STUDIES TO INSTALL A MULTIPOLE WIGGLER BY REMOVING A CHROMATIC SEXTUPOLE IN DIAMOND STORAGE RING

B.Singh[1], M. Apollonio[1], R. Bartolini[1,2], R. Fielder[1], E. Koukovini-Platia[1],
I.P.S. Martin[1], T. Pulampong[1], R.P. Walker[1]
[1]Diamond Light Source, Oxfordshire, UK
[2]John Adams Institute, University of Oxford, UK

Abstract

Investigations are underway for a possible use of achromat to install a multipole wiggler by removing a chromatic sextupole in cell-11 after first modification named as DDBA-1 in cell-2. The effect on emittance and energy spread is found to be small. The impact of removing a chromatic sextupole on lifetime and injection is significant if chromatcity is corrected globally. The MOGA genetic algorithm is used to optimize the lifetime and injection efficiency in this case. We used the local mirror chromatic sextupole and other chromatic sextupole family for chromaticity correction in which case the genetic algorithm found a solution that restores lifetime and injection efficiency. In this paper the results of MOGA simulations using various schemes of chromaticity correction and test results in presently operational optics will be discussed.

INTRODUCTION

The Diamond storage ring has been in operation since 2007 [1] and all insertion straights are being utilized to install the insertion devices (ID). There is further demand to accommodate new beamlines and one additional straight section is planned to be created with a double-double bend achromat (DDBA) in place of the double bend achromat (DBA) cell in cell2 [2]. Further exploratory studies have been carried out to create space in the achromat by removing a chromatic sextupole to install a 0.8m long multipole wiggler (MPW). However, removing a chromatic sextupole may damage nonlinear dynamics and hence lifetime and injection efficiency. Also the wiggler is planned to be located in a high dispersion region and may dilute the emittance and energy spread which in turn could affect other beamlines. In this paper we assess the impact and a possible solution to the degradation of nonlinear dynamics using Multi Objective Genetic Algorithm (MOGA) [3] is discussed. This scheme may be considered for implementation in cell-11 after the DDBA installation planned for the end of 2016.

EFFECTS OF MULTIPOLE WIGGLER ON EMITTANCE AND ENERGY SPREAD

In case the scheme is implemented, the multipole wiggler (B_0=1.4T, N=6, λ=116mm and L=0.7m) is planned to be installed downstream of achromat of cell-11. The effects on emittance and energy spread are calculated as in reference [4] and are listed in Table 1.

Table 1: The Effect of MPW116 on Emittance, Energy Spread and Effective Emittance

Case	Emittance ε_x (nm.rad)	Energy Spread (σ_E/E)	Effective Emittance (nm.rad)
MPW116	2.69	$9.586.10^{-4}$	4.08
Without MPW116	2.72	$9.596.10^{-4}$	4.05

The effective emittance of this section of achromat is 4.1nm which is only ~35% higher than that of the standard insertion straights (3nm). Another concern could be the vertical apertures requirements as β_y is significantly large in this region compared to the insertion straight. It is ~24m at the exit of the wiggler (see Fig.1) which yields the full vertical aperture requirement to about 16mm, which is normal for our case. It will be referred to as missing sextupole optics.

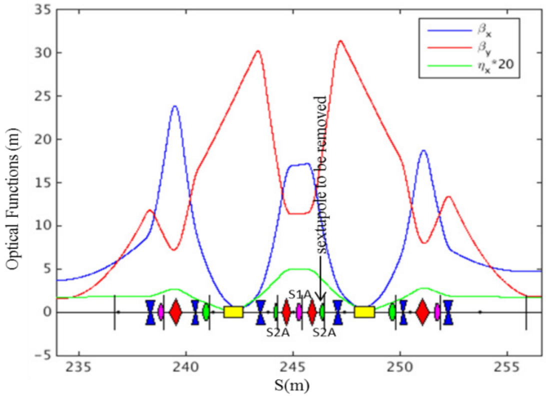

Figure 1: Optical functions in achromat of cell-11 of Diamond lattice. The chromatic sextupole S2A(11,5), which will be removed in order to locate MPW116, is indicated.

