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DESIGN CONSIDERATIONS ASSOCIATED WITH THE REPLACEMENT OF A SEXTUPOLE MAGNET BY A SHORT WIGGLER IN A CELL OF THE DIAMOND STORAGE RING LATTICE

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Abstract

All of the original straight sections in the Diamond storage ring are now occupied, and novel ways of converting bending magnet beamline locations into insertion device beamlines are being considered. Recently one cell of the 24 cells was reconfigured in to a Double-Double Bend Achromat (DDBA) to provide a new location for an Undulator and enable a formerly designated bending magnet beamline to become an Insertion Device Beamline [1]. Extending this concept for the new Dual Imaging and Diffraction (DIAD) Beamline proved to have a strong impact on lifetime and injection efficiency, so instead a proposal was made to remove a Sextupole magnet in the corresponding storage ring cell and substitute it with a short fixed gap Wiggler. The accelerator physics, mechanical and electrical design aspects associated with the change are described.

INTRODUCTION

One of the proposals emerging from the initial studies into a suitable cell configuration for an upgraded Diamond Storage Ring was a modified 4-bend achromat [1], referred to as DDBA. This had the additional benefit of providing a new achromat mid-straight for locating an Insertion Device (ID), which could replace the original bending magnet as a beamline source. Although initially developed as an upgrade for the whole storage ring it was decided to trial it in one cell to provide a new ID source for the VMX beamline. A number of factors described below prevent this solution from being deployed in a second location to provide an ID for the DIAD Beamline.

A SECOND DDBA CELL?

Although the ability of the Storage Ring to function under all operating conditions has been proved for a single DDBA cell [2], detailed studies (unpublished) have indicated that adding cells, reconfigured to a DDBA, reduces the dynamic and momentum apertures; and hence injection efficiency and lifetime to an unacceptable extent, refer to Figs. 1 and 2.

Additionally, modifying a cell to a DDBA configuration requires a complete new suit of reduced aperture magnets and vacuum vessels. Combined with re-cabling, the capital expenditure required is considerable, in the region of £2.6M excluding the cost of the new Insertion Device.

Limiting the shutdown for DDBA installation time to a maximum of eight weeks required an extensive programme of cabling up to two years in advance of the girder exchange. A set of temporary cables replicating the existing ones was installed. The existing cell was then reconnected to the temporary cables, once this was completed the existing cables could be removed and replaced by the new DDBA cables. This way when the new girder assemblies were installed they could readily be connected to the pre-terminated cables [1]

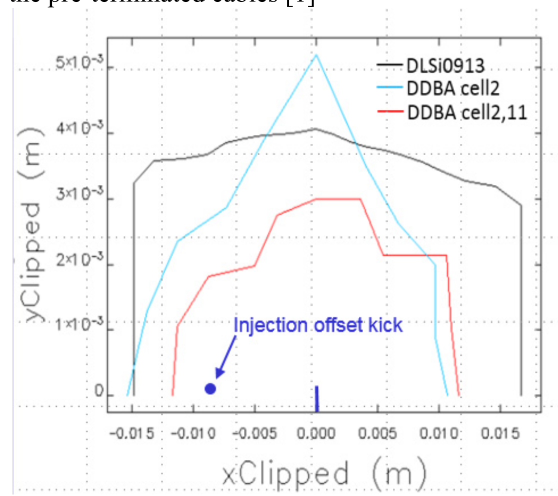

Figure 1: Reducing Dynamic Aperture for successive DDBA cell reconfigurations

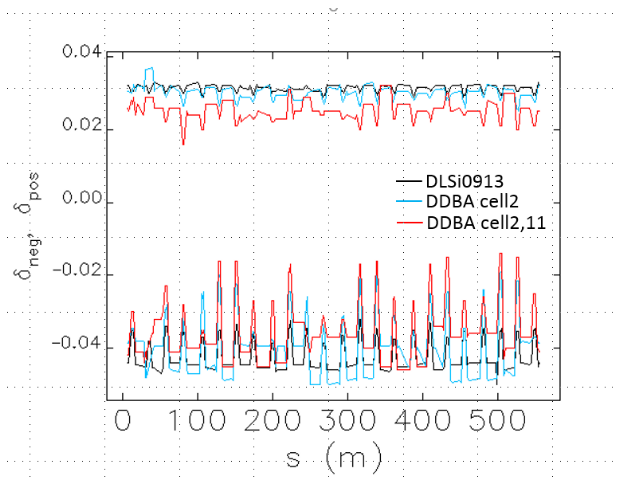

Figure 2: Reducing Momentum Aperture for successive DDBA cell reconfigurations.

