NSLS-II X-Ray BPM Mini-workshop.

Date 26th/27th Feb 2009.

The XBPM Mini-workshop was held at BNL on 26th/27th Feb 2009 to discuss recent advances in the field, review work in progress, or planned, and to help the NSLS-II project team decide on likely solutions and expected performance. There were approximately 30 attendees, three from US synchrotrons, four from Europe, and one from RHIC (BNL). The agenda is shown in an appendix to this report, and presentations will be available soon on the NSLS-II website (workshops section).

This summary report will not attempt to repeat the material in the presentations, but will seek to summarize the concluding discussions held on both days.

Performance of blade based XBPMs.

Precision/ Sensitivity to the SR beam movement

Both commercial (Diamond/ SLS: by FMB) and in-house developed (APS) systems demonstrate similar performance:

- APS reports 20 microns (<1 microradian) pk-pk over 24 hours, with uncertainties coming from residual gap-dependent systematic error offsets, and a few microns with a fixed undulator gap. Resolution is sub-micron over short periods (and likely is limited to 100nm as of the noise floor of the electronics). The temperature stabilization in the accelerator tunnel is ~+/-0.5C although there are thermally "massive" and insulated.

- Diamond believes precision is in the range of 20 microns with an ID with moderately adjustable gap; there is fast position noise in the system of ~1micron (1-1000Hz bandwidth) that comes from a different source than the electronics, and only occurs on some XBPMs (currently under investigation). With an integration time of 1 second the noise level is easily below 100nm RMS (see Rehm presentation, slide 15).

- The SLS also claims a precision of +/-10 microns pk-pk, but this does change with time, and depends on the specific monitor. Thomas Wehrli provided data showing 3 microns accuracy after 18 hours.

- Bending magnet BPMs are generally perceived to be more credible due to lack of ID gap dependency (vertical information only).

- The main problem for blade type BPMs is the fact that they are measuring only at the fringes of the beam; the signal are smaller and contamination / noise can be greater.

Calibration Procedure:

Can be derived from programmed e-beam movement or by XZ movement of the XBPM. All facilities note that these two calibrations are not identical. APS make careful XBPM calibrations annually but every week the lookup tables to compensate for gap dependent systematic error offsets are re-measured by the operations group using an automated procedure.

To avoid shadow/ optimize XBPM sensitivity, blade geometry is optimized for each ID (Diamond). FMB has a crucial knowledge (and can assist) in such beam-specific optimization. Diamond now have an SRW / Matlab simulation of their own and have kindly offered to make this available to NSLS-II.

Although two XBPM systems are often used as a part of front end, in real life geometry (~up to 5m distance between, both ~15m away from the source) they do not always provide sufficient separation between angular and spatial shift of e-beam. At Diamond, back-projection to the source of "fast data" results in a large uncertainty not consistent with the precision of the measurements (due to the uncorrelated noise in the individual XBPM blades cause problems, however with a 1 second integration time the back projection is very good, and derived source position and angle are archived from this data). Some facilities treat the two XBPMs as redundant rather that independent measurements.
APS report a single global orbit correction algorithm that uses RF and photon BPMs with best results (unsurprisingly) when the monitors are separated as far as possible along the beamline. In one canted straight they use one photon BPM for each beamline and this causes tension when they disagree, or when they disagree with the RF BPMs, although Glenn Decker states this is a healthy tension that in some senses makes for an equitable balance. (note: NSLS-II front end has provision for two XBPM, but only one XBPM per beamline is budgeted within the project scope).

At APS Decker distortion was essential to achieve reliable accuracy of ID XBPM. SLS/ Diamond correct for "parasitic contribution", but have not implemented Decker distortion of the e-beam orbit. This could be due to a relatively small ID gap range restriction of 7-12mm (compared to 10.5-30mm at the APS).

Usage/ Practice

XBPMs are sometimes used as monitors, not implemented as a part of e-beam fast feed (back/ forward) system, particularly in the newer facilities. APS use these permanently in their 10Hz global closed orbit correction feedback system.

XBPMs are maintained by accelerator groups. Diagnostics are not experiments, they need to be reliable!

Diamond reports good progress with canted ID (IVU, with ~1mrad angle) custom 8 blade BPM. Some signal interference is observed (and expected) but small and mostly outside of the ID's operational range.

EPU calibration remains a challenge (at Diamond limited to "compatible" (CR/CL) modes)

Diamond is considering e-beam switching through a pair of IDs, and developing the system capable of 5kHz performance (ID switching speed <10Hz)

Photon BPMs have lots of problems and long term calibrations are non-trivial.

Although the commercially supplied products (from FMB), are used widely at Diamond and are now proved to work well and are trusted, the recommendation is for a new facility to start early in modeling the XBPM system, and will need some time (and internal effort) in understanding system during and after commissioning. This will entail a dedicated group of staff. FMB XBPM price is ~$45K (at current exchange rate of $1.25/Eur) per channel, including stand, vessel, x/y translation stages and current amplifiers.

