# LARGE VACUUM INTERVENTION TO INSTALL NEW BPMs AND RADIATION ABSORBERS IN THE LNLS ELECTRON STORAGE RING

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## *Abstract*

In the beginning of 2008 an upgrade of the beam position monitors (BPMs) of the Brazilian Synchrotron Light Source (LNLS) electron storage ring was decided and scheduled as part of the continuous effort to improve the electron beam orbit stability. The objective was to replace most of the 24 BPMs installed in the storage ring and install new radiation absorbers inside the vacuum chamber. The original stripline BPMs were sensitive to temperature changes in the vacuum chamber. Heat, which induced mechanical stress in the striplines, could lead to fluctuations in the position readings thereby disturbing the orbit stability. The problem affected differently the BPMs. Although not a great issue during a typical user shift, the perturbations could pose some problems for the most sensitive experiments. One third of the BPMs were replaced in October 2008 and the remaining in October 2009. Thus, this large vacuum intervention aimed at improving the thermal and mechanical stability of the electron beam orbit measurement system. Finally, it will be presented the main changes made in the vacuum chambers and a survey of the evolution of the vacuum system after both interventions.

## INTRODUCTION

The Brazilian Synchrotron Light Source (LNLS) is based on a 1.37 GeV electron storage ring with 93.2 m of circumference, which operates with initial beam current of 250 mA. The vacuum system comprises a whole set of vacuum components designed and built in house and a pumping system composed of sputter ion pumps and titanium sublimation pumps. The average nominal operating pressure is in the low $10^{-10}$ mbar. The vacuum chambers were constructed using 316L stainless steel and the radiation absorbers using OFHC copper.

Up to October 2008, the machine beam orbit measurement system was mostly based on stripline BPMs [1]. The injection and the EPU undulator sections were monitored by early versions of button BPMs [2]. The effort to improve the stability of the orbit of the electron beam raised the need to design new BPMs to replace the stripline models. A new button BPM was designed, built and characterized at the LNLS [3]. A new support stand for the BPMs, sturdier and less sensitive to the temperature fluctuations of the machine tunnel, was designed and built. To prevent synchrotron radiation from hitting non-refrigerated parts of the vacuum chamber, radiation absorbers were added to the straight sections (SS) of the whole machine. That will circumvent most of the problems observed with the old BPMs. The uneven heating of the BPM produced undesired mechanical stresses in the BPM body.

In this paper, we present the main changes made to improve the thermal and mechanical stability of the electron beam orbit measurement system of the LNLS storage ring and the evolution of vacuum conditioning after the interventions.

## MAIN IMPROVEMENTS: NEW BPMS AND RADIATION ABSORBERS

Figure 1 shows a comparison between the stripline (old model) and button (new model) BPM vacuum chambers. In addition to the topology of these BPMs, the main differences between them are a synchrotron light absorber (BPM absorber) and a bellows right before the body of the button BPM. Moreover, the button BPM has a cooling channel that allows temperature stabilization of the body and a much sturdier support stand.

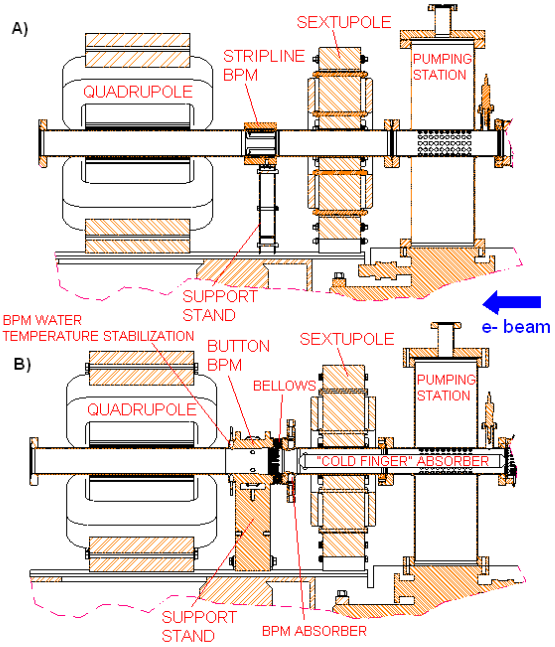

Figure 1: Comparison between the beginning of a typical short straight section (SSS) before and after replacing the BPMs: (A) stripline (old model) and (B) button (new model).

