Experience With Libera Brilliance and Libera Bunch by Bunch at the Canadian Light Source

Control and Instrumentation Department
Canadian Light Source Inc.

Outline

- Test results of Libera Brilliance
- Experimental study with Libera Brilliance
- Single bunch experiment using Libera Bunch by Bunch
- Conclusions

Test of Libera Brilliance [1,2]

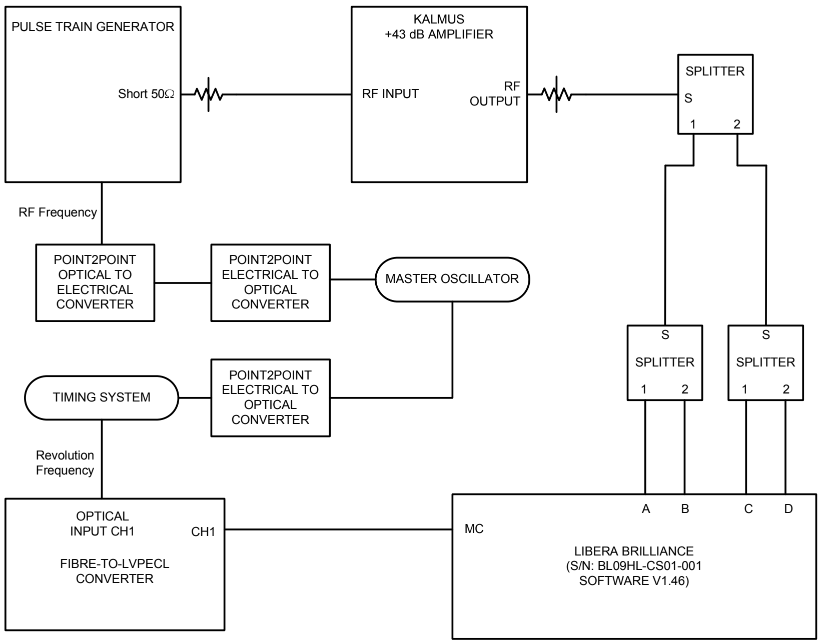
- CLS accelerator data

	Storage Ring	Booster Ring
RF frequency	500 MHz	500 MHz
Harmonic number	285	171
Revolution frequency	1.7544 MHz	2.924 MHz

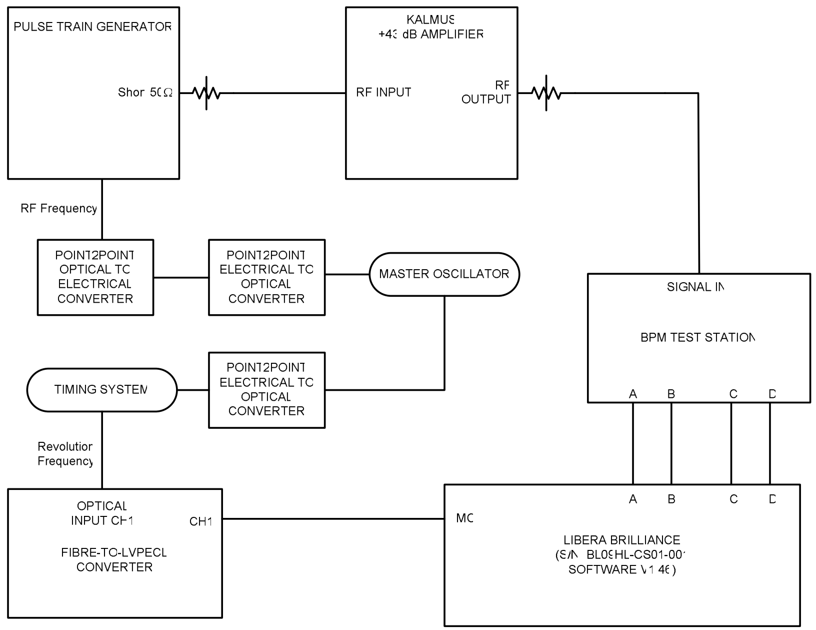
- Libera Brilliance test with the simulated beam
- Libera Brilliance test with a BPM test station

Test setup

- Simulated beam test



- BPM test station test



Test with the simulated beam

- RF frequency variance test with the simulated beam
  (RF frequency range: 500 MHz ± 10 kHz)

Test with phase unmatched cables

- The cable connected to Brilliance input B is longer than the other three cables. Phase delay introduced by the extra length is 19 degrees at 500 MHz.
- The measured beam position is strongly dependent on the RF frequency variance.

