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MONOCHROMATOR CONTROLLER BASED ON ALBA ELECTROMETER Em#

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Abstract

Guaranteeing that the X-Ray beam reaches the experimental station with optimal characteristics is a crucial task in a synchrotron beamline. One of the critical factors which can lead to beam degradation is the thermal drifts and the mechanical inertias present in the optical elements, such as a monochromator. This article shows a new functionality of the ALBA Electrometer (Em#), which ensures that the beamline receives the maximum possible beam intensity during the experiment. From the current reading of an ionization chamber and driving the piezo-actuator pitch of the monochromator, the Em# implements a Perturb and Observe (P&O) algorithm that detects the peak beam intensity while tracking it. This feature has been tested on NOTOS beamline and the preliminary results of the performance are shown in this paper.

INTRODUCTION

Monochromators are essential elements in a beamline to study the behaviour of materials and they actively play a role to perform spectra and scans in 3rd generation synchrotrons. While they are robust optical elements they are still subject to slight beam degradation caused by the mechanics inertia, temperature drifts and the parallelism of the crystals. To deal with this, several beamlines at ALBA have been using the Monochromator Controller from ESRF for many years. As the number of beamlines increases the need to guarantee stock and support of these controllers has led to explore the development of a monochromator controller using the ALBA Electrometer Em# [1]. Another motivation to implement this new functionality to the Em# is to use the monochromator controller in oscillation mode, allowing to operate at the maximum point of the intensity.

NEW FUNCTIONALITY OF THE EM#

The implementation of this new feature of the Em# is based on the usual arrangement of a beamline to monitor the intensity generated by an ion chamber in the end station. In particular, it has been designed considering the structure of the NOTOS beamline at ALBA. In the experimental hutch, an ion chamber is used at the sample environment generating a current that is measured by an Em#. The monochromator controller will apply an analogue voltage signal to the piezo amplifier that drives the piezo motor stacked over the pitch stage of the DMM monochromator in the Optical Hutch (Fig. 1). Due to this mechanical arrangement of the pitch crystal, the motion produced by both the stepper motor and the piezo will affect the same encoder reading on that stage. For that reason, the pitch axis has to operate in open loop to be closed then by the ion chamber, generating the current to be processed by the monochromator controller and applying a voltage to drive the piezo.

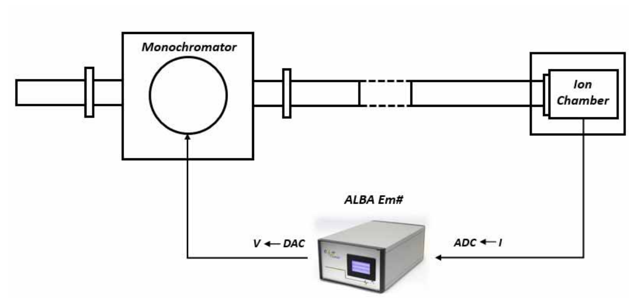

Figure 1: Schema of the Em# as monochromator controller.

The Em# will process the incoming values by executing a Maximum Power Point Tracking (MPPT) algorithm (Fig. 2), based on a Perturb and Observe (P&O) technique widely used for optimization of power management of solar cells [2].

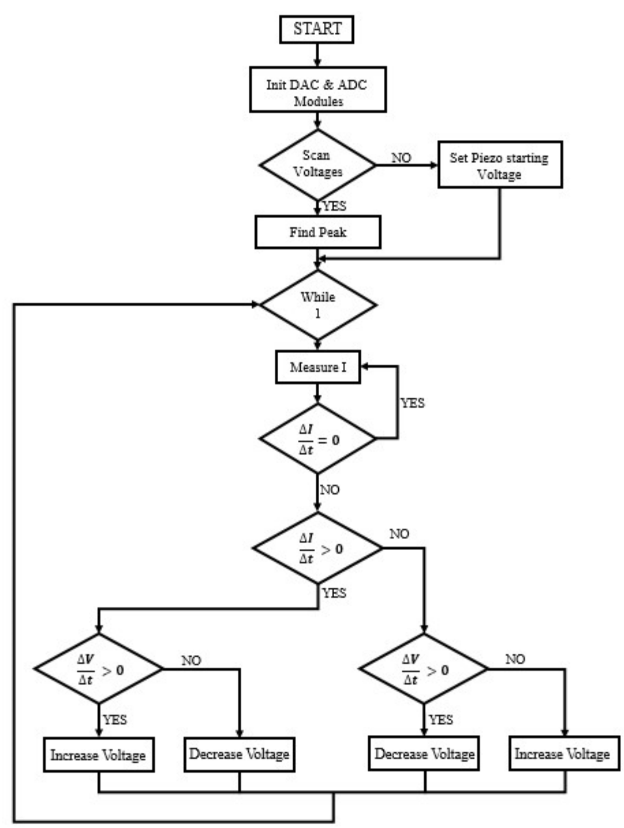

Figure 2: MPPT algorithm of the Em#.

