DESIGN OF A NEW BLADE TYPE X-BPM

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Abstract

A new photon Beam Position Monitor (X-BPM) design has been developed in collaboration between the Brazilian Synchrotron Light Laboratory (LNLS) and SOLEIL Synchrotron [1]. This blade-type X-BPM has been carefully studied in order to minimize beam current dependence and temperature dependence. The main advantage of the design is a better stability compared to the standard X-BPMs initially installed at SOLEIL. This new design is used for the new X-BPMs installed at SOLEIL and is being considered for the bending magnet front-ends of the future SIRIUS [2] light source. A first "double" unit has been constructed by LNLS for the two canted Anatomix and Nanoscopium SOLEIL beamlines, and has been installed at SOLEIL in May 2014. Design and first results are presented.

INTRODUCTION

X-BPMs are used in synchrotron machines to monitor the photon beam position in the beamline frontend. They are composed of a stand and a head that supports four blades placed in the photon beam halo (Fig. 1).

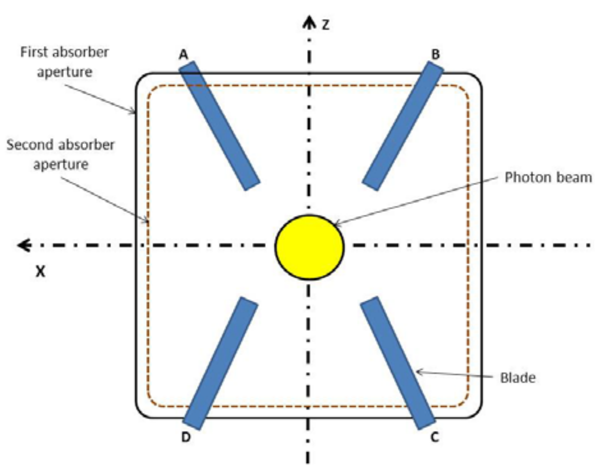

Figure 1: Layout of an X-BPM using blade signals for position measurements of a photon beam produced by an insertion device.

Taking benefit of the photoemission principle, the photon beam will create on each blade a current that vary with the distance between the beam and the blade. The centre of mass of the photon beam is then deduced using the classical difference over sum equation:

$$X_{POS} = K_X \times \frac{(I_A + I_D) - (I_B + I_C)}{I_A + I_B + I_C + I_D} \quad (1)$$

$$Z_{POS} = K_Z \times \frac{(I_A + I_B) - (I_C + I_D)}{I_A + I_B + I_C + I_D} \quad (2)$$

With I_i the current read on blade (A, B, C and D), and K_X, K_Z the horizontal and vertical geometric factors, for photon beams produced by an undulator. In the case of bending magnet or wiggler photon beams, only the vertical position is measured by two pairs of blades.

At SOLEIL, 21 X-BPMs are already installed on undulator beamline frontends, whereas 11 are installed on bending magnets/wiggler beamline frontends.

At LNLS, in total, four X-BPMs are installed, two X-BPMs in the U11 undulator front-end and other two in the bending magnet X-Ray diagnostics beamline.

STABILITY REQUIREMENTS

In its original design, the X-BPM was made of a head supported by a stand, both made of stainless steel (Fig. 2). This design was subject to mechanical deformation in case of temperature variations like tunnel air temperature drifts or changes in the heat load deposited on the X-BPM by the beam. As a consequence, photon beam position reading could be impacted by a few µm, in particular during the few tens of minutes following a reinjection (in case of beam loss).

For beamlines requiring a high stability, the stand has been made of INVAR to reduce its vertical expansion. This expansion was consequently reduced from 3 µm (stainless steel) to 0.3 µm (invar) for a 0.2 °C temperature variation.

Then it has also been decided to study a new X-BPM head to minimize the position dependence to the heat load variations. This work has been done in collaboration between SOLEIL and LNLS.

Since a 3rd generation light source is currently under construction at LNLS, the new concept of XBPM has been considered as candidate solution for all bending magnet beamline front-ends and possibly for some undulator beamlines.

MECHANICAL DESIGN

When designing the new X-BPM head, efforts have been focussed on an optimized power dissipation to minimize the effect on the position measurement.

Symmetrical Thermal Expansion

In its new design, the X-BPM head presents a (beam) axial symmetry, and is fixed to the stand by a cradle in the beam plane. The heat load deposited by the beam is supposed to be homogeneous around its axis which is true

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at least for a centred beam. The resulting thermal expansion of the head material will also be symmetric to the beam axis and cancelled when calculating the beam position using formulae (1) and (2).