EFFECT OF REMOVING SEXTUPOLE

There are two families of chromatic sextupoles, S1A and S2A, in Diamond lattice as shown in Fig. 1. The downward S2A[11,5] of cell-11 is to be removed as indicated in Fig. 1. By doing so, the chromaticity values $\xi_{x,y}$ are changed significantly and need to be restored. Touschek lifetime and injection efficiency could also be affected. Chromaticity $\xi_{x,y}$ can be restored by using; a)the remaining families of S1A and S2A (global), b) all S1A and local mirror S2A[11,3] to one removed (S1A: global

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and S2A: local), c)S1A[11,4] and S2A[11,3] of this achromat only (local). It has been found that the local and global use of S2A has significantly different effects on the lifetime and injection efficiency. The initial MOGA simulations are shown in Fig. 2 and indicate that using the local S2A[11,3] for chromaticity correction is a better option. It can also be seen that global correction does not show improvement in MOGA simulations. Therefore, in further optimization the case a was dropped. Also no big difference was noticed when both S2A[11,3] and S1A[11,4] (case c) of the same achromat were used. In further MOGA optimization, only cases b and c have been considered. The degradation seen in Fig. could be attributed to distortions of on/off-momentum dynamic aperture (DA).

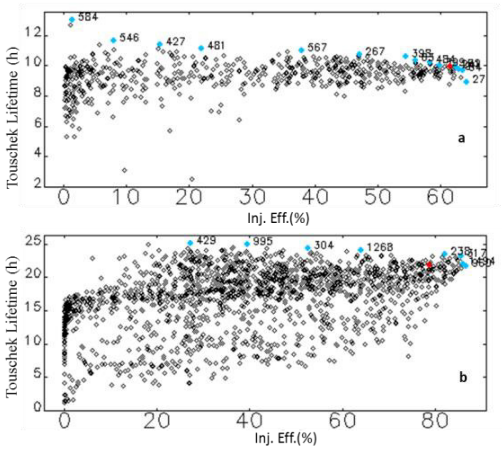

Figure 2: The red dot is initial configuration, black dots are generic solutions and blue dots are pareto-optimal front generated during MOGA optimization of Touschek lifetime and injection efficiency.

MOGA OPTIMIZATION

If a missing sextupole scheme is to be implemented in the DDBA lattice, then it should also be feasible to operate the machine in low-alpha mode. In this section the simulations for DDBA and low-alpha optics are discussed.

DDBA Lattice with a Missing Sextupole

The detailed MOGA simulations for the optimization of injection efficiency and Touschek lifetime were launched considering all multipolar errors and performing local chromaticity corrections using sextupole S2A[11,3], or all S1A, or only S1A[11,4].

Table 2: Touschek Lifetime, 3000 Turns, 900 Bunches, σ_l=5.34mm, V=2.6MV and Inj. Eff. for 1500 Turns

Case	Lifetime (h)	Inj. Eff. (%)
DDBA+ missing sextupole	18.8 ± 1.7	82.4 ± 4.5
DDBA only	19.7 ± 0.8	89.3 ± 4.0

It requires doubling the strength of S2A[11,3], while S1A[11,4] varies by few percent for chromaticity of 2/2. The chosen MOGA optimized solution was then used to calculate lifetime and injection efficiency with displacement and multipolar errors for different seeds which generated a coupling of 0.3%. The results are reported in Table 2 along with DDBA optics only. There is only marginal reduction in lifetime and injection efficiency.

