Diagnostics Tools for Couple Bunch Instabilities at ALBA

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Abstract

Couple Bunch Instabilities (CBI) have been identified at ALBA as one of the main beam current limitations since its early commissioning in 2011. In these last years, we have developed several diagnostics tools that allow us a better characterization of these instabilities. The Synchrotron Radiation Interferometry has been equipped with a Fast Gated Camera (FGC) to measure the bunch by bunch beam size evolution, which, in combination with the diagnostics tools of the Transverse Multibunch Feedback system, provides us with a fruitful insight of these phenomena. This paper describes these diagnostics tools, and as an example, compares the bunch by bunch emittance and tune evolution switching on/off some of the vacuum pumps at the Storage Ring.

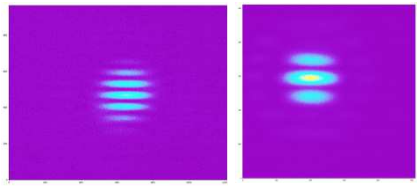
Bunch-by-Bunch Beam Size Monitor

With the usual x-ray pinhole [1], the x-rays need to be converted to visible light with a fluorescent screen (YAG:Ce).

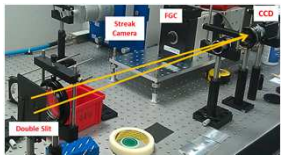
But the YAG:Ce screen has a decay time of 70ns, much larger than the 2ns ALBA bucket length.

Instead, using the ***Synchrotron Radiation Interferometry*** (SRI), we can use a Fast Gated Camera (FGC) to take pictures of 2ns gating.

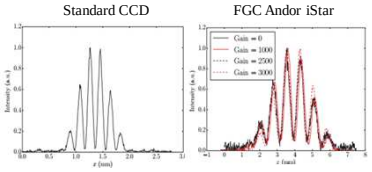
SRI with CCD | SRI with FGC



SRI with pinholes of 3mm, spaced 16mm | SRI with pinholes of 6mm, spaced 16mm



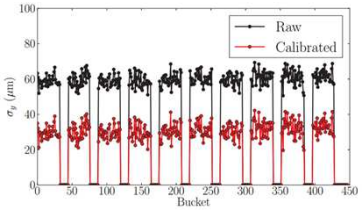
Standard CCD | FGC Andor iStar



Andor iStar 334T : interferogram visibility does not change with increasing gain.

However, the visibility in any FGC increases due to space charge effects in the MCP

We calibrate this effect with the beam itself

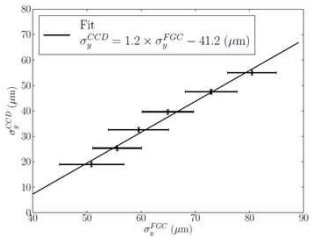


Comparing the interferometry with the CCD vs the FGC at different machine couplings, a linear relation is found between them.

This is used to calibrate the FGC measurements

Results are in agreement with theoretical values

Nevertheless, bunch size oscillates a lot due to the shot noise



Bunch-by-Bunch Tune Monitor

Using the Transverse MultiBunch Feedback (TMBF) commissioned in 2015, we can measure the tune on a bunch by bunch basis.

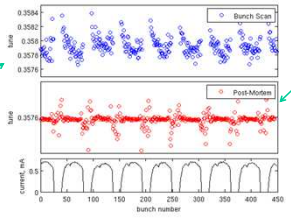
This uses the Libera BBB modules, controlled with an ad-hoc software made by Diamond [5].

Bunch Scan Analysis

In this case, we excite and measure the beam position of a single bunch, then move to the following bunch, and repeat the process for all the bunches in the filling pattern.

This is quite time consuming (~15min for the 448 bunches), and its precision is affected by the power supplies jitter (2e-4).

However, this technique is compatible with routine operation because the global disturbance to the beam is negligible



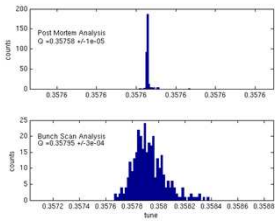
Post-Mortem Analysis

This method consists on exciting all the bunches at once, and get the position oscillations from all the bunches at the same time using the "Post-Mortem" buffer.

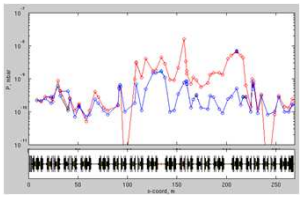
This buffer can be as big as 100kTurns, and so the precision obtained in this method is 1e-5.

Nevertheless, the whole beam is coherently excited and so the beam disturbance is significant.