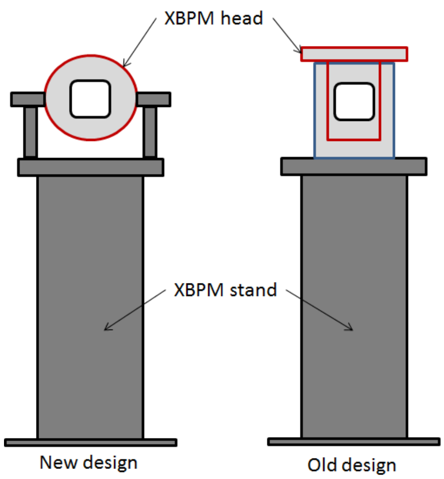

Figure 2: X-BPM head (in red) and stand in old and new designs. Whereas the old X-BPM head was plunging into the vacuum chamber, the new one is supported by a cradle and presents an axial symmetry to cancel the thermal expansion effect in the position calculation.

Heat Load

The heat load deposited by the beam is absorbed by a mask integrated in the X-BPM head. This 30 mm long mask is made of copper and water cooled. The blade support, also made of copper (32 mm), is isolated from the mask and water cooled also. Temperature sensors equip the two copper pieces that are brazed on stainless steel parts, forming the X-BPM head (Fig. 3).

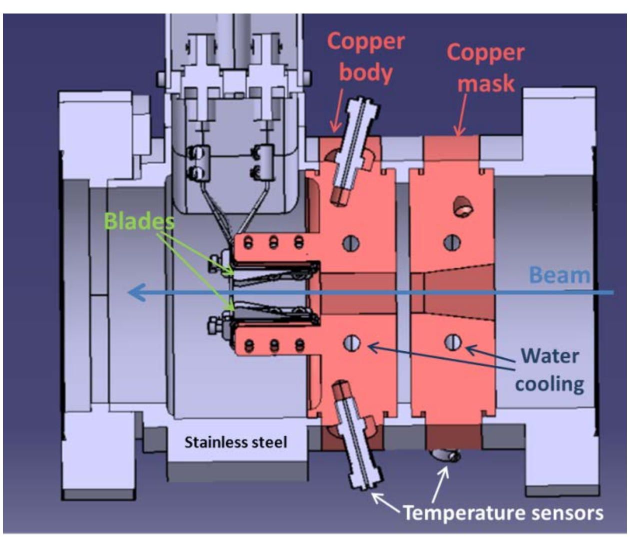

Figure 3: Different pieces of the X-BPM head: mask and body are both made of copper but separated to avoid thermal exchanges. A water cooling circuit is used to extract heat load.

Blades are electrically isolated from the copper body on which they are fixed. Insulator used is Aluminium Nitride ceramics that have a good thermal conductivity to extract

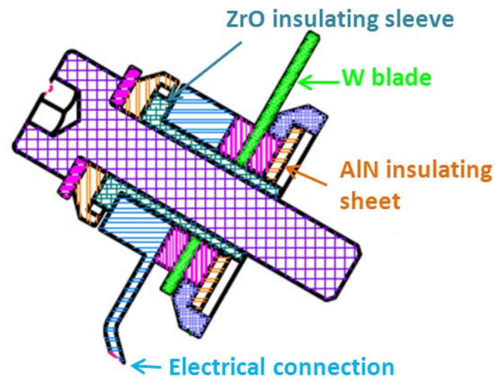

Figure 4: The stack made for blade insulation preserves a good thermal conductivity to extract the heat load deposited by the beam on the blade.

Compacity

With the old XBPM design, an additional absorber (with its associated pumping port) had to be installed upstream in order to protect the XBPM head from unwanted missteered beam. This new design integrates the absorber (mask), saving an additional pumping port and pump, and is only 191 mm long.

MANUFACTURING

It has been decided to manufacture a double unit head to take benefit of the already existing X-BPM INVAR stand installed on the double canted SOLEIL beamlines Nanoscopium and Anatomix (Fig. 5).

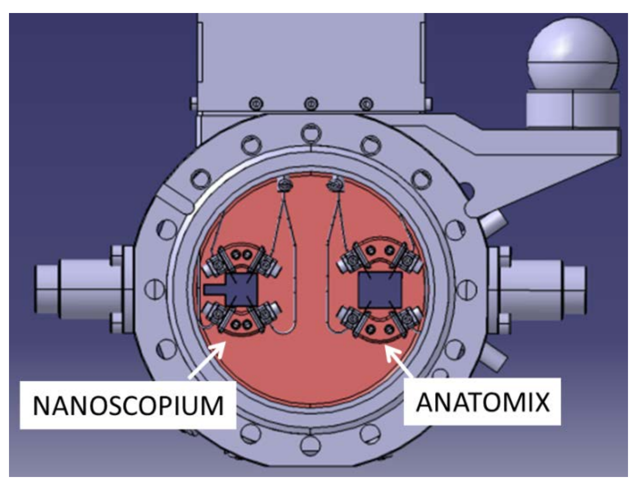

Figure 5: Double unit X-BPM head that has been manufactured for testing on the canted Anatomix and Nanoscopium SOLEIL beamlines.

