DUAL BEAM X-RAY BEAM POSITION MONITOR

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Abstract

Presented are the first results from the custom built I04 X-ray Beam Position Monitors at Diamond Light Source, using a single device to measure two adjacent beams in one front end. Synchrotron Light Sources are increasingly in demand by both academic and commercial users, and the number of 3rd generation light sources is growing rapidly. In order to make best use of the facilities a number of synchrotrons have adopted a scheme whereby two canted Insertion Devices occupy a single straight. Two beams are produced, separated by an angular divergence in the order of 1mRad, and both beams proceed down the same front end before being separated into two experimental hutches. This paper describes the techniques used at Diamond to accurately measure the position of both beams simultaneously with micron precision.

INTRODUCTION

A relatively new development in Synchrotron Sources is the concept of utilizing a single Insertion Device (ID) straight to produce two independent X-ray beams into two experimental stations. Such beamlines have been constructed and operated at both the APS [1], and at the ESRF [2]. At Diamond such a system has been designed and developed for the I04 Macromolecular Crystallography (MX) beamline. I04 has been operating now since January 2007 as an in-vacuum 23mm period undulator beamline, tunable over the wavelength range 0.5 - 2.5Å, to enable Multiwavelength Anomalous Diffraction (MAD) experiments to be carried out. J04 is a complimentary out of vacuum monochromatic undulator for MX fixed at 0.916Å that was installed in November 2008.

The IDs are located in the same straight, spatially separated by 1.9m and canted to produce beams separated by 0.98mRad (Fig. 1).

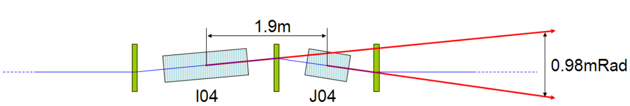

Figure 1: Schematic of I04 ID straight.

Both beams pass down the same front end and enter the first optics hutch where a beam splitter separates the beams further into two separate experimental cabins. This technique saves space within the synchrotron and allows more experiments to be performed for lower additional cost.

Each beam is capable of being independently tuned by altering each ID gap without the neighboring beam being affected. We verify this by observing the behavior of the electron orbit as the gap changes.

BEAM POSITION MEASUREMENTS

Traditional tungsten blade X-ray Beam Position Monitors (XBPMs) are capable of making sub-micron precision measurements of the position of a single beam. Four negatively biased blades intercept the edges of the X-ray beam (Fig. 2, left) and photons striking the surface of the blades liberate electrons. A low current monitor detects this loss of electrons as a current, and using the difference-over-sum method [3] one can deduce the position of the centre of the beam.

The four blade device is an elegant solution to the problem of accurately resolving beam positions, but unfortunately the system only works when dealing with a simple near-Gaussian beam distribution. Trying to resolve the centre of none-Gaussian distributions, such as that from a Helical Undulator, is much harder [4], and trying to resolve the distribution formed by two beams (Fig. 2, right) is impossible. Other Light Sources do not even attempt to measure the beam position in the front end in these circumstances.

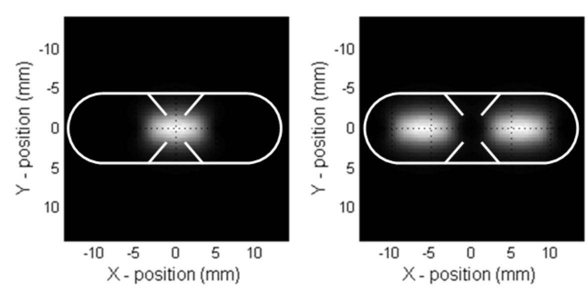

Figure 2: A standard four blade XBPM with the light from a normal ID (left) and light from two canted IDs (right). In this example the light from the two canted IDs has been normalised so they are of equal intensity.

EIGHT BLADED XBPM

However, a new XBPM designed and built as part of a collaboration between Diamond Light Source and FMB is capable of making sub-micron precision position measurements of both beams independently. Two sets of four blades are arranged within a single device using two blade holders (Fig. 3, Fig. 4). The two sets of four are treated independently and connected to separate low current monitors.