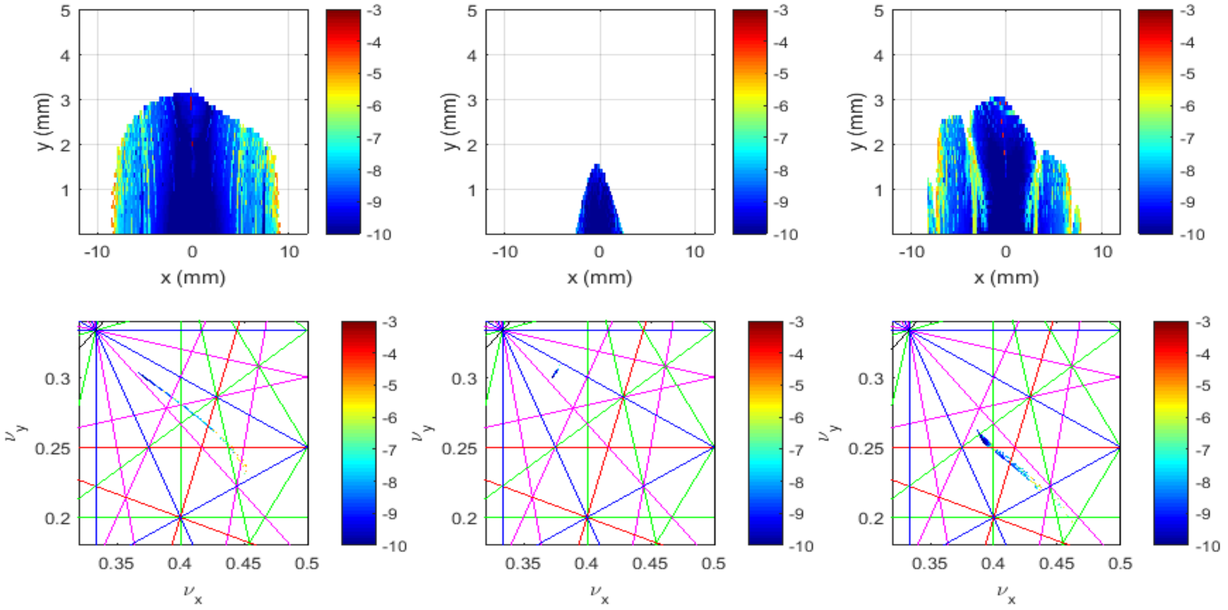

Figure 3: Dynamic apertures (top row) and frequency maps (bottom row) for the nominal low alpha DDBA lattice (left), missing sextupole with local chromaticity correction (middle) and missing sextupole with MOGA optimised tune values and sextupole strengths.

Simulations for Low Alpha Optics

Preliminary studies have also begun for adapting the missing-sextupole scheme to the low-alpha optics for the DDBA upgrade lattice [5]. A similar approach was used in this case as for nominal optics, namely the change in chromaticity resulting from switching off S2A[11,5] was initially corrected locally using the chromatic sextupoles S2A[11,3] and S1A[11,4], with the linear optics kept constant.

Inspection of the resulting on-momentum dynamic aperture (DA) and frequency map (FM) highlighted the linear chromaticity remain constant (see Fig. 3). In particular, both the higher order chromaticity and tune-shifts with amplitude are significantly altered, impacting both the lifetime and injection efficiency.

In light of these findings, MOGA optimisations of the linear and nonlinear optics are presently being carried out. Optimisation of the linear optics consists of varying the tune-point in a small region close to the existing value using all quadrupole families, whilst constraining α_1 to the desired value. For the nonlinear optics, 9 out of 12 sextupole families plus the two local sextupoles are allowed to vary freely, with the remaining 3 families used to correct the transverse chromaticity (also treated as variables) and second order momentum compaction factor, α_2. Higher-order multipole errors are applied to the quadrupoles and sextupoles during the optimisation.

The DA and FM for the best solution to date of MOGA optimization of lifetime and injection efficiency are shown in Fig. 3. Optimisation of this mode remains a work in progress, with the sensitivity of the final optics to field and alignment errors a key area yet to be assessed.