The manufacturing has been done at LNLS workshop, including brazing and electrical discharge machining (EDM) operations.

PERFORMANCES

The new double unit X-BPM was installed in May and commissioned in July 2014. We first calibrated the XBPM response and then analysed its performances in terms of stability.

The calibration consists in the experimental measurement of the geometric factors K_X and K_Z for each X-BPM unit, which finally enables to get an absolute measurement of the photon beam centroid position. The simplest method consists in displacing the X-BPM unit around the photon beam, but this new X-BPM is not mounted on translation stages as previous SOLEIL's X-BPMs. We displace instead the electron beam on parallel orbits. The displacement amplitude is about +/- 0.25 mm in both planes by steps of 0.05 mm. For the Anatomix X-BPM we found a coefficient of K_X =5.1 in the horizontal and K_Z =2.9 in the vertical plane. For the Nanoscopium X-BPM, we found a coefficient of K_X =2.64 in the horizontal and K_Z =1.68 in the vertical plane. The Nanoscopium coefficients are slightly lower than those of Anatomix because the Anatomix undulator is closer to the X-BPM, allowing higher intensity on the blades and therefore higher sensibility.

The X-BPM stability performances were evaluated using the following procedure:

- The X-BPM is initially "stable": i.e. operated in nominal conditions (at constant current in the synchrotron and constant incident photon flux from the insertion device) for several hours. In these conditions, we can assume that all X-BPM components are thermalized.
- Cooling: The insertion device gap is opened to cool down the X-BPM unit. Every ten minutes the gap is closed for a couple of seconds in order to probe its response during this process.
- Heating (1): Once cooled, the insertion device gap is closed again to observe the heating of the X-BPM by the photon beam.
- Heating (2): The electron beam is finally killed for more than 30 minutes in order to cool both the X-BPM and the whole synchrotron. And after re-injection and closure of the insertion gap, we observe the X-BPM together with the machine stabilization.

In order to ease the stability analysis of the X-BPM unit itself, we compare the X-BPM position measurement to the position predicted by the BPMs measurement using a projection in the X-BPM plane. We compared those measurements to those performed on the previous X-BPM, which was also double unit though only equipped with blades on the Nanoscopium unit. A trend of the experimental session for the characterization of the Nanoscopium unit is presented in Figure 6. The results are summarized in Table 1.

Table 1: Performances in terms of stabilization of the Nanoscopium X-BPM. Difference between position measured by the XBPM and the projection of the eBPM at the XBPM location is evaluated and time needed to stabilize.

		H	**V**
Nanoscopium			
Old Design	XBPM – eBPM projected	**12 µm** stabilized in **20 min**	**27 µm** stabilized in **30 min**
New Design	XBPM – eBPM projected	**26 µm** stabilized in **5 min**	**24 µm** stabilized in **15 min**

Thanks to the new X-BPM design, the time required by the X-BPM measurement to stabilize after machine injection and/or insertion device gap closing has been reduced and is found below 15 minutes i.e. two to four times shorter than with the old design. The time to stabilize the machine itself after injection is now the limiting factor in terms of stability.

COSTS ANALYSIS

The first X-BPM heads of SOLEIL were designed and manufactured by the FMB company (Germany) [3]. The stands were designed by SOLEIL and manufactured in France. The use of INVAR instead of steel or 316L to improve the thermal stability of the X-BPM also caused a huge increase of the material cost. A stand in INVAR is 3 times more expensive than a stand in stainless steel. Because of the lower quantity of INVAR, the price difference of an X-BPM head in INVAR instead of 316L is negligible. But the manufacturing of the head in INVAR caused other issues. All SOLEIL front-end vacuum chambers are 316L and baked up to 250°C. Using a copper ring to link a 316L with an INVAR flange, with respectively $12*10^{-6}$ K^{-1} and $1.2*10^{-6}$ K^{-1} thermal expansion coefficients, causes systematic leakages at the junction after baking. To prevent such situation, baking is locally reduced at 150°C but was still considered inconvenient by the vacuum group. The manufacturing in 316L according to the new design therefore also presented advantages in terms of operation at SOLEIL. The first XBPM head unit based on the new design has been manufactured at LNLS. Since then, SOLEIL ordered two additional "single unit" XBPM to private companies, we could compare the price of an old and new design head in 316L. The difference is negligible. But we do no longer need to install an absorber before the XBPM since it is included in the new head design, which corresponds to a money save of approximately 10.000 €.

