UPGRADE OF THE BEAM POSITION MONITORS AT THE BRAZILIAN SYNCHROTRON LIGHT SOURCE

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Abstract

We describe the development of a new button-type beam position monitor (BPM) for the Brazilian Synchrotron Light Source (LNLS) storage ring. One third of the storage ring stripline BPMs have been replaced with this new model. We also present performance results.

INTRODUCTION

Since experiments and simulations demonstrated that false readings in some of the stripline BPMs were caused by thermo-mechanical problems [1], the design of a new button type BPM for the LNLS storage ring was started. Besides solving the mentioned problem, the design is also focused on minimizing the long term positional drifts which are observed in the BPM bodies. The first two prototypes were installed in 2007. After the installation, the superior performance was proved in several preliminary experiments [1].

In late 2008 seven of the twenty-four old BPMs were replaced with a modified version of the prototypes. Also, in-vacuum heat absorbers were installed downstream of the 5 adjacent dipoles. It is important to emphasize that this project affects several other equipment in the storage ring; in the dispersive sectors, for example, all the vacuum chambers (except the dipole ones) were replaced in order to allow the replacement of the BPMs. All the activities were planed several months in advance as an effort to ventilate, replace several devices and start commissioning the storage ring within one week. Details of the design, construction, characterization and installation of the new BPMs and accompanying devices are described below.

IMPROVEMENTS ON THE FIRST DESIGN

The two button-type BPMs installed 2 years ago in sector 11 (undulator straight section) were already protected by an upstream cooled mask and bellows to increase the stability of the BPM against ambient temperature variations and vacuum chamber displacements caused by heating. In addition to these, several other modifications were implemented in the recently installed BPMs:

In-vacuum Heat Absorbers

Due to the uneven heating of the vacuum chamber, the varying thermal load along the user's shifts, and also to the injections carried out in the low energy top-up mode [2], movements of the vacuum chamber caused by thermal expansion are inevitable and are not fully absorbed by bellows. To minimize this effect, in-vacuum heat absorbers were developed. These devices are made of cooper and cooled with water at 35ºC. They are designed to prevent synchrotron light from hitting the stainless steel vacuum chamber. Each of these devices avoids the deposition of about 170 W on the chamber walls. Figure 1 shows a 3D model of the in-vacuum heat absorber.

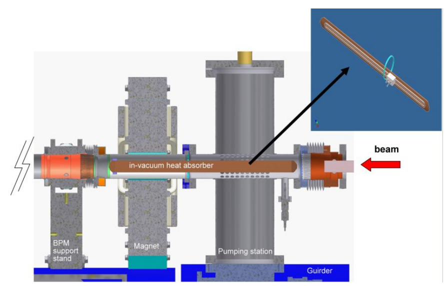

Figure 1: 3D model of the in-vacuum heat absorber used to prevent synchrotron light from hitting the vacuum chamber downstream the dipole magnet.

New Support Stands for the BPMs

The main concern in the design of the new BPM support stand was long term thermal stability. Thermal simulations have indicated that brass is a cost-effective choice for our application. Invar (64FeNi alloy) was not used due to the high costs involved. The manganese-brass alloy (UNS C86300) was the selected material to construct the support stand in spite of this alloy having a relatively high magnetic permeability. However, measurements showed that the quadrupole magnetic field was changed by less than 0.1% due to the presence of manganese-brass pieces in the proximities of the iron poles, and that is within acceptable limits. Figure 2 shows

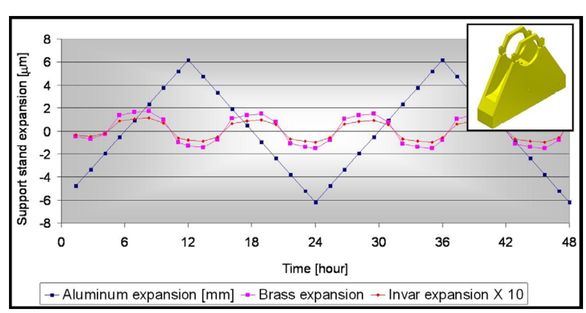

Figure 2: Simulation of the support stand thermal performance.

the BPM displacement simulated for different materials, considering a worst case slow 24 hours periodic variation of the temperature within ± 1 degree Celsius. The result

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shows the low pass filter effect of the brass and invar support stands on the BPM displacement as well as the obvious superior performance of the invar over the brass.