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The main reason to carry out this large intervention was to improve the thermal and mechanical stability of the electron beam orbit measurement system of the storage ring. The original stripline BPMs were sensitive to temperature changes in the vacuum chamber, because they had direct connection to all pieces of vacuum chambers of the SS (Figure 1). Heat, which induced mechanical stress in the striplines, could lead to fluctuations in the position readings thereby disturbing the orbit stability. Figure 2 presents the linear power density distribution, at a current of 250 mA, along a SS and the measured temperature distribution, at the same current, along a typical long straight section (LSS) before installing the new radiation absorbers (BPM absorber and the so called "cold finger" absorber). According to the irradiated power, the vacuum chambers along the SS can heat up and undergo thermal stress. The measured temperature distribution clearly shows the beam power heating up parts of the vacuum chamber and the BPMs. The most critical part was the beginning of the SS and the first BPMs of each section were the most affected ones (Figure 2). A detailed study of the thermal variations of the stripline BPMs can be found in Ref. [2].

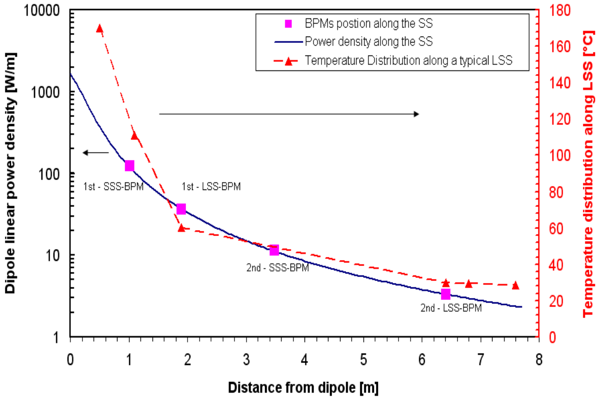

Figure 2: Linear power density distribution along the SS and temperature distribution along an LSS before installing the new radiation absorbers.

The approach followed to solve this problem was to reduce the power incident on the walls of the vacuum chamber using radiation absorbers (BPM absorbers and "cold finger" absorbers). In addition, a bellows is now used to decouple the BPM body from the upstream vacuum chamber. The BPM absorbers and the "cold finger" absorbers were installed just before the BPMs (Figure 1). In this way, they prevent synchrotron radiation from hitting the BPMs and the sections of the vacuum chambers attached to them. Thus, the heat induced thermal stress in the BPMs and upstream vacuum chambers is drastically reduced. After installing these absorbers, a reduction of more than 30 °C was measured in the first BPMs of the SSSs. Table 1 shows the total power each new absorber will have to deal with, according to their position in the SS.

Table 1: Total power dissipated in each new radiation absorber according to their position in the SS.

| Absorber | Distance from dipole [m] | Total power [W] |
|---|---|---|
| "Cold finger" absorber | 0.429 | 131.8 |
| 1st BPM absorber (SSS) | 0.938 | 32.9 |
| 1st BPM absorber (LSS) | 1.803 | 16.0 |
| 2nd BPM absorber (SSS) | 2.950 | 10.1 |
| 2nd BPM absorber (LSS) | 6.297 | 5.6 |

## VACUUM CONDITIONING AFTER INTERVENTIONS

The vacuum system of the LNLS electron storage ring consists of 6 cells isolated by all metal rf-shielded gate valves, each cell encompassing two dipoles, one SSS and two half LSS. Each cell has 4 pumping stations (PS), each one comprised of a sputter ion pump (SIP) and a titanium sublimation pump (TSP), which amounts to a total pumping speed of 4520 l/s. For more details about the vacuum system of the LNLS electron storage ring see Ref. [4].

Each cell contains 4 BPMs. To replace the whole set of BPMs scheduled for the two interventions, 22 of the total of 24 BPMs, it was necessary to vent to atmosphere all the 6 cells of the storage ring. Two BPMs were not replaced because they are an early but improved version of a button BPM installed together with the EPU undulator in 2007. The procedure adopted to install the "cold finger" absorbers and to replace the BPMs was to vent one cell at a time. To minimize the exposure time to atmosphere, each cell was vented and pumped back in vacuum in the same day. In other words, the BPMs in one cell were all replaced in one day of work. The 22 BPMs and the "cold finger" absorbers were installed in about 6 days. Almost half of the entire machine SS vacuum chambers were replaced to hold the new components.

