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DIAGNOSTICS FOR TRANSVERSE COUPLED BUNCH INSTABILITIES AT ALBA

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INTRODUCTION

Beam current limitations have been observed at ALBA since its early commissioning in 2011. They are mainly related with Transverse Coupled Bunch Instabilities (TCBI), which appear above certain current thresholds and they could be cured by increasing the beam chromaticity. The origin of these beam instabilities is mainly related with the Geometrical and Resistive Wall impedances [1], although the influence of ion effects due to large pressures inside the chamber is not ruled out. In these phenomena, the perturbing field produced by a given bunch affects the subsequent bunches and therefore, bunch-by-bunch (BbB) instrumentation is required to obtain reliable diagnostics of these effects.

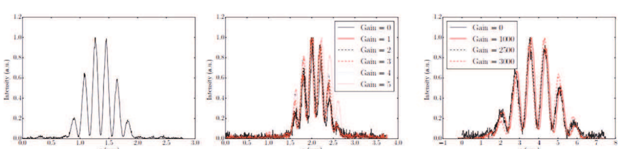
During these last years, we have developed two bunch-by-bunch instruments that provide us with a better insight into these effects. First, we have equipped our visible light interferometry [2] with a Fast Gated Camera with gating times as short as 2 ns [3], which provides a bunch-by-bunch emittance monitor. Second, we have set-up into operation our Transverse Multi-Bunch Feedback [4], which allows tune measurements to be performed also on a BbB basis. With these instruments, we have performed several experiments switching on/off the vacuum pumps in different sectors of the storage ring in order to evaluate the influence of ion effects on these beam instabilities. This paper reviews this BbB instrumentation and shows the results of these beam experiments.

BEAM SIZE MONITOR

In addition to the X-ray pinhole camera, since 2013 ALBA has been developing a beam size monitor using the Synchrotron Radiation Interferometry (SRI) with visible light [5–7]. Imaging with the X-ray pinhole has two main timing limitations: a)the YAG:Ce screen decay time is typically in the order of 100 ns [8]; and b) the minimum CCD exposure time (around 100 μs). This is obviously too much for ALBA's storage ring, where the bucket length is 2 ns. Since the SRI uses visible light (not X-rays), only the latter one affects the SRI. This can be circunvented by using a FGC with gatings as short as 2 ns.

The general principle of FGCs is as follows: when the light impinges on the photo-cathode of an image intensifier, photo-electrons are emitted and guided through a Multi-Channel Plate by an electric field. A high potential (whose duration can be as short as 2 ns) is applied across the MCP to accelerate and multiply the primary electrons. The final electron avalanche reaches a phosphor screen, whose light is read by a CCD.

The main FGC limitation stems from the space-charge effects produced when the electrons exit the photo-cathode, which enlarges the inteferograms fringes and so the measured beam size is larger. Figure 1 shows interferograms produced by a standard CCD (left) and two types of FGC: the Hamamatsu II C9546 (middle) and the Andor iStar 334T (right). Compared with the CCD camera, the visibility produced by FGCs is lower due to space charge effects, hence the measured beam size is larger. A thorough explanation, as well as a comparison for different cameras is shown in [3].



(a) Standard CCD (b) Image Intensifier C9546-01 (c) FGC iStar 334T

Figure 1: Comparison of interferograms produced by a standard CCD camera (left) and two types of FGC. The lower visibility (with higher valleys) is due to space charge effects, and increases the measured beam size.

Nevertheless, this beam size enlargement can be calibrated using the beam itself: we measure the beam size with both the standard CCD and the FGC by changing the beam coupling in a controlled way. This shows a linear relation (see Fig. 2), which we use to calibrate the FGC measurements. Our SRI system is equiped with the Andor FGC camera.

Figure 3 shows the measured bunch-by-bunch beam size with 130 mA in routine operation at ALBA. The calibrated beam size is consistent with the theoretical one. Nevertheless, the resulting size oscillates due to bunch-by-bunch shot noise, which explains the large error bars in Fig. 2. Due to low amount of light, the bunch size is not obtained from a single shot (i.e. single bunch passage), but rather by integrating the light produced by many (typically ~100) passages, for which the gating and trigger are carefully synchronized.