MACHINE TESTS OF CONCEPT

To develop confidence for a possible use of the missing sextupole scheme, it was decided to test the concept in presently operational lattice. We used MOGA optimizer with local chromaticity correction in cell-11. Since the strength of S2A[11,3] is doubled. The present magnet lies in nonlinear region.

Power supply current ratings were increased from 100A to 120 A to check the possible chromaticity correction. The MOGA optimized sextupoles were tested in the machine. The results are shown in Fig. 4 and indicate the severe reduction in lifetime from 33h to 7h once S2A[11,5] is switched off. The lifetime restores to 32h once the optimized sextupoles are applied. The injection efficiency was nil once the sextupole is switched off but it recovers to 40% after the optimized sextupoles are applied to 40% and 90% once the kickers' current is raised. The chromaticity measured was ~1/1 and could be increased to 1.2/1.1 after chromaticity correction using the local sextupoles S1A[11,4] and S2A[11,3] using matlab scripts written for this purpose before reaching the power supply limit of 120A of S2A[11,3]. Initially, experiments were performed with all IDs, collimators fully open and wigglers switched off (results of Fig. 4). The effects of closing the collimators and IDs to injection gaps were negligible. Further observations were made that injection was not possible if global chromaticity correction was applied after switching off S2A[11,5]. Also the lifetime did not improve even though chromaticity was corrected to 2/2, which was also shown in MOGA optimization.

CONCLUSIONS

The missing sextupole optics has potential to be implemented. The MOGA optimization yields a good solution for the DDBA optics which restores the lifetime and injection efficiency. The low alpha optics has also been found though more work is required. For the local chromaticity correction, a sextupole with 2.5 times the strength of the present magnet will be required.

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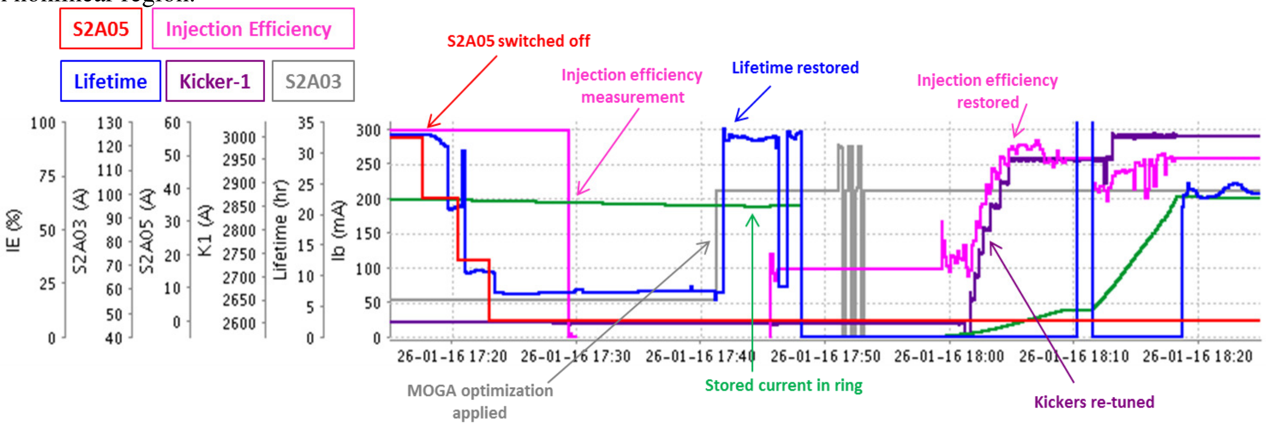

Figure 4: Machine tests for the concept of missing sextupole in cell-11 in presently operational lattice. A significant reduction in lifetime is observed once S2A05 (S2A[11,5]) is switched off, which restores once the MOGA optimized sextupoles are applied. The injection efficiency, once the current of kicker magnets is increased, is also restored.

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