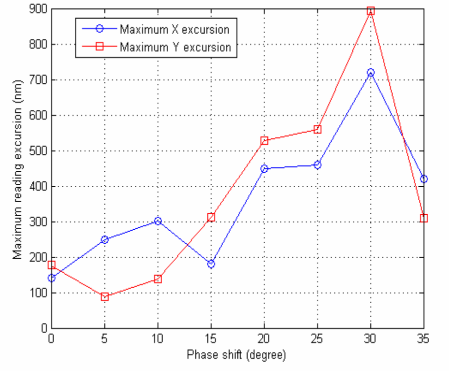
Max X excursion	1308 nm
Max Y excursion	275 nm
X std deviation	83 - 91 nm
Y std deviation	42 - 53 nm

Test with phase matched cables

- The phase match of four cables is within ±1 degree at 500 MHz.

Max X excursion	83 nm
Max Y excursion	163 nm
X std deviation	27 - 28 nm
Y std deviation	39 - 48 nm

- For better performance, four cables need to be matched within 15 degrees at 500 MHz.

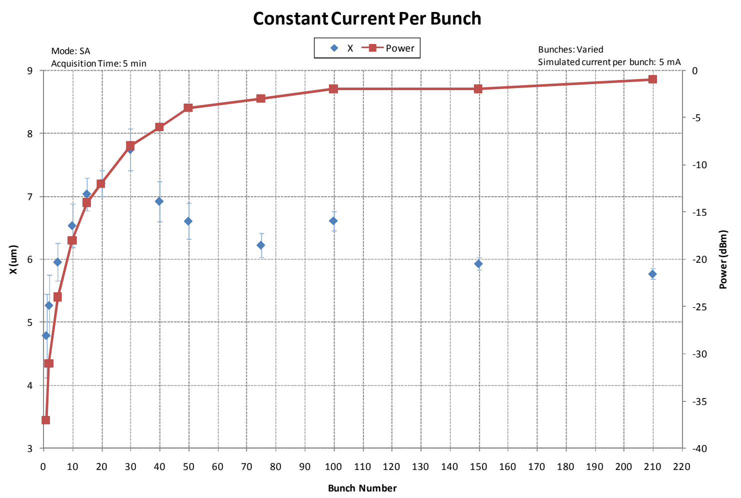


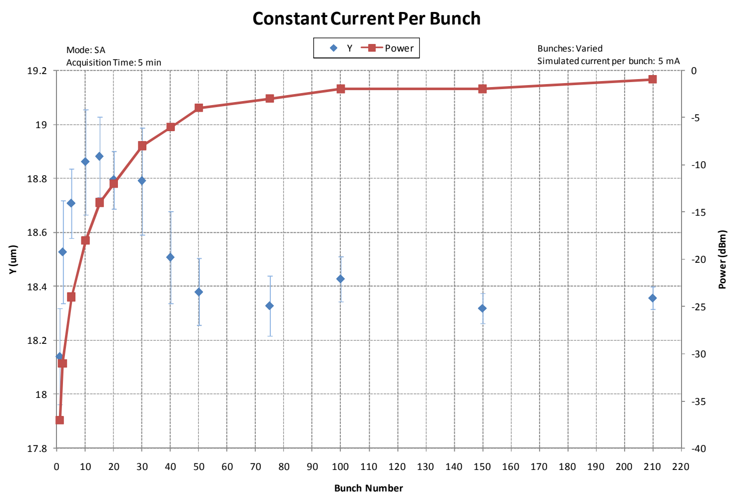
Test with the simulated beam

- Constant current per bunch

  (Number of bunches: 1 to 210)