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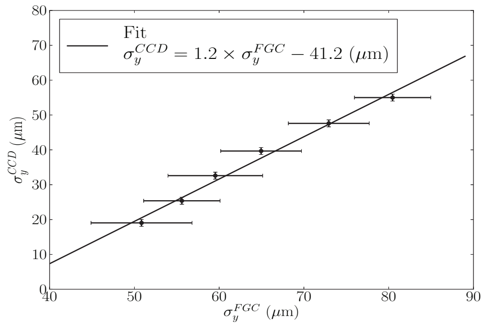

Figure 2: Resulting beam size, measured by the FGC for different couplings versus the same measurement done with a standard CCD.

After the inteferogram of bunch N is obtained, the process is repeated for bunch N+1, until all 448 buckets are scanned. In total, the scan is performed in ~5 min. More details are shown in [3].

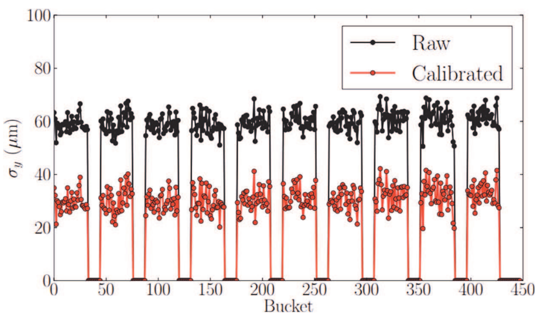

Figure 3: Measured BbB beam size with the ALBA filling pattern: 10 trains, with 32 bunches/train spaced by 12 empty buckets. The final gap is larger (20 buckets).

TUNE MONITOR

With the commissioning of the Transverse Multi-Bunch Feedback (TMBF) in 2015 [4], ALBA is able to measure the tune on a BbB basis. This can be done in two ways. The first one, which we call the *Post-Mortem Analysis*, consists of exciting all bunches at once and getting their position oscillations also at the same time using the *Post-Mortem buffer*. This time frame can be as big as 100k turns, so the precision obtained in this method is 1e-5.

The second one, which we call the *Bunch Scan Analysis*, is to excite and measure the beam position of a single bunch, then move to the following bunch, and repeat the process for all bunches in the filling pattern. Compared with the previous one, this method is significantly slower (in the order of 15 min for the 448 bunches) and is affected by the power supplies jitter, which amounts to 2e-4 (see [9]). This becomes a main limitation in measurements of this kind.

Figure 4 shows an example of tune measurement obtained over 320 bunches, when the machine is filled with 200 mA. For the *Post Mortem Analysis* (top histogram), the tune spread (σ_Q=1e-5) is only limited by the number of acquired turns; while for the *Bunch Scan Method* (bottom histogram) the tune spread is limited by the jitter of power supplies (measured σ_Q=3e-4).

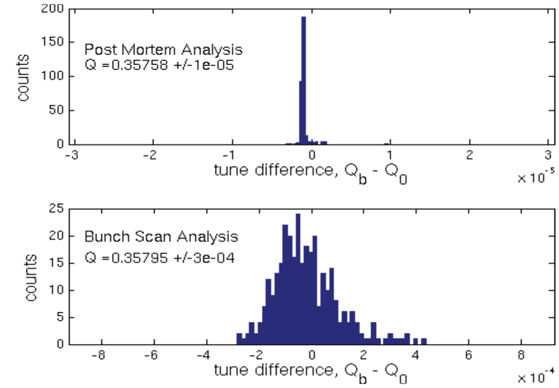

Figure 4: Bunch-by-bunch tune using the *Post Mortem Analysis* (top) and the *Bunch Scan Method* (bottom).

RESULTS WITH PRESSURE BUMPS

In order to investigate the vacuum pressure influence in the CBIs observed at ALBA, we did an experiment in which we switched off the vacuum ion pumps in almost half of the SR (7 sectors out of 16). The NEG coating and cartridges were still active, so the pressure rose only by about 1 order of magnitude. Figure 5 compares the pressure profile as measured by the Cold Cathode Gauges (CCG) in the SR with the pumps on/off. The points below 1e-11 bar indicate a malfunctioning of the CCG.

