REDUCTION OF X-BPM SYSTEMATIC ERRORS BY MODIFICATION OF LATTICE IN THE APS STORAGE RING*

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Abstract

With recent developments, X-ray beam position monitors (BPMs) are capable of making accurate photon position measurements down to the sub-micron level. The true performance of X-ray beam position monitors when installed on insertion device beamlines is, however, severely limited due to the stray radiation traveling along the beamline that contaminates the insertion device photons. The stray radiation emanates from upstream and downstream dipole magnet fringe fields, from steering correctors, and from sextupoles and quadrupoles with offset trajectories. While significant progress has been made at the APS using look-up tables derived from translation stage scans to compensate for this effect, performance of ID X-BPMs to date is at the 10 to 20 micron level. A research effort presently underway to address this issue involves the introduction of a chicane into the accelerator lattice to steer the stray radiation away from the X-ray BPM blades. A horizontal parallel translation of the insertion device allows only ID photons and radiation from two nearby correctors to travel down the beamline, simplifying the radiation pattern considerably. A detailed ray tracing analysis has shown that stray radiation gets displaced by up to 2 cm horizontally at the X-BPM locations so that it can be easily masked. Results from such a modified lattice, implemented for one of the insertion devices, are reported here.

1 INTRODUCTION

During the design of the APS, much consideration was given to the requirement for micron-scale beam position stabilization. To this end, a very careful mechanical design for photoemission gold-plated diamond blade-based X-ray beam position monitors was executed [1]. As described elsewhere [2], a method has been developed at the APS for reducing stray radiation background signals from X-ray beam position monitors on insertion device beamlines. This radiation originates not only from the fringe fields of the dipole magnets located upstream and downstream of the insertion device source point, but also from collinear steering corrector magnets and off-axis particle beam trajectories through quadrupole and sextupole magnets in the straight section. By realigning girders in the two sectors straddling the insertion device, one can eliminate all of the stray radiation with the exception of that emanating from two corrector magnets located immediately upstream and downstream of the insertion device.

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Figure 1 illustrates the concept of displacing accelerator girders in such a way that stray radiation is directed away from the X-ray BPM field of view. The strength of the dipole magnets on either side of the insertion device is decreased by 1 mrad, while two corrector magnets located immediately upstream and downstream of the insertion device are powered to compensate for this 1-mrad loss of bend angle in the main dipoles. With these changes in magnet strengths comes an accompanying displacement in the girders and an approximately 6-mm parallel horizontal displacement of the insertion device.

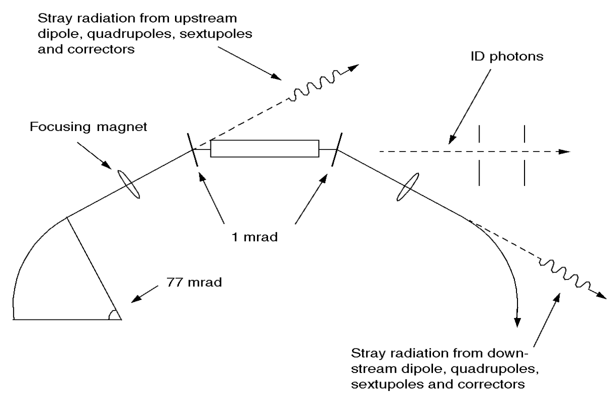

Figure 1: X-BPM stray radiation realignment concept

Because there are many insertion device beamlines in operation at the APS, an alternative concept was implemented that was less disruptive to users. Rather than displacing the insertion device outboard, the two adjacent accelerator sectors were displaced inboard, leaving the insertion device and its associated front-end and beamline components undisturbed. This required changing the strengths of four main dipole and four corrector magnets and realignment of ten girders (each APS sector is composed of five girders in addition to an insertion device).

2 IMPLEMENTATION

The lattice modification just described required a significant planning and analysis effort over a period of 15 months prior to its implementation in the APS storage ring. Among the tasks undertaken was an extensive program of computer-aided design ray tracing to ensure that no uncooled interior vacuum chamber surfaces would be struck by X-rays, both with standard particle beam steering and in the presence of large but physically possible beam misalignment conditions. Shown in Figures 2 and 3 are plots indicating some results of this ray tracing effort.

