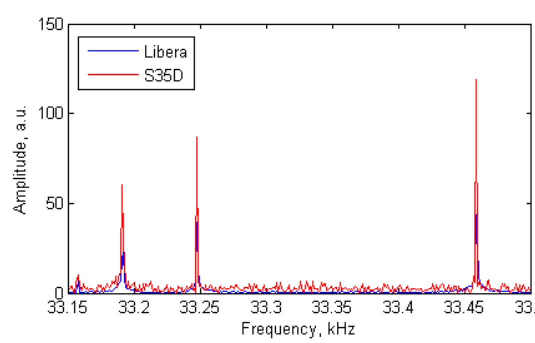

Figure 4: Details of horizontal beam motion in 30 kHz region observed by two BPM receivers (Libera Brilliance and FPGA based).

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INJECTION TRANSIENT STUDIES

The injection trigger signal was split and used to start simultaneous data acquisition for both the APS FPGA-based BPM receiver and Libera Brilliance. Final fine alignment on the time axis was done during post processing. The relative delay was the same for both planes. The beam transients are shown in Fig. 5 and Fig. 7, and the spectra of transient motion in Fig. 6 and Fig. 8, respectively.

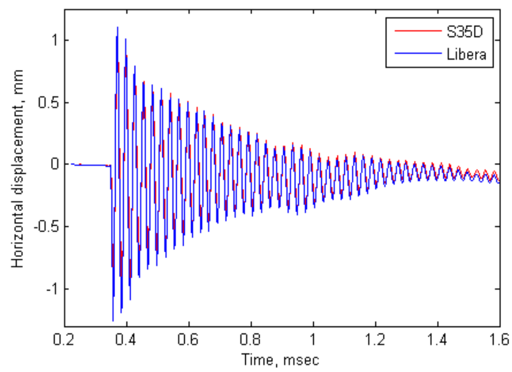

Figure 5: Horizontal transient caused by the injection kickers. There is a remarkable agreement in the two curves except only small offset are observed towards the end of the transient.

The vertical transient has good agreement but not as good as for the horizontal plane.

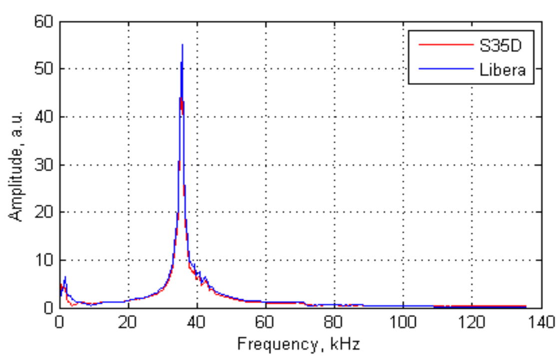

Figure 6: Spectra of horizontal beam motion excited by the injection transient. The strong line at 35.6 kHz corresponds to the horizontal betatron frequency and synchrotron oscillations manifest themselves as a small peak at low frequency.

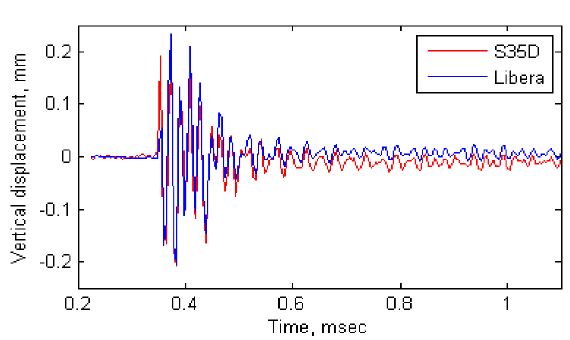

Figure 7: Vertical transient caused by injection kickers.