	Electron	Brilliance
Max X excursion	14 µm	2.95 µm
Max Y excursion	10.6 µm	0.74 µm
X std deviation	80 - 985 nm	86 - 663 nm
Y std deviation	117 - 1158 nm	42 - 198 nm

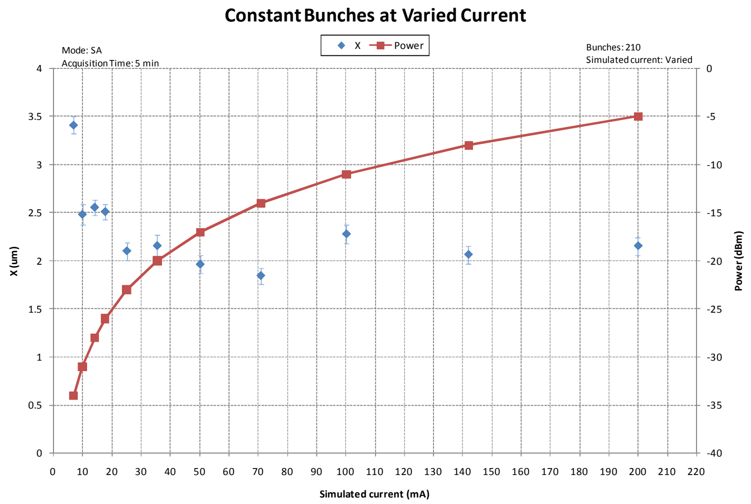


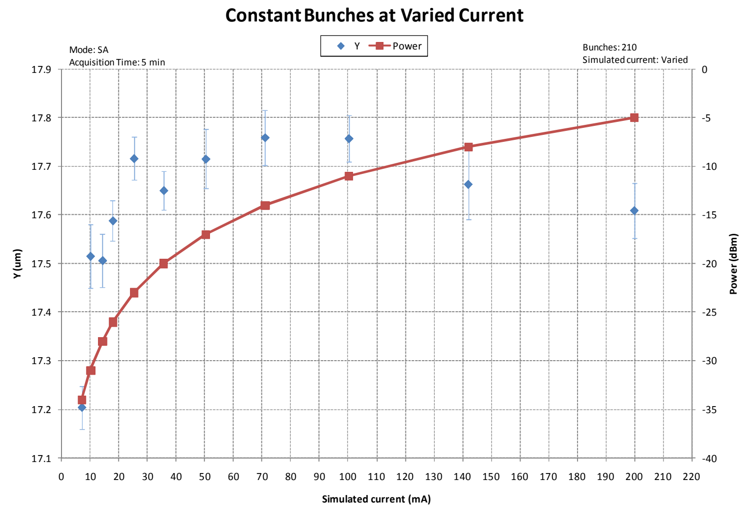


Test with the simulated beam

- Constant bunches at varied current
  (Current: 7 – 200 mA)

	Electron	Brilliance
Max X excursion	5.1 µm	1.57 µm
Max Y excursion	7.9 µm	0.56 µm
X std deviation	77 - 313 nm	80 - 115 nm
Y std deviation	116 - 564 nm	41 - 73 nm