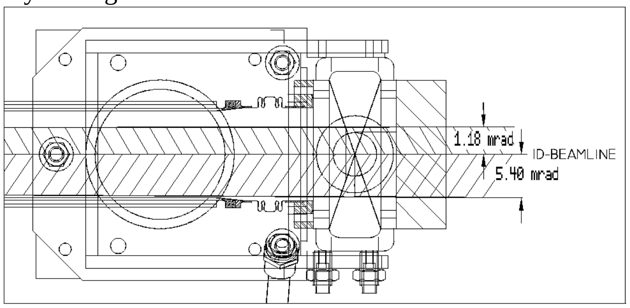

Figure 2: Insertion device exit port ray tracing result

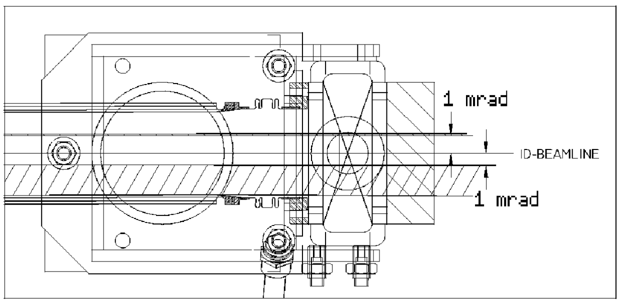

Figure 3: Ray tracing results showing separation of bending magnet radiation (crosshatched areas) relative to insertion device beamline axis after lattice change

The crosshatched areas in Figures 2 and 3 indicate the regions where bending magnet radiation, streaming from left to right, is present at the insertion device beamline exit port. The region above the beamline axis represents bending magnet radiation emanating from the downstream fringe fields of the dipole bending magnet located upstream from the insertion device, while the lower crosshatched area corresponds to bending magnet radiation emanating from the upstream end of the downstream dipole magnet.

In Figure 3, notice the separation between the dipole "fans" and the insertion device centerline resulting from the girder realignment. Note that only a sliver of radiation from the upstream dipole fan survives, with the majority of it having been occluded by an upstream radiation absorber. The downstream dipole fan is not displaced inboard by as much as the upstream fan has been displaced outboard, a consequence of the relative distances to the associated source points.

3 EXPERIMENTAL CONFIRMATION

Figure 4 gives the approximate geometry for the two X-ray beam position monitor blades installed in all standard APS beamline front ends. The views shown are taken from inside the accelerator looking out along the beamline, with the center of the accelerator on the right-hand side. The geometry was chosen such that the upstream assembly would not shadow the downstream blades and to avoid strong radiation background from dipole radiation lying in the plane of the particle beam trajectory.

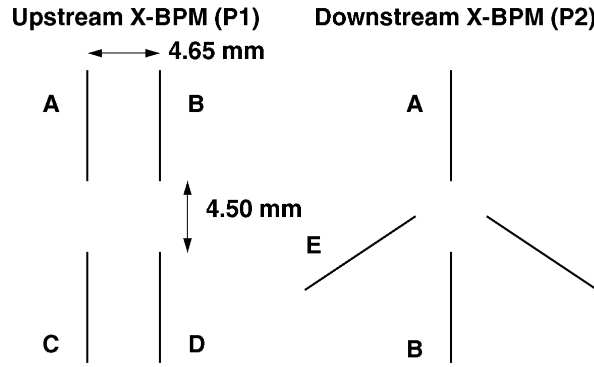

Figure 4: APS X-BPM blade geometry

Figure 5 shows plots of the blade sum signal for each of two X-BPMs located along two different beamlines, as a function of insertion device gap. One of them, beamline 1-ID, is a standard configuration, while the second, 34-ID, has undergone the "alternative" lattice modification described in the text following Figure 1 above.

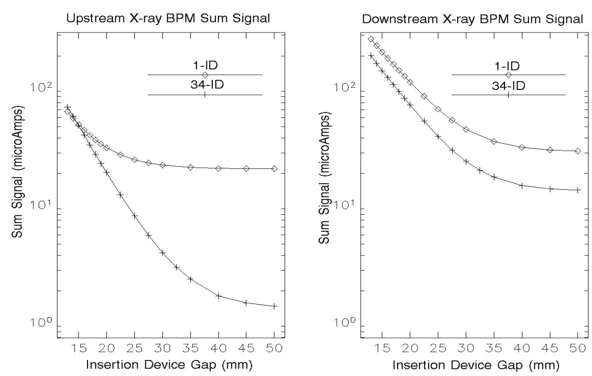

Figure 5: X-BPM sum signals vs. insertion device gap

Notice for the upstream X-BPM in the left-hand figure that the 34-ID background signal seen with the gap open (approaching 50 mm) is more than a factor of ten reduced in comparison to the signal from 1-ID. A factor of more than two improvement is seen for the downstream X-BPM.

While these results are encouraging, it is important to understand the characteristics of the remaining background signals. While radiation from the main dipole bending magnets should have been all but eliminated, keep in mind that the 1-mrad corrector magnets are themselves sources of synchrotron radiation. Because this radiation is predominantly off-axis horizontally, one would expect that the "E" and "F" blades would be strongly affected by it. As reported elsewhere [2], this is, in fact, the case. By steering vertically with the gap open, one sees a rapid variation of the signals on these two blades.