The reduced machine performance combined with the associated costs of procurement, preparation, and installation have made an alternative configuration an attractive proposition.

An alternative reconfiguration was proposed whereby the first sextupole magnet upstream of the second dipole in the standard DBA configuration was replaced by a short 10 pole fixed gap Wiggler.

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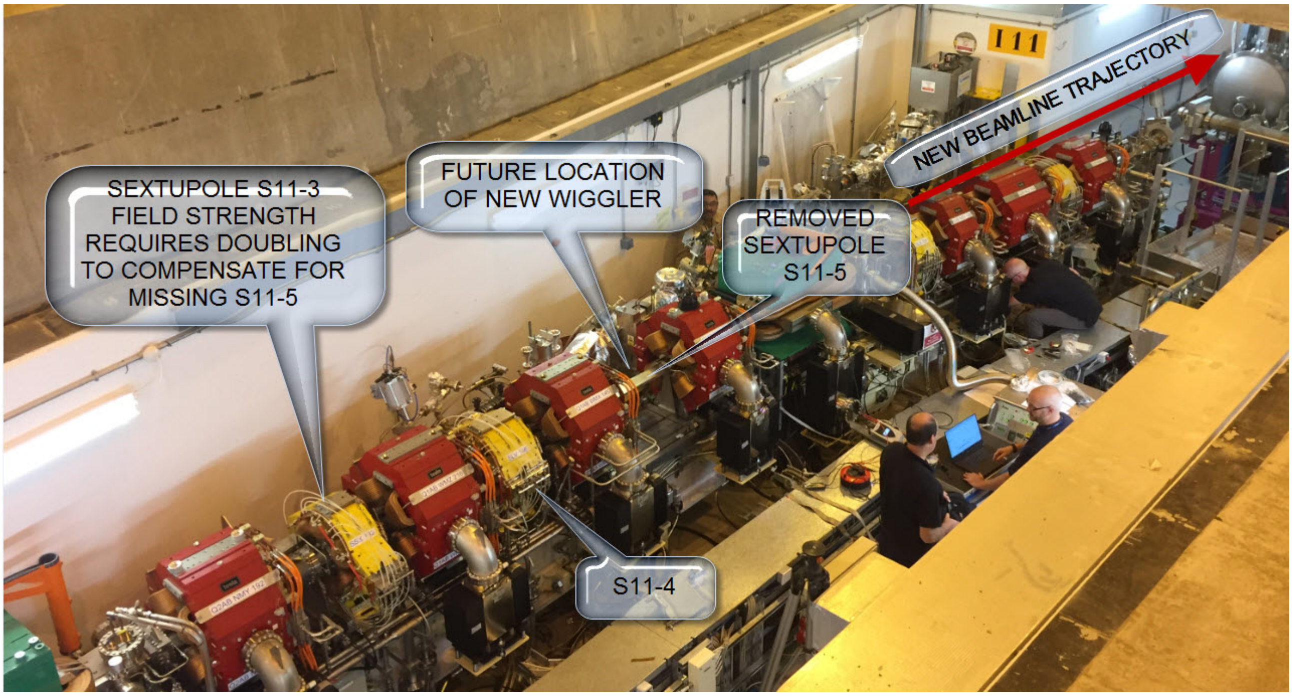

Figure 3: Illustration of newly installed storage Ring Cell for DIAD.