EPICS approach works well (both for high frequency analysis and long term archiving). The accelerator control system can use same algorithms even when different undulators and XBPM blade geometry are used.

Blade material; APS use diamond and Molybdenum (for BM), Diamond use Tungsten and Copper (for BM). This may be dictated by the spectrum and material response. See recommendation #5.

Biasing voltage; Diamond use -70V based on advice from FMB/BESSY; they believe this is beneficial. APS do not use a bias voltage, having seen no practical benefit.

Glenn Decker strongly advocates an independent white beam position monitor to provide an absolute datum to give beam position relative to the beam defining aperture for the beamline. Therefore, by cross-referencing the absolute datum as a function of gap, he can do a proper job of quantifying the residual gap dependent systematic error offsets in the FE XBPMs. This could also be used to assist with calibration of RF buttons and FE XBPMs (see recommendation #1).

Om Singh commented that 100nm is the noise floor of the electronics; this is not generally thought to be a problem.

SLS have done a lot of careful investigation of the response of the blades on positional shifts of the photon beam (see presentation). Using single blades as independent monitors they are able to monitor some effects in a phenomenological way. They do not have any theoretical or even quantitative modeling of these systematic effects. To date, qualitative correlations of XBPM readings have only been possible with vacuum pressure dependence.

Bending magnet BPMs are generally perceived to be more credible due to lack of ID gap dependency.

A pair of XBPMs per beamline are desirable, even if one set is only used as a reference. Photon BPMs have problems with long term calibrations being non-trivial due to aging (dark current increasing due to insulator degradation, damaged blades after overheating, changes in sensitivity due to deposits caused by poor vacuum etc). (see recommendation #1).
Note for reference: NSLS-II front end designs will accommodate two XBPMs, however only one XBPM per beamline is budgeted within the project scope.

Advantage to using fixed gap IVU (XBPM calibration is easier); this will be the case with IXS beamline (which will be very useful since the ID beam exit angle for this beamline is critical).

The accelerator control system can use same algorithms even when different undulators and XBPM blade geometry are used (this seems to have worked well at Diamond; FMB will ensure that blade positions are optimized for a given undulator and position from the source).

Other considerations.

Reliability needs to be high (it is for currently installed blade-based XBPM units at all commenting facilities)!

Decker distortion is used at APS (and believed to be important), but the effects are simply subtracted at Diamond (which they consider to be acceptable). The reasons for this discrepancy are possibly that 7GeV versus 3GeV will make a large difference (for NSLS-II the large bend radius dipole will help minimize problems). The different blade materials at the APS and Diamond will affect the relative sensitivity to dipole and ID radiation. A full simulation is strongly recommended.

Possible explanation from Om (and supported by Glenn Decker): one advantage at Diamond that ID gap remains fixed and it is kept at the lower end of the gap range. This means lot of flux from ID radiation. The subtraction technique will knock out chunk of that background radiation which stays constant or if electron beam does not move. There is always some background radiation due to change in electron beam going through multipole magnets. However, these changes could be small.

Advice on what would have been done differently, based on current knowledge.

Glenn Decker – "view facility as a system". Information from beamline is extremely useful feedback for the accelerator. This may be simply using an ion chamber at the end station to maximize flux by steering (this should normally be available via EPICS) Diagnostics at first optic to be available as a PV (would help with <1microradian angular stability).

Diagnostics are not experiments, they need to be reliable!

Guenther Rehm – slow movement of concrete floor can be corrected with slow feedback system. Accelerator can optimize on an arbitrary signal, such as an ion chamber – we should consider implementing this as part of the basic system.

FMB XBPMs used widely at Diamond, this is now proved to work well and are trusted. Need to start early in understanding system (as soon as possible in commissioning NSLS-II, and prior at other facilities) – no real benefit in developing a new system.

Thomas Wehrli – concerned about the systematic errors in XBPMs.   He also advocates cooperation between accelerator and beamlines (comment incorporated into recommendation #1).

Petr Ilinski – XBPMs will not be integrated to global system at start of operations at DESY. Recommend to use a diamond window or foil as the basis for a BPM system (also fits with recommendation #1).

There was unanimous agreement that the fostering of a culture which avoids a counterproductive “us and them” mentality between Accelerator and Beamline staff was of vital importance. It was also considered to be important to ensure that collaboration occurred between light sources.

Stands

NSLS-II (B Kosciuk) has measured the CTE of composite tubes and these were found to be very poor, and did not meet the manufacturers’ claims. Diamond did a type approval check on one tube, but did not measure the rest of the batch. Suppliers are unwilling to provide guarantees on CTE.

Luminescence detectors

Petr Ilinski – drawback is pressure and application is limited (eg windows required, when many beamlines are wanting to go windowless for coherence and low energy reasons). Precision however could be very good (sub-micron).

Rob Michnoff, RHIC (private comment). RHIC have an Ionization Profile Monitor (IPM) system similar to the luminescence monitor outlined by Petr Ilinski which are not currently used (the MCPs need to be replaced every few years due to contamination, and the signals get weaker as the system vacuum improves)!