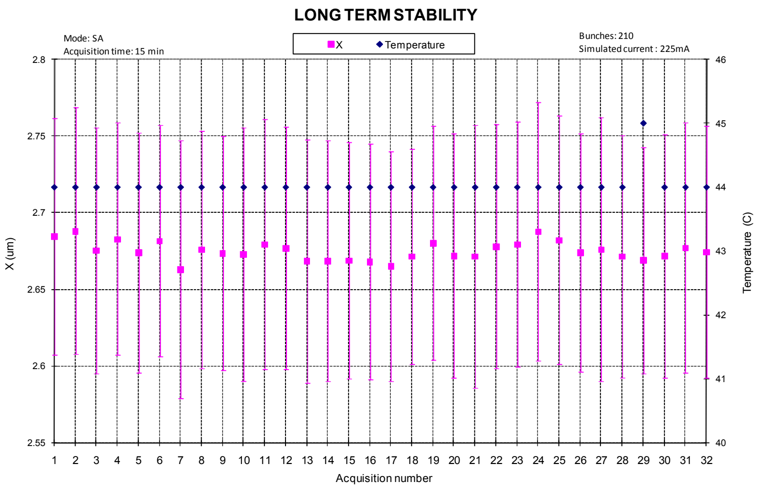


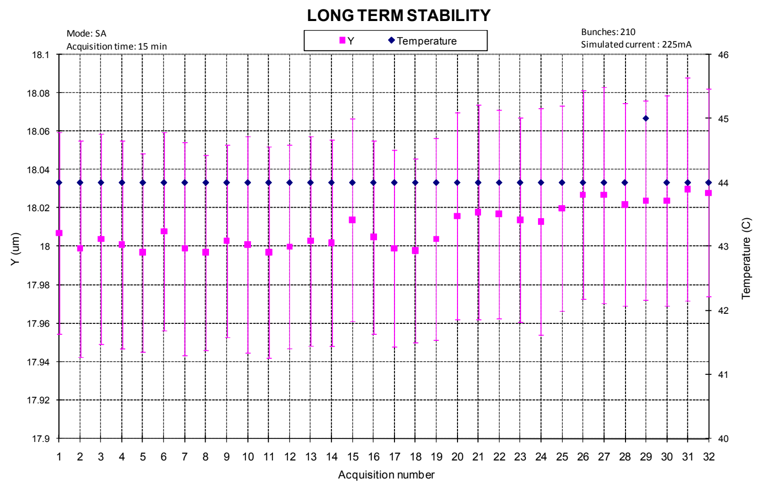


Test with the simulated beam

- Long term stability
  (8 hours acquisition @ 225 mA)

	Electron	Brilliance
Max X excursion	191 nm	25 nm
Max Y excursion	199 nm	32 nm
X std deviation	99 - 121 nm	70 - 86 nm
Y std deviation	129 - 161 nm	48 - 59 nm