This setup requires very precise positioning of the XBPM blades. At the location of XBPM-01, 12m from the centre of the straight, the beams are separated by only 11mm.

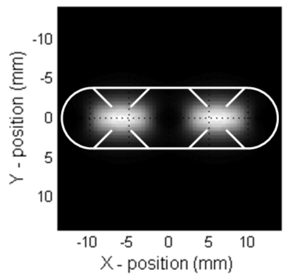

Figure 3: Eight blades, positioned correctly, are able to resolve the two beams.

In order to minimize noise or interference from one set of blades to the other (and to help ease overcrowding within the XBPM) the blade holders are longitudinally offset by 70mm (Fig. 4). This helps prevent liberated electrons from one set of blades interacting with the second set of blades.

The photo-electric cross section of tungsten dictates at what photon energy electrons are liberated. This cross section is weighted heavily towards low energy photons [5] and as a result most electrons liberated have an energy of less than 10keV. Electrons in the energy range of a few keV tend to be emitted approximately perpendicular to the photon path, as described by the Sauter distribution [6]. As a result free electrons released from one set of blades do not tend to interfere with the other set of blades in this configuration.

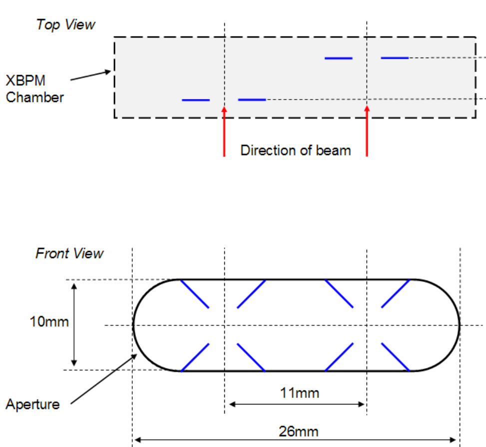

Figure 4: Dual beam XBPM schematic.

Each of the blades is biased at -70V in order to aid the liberation of electrons, and to ensure that free electrons are repelled.

Although the two beams are separated by 0.98mRad there is some overlap of their fringes. Each set of blades picks up a small amount of signal from the neighboring beam. However, we expect this cross talk to be a constant signal and thus can correct for it using a simple background subtraction script.

DETERMINING THE BEAM POSITIONS

The XBPMs are mounted on 2-axis stepper motors. By scanning the stepper motor back and forth across the aperture it is possible to build up an image of the flux seen at each position by each of the XBPM blades. This is a useful diagnostic aid for determining the position and approximate shape of the beam, and can be used to calibrate the XBPMs as relative beam movements can be compared to absolute and known stepper motor positions.

These scans can be performed with the ID closed in order to determine the effects of the beam, and also with the ID open as a way of gauging background contamination from other sources.

The scan presented below taken using XBPM-01 (Fig. 5) shows the flux seen by each XBPM blade when both IDs are closed to their nominal operating gaps (I04 to 7mm and J04 to 16mm). The image from each blade is scaled to the same limits, distances are in mm. The signal received (nA) has been normalised to a constant storage ring beam current of 1mA.

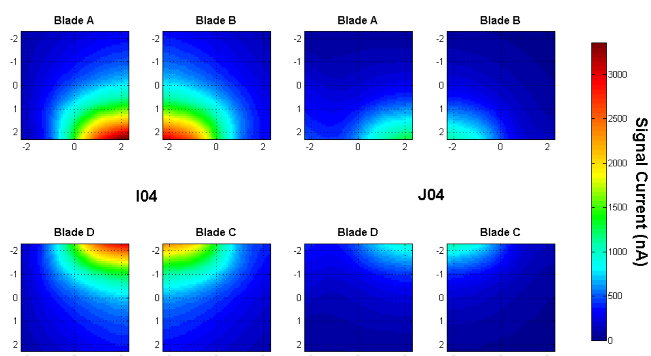

Figure 5: When both IDs are closed each beam is clearly visible.