Buttons Brazed in Vacuum Flanges

In order to perform further electric tests with the buttons and make button replacement possible without replacing the entire BPM bodies, the button was adapted to be brazed onto a special flange DN 25 CF-F.

The brazing processes of the flange parts were completely done in the LNLS facilities. The housing for the buttons and ceramics were machined from kovar and the ceramics used is alumina (Al2O3 96%). Figure 3 shows a picture of the button and the 3D model.

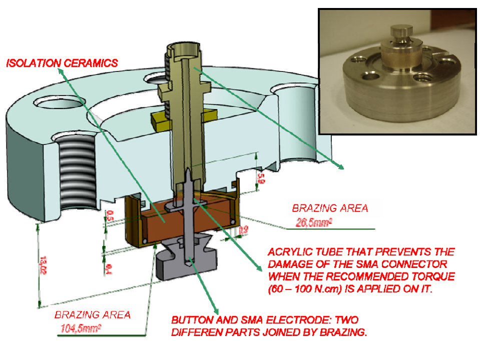

Figure 3: 3D model of the button and a picture of the button after all brazing processes.

During the tests the optimum torque to tighten the flange to the BPM block was determined to be 15 N.m. When this torque is used, the repeatability of longitudinal positioning of the buttons after several assembly / disassembly cycles fell below 15 µm (verification performed using a 3D coordinate measuring machine).

ELECTRICAL CHARACTERIZATION

Capacitance measurements were performed on all buttons in the frequency domain using a network analyzer set at 476 MHz (storage ring RF frequency) within 1 MHz bandwidth. The average value of the measurements was 8.2 pF with a deviation of 0.3 pF. Isolation measurements on all buttons were also performed and showed values around 30 GΩ (@ 500 V), except for one button that showed low isolation after the installation. As in the case of SOLEIL BPMs [4], this problem was solved by applying high voltage to the SMA connector. During this “cleaning” process, pressure peaks were observed in the pump station near this BPM indicating that the problem was in-vacuum. After the operation, this button showed a good 1 GΩ isolation.

Extensive dimensional checks of the BPM blocks and buttons were planned and performed. The BPM sensitivity is determined (to first order) by the BPM geometry factors. Due to that and inspired by the recent experience of some laboratories [3-4] that prioritized offset measurements and beam-based alignment procedures, we decided not to perform the time consuming sensitivity X/Y characterization. Based on the solution adopted at SOLEIL [4], a bench was constructed in order to measure only the offsets of the BPMs, but the results were not conclusive. The measurements showed a strong dependence on the cable lengths used in the tests. The problem is probably related with multiple reflections caused by mismatched electronics inputs. The phenomena that invalidate these measurements are being studied.

MECHANICAL CHARACTERIZATION

The mechanical characterization of all buttons and the BPM blocks was performed using a 3D coordinate measuring machine Mitutoyo B241. The effective machine repeatability was determined through systematic observation of the measurements at the beginning of the process and it is less than 10 µm, so that the RMS error introduced by the measuring system is just few microns.

The face to center distance of each flange receptacle was verified and the 10 µm RMS error represents an excellent result. The longitudinal dimension of the button, in contrast, showed a wider distribution with a peak-to-peak error grater than 100 µm.

After characterizing separately the BPM blocks and buttons, the assembly of blocks and buttons was done and checked in the same 3D measuring machine. Buttons and blocks were matched in order to minimize BPM mechanical center positional errors. By measuring the BPM circumference and buttons longitudinal position, the mechanical center of the BPM is determined. A total 50 µm error was achieved as shown in figure 4. This center determination does not consider the angular error of the button surfaces (0.3 º average error).

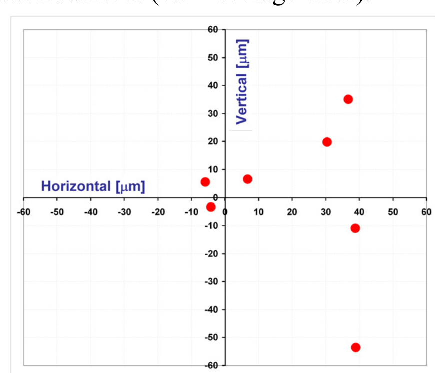

Figure 4: Mechanical offset of assembled BPM blocks. Data obtained from 3D coordinate measurement machine.