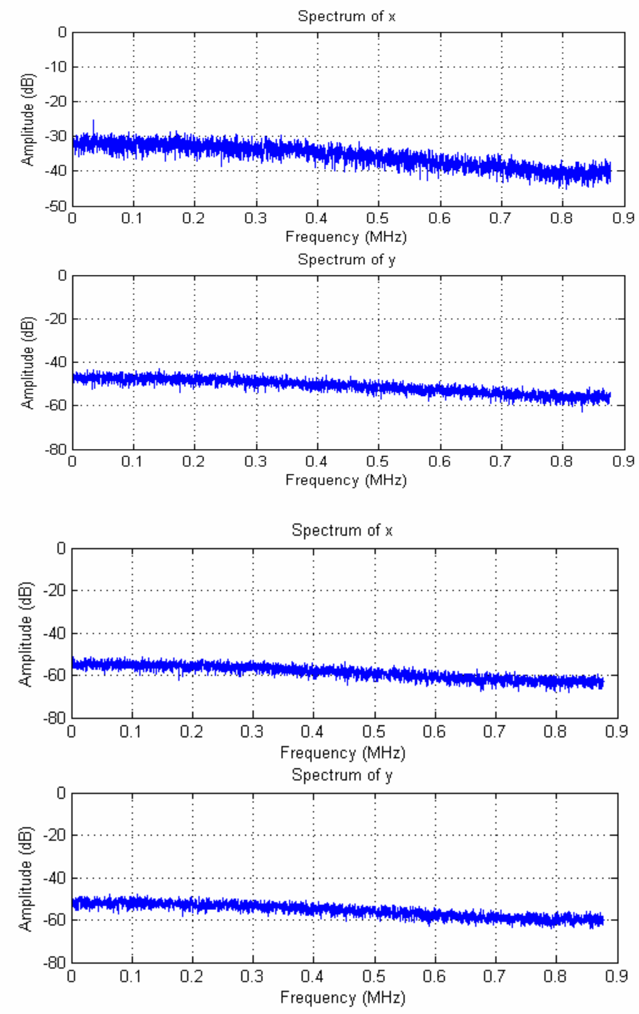




Test with the simulated beam

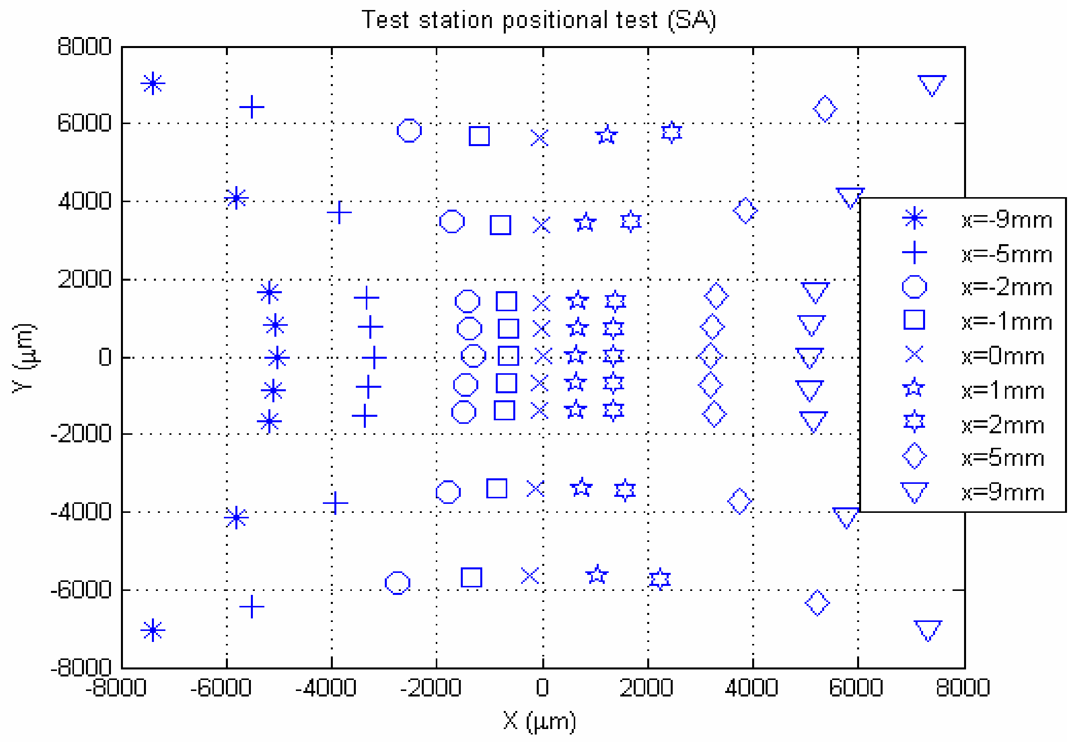
- Turn by turn data

  - A 35 kHz component consistently shows in X or Y spectrum
  - After connecting 10 MHz reference for Libera Brilliance, the spur moves to 28 kHz → 500.028 MHz – 500 MHz.
  - After adjusting the RF frequency to 500 MHz, the spectrum is clean.
  - Main reason → Our master oscillator is typically running at around 500.028 MHz instead of 500 MHz.



