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IMPACT OF IDs ON THE DIAMOND STORAGE RING AND APPLICATION TO DIAMOND-II

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Abstract

When investigating the effect of insertion devices (IDs) on storage ring operations, it is not possible to simulate all of the large number of gap, phase and field settings that are available. This can be of particular concern for transient effects in IDs that are moved frequently, or APPLE-II devices which may use many different polarisation states. We therefore present measurements of the impact of selected IDs on various parameters in the current Diamond storage ring including orbit distortion, tunes, chromaticity and emittance, and assess the expected impact when applied to the Diamond-II lattice.

INTRODUCTION

IDs cause a closed orbit distortion (COD) when changing gap due to non-zero field integrals through the device. Dipole trim coils are installed at the ends of each ID to provide a local orbit correction through feed-forward tables. Diamond-II [1] will use many similar IDs, some of which are already present in the operational Diamond ring. Due to the difficulty in simulating the large number of variations in ID settings, it is useful to assess the impact of selected IDs in the current ring and project what the effect of the same devices would be in Diamond-II.

By looking at the resulting COD at the location of the IDs, it is also possible to assess how effective existing correction schemes are at improving photon beam stability as well as the electron beam.

CLOSED ORBIT EFFECTS

The COD caused by a selection of IDs installed in the existing Diamond storage ring [2] was measured with and without the trim correction applied. Due to differences between types of ID, these have been grouped into three different classes: in-vacuum cryogenic permanent magnet undulator (CPMU), APPLE-II, and multipole wigglers (MPW). Two kicks, one at each end of the ID, could then be fitted for each type of ID in the accelerator model in Accelerator Toolbox [3] for Matlab, using the I03 CPMU, I05 APPLE-II undulator in horizontal and circular polarisations, and I20 MPW IDs as examples. These kicks were then applied in the Diamond-II model to calculate the total orbit distortion anticipated during operation.

Results

The projected COD in Diamond-II for each ID type is shown in Fig. 1. The MPW and circularly-polarised APPLE-II devices cause significant orbit distortions, especially in the vertical plane, which are well corrected by the local trim correctors. Horizontal polarisation for the APPLE-II is much less disruptive, as is the CPMU. The corresponding RMS values of the orbits are shown in Table 1.

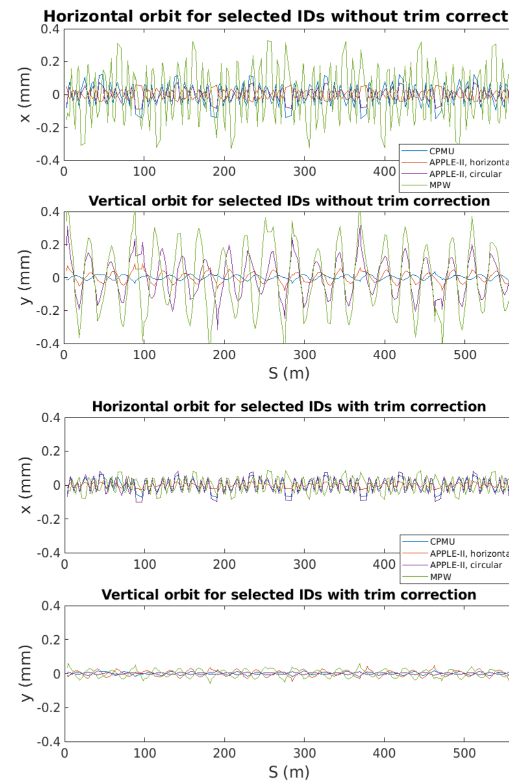

Figure 1: Simulated closed orbit distortion in Diamond-II for selected IDs. Without local trim correction (top), with trim correction (bottom).

Table 1: Simulated RMS Closed Orbit Distortion in Diamond-II for Different ID Types in Horizontal and Vertical Planes After Local Correction

	Uncorrected		Corrected	
ID Type	**H (um)**	**V (um)**	**H (um)**	**V (um)**
CPMU	63	13	32	8
APPLE-II (horizontal)	24	33	10	18
APPLE-II (circular)	38	121	43	4
MPW	165	219	16	13

Motion Timescale

The time taken for IDs to move ranges from seconds to minutes depending on the type of ID and the range of gap motion. CPMUs and other in-vacuum IDs have a relatively small range of movement, usually between 4-30 mm, and so can move their full range in 25 seconds. APPLE-IIs and other ex-vacuum IDs have a larger range of movement, up

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to 300 mm in some cases, and can take 180 seconds to move their full range. Diamond also has two superconducting wigglers which will continue to be used in Diamond-II, which can ramp from zero to full field in just over 5 minutes but take significantly longer, almost 15 minutes, to ramp the field down to zero due to the difficulty in controlling the field at low currents. However, their field will not normally be changed during user beam. Orbit distortions on these timescales are well within the capabilities of the fast orbit feedback (FOFB) to suppress and so are not expected to be of concern for Diamond-II users.