The new parts of the vacuum chambers were not baked *in situ*. After installation, vacuum conditioning relied only on beam cleaning. However, prior to their installation in the storage ring, all the new vacuum chambers were *ex situ* conditioned. They were baked to 150 °C during about 48 hours. After the bakeout, all the chambers reached pressures in the low $10^{-10}$ mbar, hence being approved to be installed in the storage ring. The vacuum chambers were maintained in vacuum and were vented immediately before installation. Figure 3 shows the beam conditioning behavior of two typical SSSs after the interventions in October 2008 and October 2009. It can be observed that the behavior of the pressure in both situations is quite similar. In other words, the pressure rise and the decrease slope, also known as "beam-cleaning effect", are similar. The slope of about -0.73 for both curves is close to results obtained in other synchrotron facilities [5, 6]. To increase the conditioning performance, the TSPs were flashed at every injection period. Therefore, in the beginning of the conditioning time the TSPs were flashed several times a day and after the beam lifetime reach the machine design target (longer than 10 h at 100 mA) flashing is being performed twice a day.

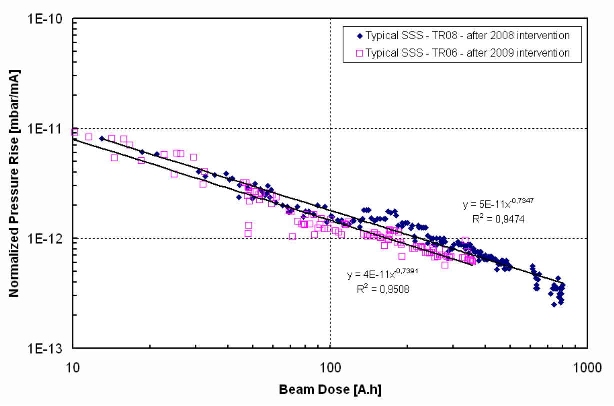

Figure 3: Typical SSSs pressure behavior after the interventions in 2008 and 2009.

Figure 4 shows the product of the electron-beam current (I) and the beam lifetime (Tau) against the accumulated beam dose. The behavior of the beam lifetime after the intervention in 2008 shows that it was still improving with the accumulated beam dose at the time the 2009 intervention started. The evolution of beam lifetime shows a similar conditioning behavior after the second large intervention. A drop in beam lifetime at 170 Ah accumulated beam dose is due to a small intervention in one LSS to remove an insertion device out of the machine. The impact of this small intervention in the vacuum conditioning was not significant and beam lifetime has been increasing with the same slope as before.

Beam lifetime behavior shows clearly that the machine is still being conditioned by the beam. It is expected that it will continue at least up to the same accumulated beam dose reached after the intervention of 2008, i.e., that vacuum conditioning is expect to improve at least up to an accumulated beam dose of about 800 Ah, since there is no evidence in contrary up to this moment.

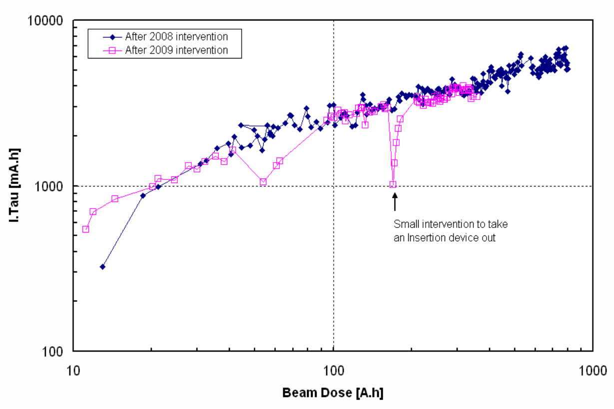

Figure 4: Beam lifetime evolution after the interventions in 2008 and 2009.

## CONCLUSION

We have described the LNLS electron storage ring vacuum conditioning behavior after replacing 22 of 24 machine BPMs and installing new radiation absorbers. The work was done in two steps, 1/3 of the BPMs and the radiation absorbers were installed in a shutdown in October 2008 and the remaining 2/3 in a shutdown in October 2009. Almost a half of all machine SS vacuum chambers were replaced to hold the new components.

The behavior of vacuum conditioning after the two interventions is similar. The pressure rise and the beam-cleaning effect were almost the same when comparing two typical SSSs. The beam-cleaning effect (slope of -0.73) is close to results obtained in other synchrotron facilities. In addition, the beam lifetime evolution has been improving similarly with accumulated beam dose after the two interventions. Finally, the machine is still under conditioning and the beam lifetime is still improving. The vacuum conditioning is expected to last at least up to the end of this year since the lifetime tendency shows no evidence of leveling off.

## ACKNOWLEDGMENTS

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