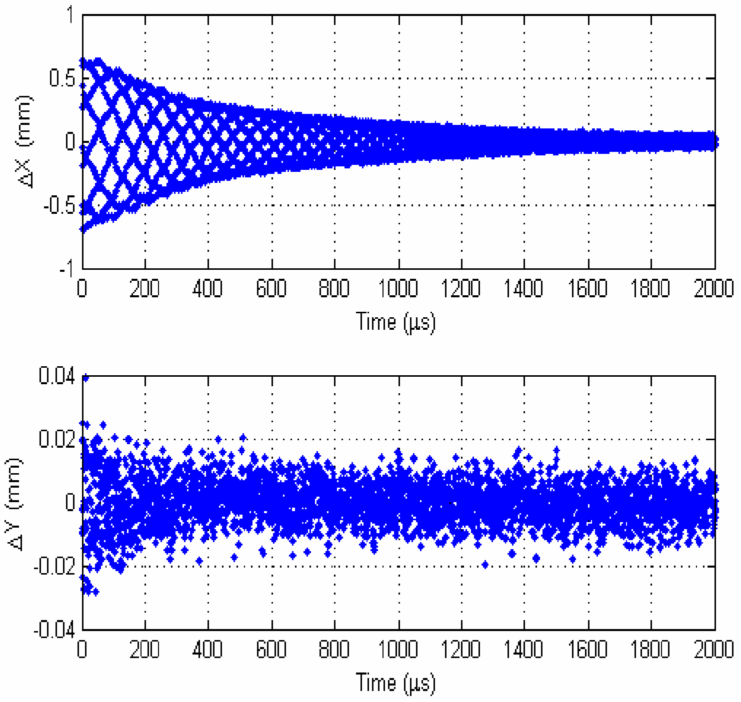
Test with a BPM test station

- The central positions were found manually.
- X and Y were adjusted to 0mm, 1mm, 2mm, 5mm, 9mm, -1mm, -2mm, -5mm and -9mm.

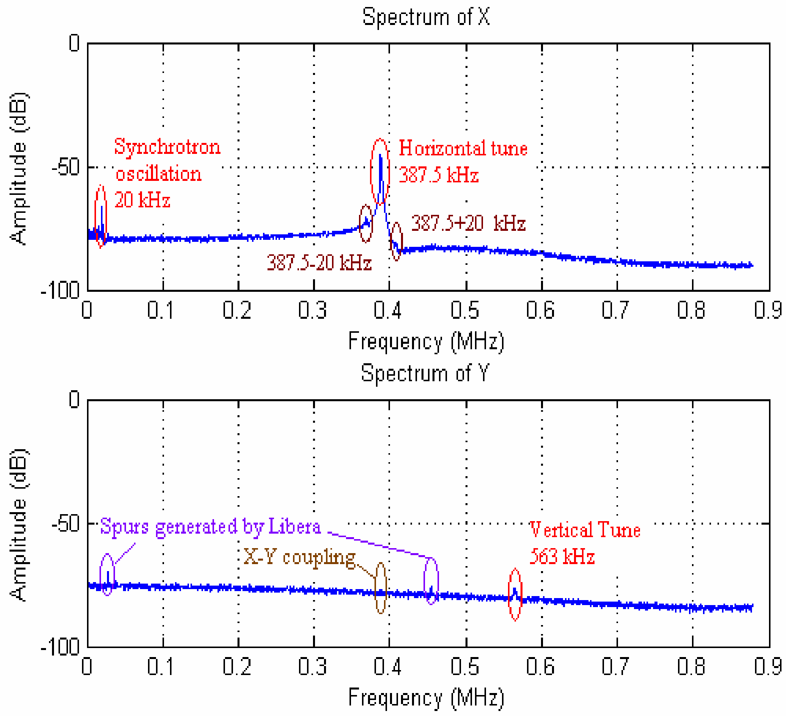


Experimental study with Brilliance [3]

