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THE XBPM PROJECT AT MAX IV FRONTENDS, OVERVIEW AND FIRST RESULTS

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Abstract

All the frontends installed on the 3GeV storage ring at MAX IV are equipped with two X-Ray Beam Position Monitors. Having recently finished the installation of the acquisition system, it was possible to record and analyse data. This presentation describes the setup and shows the first results.

INTRODUCTION

Since the writing of the technical specifications for the MAX IV frontends [1], it was foreseen to include X-ray Beam Position Monitors in the design. Being the first real diagnostic tool for the photon beam, and being upstream of all the beamline optics, these devices are capable to decouple beam instabilities and fluctuations originated in the storage ring from the ones originated the beamlines. This makes them an important device when trying to pinpoint the source of a specific disturb. Additionally, they can be used to cross check the readouts of the ring BPMs, and possibly be included in closed loop orbit correction as feedback. Finally, being sensitive to energy and flux, and being the closest diagnostic tool to the synchrotron sources, they are interesting as a verification of the insertion device output.

WORKING PRINCIPLE

The XBPM working principle is based on the photoelectric effect: the emission of electrons from a material when light shine on it. Each XBPM is equipped with 4 tungsten blade that are placed in the outer region of the white beam, usually spaced in a way to have symmetries along X and Y in the beam cross section, as shown in Figure 1.

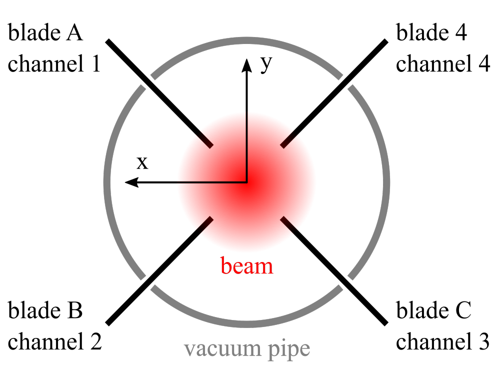

Figure 1: XBPM schematics.

These blades are then electrically connected to an electrometer, so that when photons hit the blades and electrons are emitted, the electric current flowing out of the blades can be precisely measured. Knowing the photon cross-section of interaction of Tungsten, the energy and flux of the white beam and all the involved geometries, it is possible to calculate the theoretical current flowing out of each blade. But most importantly, if the symmetry is not broken anywhere else, imbalances between different blade currents are a direct sign of a difference between positions of white beam center and XBPM center.

This particular characteristic of being sensitive to *relative* signal differences makes these devices quite robust again other sources of error or uncertainties. For this reason, the XBPM are mounted on top of movable stages, and can be moved until the imbalances between different blade signals are zeroed. This placement is then fixed and maintained for long periods, so that short and long term beam movements can be both quantified.

Finally, there is one important complication: since the blades are usually close to each other, the electrons emittted from one blade can end up in another blade, and therefore alter the measurement. This is usually referred to as cross talk, but this issue can be avoided completely by applying a negative bias voltage to the blade themselves. The resulting electric field will then prevent emitted electrons from ending up in neighbouring blades, and each blade will show a reading that is closed to the theoretical one. Some XBPM designs take one step further in this direction and include an additional positive electrode in proximity of the blades, that distorts the electric field even more favourably.

Electric Measurement

The addition of a negative high voltage bias makes electric measurements slightly more complicated. Considering that we are interested in having really high accuracy, since we are interested in a differential measurement between similar blades, and also considering the small absolute value of the currents involved, it is important that all the current produced at a blade is transported to a high accuracy electrometer. The presence of the high voltage bias, however, can lead to very small, but problematic current leakages through the cable insulation. To avoid this problem, triaxial cables are adopted: they consist in a core at the bias voltage carrying the current from blade to electrometer, a first coaxial “shielding” named guard, that carries no signal but is elevated to bias voltage, and a third, proper shielding connected to ground. In this way, having the voltage difference between signal and guard equal to zero, we can guarantee no current leakages through the cable insulation. There will be leakages from guard to shield, but that has no effect on the measurement.

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THE ELECTROMETER

To measure the current of each blade, we adopted the high voltage EM# electrometer, fruit of a collaboration between ALBA synchrotron and MAX IV [2]. This device is fully capable of the resolution necessary for the XBPM electric measurements, it has four channel and the possibilty to add a bias voltage, and finally, its acquisition frequency can go as high as 3.2 kHz. These units come with an ethernet connection and host a webserver with basic functionalities that help make the setup and first measurements extremely quick. A picture of the device is shown in Fig. 2, while Fig. 3 shows the web interface, with the four channel readings in different colors.

Figure 2: the EM# electrometer.

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Figure 3: EM# electrometer web interface.

DATA HANDLING

The XBPMs acquisition can output the current reading of each blade with a rate of up to 3.2kHz. But more interesting than the raw data, are four derived quantities: X position, Y position, Q factor, and the sum S. Naming A, B, C, D the current readouts of the respective blades according to Fig. 1; these quantities are defined as follows:

$$S = A + B + C + D$$

$$X = \frac{A + B - C - D}{S}$$

$$Y = \frac{A - B - C + D}{S}$$

$$Q = \frac{A - B + C - D}{S}$$

The quantities X and Y represents movement of the electric signals center, Q is an indication of either a physical tilt, dipole light presence or other asymmetries, and S is mostly related to flux, and therefore stored current and insertion device gap. Two calibration coefficients K_x, K_y are then required to convert X and Y into physical displacements in µm.

Archiving Strategy

The four values X, Y, Q and S are the ones to be stored, and in particular we are planning to use the newly coming MAX IV FA archive, based on the Diamond light source FA archive [3]; to store a rolling buffer of approximately two weeks of high frequency data.