CELL RECONFIGURATION FOR DIAD

Overall, the inclusion of a Wiggler upstream of dipole 2 of the DBA changes the trajectory of the emitted light. Dipole Beamlines are provided with light between 5 and 25 mrad around the dipole arc (see Fig. 3). As a result, the aperture through the concrete shield wall is centred on 15mrad from the straight-ahead direction. Placing the Wiggler before the dipole fan switches trajectory back to the zero degree direction as illustrated in Fig. 4.

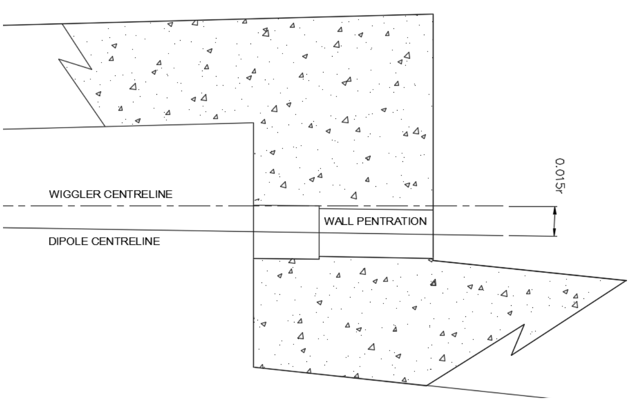

Figure 4: Differing trajectories of Wiggler and dipole light with respect to the Storage Ring wall penetration.

The difference between the new and old photon trajectory is significant and a new penetration through the concrete shield wall had to be prepared. This was achieved by core drilling an enveloping hole through the concrete and existing steel penetration liner, positioning a new liner in the void and back filling the interspace with high-density grout. The drilling process is illustrated in Fig. 5.

Figure 5: Core drilling for the new shield wall penetration.

The altered trajectory also meant that access to the outboard area between the new Front End and the shield wall will not be possible. Services and search routes will be redefined, as access will only be possible from the inboard side.

In addition, a number of design and component changes are required due to the altered trajectory:

1. A new shield wall penetration is required.
2. The photon absorbers in dipole 2 vessel require redesign.

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3. The photon leg of the crotch vessel requires redesign to correspond to the new photon exit trajectory.
4. The yoke of the downstream quadrupole requires modification to avoid the new photon leg of the crotch vessel, see Fig. 6.
5. The inclusion of an insertion device on girder 2 with a pole tip gap of 22mm in place of a sextupole required a reduced aperture vacuum vessel (external height 21mm).

Capital expenditure for these cell modifications was in the region of £0.5M.

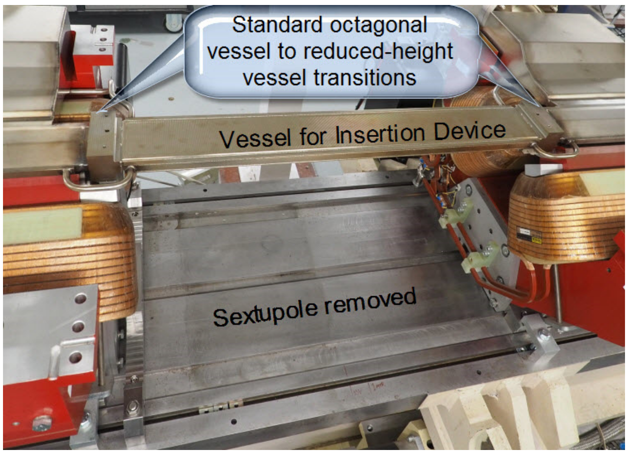

Figure 6: Vessel transition to the profile required to pass through the Wiggler (Magnet tops removed).

The girders removed from the storage ring for the DDBA installation were partially dismantled and reconfigured for DIAD. This allowed fully configured girders to be prepared in advance of the swap over during a shutdown.

The build of the 0.7 m long 10 pole Wiggler was scheduled to allow a trial fit at the girder build stage which was successful, see Fig. 7. The intension is to complete the Wiggler build after installation of the girders. To enable installation and removal of the Wiggler in situ a manually operated loading platform was designed which can span the cable tray stack adjacent to the girder in the storage ring. A short section of this apparatus is permanently fixed to the girder to enable the Wiggler to be moved horizontally when it is required to take it offline.

