ACDIV-2017-05
August 2017

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The beam position and size of the electron beam in the ALBA Booster-To-Storage (BTS) transfer line are monitored using Beam Position Monitors (BPMs) and Synchrotron Radiation Monitors (SRMs). However, their performance was not fully optimized and the beam trajectory in the transfer line was not properly controlled. Consequently, the transfer efficiency in the BTS has been fluctuating since day one, so more studies and precise beam measurements were critically needed to optimize it. Firstly, the SRMs mechanics and automation were significantly improved to provide a more robust optics alignment. Secondly, BPM electronics have been upgraded for single-pass beam detection, showing a factor 10 better position resolution than the former units. Both SRMs and BPMs are now routinely used to keep transmission efficiency along the BTS above 90%.

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The beam position and size of the electron beam in the ALBA Booster-To-Storage (BTS) transfer line are monitored using Beam Position Monitors (BPMs) and Synchrotron Radiation Monitors (SRMs). However, their performance was not fully optimized and the beam trajectory in the transfer line was not properly controlled. Consequently, the transfer efficiency in the BTS has been fluctuating since day one, so more studies and precise beam measurements were critically needed to optimize it. Firstly, the SRMs mechanics and automation were significantly improved to provide a more robust optics alignment. Secondly, BPM electronics have been upgraded for single-pass beam detection, showing a factor 10 better position resolution than the former units. Both SRMs and BPMs are now routinely used to keep transmission efficiency along the BTS above 90%.

INTRODUCTION

ALBA's booster and storage ring have a concentric layout with a short (~15 m) transfer line between them. Following the extraction elements (kicker, dipole and septum), the BTS consists of 2 dipoles (in blue in Fig. 1), 7 quads (in purple) and 3 H/V correctors. It follows into an injection section consisting of 2 kicker pairs (in yellow) and a septum (in green) in between them. The booster ramps up the energy of a 0.2 nC Linac charge from 110 MeV to 3 GeV and fires at a 3.125 Hz rate. The BTS diagnostics are quite numerous: 4 BPMs (red crosses), 3 SRMs (yellow stars), 3 FSOTRs and 2 FCTs.

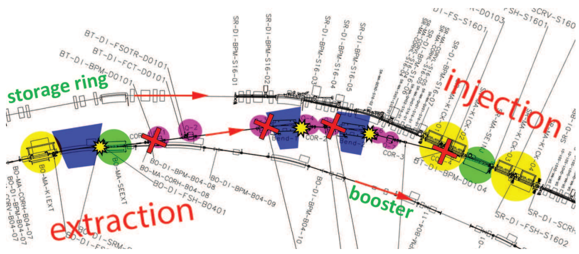

Figure 1: Layout of booster-to-storage transfer line of ALBA.

The injection efficiency measured from the Booster to the Storage Ring has been, for a long time, maximized by scanning mostly the pulsed elements and the BTS last pair of correctors, without paying much attention to the electron beam trajectory in the BTS. This worked reasonably well when we were operating the accelerators in decay mode, injecting only two times per day with the Front Ends (FE) closed. Nevertheless, once we had moved to top-up operation, the instabilities of the injector became an issue since the injection times could be significantly extended and disturb some beamline experiments.

In order to improve and stabilize the injection efficiency, we first performed a beam alignment campaign based on the FSOTRs. This already improved the injection efficiency stability. Nevertheless, since these components are beam destructive elements, we decided to work on the non-destructive instrumentation (SRMs and BPMs) in order to improve the diagnostics and provide a real-time monitoring tool during routine operation. These should not only provide a better understanding of the transmission oscillations, but also should help in finding more stable beam trajectories. This paper describes the improvements in the SRMs and BPMs, and shows the results obtained with them.

SRM UPGRADE

As a non-destructive diagnostic tool, the SRM uses the synchrotron radiation produced when the electron beam traverses a bending magnet. The visible light is guided away by a 45^{o} mirror into the CCD optics, producing a transverse beam image in real-time. The diffraction limit does not significantly affect the beam imaging in the BTS, since the beam size is in the order of ~(200, 100) μm.

There are 3 locations of SRMs in the transfer line [1, 2]. One is placed after a booster dipole in between the extraction elements, and two more SRMs are located after each dipole in the BTS. The SRM setup and optics are all identical: a telephoto zoom lens (Sigma 70-300 mm) is used with a commercial CCD (Basler scA1300-32gm). Each is focused at 1.5 m distance to a source point in the center of the corresponding upstream dipole. Even though the set-up is the same as the one working since day-one in the Booster [3], the SRMs in the BTS did not properly function due to problems with alignment and low visibility, and consequently, the BTS-SRM system received a major upgrade taking care of its a) mechanical stability and b) centering on beam.

