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PHOTON POLARIZATION SWITCH AT ALBA

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Abstract

The polarization of the synchrotron radiation produced by a bending magnet can be selected by properly choosing the vertical emission angle. At beamlines this can be done by moving a slit to block unwanted polarization: this method is time consuming and not very reproducible. Another option is to fix the slit position, generate a local bump with the electron beam, and vary the emission angle at the source point such that the sample is illuminated with the desired polarization. At ALBA, we have implemented this option within the Fast Orbit Feedback, which allows to perform the angle switch in less than one minute without affecting other beamlines. This report describes the implementation of this technique for the dipole beamline MISTRAL at the ALBA Synchrotron.

INTRODUCTION

Some experimental techniques, such as imaging in the magnetic domain, take great advantage from using different polarizations of synchrotron radiation. At ALBA, the MISTRAL beamline is devoted to these technique and a fast and reliable polarization selection mechanism is demanded.

The polarization of the synchrotron radiation produced by a bending magnet is distributed as a function of the emission angle, as depicted in Fig. 1. Until last year, polarization was selected by means of movable slits. This process works fine but creates problem of optics stability related with heat-load of components: when changing the mask position, a different part of the optics is enlightened and time for thermalisation is needed for thermal stabilization. Moreover, since the radiation follows a different optical path, the sample location also had to be adjusted, making the process unpractical and time consuming.

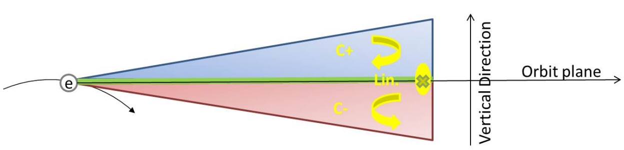

Figure 1: Synchrotron radiation produced by an electron beam passing through a bending magnet: the polarization is different according to the emission angle (C+: Circular Positive, C-: Circular Negative, Lin.: Linear).

Another approach, already experimented at PSI [1], is to generate bumps with the electron beam. Doing this the radiation follows always the same optical path, and the desired polarization can be selected without varying the position of the slit.

At ALBA, we decided to implement the Polarization Switch for the MISTRAL beamline within the Fast Orbit FeedBack (FOFB) architecture.

SWITCHING MECHANISM

In order to switch the polarization of synchrotron radiation, the idea is to create bumps at the MISTRAL source point so to locally change the direction of the orbit plane. In this way, when switching polarization, the position of the electron beam is kept while the angle changes, allowing to select a different polarization. Figure 2 shows the bump necessary to obtain positive and negative circular polarization.

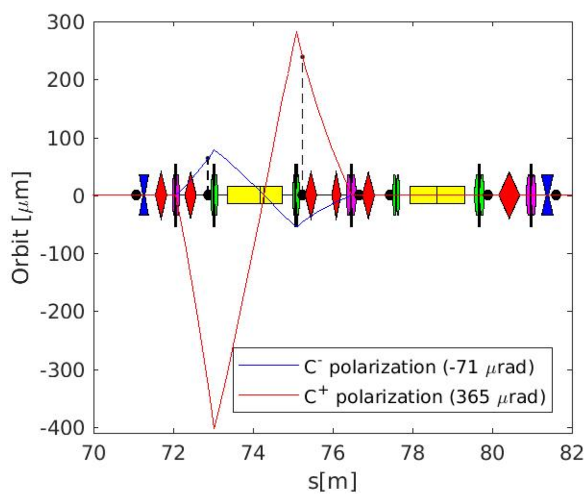

Figure 2: Bump to select different polarization at MISTRAL source point: negative polarization in blue, positive polarization in red. The dashed line represents the position of BPMs involved in the bump. The asymmetry is due to the initial alignment of the beamline.

At ALBA, before the switching mechanism was implemented, it was not possible to generate such a bump during normal operation since a FOFB system is running to keep the distortion with respect to to the golden orbit lower than 1 μm RMS.

At the beginning, the choice of not changing the FOFB code was taken, and thus an online modification to the golden orbit was discarded. The other option was then to displace offsets of BPMs involved in the bump to "trick" the FOFB system to actually produce it.