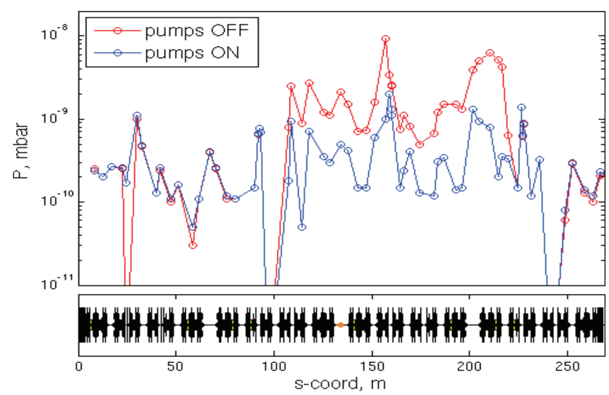

Figure 5: Normal vacuum pressure profile (in blue, with pumps on), compared with the pressure profile (red trace) when the pumps in Sectors S07 - S13 are switched off.

Figure 6 shows the horizontal (blue trace) and vertical (black dots) beam size evolution as measured by the X-ray pinhole camera while this experiment takes place. In this experiment, the pumps are switched off at $t = 0$, and the vertical chromaticity is set to ξ_v=0. The current injection is halted everytime there is a vertical beam blow up. At this point, we take measurements of the tune and bunch-by-bunch beam size; later we cure the instability by increasing the chromaticity (for example, at $t = 1000$ s or $t = 3000$ s). Next, the injection is resumed until a new threshold is reached, and the process is repeated. Finally, we reach 150 mA with a vertical chromaticity of ξ_v=4.4, and no instability is seen. At this point, we switch on the ion pumps ($t \sim 4500$ s), and note that the vertical beam size reaches a smaller equilibrium (from 33 to 28 μm).

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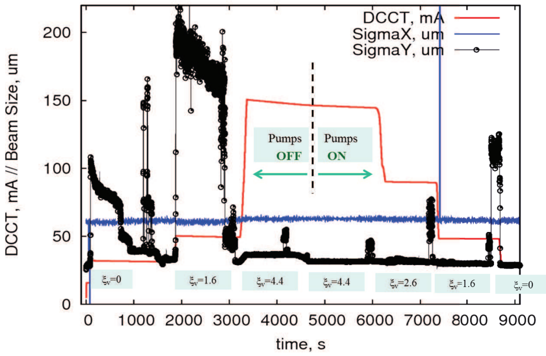

Figure 6: Evolution of DCCT, together with the hor and ver beam size, while switching the ion pumps OFF/ON. The ver chromaticity (ξ_v) is changed during the experiment.

Figure 7 compares the vertical bunch-by-bunch beam size with the pumps on/off for two different currents. For chromaticity ξ_v=2.6, the instability threshold is found at 90 mA with the pumps off, while the beam is stable with the pumps on. This clearly indicates that the presence of ions decreases the expected instability thresholds. Furthermore, the bunch size monitors allow measuring the TCBI rise time (150 bunches, orange dots). On the other hand, there is no significant difference in the bunch-by-bunch comparison for the pumps on and off for a 150 mA beam (even though the pinhole camera shows a vertical beam size difference of 4 µm). On one side, this is related with the resolution given by the FGC camera, which is quite large due to the above-mentioned space charge effects. This could also be an indication that this is not related to Fast Beam Ion Instabilities, but rather to an ion trapping effect.

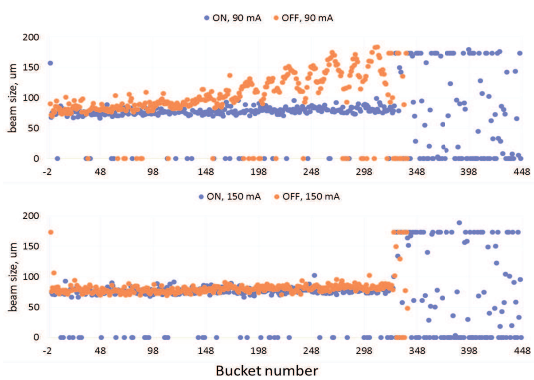

Figure 7: Vertical beam size along the bunches for 90 mA and ξ_v=2.6 (top) and 150 mA with ξ_v=4.4 (bottom) with pumps on/off.