Initially, the SRM optics were lightly attached to the girder (Fig. 2, left), and its alignment relied on the viewport. However, in this configuration the SRM weight was partially supported in the viewport as well, thus risking bending it downwards. Moreover, any manipulation of the optics would mean losing any reference of the CCD position with respect to the viewport. Instead, the new generation of ALBA's SRM supports have been designed to be firmly clamped to the girder (Fig. 2, right), allowing independent mechanical adjustment of its optics without forcing the viewport. On the contrary, the viewport is now a stable reference for SRM optics alignment.

ISBN 978-3-95450-192-2

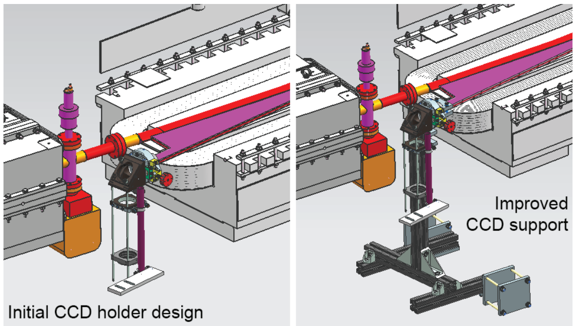

Figure 2: Initial (left) and a heavier redesigned (right) mechanical support of BTS SRMs, allowing stable viewport position.

The alignment of SRMs was done by “looking" for beam manually by stopping the beam and entering the tunnel in between the attempts to tune the mirror angular adjustment screws at minimal zoom of the objective. After both beam spots in SRMs were found, the zoom was increased for more resolution and the internal iris of the objective is set to fully open. Figure 3 shows the beam image of the two SRMs in the BTS after the alignment process had been performed.

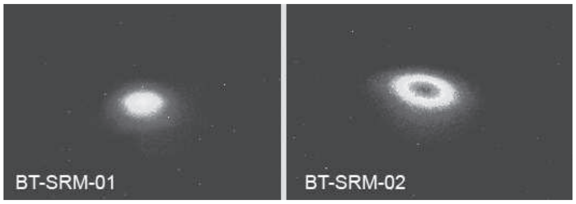

Figure 3: Transfered beam as seen by two SRMs in the transfer line.

BPM UPGRADE

The BTS BPMs are based on button-type feedthroughs, directly welded on the round vacuum chamber. The signals from four buttons are delivered to the processing electronics via long RF coax cables (near 40 meters). BPM signals were formerly digitized and processed by standard Libera Brilliance modules from Instrumentation Technologies [4]. These electronics were meant to take data from multi-turn BPMs, where the beam passes continuously and the acquisition and processing times can be relaxed, leading to acceptable functionality in decay mode. However, ALBA’s operation in top-up requires very low charge beams from the injector, leading to beam currents in the order of tenth of µA through the BTS.

Hence, the combination of very low charge beams, long RF cables and long integration time of electronics had significantly degraded the position resolution of BTS BPMs.

In order to improve their position measurement, the new Libera Spark EL [4] electronics were tested. Such electronics are designed to cope with single pass beams and are based on time definition of the processing window when the beam passes through the BPM. This improves the resolution because the contribution of no-beam signal to position calculation is reduced. Various tests have been done at ALBA with Sparks electronics, both in the BTS transfer line and also in the LINAC exit.

Figure 4 shows the Libera’s difference of position calculation for a BTS BPM during top-up reinjections using a pure 50 µA single bunch beam. Here, the position calculation improves by a factor 10 (std) by using the Spark units wrt the former Brilliance one.

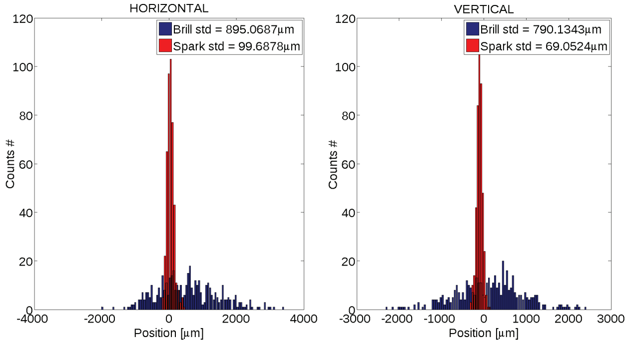

Figure 4: Spark-Brilliance comparison for BTS BPMs on a 50 µA single bunch beam.

APPLICATION IN ROUTINE OPERATION

In the booster, the displacement of an extracted beam with respect to the stored one can be measured at the SRM placed in the booster dipole between the kicker and the extraction septum. With a proper adjustment of time delay and integrating the signal of the CCD camera over the last turns before the extraction, an image with both the stored and the extracted beam is observed (see Fig. 5), and so the distance between them can be set to the design value using the extraction kicker. Next, the extraction kick angle is crosschecked with the fluorescent screen in front of the septum.