EFFECT ON MACHINE PERFORMANCE

At the proposal stage, a number of computer simulations and experiments were carried out to assess the impact of switching off the chromatic Sextupole magnet corresponding to the new Wiggler location (S11-5). Simply powering off this magnet was found to have an unacceptable impact on lifetime and injection efficiency. In order to recover the original performance level, the strengths of two local Sextupoles had to be adjusted (S11-3 and S11-4), combined with a small correction to the remaining sextupole families around the ring [3]. This solution required the magnet field strength of S11-3 to be doubled, which could only be achieved by replacing the existing power supply. Rebalancing of the water cooling circuit for the sextupole magnets was also necessary to compensate for the removal of S11-5 and the increased cooling requirement of S11-3.

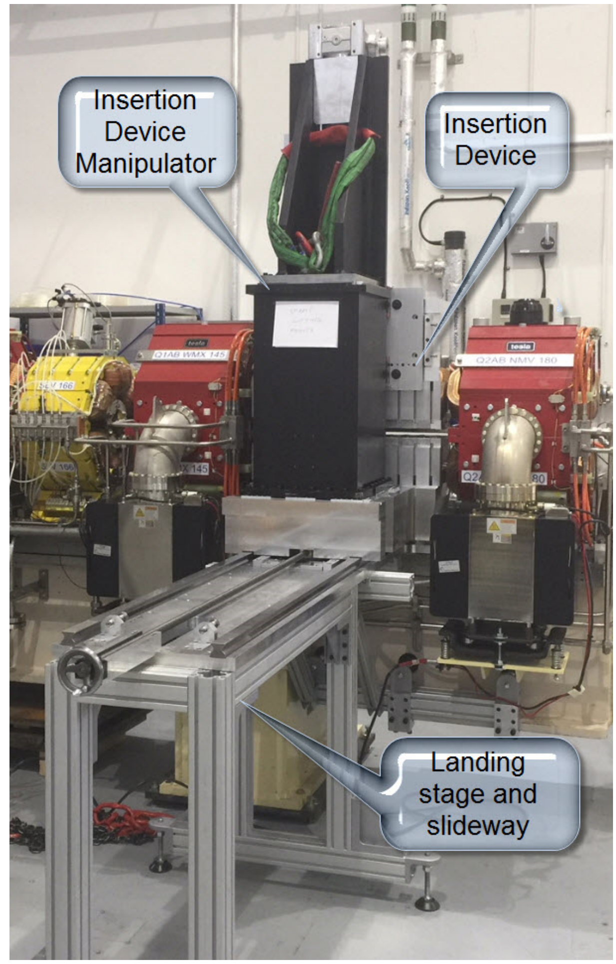

Figure 7: Trial fit of the 10 pole Wiggler in the Girder Build area.

CONCLUSION

The proposal of the inclusion of a short Wiggler as a source for the DIAD Beamline has delivered an alternative to the DDBA configuration that was trialled for the VMX Beamline with minimal impact on machine performance. The capital cost for DIAD represents a £0.5M cost saving and a one year reduction in delivery timescale when compared with DDBA.

REFERENCES

[1] R. P. Walker *et al.*, "The Double-double Bend Achromat (DDBA) Lattice Modification for the Diamond Storage Ring", in *Proc. IPAC'14*, Dresden, Germany, pp. 34-52, doi:10.18429/JACoW-IPAC2014-MOPRO103

[2] I. P. S. Martin and R. Bartolini, "Optimising the Diamond DDBA upgrade lattice for low alpha operation", in *Proc. IPAC'15*, pp. 525-527, 2015, doi:10.18429/JACoW-IPAC2015-MOPMA002

[3] B. Singh *et al.*, "Studies to Install a Multipole Wiggler by Removing a Chromatic Sextupole in Diamond Storage Ring", in *Proc. IPAC'16*, Busan, Korea, May 2016, pp. 3518-3521, doi:10.18429/JACoW-IPAC2016-THPMR050