One fascinating observation was that the response of the P1 blade signals to local vertical steering with the insertion device gap open was almost perfectly symmetric. The top two blades tracked each other and were mirror images of the response of the bottom two blades. This raises the possibility of using the corrector magnet radiation itself as a position diagnostic. One would expect this radiation to show a peak value at a location 0.5 mrad horizontally off-axis from the insertion device beamline centerline. A blade monitor design similar to P1 and located 0.5 mrad off-axis would hold promise as a gap-independent X-ray position monitor.

Shown in Figure 6 are insertion device gap scans for the individual blade signals of the upstream (P1) X-BPM on beamline 34-ID, after the lattice modification.

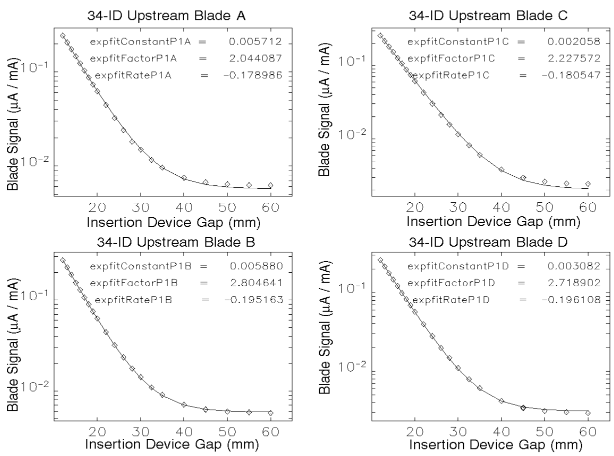

Figure 6: Normalized 34-ID X-BPM blade signals vs. gap

The data plotted are normalized by dividing the blade photocurrent signals in microamperes by the total stored beam current in milliamps. Each blade signal was fit to a function of the form

Signal = Constant + Factor * Exp(– Rate * Gap) ,

which is shown by the solid lines in Figure 6. The data is indicated by diamond-shaped symbols, and the fit parameters are shown on each plot.

An important aspect of the data in Figure 6 is that the slopes of the four curves (i.e., the "rates" for the fit) are significantly different from blade to blade. Whatever the cause, this phenomenon has serious consequences if one is interested in using these blade monitors as gap-independent position diagnostics. Suspecting a nonlinear electronics effect to be responsible for the observed differences in slope in Figure 6, the cables were swapped so that the top blades' electronics were connected to the bottom blades, and vice versa. The effect was observed to move with the blades and not the electronics, thus exonerating the electronics as the culprit.

Shown in Figure 7 are plots showing the variation of the "factor" and "rate" fit coefficients as functions of horizontal and vertical beam position at the P1 blade monitor location resulting from a local orbit distortion at the insertion device source point. The transverse beam positions were computed by an extrapolation from rf beam position monitors employing capacitive pickup electrodes mounted on opposite ends of the insertion device vacuum chamber.

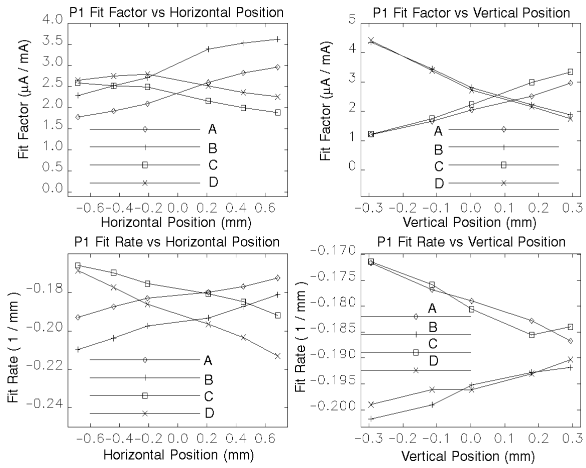

Figure 7: Gap scan fit coefficients vs. position

One possible explanation for the behavior seen in Figure 7 is that it is a result of detailed fabrication differences from blade to blade, for example, small variations in blade rotation angle. While in principle it may be possible to compensate for this effect, it is unlikely that the beam can be stabilized at the sub-micron level long enough to determine the coefficients to the required accuracy to support submicron level compensation.

4 CONCLUSIONS

A technique to substantially reduce stray radiation background levels from insertion device X-ray beam position monitors has been implemented at the APS. While use of these devices as a submicron-stable position diagnostic remains a challenge, it appears that a device sensitive to corrector magnet synchrotron radiation may hold the potential to be a stable gap-independent X-ray position diagnostic.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] D. Shu, et al., Nucl. Instr. Meth. A, **319**, p. 56 (1992).

[2] G. Decker, O. Singh, "A Method for Reducing X-ray Background Signals from Insertion Device X-ray Beam Position Monitors," Phys. Rev. ST–AB (to be published).