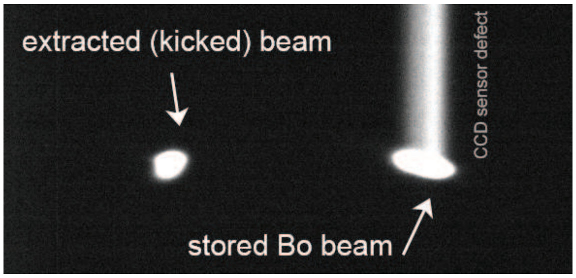

Figure 5: SRM placed in the booster dipole embedded between the extraction kicker and the septum. The separation between the stored beam (the spot at the center of the screen) and the extracted beam (displaced on the left) can be directly monitored and adjusted to the nominal value.

A high-level software has been developed in order to track the beam position along the BO extraction and BTS trajectory. This has become very useful to detect displacements of the beam at the entrance of the first dipole of BTS, and has provided a diagnostic tool for the operators to compensate those displacements by changing the setting of the BO extraction septum.

Figure 6 shows the BTS efficiency (green trace), the beam position at the booster SRM, and the first SRM1 in the BTS (red and black lines, respectively) during 6 h of routine operation with top-up injections occurring every 20 minutes. The beam is displaced at the first SRM when the injection efficiency drops from 90 to 60%.

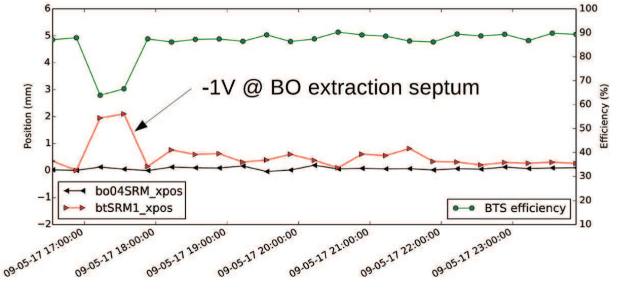

Figure 6: Beam position at BO extraction, BTS entrance and the injection efficiency during 6 h of top-up operation. The efficiency is recovered by bringing back the beam position at the BTS entrance by tuning the extraction septum.

Since the position of the extracted beam stays stable at the booster SRM (between the extraction kicker and septum), the operator reacts decreasing the BO extraction septum setting to recover the previous position at the first SRM. The injection efficiency is immediately recovered in the following top-up injection once the beam displacement is compensated. At the time of this example, the new BPM electronics were not yet commissioned and so we cannot show the BPM data of this incidence.

After the BTS improvement campaign, we conclude that the most probable sources of injection efficiency oscillations are the pulsed elements of BO extraction and SR injection. The effect of BO orbit oscillations (which displaces the beam at the extraction kicker entrance in the order of 100 µm peak-to-peak) is still under study. Currently the Pulsed Magnets group are also monitoring the read-back of the pulsed elements. They had detected drifts and sudden steps in the SR injection septum pulse amplitude, which have been identified as one of the sources of the injection efficiency oscillations.

CONCLUSION

The SRMs and BPMs systems in the BTS transfer line have been improved during 2016 and despite the single pass of low charge beams, they offer a reliable tool to control the beam trajectory. The BPMs have been equipped with the Sparks electronics, providing a factor 10 better resolution in the beam position. Furthermore, the new mechanical design of the SRMs provide a robust and repeatable position system that allowed a proper beam imaging centering, and allow a continuous monitoring of top-up injections. As a result, the fluctuations in the top-up transmission efficiency in the BTS transfer line is reduced, and on average it increased from about 60 to 90% (see blue dots in Fig. 7).

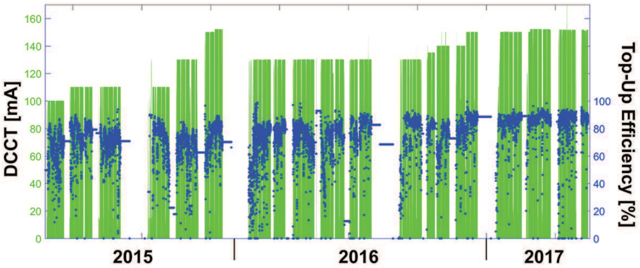

Figure 7: Injection efficiency evolution in BTS, correlated with beam current over time.

ACKNOWLEDGMENTS

We would like to thank M. Pont for fruitful discussions, and triggering the need to improve the BTS transmission efficiency; and N. Ayala for setting-up the required instrumentation to monitor the pulsed elements during machine development shifts.

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