Peter Revesz believes the precision of his devices to be submicron during lab testing, and probably around 1 micron in real installations.

Conclusion; these devices are not suitable for general implementation on all beamlines; however some small subset of beamlines may benefit considerably. Maintain watching brief.

Diamond based detectors

Much work has been undertaken previously on the use of diamonds for XBPMs, the issue seems to involve the quality of the diamonds. Work is proceeding involving diamond film from Element 6, a subsidiary of DeBeers, there are concerns over cost; ordinary diamond is not suitable and “research grade” is required.

Recommendations

Recommendation #1. Based on sensible advice from Glenn Decker, and echoed amongst other delegates, the NSLS-II project team should consider an independent monitor of beam position downstream of the shield wall. This monitor;

- Would ideally provide position information in the form of PVs that may be used by the accelerator staff, however this could comprise a flux monitor immediately downstream of the primary beam defining aperture. By maximizing the flux through this aperture one can have an absolute datum on the beam's location.
- May be invasive. A non-invasive BPM would be preferred, but there are practical difficulties with this. The signals are not required to be constantly on-line (they will be downstream of the beamline shutter), but will be used intermittently and in agreement with beamline staff.
- Should be mounted on a stand with comparable stability / rigidity to the RF buttons and XBPMs.

The project team should include a Conflat port between the shield wall and the first optical element to allow such a beam positioning / monitoring device to be incorporated later.

Recommendation #2. Learn from others, and collaborate! Maintain dialog with other facilities, keep abreast of development work and get involved with collaborations. Take advice from other facilities not represented at this workshop (eg SPRing8). Consider alternatives where applicable (eg diamond and luminescence type systems), and monitor developments at other sources carefully. There was a feeling that collaboration between light sources could be considerably improved.

Recommendation #3. A commercial blade based XBPM system should be seriously considered.

The APS system was developed in-house (no commercial solutions were available at the time) and works very well ("performance is ahead of User demands"), although a lot of effort (and time) was required for getting the system working well. The feeling from SLS and Diamond that commercial solutions work well, provide an excellent starting point from which incremental improvements can be made. There is no requirement at present for the development of new electronics.

Recommendation #4. Whatever system is implemented, some time and budget should be allowed for post commissioning development – which may continue at a low level over a few years.

Recommendation #5. NSLS-II to discuss with Oleg Chubar the possibility of adding some XBPM modeling capabilities into his ID design codes. This may allow simple work on energy response of blades (as done at the SLS) to be repeated, and expanded to look at differing blade materials.

Recommendation #6. The need for Decker distortion needs to be analyzed. This links to recommendation #5 since an analysis needs to include the specific ID and BM spectra, and the relative sensitivity of the blade material to these spectra. Guenther Rehm recommends a comparative simulation of photon yield for ID and dipole between APS, Diamond and SLS configurations, and has offered help with this (e-mail 10th March 2009).

Agenda for XBPM mini-workshop 26/27 Feb 2009

Large Ground Floor Conference Room, Building 703, NSLS-II

26th Feb 2009

8:30 AM	Continental breakfast	
9:00 AM	Introduction and welcome, summary of workshop objectives	Q Shen
9:15 AM	NSLS-II requirements and plans	O Singh
9:45 AM	Discussion	
10:00 AM	XBPM experience and plans at Diamond	G Rehm
10:30 AM	Discussion	
10:45 AM	Coffee	
11:00 AM	Development of Residual Gas X-ray BPM for PETRA III	P Ilinski
11:30 AM	Discussion	
11:45 AM	Properties of X-Ray Beam Position Monitor at the Swiss Light Source	T Wehrli
12:15 PM	Discussion	
12:30 PM	Lunch	
1:15 PM	R&D at the APS toward a hard x-ray beam position diagnostic	G Decker
1:45 PM	Discussion	
2:00 PM	Video-based X-Ray Beam Position Monitoring at CHESS	P Revesz
2:30 PM	Discussion	
2:45 PM	Coffee	
3:00 PM	X-ray beam diagnostics at NSLS-II	P Siddons / P Yoon
3:30 PM	Discussion	
3:45 PM	Development of synthetic-diamond-based front end XBPM at the APS	D Shu
4:15 PM	Discussion	
4:30 PM	Summary discussion and draft report	A Broadbent
5:00 PM	Finish for the day	

27th Feb 2009

8:30 AM	Continental breakfast	
9:00 AM	Outlook for a new Residual Gas Beam Profile Monitor at the SLS	T Wehrli
9:30 AM	Discussion	
9:45 AM	In-Situ Measurement of Heat-bumps at the CHESS A2 Beam-line	P Revesz
10:15 AM	Discussion	
10:30 AM	Coffee	
10:45 AM	Development of high stability stands for BPMs	B Kosciuk
11:15 AM	Discussion	
11:30 AM	Sumary discussion and draft report	A Broadbent
12:00 PM	Finish for the day	