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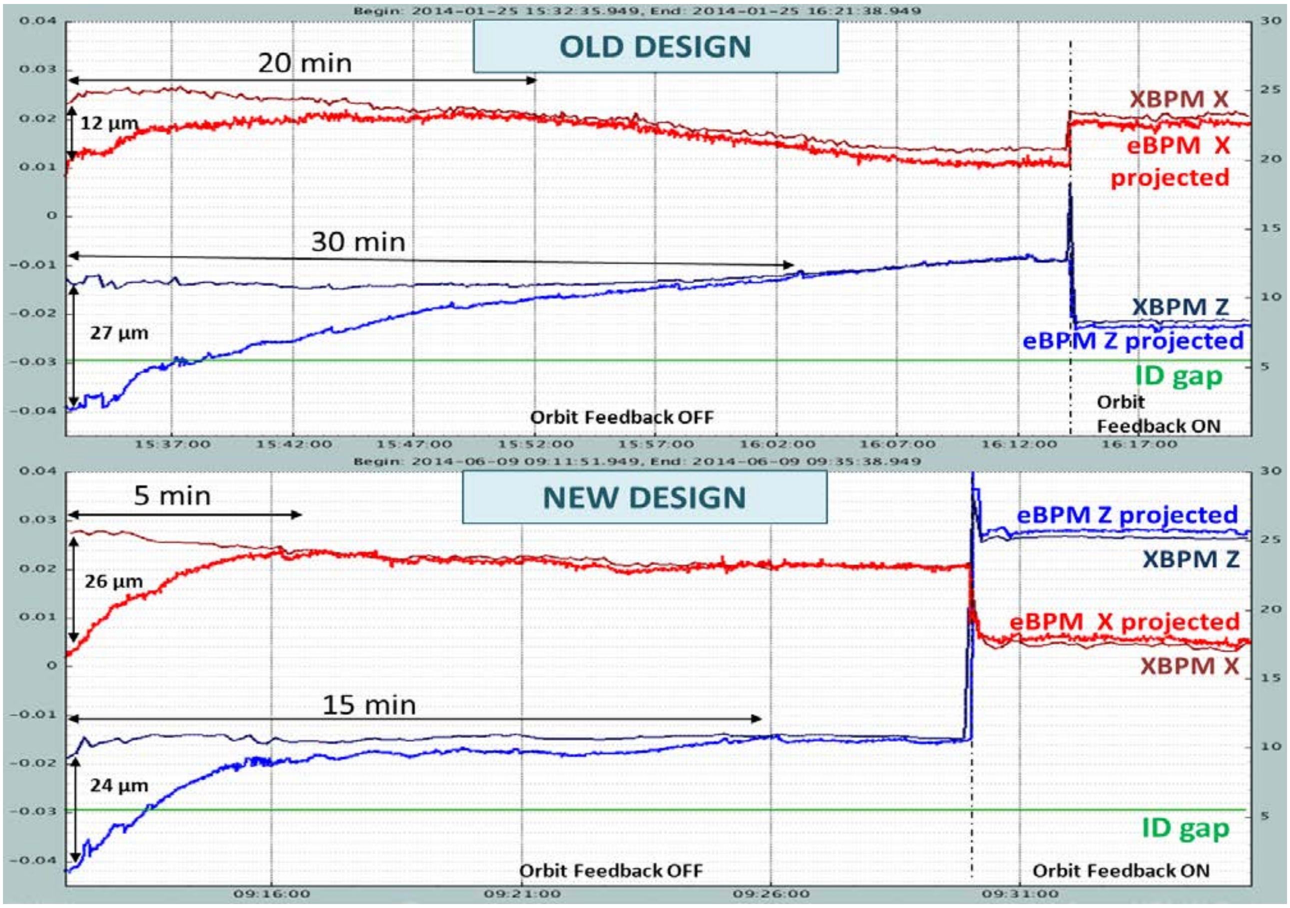

Figure 6: Stability comparison of the Nanoscopium X-BPM: (Up) for the old design and (bottom) for the new design in both horizontal and vertical plane. Stabilization time of the measurement after an injection from 0 to 430 mA has been reduced in both planes with the new design.

CONCLUSION

A fruitful collaboration between LNLS and SOLEIL has been set up to design a new blade type X-BPM head. The main goal which was an improvement of the thermal stability compared to already existing designs, preserving the manufacturing budget, has been achieved. This new design is now used for the new X-BPM to be installed at SOLEIL (already two more units have been manufactured) and is supposed to be used for the bending magnet X-BPM of the future SIRIUS light source.

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