- Turn by turn data

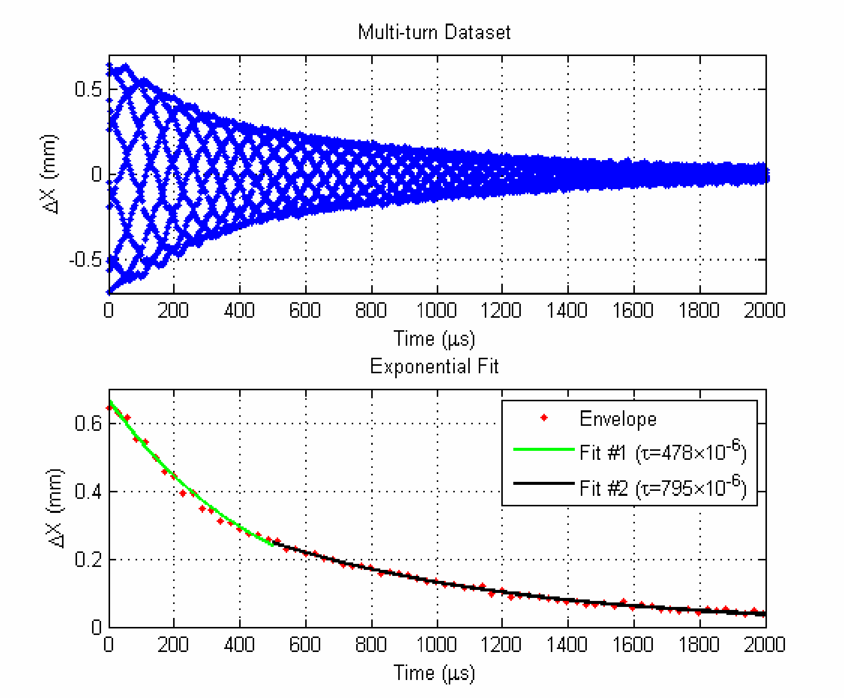


- Fractional tune

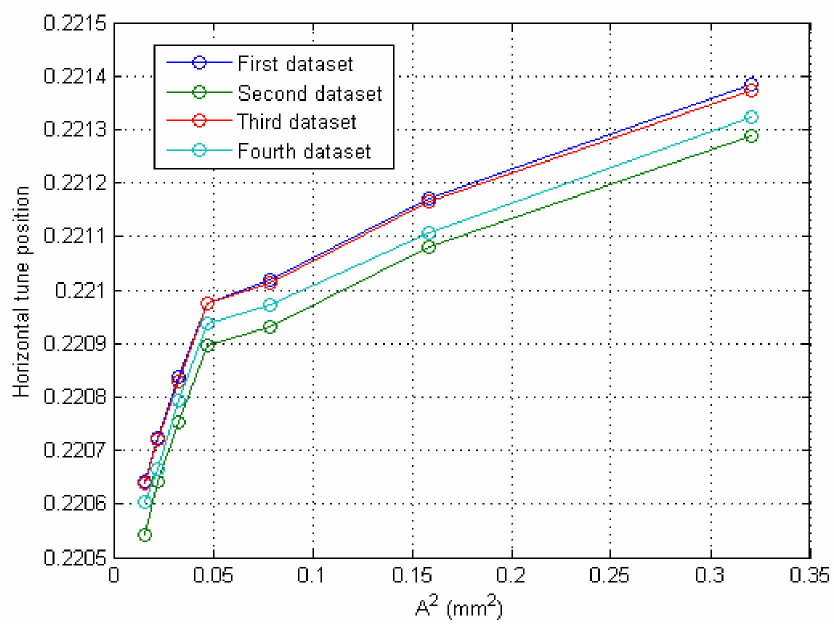


Experimental study with Brilliance

- Damping time
  - The measured damping time is much faster than the natural damping time 2.4 ms.



- Tune shift
  - The bunch tune gradually increases with increasing betatron amplitude according to the prescription,
    $\nu(A) = \nu(0) + K_x \cdot A^2$ [5]
  - The analytical interpolation of the FFT [4] was used to estimated the tune with 300 samples.



Single bunch experiment using BbB

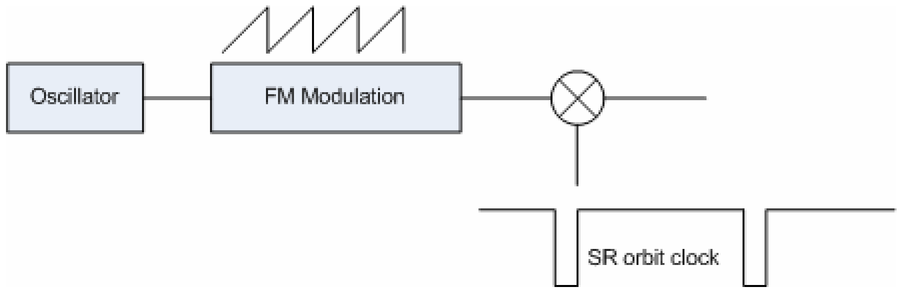
- Bunch cleaning mechanism [5,6]

  - Driving unwanted bunches into betatron oscillation of sufficient amplitude and remove them from the stored beam.
  - It is done in the vertical plane at the CLS.
  - Since the tune varies with the bunch charge and the amplitude of oscillation, the oscillator frequency is frequency modulated to ensure all unwanted bunches are driven out.
  - A mask is applied to select the bunch we want to keep.