The formula to obtain the beam position x from a BPM button is:

$$x = k_x \frac{\Delta}{\Sigma} - \delta x$$

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where k_x is the BPM sensitivity and $\frac{\Delta}{\Sigma}$ depends on the real position of the beam within the buttons. δx is the BPM offset that takes into account mechanical imperfection of BPM blocks and defects related with the electronics. The offset is obtained by Beam Based Alignment [2] and it is usually fixed unless any change in the electronics occurs.

The FOFB ensures that x is always as close as possible to the ideal beam position provided by the golden orbit within 1 µm RMS. An offset variation (δx) with the FOFB running would then produce a real displacement of the beam. Producing a synchronous offset variation in two BPMs, one before and one after the source point, generates the bump.

ALBA FOFB

ALBA FOFB system is a distributed system based on Diamond Communication Controller (for BPMs) and PSI protocol (for power supplies) working at 5 kHz and dumping frequencies up to 100 Hz [3–5].

At a glance, it is composed of 88 BPMs and correctors in the horizontal plane and 87 BPMs + 1 XBPM and 88 correctors in the vertical plane. For each of the 16 ALBA sectors, data from 7 or 8 BPMs are collected and treated by a FOFB processing node which also controls correctors power supplies.

Libera Brilliance electronics are used for BPM data treatment and a Libera Photon is used for the X-BPM [6]. Horizontal and vertical position is then collected to the processing node via an FPGA used as sniffer. Data are then passed to a CPU in which the correction is calculated and sent to correctors.

At ALBA the XBPM located in the MISTRAL frontend is integrated in the FOFB since the early time of operation. Strong thermalisation drifts were observed when the machine was still operating in decay mode [7]. The heat load of the accelerator beam pipe was provoking a drift with respect to the frontend, visible in the XBPM (Fig. 3), which has been finally compensated by adding this device in the FOFB loop.

IMPLEMENTATION OF POLARIZATION SWITCH

As explained in previous sections, the polarization switch is performed by modifying offsets of two BPMs to perform a local bump around the MISTRAL source point. The goal is to achieve

$$\frac{\text{Orbit Distortion}}{\text{Vertical Beam Size}} < 5\%$$

when moving from one polarization to the other, so that the process is transparent for other beamlines.

To achieve this requirement, a BPM-corrector pair for the vertical plane had to be added. Also, since the beam is passing off-center in the nearby quadrupoles when one of the polarizations is selected, an extra skew was added to correct the coupling.

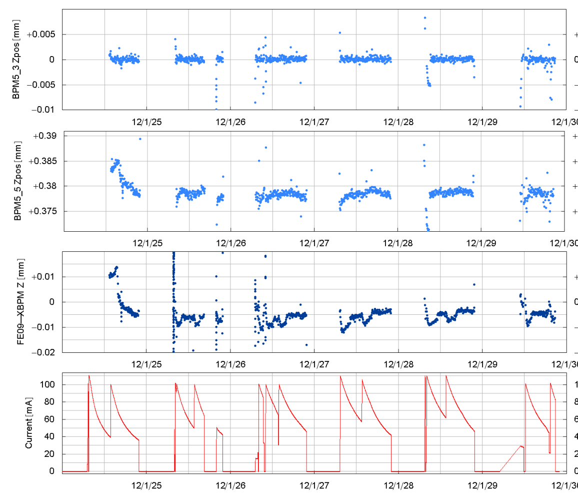

Figure 3: Drift of the x-ray beam when using only electron BPMs in the FOFB. First two plots in light blue represent the position measured at BPMs (in the loop), while the third plot is the position measured at the XBPM (mind the vertical scale). Finally, in the last plot, the current during decay mode.

During operation, two BPMs and the XBPM are involved in the swap. Two of them are used to perform the bump and another to monitor the performance.

BPMs Offset Change

The final offset to produce the bump is in the orders of hundreds of µm, thus little steps in the order of 1 µm at a 20 Hz rate are used to go from one position to the other to minimize perturbation.

It has been observed that the BPMs device server was not fast enough to send the "change of offset" command. Figure 4 shows the response of the FOFB when data were sent at 10 Hz: glitches due to the sudden change of offset only appear at a rate of roughly 1 Hz.