A slower, periodical beam position archiving will take the data from the fast archive, apply the calibration coefficient, and store the beam position permanently.

Finally, at regular intervals, a Fast Fourier Transformation will generate a snapshot of the beam position in the frequency domain, and these snapshots will also be stored permanently.

This will allow us to have, at the same time, extremely detailed data to investigate exceptional events, and also long term storage to observe slow phenomena, all without consuming unreasonable amounts of storage space.

THE MAX IV SETUP

As mentioned above, we will have two XBPMs per frontend on all the 3GeV ring beamlines. Having currently eight frontends installed, we are operating sixteen EM# electrometers. Due to the use of short triaxial cables, we installed the electrometers in the storage ring tunnel, with a 50 mm thick lead shielding. At the present time, we received all electrometers and all cables, we installed some of them with a temporary set up, and we have plans to finish the permanent installation during the forthcom-ing MAX IV summer shutdown 2018.

RESULTS

We currently have most of the XBPM functionalities on three beamlines: NanoMAX, BioMAX and HIPPIE. The control group installed the first tango devices for the electrometers in BioMAX and we were able to perform XBPM scans in this beamline: the motors controlling the X, Y stages of the XBPMs are moved, and the four signals are recorded together with the axis position. The very first plot obtained with this technique on BioMAX beamline, XBPM 01, is shown in Figure 4.

This scan allowed us to extract the calibration coefficients K_x and K_y, which for these devices are in the order of 1mm for K_x and 0.5 mm for K_y (ring current 200 mA, insertion device gap 5mm). This first difference tell us that the device is about twice as sensitive in the X direction with respect to Y, and this can be traced back to the white beam cross section.

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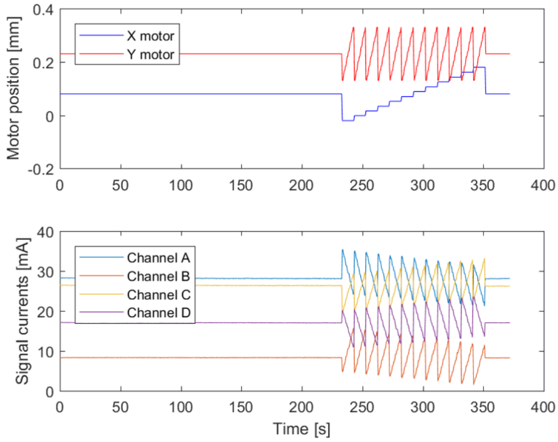

Figure 4: First scan of XBPM 01 at BioMAX.

These coefficients can then be used to plot maps of the XBPM estimated X and Y beam center with respect to real movement of the device itself.

These plots, represented in Figs. 5 and 6, show that the X and Y sensitivity of the device are fairly decoupled, while it is possible that the device itself is mounted with a very small angular error.

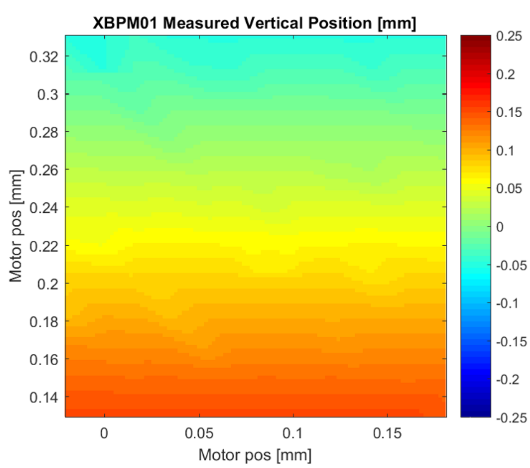

Figure 5: X readout of the calibrated XBPM 1.

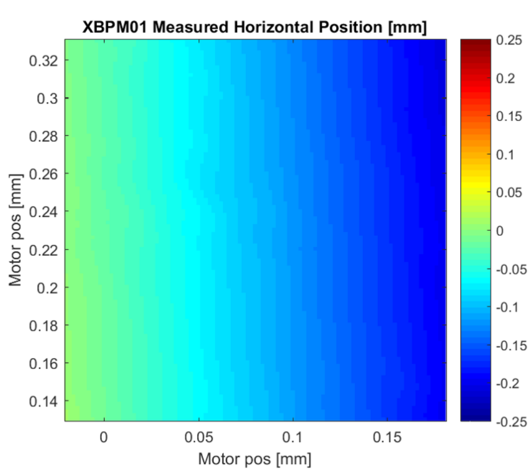

Figure 6: Y readout of the calibrated XBPM 1.

CONCLUSIONS

The XBPM project at MAX IV is starting to deliver results, as an important diagnostic tool that is showing new, unprecedented information about the 3 GeV storage ring, its alignment, its stability and its insertion devices. With the final installation planned to happen in summer 2018, we are now looking forward for a fully functioning set of XBPMs in late 2018 operations.

ACKNOWLEDGEMENTS

A great number of people have been involved in the XBPM project at MAX IV. Most notably, Dr. Krempaski Juraj from PSI, who is in charge of these devices at the SLS and has a deep knowledge of all the aspects of the design, operation and maintenance of XBPMs. Chris Bloomer from Diamond light source was also very generous in sharing his vast expertise on these, and other kinds of XBPMs. And Dr. Michael Böge from PSI contributed with his expertise on feedback system, having implemented the XBPM in the SLS slow orbit feedback himself. Precious help, interest and assistance also came from the beamline staff at MAX IV, the machine and operators group, and of course the controls and software groups both at MAX IV and ALBA. Without all these contributions, this project could never have been successful.

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