Single bunch experiment using BbB

- Bunch cleaning using an oscillator

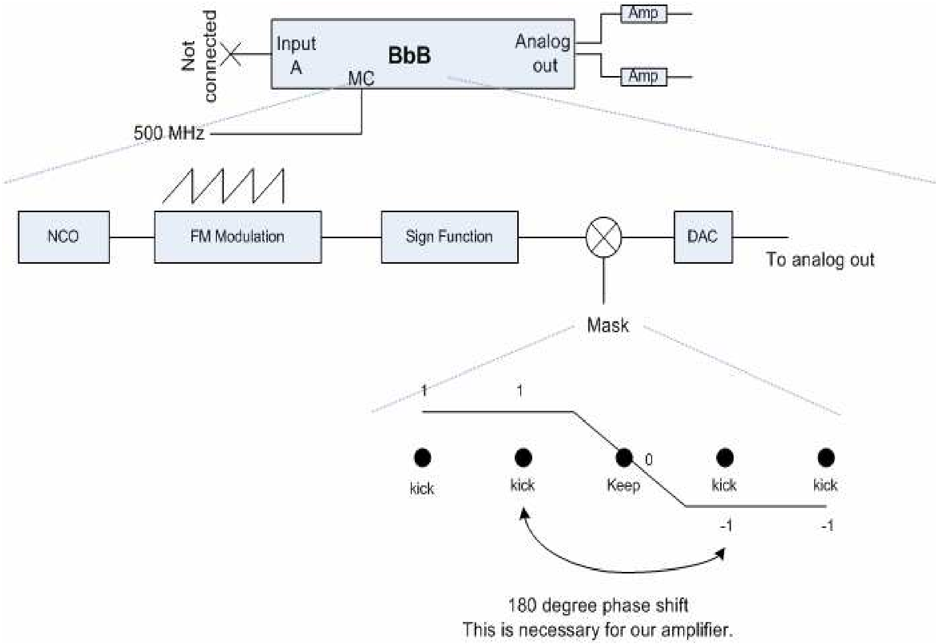
  - Oscillator frequency: (N*1.7544+0.563) MHz
  - FM modulation bandwidth: 15 kHz
  - Sweep frequency: 100 Hz
  - Bunch purity achieved: 1e-4



Single bunch experiment using BbB

- Libera BbB

  - NCO central frequency: (N*1.7544+0.563) MHz
  - FM modulation bandwidth: 150 kHz
  - Sweep frequency: 10 Hz
  - Bunch purity achieved: 1e-6



Conclusions

- Compared with Libera Electron, Libera Brilliance shows less dependence on beam current and bunch pattern. Higher reproducibility is also observed. We have installed three units in the SR and one unit in the BR.

- Libera Bunch by Bunch helped us to achieve a bunch purity of 1e-6.

- Instrumentation Technology also provided great technical support for us.

- Our to do list:

  - Try to find a fast way to synchronize Libera BbB with our machine for bunch cleaning
  - Transverse feedback system implementation with Libera BbB and Libera BbB Front end
  - Integrate Libera BbB into EPICS

References

[1] C. Sewell, “Libera Electron Evaluation”, CLS Document 7.5.36.60 Rev.0, 2007

[2] S. Hu, “Libera Brilliance Evaluation”, CLS Document 7.5.39.67 Rev.0, 2008

[3] S. Hu, “Experimental Study with Libera Brilliance”, CLS Document 7.5.38.6 Rev.0, 2008

[4] R. Bartolini, A. Bazzani, M. Giovannozzi, W. Scandale and E. Todesco, “Tune Evaluation in Simulations and Experiments”, European Organization for Nuclear Research, CERN SL/95-84 (AP), 1995

[5] J. Bergstrom, “Storage Ring Bunch Cleaning with a Free Running Oscillator”, CLS Document 5.2.39.6 Rev. 0, 2008

[6] J. Bergstrom and J. Vogt, “A Transverse Feedback System for the CLS”, CLS Document 5.2.39.2 Rev. 0, 2005