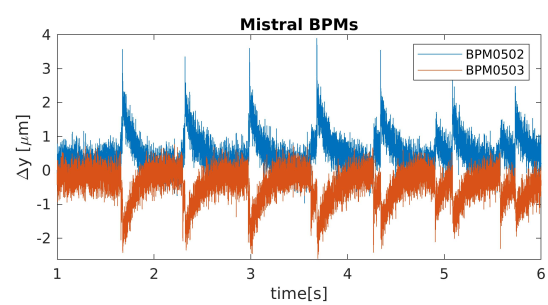

Figure 4: Response of the FOFB to a change of offset of 4 µm at a rate of 10 Hz, the actual offset change appears at a frequency of 1 Hz

For this reason, a script to modify the offset directly running in the Libera has been developed. On the other hand, in order to run the software the device server of the specific BPM has to be off. This is not a problem with FOFB or

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interlock, since everything runs by hardware. Some disadvantages appear with the archiving system, taking data from the device server. This has been solved by acquiring and decimating data directly from the Fast Archiver [8].

Gain and Regularization

Also, a trade between speed and noise when moving from a position to another of the bump had to be found. The chosen solution was to decrease the regularization of the inverse response matrix (α) and integral gain of the PID (K_i) only in the sector of MISTRAL source point. Several tests were performed showing this was the good compromise, as presented in Fig. 5. At ALBA, the typical values are $\alpha = 1$ and $K_i = 1000$, while, after the implementation of the polarization switch, the regularization and gain for the MISTRAL sector are set to $\alpha_{loc} = 0.01$ $K_{i,loc} = 100$.

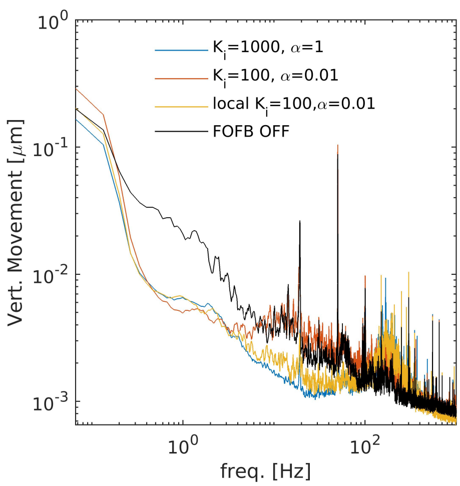

Figure 5: ALBA beam spectrum without FOFB (black) and with FOFB using different regularization (α) and feedback gains (K_i). In yellow the chosen combination: local $\alpha = 0.01$ and $K_i = 100$.

XBPM Range

The bump for polarization switch can be performed using either two standard BPMs or using one BPM (the one before the MISTRAL source) and the XBPM.

After discussions with the beamline, the second option was chosen in order to guarantee photon beam stability at the frontend. The main disadvantage related with this choice is the lack of linearity of this detector over the whole span of the bump. Moreover, position measurement accuracy strongly depends on the range in which the Libera Photon is operating.

Another issue comes from the fact that the XBPM electronics is close to the cross between two different operation ranges. Figure 6 shows a a bump performed using the two electrons BPMs and monitored using the XBPM for several acquisitions: while the bump is changing, the range of the XBPM changes generating some glitches, which the FOFB attempts to correct, generating perturbations.

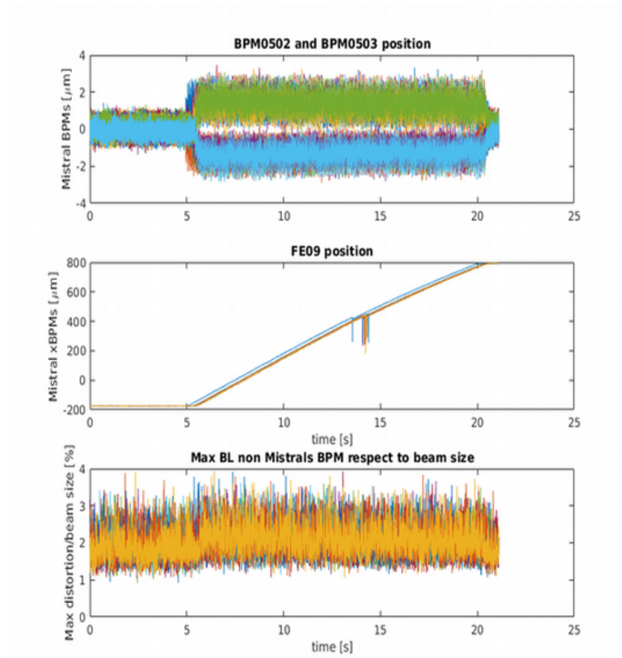

Figure 6: Top: position at the BPMs where the bump is generated. Center: position at the XBPM used to monitor the bump (note the glitches in the center). Bottom: perturbation generated in BPMs of other beamlines.