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After initializing the modules for the acquisition, the Em# will do (if selected) a scan of the voltage range (0 to 10V) to find the peak of intensity and will set the piezo to the corresponding position. If the voltage scan is not performed, the user should set the starting voltage from which the controller regulates. At this point the Em# will constantly measure the current. After each measure, it will evaluate the current value with the past one. While the value is the same as the past one it will not change the voltage because is already on the maximum point. While the value is different, it will analyse if the current is increasing or decreasing and to which side of the peak is approaching by comparing the values of the voltages at each iteration.

PIEZO CHARACTERIZATION

Before starting the test of the monochromator controller operation, it was decided to test and characterize in open loop the behaviour of the piezo motor by reading the current generated in the ion chamber.

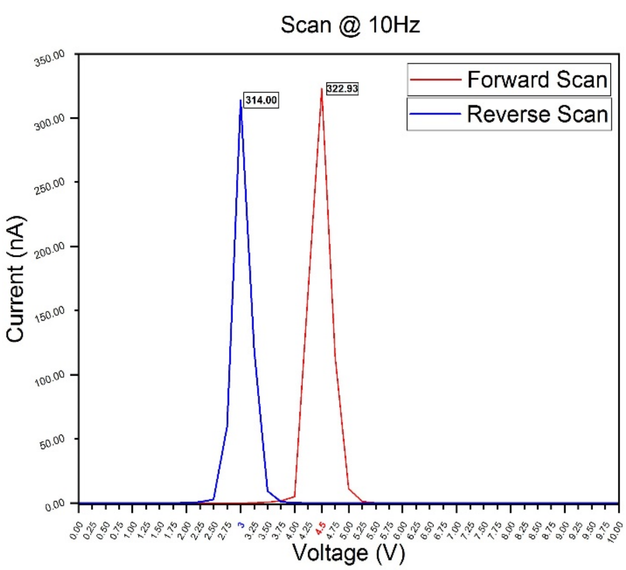

Figure 3: Scan of the voltages at 10Hz.

Figure 3 shows the curves of the scans of voltage to find the maximum value of the current (scan done before the while loop in Fig. 2). The frequency of this scan is 10Hz and the step is 0.25V. The red line belongs to the forward scan having the maximum of 322.93 nA corresponding to a piezo voltage of 4.5 V. In the reverse scan the peak value is 314 nA for a voltage of 3 V. It is clearly observed that the error occurred by the non-linearity issue of hysteresis is about 15% of the range.

As it is shown in Fig. 4 the peaks of the current curves (forward and reverse scans) are much closer. This scan has a step of 0.1 V and a frequency of 1 Hz. The error incurred by hysteresis is reduced to 0.2 V (2 % of error of the piezo travel range).

Comparing Figs. 3 and 4, it is seen how the hysteresis depends on the frequency of the voltage applied [3]. However it is questionable if this will entail a limitation in the controller operation because the delta steps applied to increase or decrease the piezo voltage are much lower than 0.1 V in real operation.

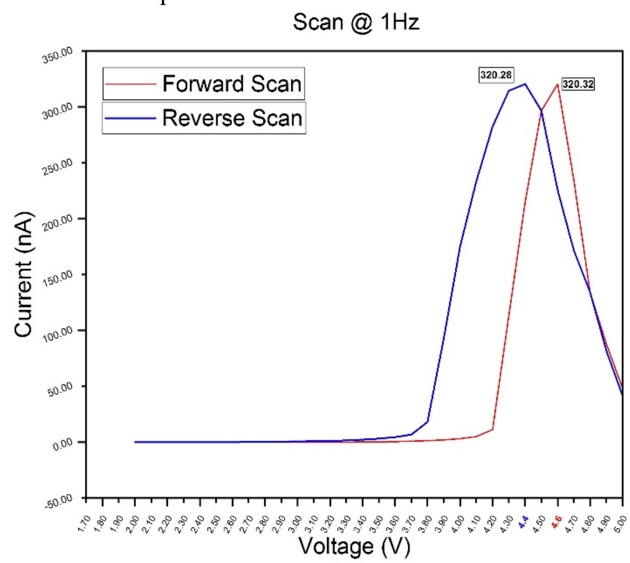

Figure 4: Scan of the voltages at 1 Hz.

In the same way, the creep phenomenon is not considered to be disturbing the regulation of the algorithm because it is known that is a slow drift response that appears some milliseconds after the voltage is applied. Furthermore, it has not the same creep effect two signals with different history [4]; i.e., a signal from 0 to 5 V than a signal from 3 to 7 to 5 V.