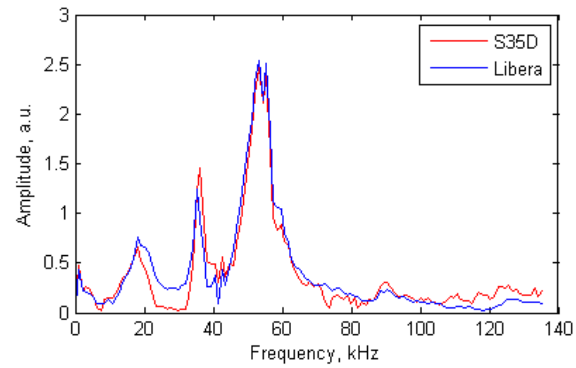

Figure 8: Spectra of the vertical oscillations caused by the injection transient. 54 kHz line corresponds to the vertical betatron oscillations.

FILL PATTERN DEPENDENCE

Fill pattern dependence was considered as a perceptible intensity dependence seen when a gap in the 324 bunch fill pattern is present while maintaining constant total circulating charge. A single button was attached to a four-way splitter at the input to the Libera Brilliance module. Intensity dependence was simulated by large horizontal steering. For the uniform fill of 90 mA beam in 324 bunches Fig. 9 demonstrates time dependence of beam position readback in the both planes as well as beam intensity as seen by Libera. Effects are more profound at the lowest signal strength.

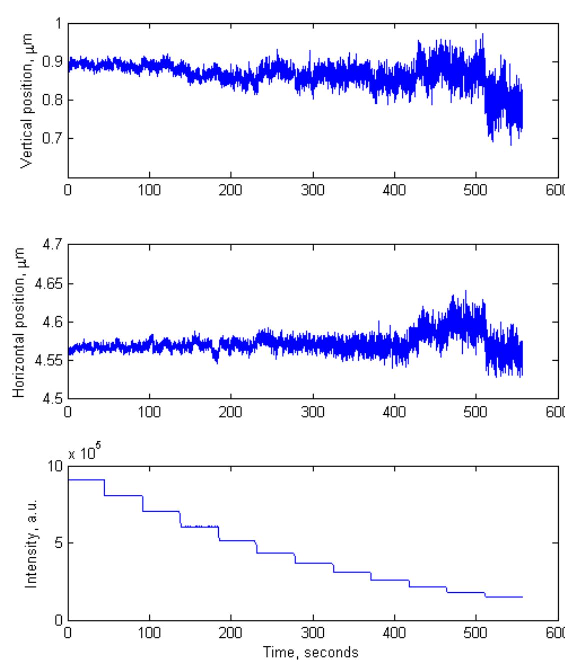

Figure 9: Time dependence of Y, X and Sum signals while the uniform beam is being steered in the horizontal plane.

The beam was refilled to 102 mA and then with a mismatched kicker (IK2 had 9 kV instead of normal 6 kV) part of the beam was blown away. 270 bunches had full charge and 10-15 bunches on each side had reduced charge. Again dependences of beam position and measurement noise on signal intensity were found. The process of refill and cleaning followed by measurements was repeated to obtain a fill pattern with 75 mA and a larger hole.

For the more direct study of the dependence of position and noise on signal intensity all readbacks associated with certain level were averaged and the standard deviation was found. The peak-to-peak position variations did not exceed 80 nm for both planes (see Fig. 10) and the noise levels are shown in Fig. 11.

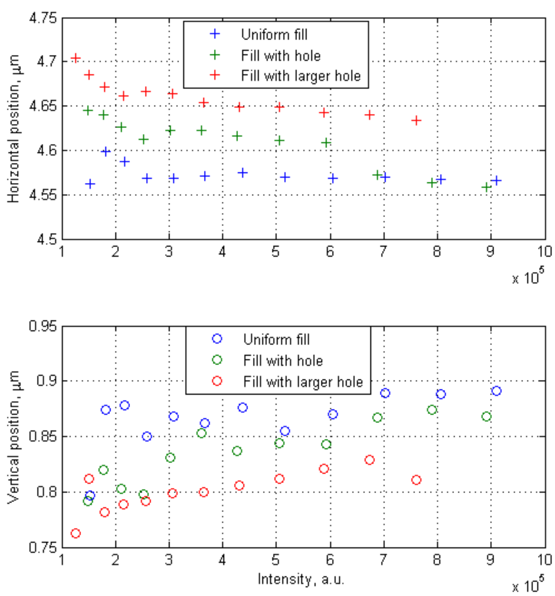

Figure 10: Beam position measured by Libera Brilliance vs. intensity for different fills.