Photon Beam Angle

While the closed orbit for the electron beam can be well corrected at electron BPMs, there are no BPMs or correctors inside an ID. This means that the angle of the electron beam at the source point, and hence of the photon beam, is not well controlled.

This effect was assessed by applying the previously calculated ID kicks to the Diamond-II model, running a global orbit correction to correct the orbit at the BPMs, then extracting the beam pointing angle at a watchpoint at the centre of the ID. The beam angle at the source point vs. ID gap is shown in Fig. 2 for the CPMU. As can be seen, not only do orbit corrections at electron BPMs not control the source angle well, at some ID gaps the angle is actually larger with corrections than without.

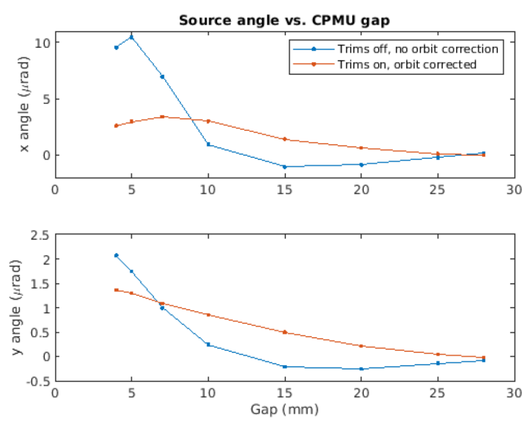

Figure 2: Photon beam angle for a CPMU comparing the angle with no orbit corrections applied and with local trims plus global orbit correction.

The source angle vs. gap including orbit corrections is shown in Fig. 3 for the CPMU, MPW and an APPLE-II in horizontal polarisation. Figure 3 also shows the source angle as a percentage of the beam divergence at the source point. Both the CPMU and MPW produce large angles which can be greater than the beam divergence.

Solutions

The lack of control of the photon beam is largely due to traditional orbit correction schemes focussing only on the electron beam orbit. In particular, local feed-forward corrections are usually tasked to minimise the global COD in order to reduce the strength needed in the correctors used for global orbit feedbacks.

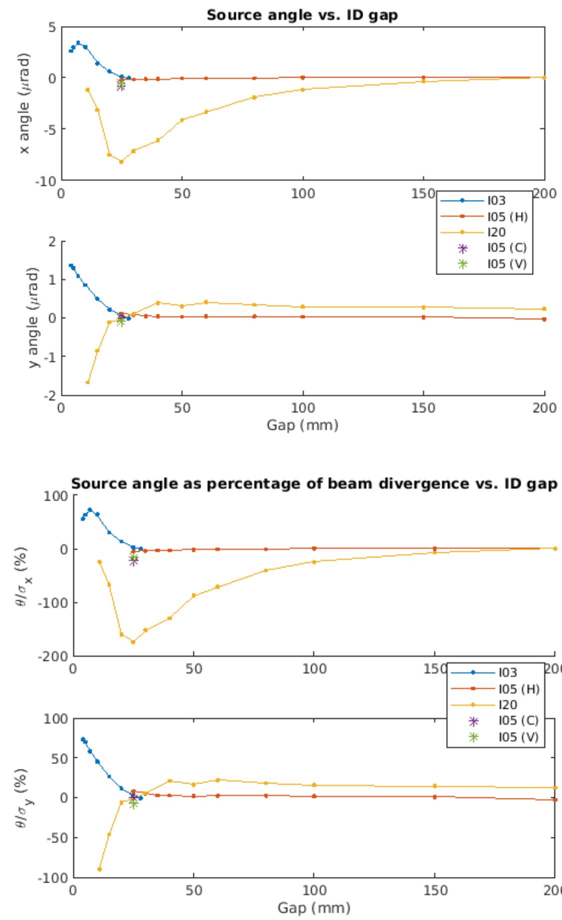

Figure 3: Photon beam angle vs. ID gap for selected IDs. Angle (top), percentage of beam divergence (bottom).

However, assuming enough headroom is available in these correctors, feed-forward trims can instead be calculated based on photon beam positions at x-ray BPMs (XBPMs), or other beamline diagnostics.

This has been tested in the existing Diamond storage ring on the I22 in-vacuum undulator, since this beamline was especially sensitive to changes in the beam angle. Figure 4 shows the effect on the photon beam position at the first XBPM in the beamline with horizontal trim corrections based on XBPM positions compared with those based on the electron beam orbit. The XBPM corrections were only applied between 5-7 mm ID gaps, where the ID is normally operated. As can be seen, there is a significant improvement in the photon beam stability when the ID is moved.