FIRSTS TESTS ON THE BEAMLINE

The tests have been carried out in the BL16 NOTOS beamline to show the performance of the ALBA Em# as monochromator controller. It is worth to note that the current algorithm is only focused on maximizing the current of the ion chamber, acting as an equivalent to what is called oscillation mode in the monochromator controllers that are already being used at ALBA. The purpose is to deal with two of the common monochromator issues mentioned previously: the mechanics inertia and the parallelism of the crystals. The third one, the temperature drift, is out of the scope of the regulation since, due to its nature, this behaviour is much longer in time (around hours).

The test was executed by performing a qExafs (quick Extended X-ray Absorption Fine Structure) scan where it can be visible the regulation of the algorithm by superimposing a reference scan (without the Em# new functionality) and the regulation one. Prior to launching the energy scan, a rocking curve is used to align the pitch crystal within the stepper motor range, on top of which the piezo is actuating.

In Fig. 5 it is shown the results of the scan of an energy range from 5000 eV to 12000 eV, an acquisition of 3500 points and integration time of 0.1s. The scale of the current is in the range of hundreds of nA since a filter of Aluminium 10 µm thick was inserted. In these scans, to move within the energy range it was not used the perp motor, the one that changes the crystal gap, to easily compare the performance of the Em# regulation.

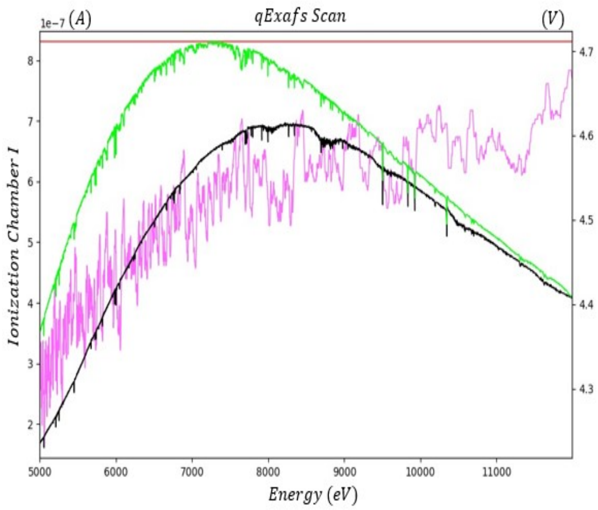

Figure 5: Energy scan with and without algorithm.

Figure 5 shows that the Em# regulation, green curve, is maximizing the current in the first half of the scan while maintaining it in the second half with respect to the reference scan (black curve for current and red curve for the steady voltage). As the energy is increasing, the current also increases and the controller maintains this tendency by adjusting the crystal inclination (pink curve) to compensate any disturbance inherent to the motion (bragg motor to increase the energy) and any instabilities of the mechanics. However, this regulation is clearly introducing noise to the system as well. Since the measurements of the electrometer are punctual, any noise added to the measurement can fake some value so the algorithm will make the piezo to oscillate. In order to deal with this disturbance, a fifo queue was implemented in the algorithm to average an amount of values (the user can set this window size). Besides the noise in the signal, the downwards peaks of diffraction (inherent to the crystal of the monochromator) seen in the black curve also disturbs the regulation. This intrinsic artifact is not aimed to be corrected, in fact, a filter to ignore compensation of these glitches is implemented. By getting the standard deviation of the fifo and comparing if the difference, maximum minus minimum values in the queue, is greater than the standard deviation times a factor (that needs to be set), the algorithm will ignore this value and, hence, not regulate.

CONCLUSION

After the initial tests on the beamline of this new feature of the Em#, it has been proved that the device can act as a versatile element.

The performance of the monochromator controller belongs to a preliminary design that establishes the proof of concept and gives an insight of its potential use for beamline operation in the future. This implementation will solve the problem of stock of this type of controllers and will ensure a continuous support taking advantage of the in-house foundation of the Em#. Furthermore, for the same reason, it will ease the integration of the controller within the ALBA control system.

It was observed that it is achieving to maximize the current over the energy range, but at the expense of introducing noise. Another drawback of the actual implementation is that the parameters of the algorithm needs very accurate fine tuning and can vary within the environment (i.e. beamline).

The functionality is designed with the possibility of having a variable delta step, but it was not implemented due to the initial stage of the project. It is still in development stage, where the main efforts will be focused on reducing noise. As a first approach, a hardware filter is aimed to be implemented in the input of the piezo driver to lessen the noise introduced by applying the voltage from the electrometer. Modification of the algorithm will be done regarding the same objective as well as changing the measurement of the electrometer by oversampling the acquisitions. More tests will be performed on different energy ranges and conditions, as the use of the perp while moving in energy. Further steps will be done to explore other types of regulation and on the integration of the new functionality in the control system.

ACKNOWLEDGEMENTS

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