FIRST RESULTS

Displacement measurements performed in several BPMs (old and new ones) showed that the new button BPMs drift at least one order of magnitude less. Figures 5 and 6 show one of the tests that prove the superior performance of the new BPMs regarding long term position stability.

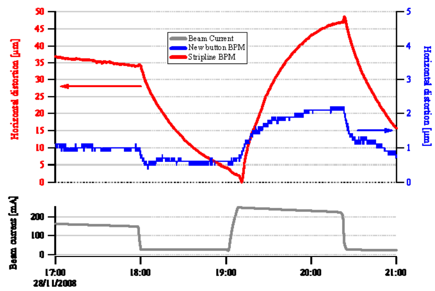

Figure 5: The horizontal distortion (uneven expansion) is more than one order of magnitude smaller in the new button BPMs.

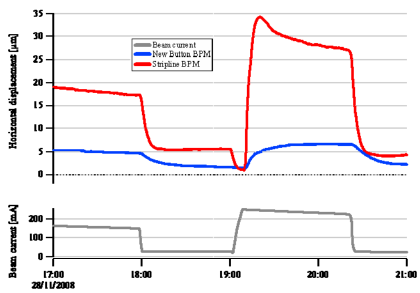

Figure 6: The horizontal drift of the new BPMs is almost one order of magnitude smaller than in the stripline BPMs.

Another important result observed after the partial replacement of the BPMs in the storage ring is the reduction in the absolute temperature at several devices installed in the vacuum chamber. In BPMs located at the dispersive sectors the maximum temperatures was reduced from 76 to 35ºC and the peak-to-peak variation was dramatically decreased from 36 to 3ºC. At the present time the BPMs are not cooled with temperature stabilized water. The positional stability should improve even more when the BPMs are thermally stabilized.

Beam-based calibration (BBC) experiments carried out during several hours in both BPM models also indicated that the positional drift observed is much smaller in the new BPMs [5] mainly in the horizontal plane; despite our assumptions, BBC experiments roughly showed the same result for both BPM models for the vertical plane. Figure 7 shows the 3D model of the new BPM installed in the storage ring.

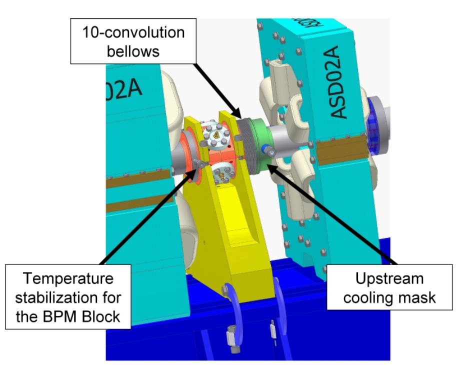

Figure 7: 3D model of the new BPM in the storage ring.

FUTURE PLANS

In November this year we plan to replace all other BPMs. We expect to quantify the improvements using photon beam stability parameters after the entire replacement. The new BPMs installed at the end of 2008, as mentioned before, count on two different inputs for the cooling water: upstream mask and block stabilization. One of the initial ideas was to use the same water circuit that cools the magnets for cooling and stabilizing the BPMs, but it was not implemented due to the temperature variation that occurs in this circuit during the injection periods (usually ten to fifteen minutes twice a day). The water temperature changes nearly a degree during the injection and stabilizes (usually) five minutes after the energy ramp. After stabilization, the temperature is controlled within 0.07 ºC. We plan to test and implement a final solution for the stabilization of the BPMs temperature before starting the second part of this large replacement program.

An intensive effort on the tunnel temperature stabilization is in progress. The overall light source stability will improve significantly when both BPMs replacement and tunnel temperature stabilization are completed.

CONCLUSIONS

The large project that aims to replace all the BPMs of the LNLS storage ring was described. Seven out of twenty-four BPMs have been replaced and the initial results are very encouraging. All tests indicate that the remaining long term drifts are well bellow one tenth of the RMS vertical beam size (about 100 µm).

ACKNOWLEDGMENTS

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