This image clearly depicts the two beams passing down the front end, each beam centred on one of the sets of four blades. The J04 beam appears so much weaker than the I04 beam since it is produced by a 31mm period out of vacuum undulator whilst I04 is an in-vacuum 23mm period undulator. The lower photon count from J04 is exactly what one would expect from this device, but it does present some problems in accurately calculating the beam position since the signal detected has the potential to be skewed by stray radiation from the I04 beam.

Before an exact beam position can be calculated these stray radiation effects on one set of blades from the neighbouring beam must be determined. To do this one ID remains closed whilst the other is fully opened, and then the signal from both sets of blades is recorded.

The I04 blade signal at the nominal XBPM position

(0mm, 0mm) is 500nA per mA stored beam current. In order to determine how much of the signal comes from the 'wrong' beam, J04 is fully opened whilst I04 remains closed. In this arrangement J04 blade signal is 40nA per mA stored beam, 10% of the signal seen on I04. This signal is coming from the outer fringes of the I04 beam striking the J04 blades.

	I04 signals		J04 signals	
	$I04_{open}$	$I04_{closed}$	$I04_{open}$	$I04_{closed}$
$J04_{open}$	10	498	13	40
$J04_{closed}$	16	504	148	171

Table 1: Average blade signal received by each XBPM for various I04 and J04 undulator positions. Values are nA signal current per mA stored beam.

Since we know that the beam maintains a stable position we can assume that this signal remains constant as long as the I04 gap remains unchanged. By taking data at various I04 gaps a lookup table of background contamination is made, and the detected background signal seen on J04 is interpolated from this for any I04 gap. It becomes a simple matter to subtract one from the other to correct for the background signal.

This problem has less impact when considering the effect of the J04 beam on the I04 blades since the J04 beam is considerably less intense than I04. Only a small signal of a few nAs per mA stored beam contaminate the I04 blades. The corrections will still be applied though in order to eliminate even this small error.

CALIBRATED BEAM POSITION

Once the background signals have been subtracted a calibration of the XBPM is made. The response of the blades is measured against the known electron beam movements (Fig. 6). The fast orbit feedback system is used to alter the path of the electron beam through the IDs and produce parallel bumps. These known offsets are compared to the XBPM readings in order to provide calibrated position measurements in mm.

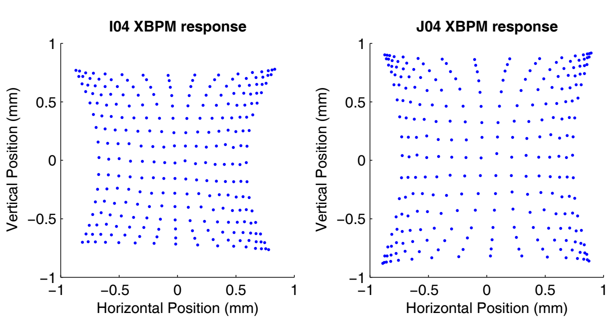

Figure 6: Response of the XBPM as the stepper motor position changes.

From this the two separate beam positions can be calculated using a simple asymmetry calculation [3].

CONCLUSIONS

The new twin beam XBPM is able to simultaneously resolve the position and pointing angle of two separate and independent ID beams in a single front end, despite only using one stepper motor to centre the XBPM. This device has enabled us to make accurate position measurements of the X-ray beam and thus confirm the alignment of the canted electron beam. Horizontally the separation of the two beams is measured to be 0.98mRad, and the vertical separation is measured to be 0.01mRad. This confirms the canting angle of the two IDs, as well as the quality of the ID trim tables to produce such small deviations from the expected alignment.

In summary this design of XBPM is verified to be capable of making sub-micron position measurements of adjacent beams from twin canted ID straights. The design is flexible enough to meet the requirements of a range ID parameters and positions within the front end (at DLS we have another set of these XBPMs installed for use on a U21 beamline). Their manufacture is not significantly more costly or time consuming compared to that of a normal XBPM, and their setup and calibration is relatively easy. These XBPMs are a very valuable addition to our diagnostics equipment.

ACKNOWLEDGEMENTS

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