Since the Post-Mortem Analysis needs to coherently excite all bunches at the same time, this could affect the TCBI itself. Therefore, for this experiment we decide to use the *Bunch Scan Analysis* method. Figure 8 (top) shows the measured detuning per bunch when the machine is filled with 150 mA in 320 consecutive bunches (bottom plot). Although small, the detuning with the pumps off is smaller than with the pumps on (from 1.5e-7 to 5e-7/bunch). This is arguably related with the larger presence of ions when the pumps are switched off, since the ions act as a focusing force. This can be used to infer the ion cloud density, and we are currently investigating it.

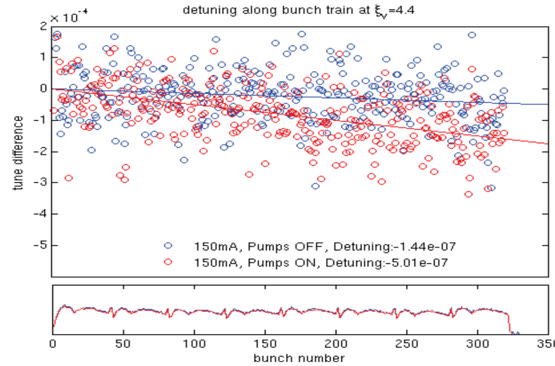

Figure 8: Tune difference along the bunch train wrt tune at bunch 0, with ion pumps on/off. The bottom plot shows the measured filling pattern for both cases.

CONCLUSIONS

ALBA is now equipped with both a BbB beam size and a tune monitor. The BbB size measurements are performed using a FGC that allows gating times as short as 2 ns. Unfortunately, the resolution is limited by the space charge effects produced in the FGC. Nevertheless, qualitative measurements of relative BbB size changes allow to measure the instability rise times with bucket-time resolution. The BbB tune monitor relies on the TMBF electronics described in [4] and can perform two types of tune measurements: using a single bunch excitation/measurement, and using a coherent beam excitation on all bunches, analyzing the position oscillations of the Post-Mortem buffer.

An experiment with switching on/off the vacuum pumps have shown that indeed, the instabilities thresholds are significantly reduced with higher pressure. The BbB beam size monitors showed that the instability rise times are in the order of 150 buckets (for 90 mA and ξ_v=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 an ion cloud focusing effect.

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REFERENCES

[1] T.F. Guenzel and U. Iriso, "Revision of the Impedance Model for the Interpretation of the Single Bunch Measurements at ALBA", in *Proc. of IPAC'15*, Richmond, VA USA, paper MOPJE026, 2015.

[2] L. Torino and U. Iriso, "Transverse beam profile reconstruction using synchrotron radiation interferometry", *Phys. Rev. Accel. Beams* 19, 122801, 2016.

[3] L. Torino, Phd Thesis, ALBA Accelerator Internal Report, ACDIV-2017-02 (2017). `https://intranet.cells.`

ISBN 978-3-95450-192-2

es/Divisions/Accelerators/publications/ACDIV-2017-02.pdf

[4] A. Olmos, U. Iriso, J. Moldes, F. Perez, M. Abbott, G. Rehm, and I. Uzun, "Integration of the Diamond Transverse Multi-bunch Feedback System at ALBA", in *Proc. of IBIC'15*, Melbourne, Australia, paper TUPB046, 2015.

[5] U. Iriso, L. Torino and T. Mitsuhashi, "First Steps Towards a Fast Orbit Feedback at ALBA", in *Proc. IBIC'13*, Oxford, UK, paper WEPC22, 2013.

[6] L. Torino, U. Iriso, and T.M. Mitsuhashi, "Beam Size Measurements using Synchrotron Radiation Interferometry at ALBA", in *Proc. of IBIC'14*, Monterey, CA, USA, paper TUPF23, 2014.

[7] L. Torino and U. Iriso, "Limitations and Solutions of Beam Size Measurements via Interferometry at ALBA", in *Proc. IBIC'15*, Melbourne, Australia, paper TUPB049, 2015.

[8] U. Iriso, M. Alvarez, F. Fernandez, F. Perez, and A. Olmos, "Diagnostics during the ALBA Storage Ring Commissioning", in *Proc. DIPAC'11*, Hamburg, Germany, paper TUOA02, 2011.

[9] M. Carla, G. Benedetti, T. Guenzel, U. Iriso, and Z. Marti, "Local transverse coupling impedance measurements in a synchrotron light source from turn-by-turn acquisitions", *Phys. Rev. Accel. Beams* 19, 121002 (2016).

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