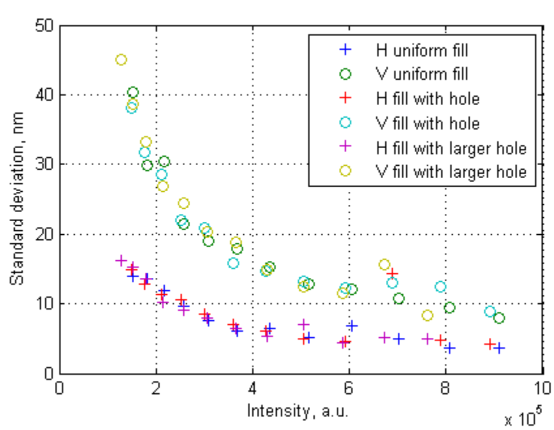

Figure 11: Libera Brilliance beam position measurement noise dependence on intensity for different fills.

With high level signal for all three patterns the noise was around 5 nm in the horizontal plane and 10 nm in the vertical plane (due to the difference in the programmed sensitivities). Reduction of the signal level increased noise in both planes by a factor 3. In the medium range change of the beam position readback with fill pattern was about 80 nm for both planes.

For the Bergoz BPM receivers in similar conditions drift was 50 nm in the horizontal plane and 170 nm in the vertical plane. For the APS FPGA-based receivers drift was 240 nm in the horizontal plane and 680 nm in the vertical plane. So, the Bergoz and Libera Brilliance had comparable performance, while the APS FPGA-based module was a factor of 3 worse.

Table 1 shows results from data logged for 24 hours while top-up was running with the 24-bunch (154 ns spacing) fill pattern. A single button was connected to a 4-way splitter and then into the Bergoz inputs, and a second button was sent into a second splitter and routed to the Libera Brilliance. For both receivers the simulated electron beam was on center (i.e. after splitter signals were directly connected to inputs). The Libera data rate is 9.82 Hz with 2 Hz low-pass filtering. The Bergoz is one sample per minute, with a 20-second time constant filtering. In general the variation in the vertical plain is larger due to the calibration factor difference for the unrotated button geometry (for Libera K_x/K_y=0.407).

The performance was also verified for beam with a simulated "offset" by the installation of a 4 dB attenuator into one of the four inputs for both receivers.

Table 1. Summarized data for BPM receivers drifts during 24 hours of top-up operation.

	Bergoz		Libera Brilliance	
	X, nm	Y, nm	X, nm	Y, nm
Rms motion for centered beam	54.0	90.6	7.6 (4.1)	27.1 (22.1)
Rms motion for beam with simulated offset	44.0	49.5	12.8 (6.1)	36.6 (25.2)

The drift performance of the Bergoz unit is somewhat better than the first data set; perhaps the rack temperature was more stable. The Libera Brilliance rms values seem to have increased by about 70% for the horizontal plane, and 33% for the vertical plane and now their ratio is more in line with the ratio of calibration factors. The summarized data are shown in Table 1. As it was mentioned before the signal bandwidth was different for the two units. To make comparison more direct the position signals from the Libera Brilliance were averaged using a 20 sec Hanning window: the corresponding noise is shown in parentheses.

CONCLUSION

There is excellent agreement between observations of beam motion with a Libera Brilliance and APS FPGA-based receiver, with the Libera Brilliance unit having less noise in the high-frequency part of spectrum. For fill pattern dependence Libera Brilliance outperformed both the APS FPGA-based unit and the Bergoz BPM receiver.