The COD when the ID is closed rises to 400 µm maximum in the horizontal, compared to <5 µm with trims calculated to correct the COD, and ~50 µm with no trim corrections. While significantly larger, this has not presented any issues with running FOFB as normal. It also remains well inside the orbit interlock for the machine protection system (MPS) in the existing storage ring even if FOFB is not running.

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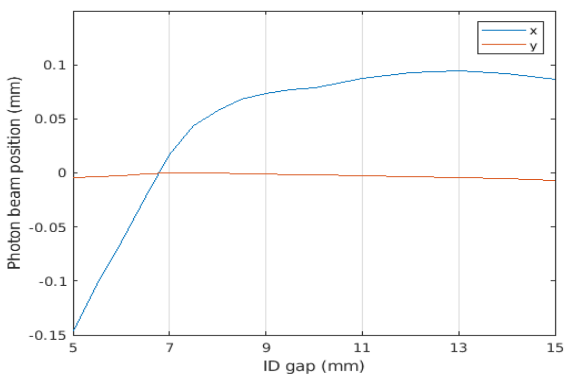
Table 2: Effect of Selected IDs on Electron Beam Parameters in the Current Diamond Storage Ring

ID Type	CPMU	APPLE-II (horizontal)	APPLE-II (circular)	MPW
Tune (x)	-0.0004	0.0106	0.0085	-0.0012
Tune (y)	-0.0033	0.0012	-0.0014	0.0040
Chromaticity (x)	-0.14	0.01	-0.07	-0.09
Chromaticity (y)	-0.02	0.05	-0.09	0.09
Emittance (x) (nm)	0.05	0.15	0.10	-0.05
Emittance (y) (pm)	0.49	0.28	-0.03	-0.03
Lifetime (%)	-13.6	-9.3	-14.9	-0.2
Injection efficiency (%)	-1	-6	-3	0

Since Diamond-II will have a significantly smaller beam size and more stringent beam stability requirements, feed-forwards and feedbacks based on photon beam diagnostics are likely to be useful additional tools. However, the MPS interlock will be at 250 µm at all BPMs, so some compromise may be necessary between photon beam correction and constraints on the electron beam.



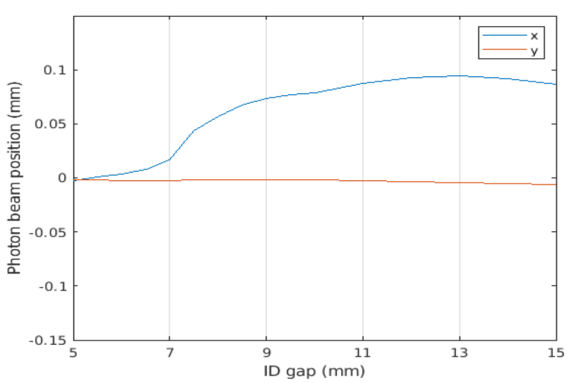


Figure 4: Photon beam position for I22 at XBPM with trim corrections calculated using electron BPMs (top) and XBPMs (bottom).

OTHER BEAM PARAMETERS

IDs also have an impact on a variety of other electron beam parameters, in particular betatron tunes and chromaticity. While tunes and vertical emittance can be easily corrected using local feed-forward corrections and/or global feedbacks, parameters such as chromaticity are more difficult to correct in real time. Table 2 shows the measured effect of the sample IDs on a range of electron beam parameters in the existing Diamond storage ring. The measured data here can be used to benchmark the effects of IDs for simulations of Diamond-II.

Unlike the effects on orbit, the MPW has relatively little effect on most beam parameters. The CPMU has a significant effect on vertical beam size, which results in a drop in lifetime when the beam size is corrected by the vertical emittance feedback. APPLE-II devices can have larger effects on non-linear dynamics resulting in a reduction in lifetime and injection efficiency.

CONCLUSION

Closed orbit corrections for an electron beam are well understood, and measurements from the current Diamond storage ring show that there should be no problem correcting the COD caused by ID movements in Diamond-II with a combination of local feed-forwards and global feedback. However, with tighter requirements on photon beam stability, these traditional approaches do not necessarily do a good job correcting the photon beams due to a lack of electron beam diagnostics inside IDs.

Using photon beam diagnostics as a data source for corrections can greatly improve photon beam stability, at the cost of needing greater corrector strengths in the global feedbacks as a result of the larger COD this causes.

Local feed-forwards and global feedbacks for other beam parameters such as tunes and emittance are well established, but corrections to non-linear effects which can impact lifetime and injection efficiency may also need consideration in modern light sources with high stability requirements.

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