To avoid these glitches, the auto-range functionality of the Libera Photon has to be disabled. This creates some problems when injecting from zero current and trying to start to correct the orbit at 2 mA while using a range suitable for 2 mA. This leads to saturation of the FOFB and, as a consequence, to beam loss. To avoid this, the polarization switch operation mode can be activated only at full current.

Beam Size

Finally, a feed-forward on the vertical beam size has to be used to maintain it constant when bumps are active. To do so, a new skew magnet was added. Figure 7 shows the beam size with and without the feed-forward for different polarization which can be identified with different positions in the monitoring BPM.

OPERATION

After several tests performed during machine dedicated time in collaboration with MISTRAL beamline, the polarization switch operation mode is available for user since December 2021. A Graphical User Interface (GUI, Fig. 8) allows to arm and to select the desired polarization. Little adjustment to the bump in steps of 5 μm can be performed if requested from the beamline.

The operation mode can be enabled or disabled directly from the general Insertion-Device GUI. If the operation mode is enabled, polarization switch can be performed directly from the beamline via a Tango gateway.

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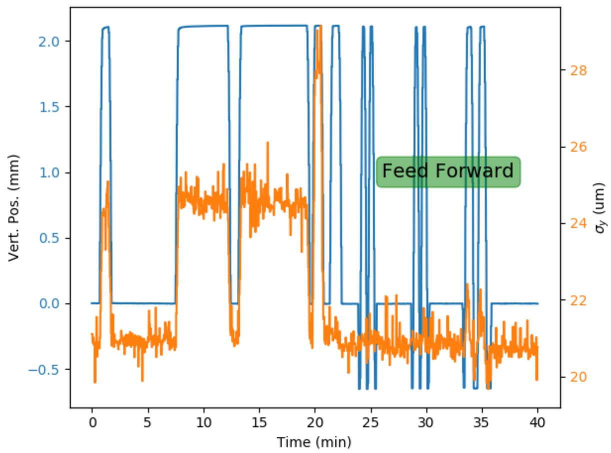

Figure 7: Vertical beam size when performing polarization switch with and without the feed-forward. Blue: position of the beam at the monitoring BPM. Orange: beam size.

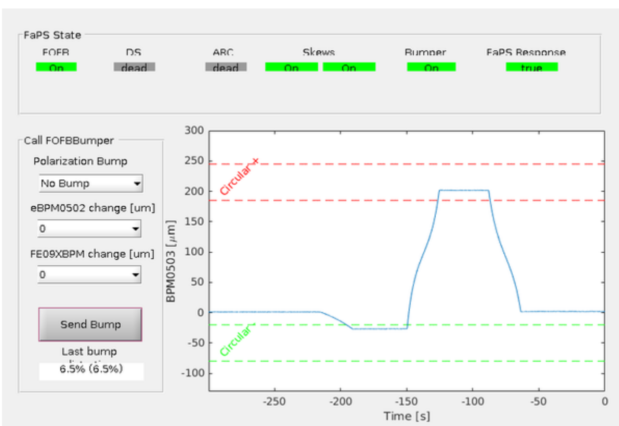

Figure 8: GUI used in the control room to arm and control polarization switch.

For all the possible polarization changes, the average perturbation seen from BPMs which are not involved in the bump is always lower than 5%, as shown in Table 1.

Table 1: Perturbation of the Orbit with respect to the Beam Size when Switching Polarization

	C+	**C-**	**0**	**Lin.**
C+	–	5%	4.6%	4.3%
C-	5%	–	3.8%	3.8%
0	4.6%	3.8%	–	3.9%
Lin.	4.3%	4.6%	4.3%	–

SUMMARY

A polarization switch operation mode has been developed at ALBA for the MISTRAL beamline. The polarization of the synchrotron radiation is selected performing a bump at the MISTRAL source point to modify the emission angle and select only the desired polarization.

Since December 2021, this operation mode is available for the beamline which can perform the switch without interaction with the control room.

Techniques such as magnetic imaging have already taken advantages of this type of operation showing interesting details that could not be achieved before at ALBA.

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