Bunch Scan vs PostMortem Analysis



Results with Pressure Bumps

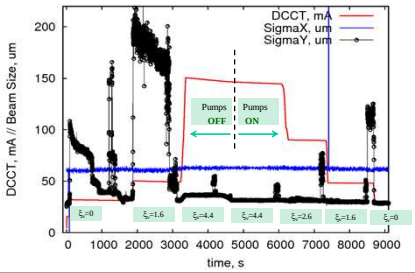


In order to study the effect of possible ion clouds, we switch off the vacuum pumps in 7 out of 16 ALBA sectors.

NEG cartridges were kept active, and so the pressure only rises by ~1 order of magnitude

Instability thresholds for different chromaticites are compared with pumps off/on.

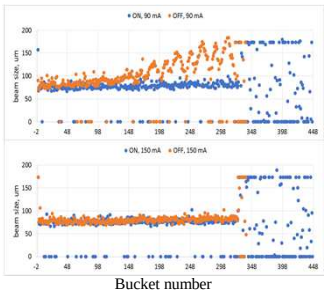
At the instability onset, bunch by bunch tune and beam size measurements are performed



Beam Size Comparison

The bunch size comparison allows to compare instability rise times: for 90mA with pumps off, the instability rises in about 150 bunches. With the pumps off, no instability appears.

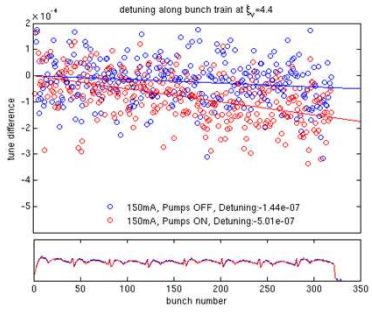
Nevertheless, at 150mA thre is barely no difference, yet the x-ray pinhole shows ~4um difference with pumps off/on. This shows the limit resolution of the FGC



Tune difference comparison

For the same beam current (150 mA), the detuning along the bunches with pumps ON is (in absolute numbers) larger (5e-7 / bunch) wrt detuning with the pumps OFF (1.5e-7 / bunch).

This is arguably related with an extra-focusing produced by the ion clouds, from which the ion cloud density could be inferred.



Conclusions

ALBA is now equipped with a both a bunch by bunch beam size monitor and tune monitor that allow to infer detailed information about bunch by bunch phenomena, like for example CBI. The BBB size measurements are performed using a FGC that allows gating times as short as 2ns, although unfortunately the resolution is limited by the space charge effects produced in the FGC. Nevertheless, qualitative measurements of relative BBB size changes allows to measure instability rise times with a bucket time resolution. The BBB tune monitor relies on the TMBF electronics described in [5], and two type of tune measurements can be performed: one uses the single bunch excitation/measurement, the other using a coherent beam excitation on all bunches and analyzing the position oscillations of the Post-Mortem buffer.

Not surprisingly, an experiment switching on/off the vacuum pumps have shown that indeed with a larger pressure the instabilities thresholds are significantly reduced. The BBB beam size monitors showed that the instability rise times are in the order of 150 buckets (for 90 mA and ξ_y=2.6). The BBB tune monitor showed that the detuning with pumps off is smaller, and we are currently investigating if this is consistent with the focusing effects of an ion cloud.

[1] T.F. Günzel and U. Iriso, *Revision of the impedance model for the interpretation of the single bunch measurements at ALBA*, Proc. of IPAC'15, Knoxville (USA), 2015.
[2] U. Iriso, M. Alvarez, F. Fernandez, F. Perez and A. Olmos, *Diagnostics during the ALBA Storage Ring Commissioning*.
[3] L. Torino and U. Iriso, *Transverse beam profile reconstruction using synchrotron radiation interferometry*, Phys. Rev. Accel. Beams 19, 122801, 2016.
[4] L. Torino, Phd Thesis, ALBA Accelerator Internal Report, ACDIV-2017-02 (2017). https://intranet.cells.es/Divisions/Accelerators/publications/ACDIV-2017-02.pdf
[5] A. Olmos, U. Iriso, J. Molden, F. Perez, M. Abbott, G. Rehm, I. Uzun, *Integration of the Diamond TMBF system at ALBA*, Proc. of IBIC15, Melbourne (Australia), 2015.
[6] U. Iriso, L. Torino and T. Mitsuhashi, *First steps towards SRI at ALBA*, Proc. of IBIC13, Oxford (UK) 2013.
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[8] L. Torino and U. Iriso, *SRI at ALBA*, Proc. of IBIC15, Melbourne (Australia), 2015.
[9] M. Carla, G. Benedetti, T. Guenzel, U. Iriso, Z. Martí, *Local transverse coupling impedance measurements in a synchrotron light source from turn-by-turn acquisitions*, Phys. Rev. Accel. Beams 19, 121002 (2016).