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OPTIMIZED LINEAR AND SECOND ORDER CHROMATICITY SETPOINTS FOR THE ADVANCED PHOTON SOURCE UPGRADE*

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Abstract

The nominal single particle dynamics optimizations of the Advanced Photon Source upgrade (APS-U) lattice are performed with dense numerical simulations of local momentum acceptance and dynamic acceptance. These simulations are quite time consuming, which may take weeks for optimizing one setpoint of linear chromaticity. In this paper, an alternative optimization method is adopted to generate optimized linear and second order chromaticity setpoints for the Advanced Photon Source upgrade lattice. This method is efficient in computing time needed, which is capable to generate a grid of optimized linear chromaticity setpoints in a relatively short time. The performance of these lattice solutions are verified by simulations with reasonable errors. These lattice solutions with different linear (or second order) chromaticity may be useful for the future APS-U commissioning and operations.

INTRODUCTION

For next generation storage rings light source, the combination of small physical apertures (for both insertion device and the arc sections) and strong chromaticity correction sextupoles introduces small dynamic acceptance and short lifetime. To optimize the nonlinear beam dynamics performance and achieve better injection efficiency and lifetime, the effectiveness of several different optimization methods and objectives [1] were benchmarked for the nonlinear beam dynamics optimization of Advanced Photon Source upgrade (APS-U) lattice [2].

In addition to these different optimization methods [1], recently it was found that optimizing the overall tune spread from transverse and energy offsets (this method is named as DET) seems to be a better approach, which is reliable and computationally efficient. The nominal single particle dynamics optimizations of the APS-U lattice are performed with direct simulations of local momentum acceptance (LMA) and dynamic acceptance (DA). This nominal approach is very reliable, as it employs same optimization and evaluation objectives. However, the LMA/DA simulations are quite time consuming, which may take weeks for optimizing one setpoint of linear chromaticity.

In this paper, DET optimization method is adopted to generate optimized linear and second order chromaticity setpoints for the APS-U lattice. This method is computationally efficient and capable to generate a set of optimized chromaticity setpoints in a relatively short time. Although using tune spread as the optimization objective, it is shown that the derived solutions have good performance, when evaluated with different objectives of LMA and DA.

OPTIMIZED LINEAR CHROMATICITY SETPOINTS

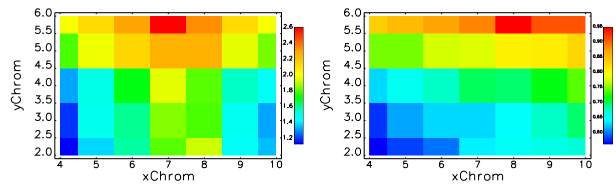

Figure 1: Initial (left) and final tune spread penalty on a grid of linear chromaticity setpoints. Max penalty reduced from 2.6 to 0.9.

Linear chromaticity knobs are widely used in storage ring operations. For APS DBA ring, the combination of two sextupole families (one focusing and one defocusing) out of a total of four families is employed for linear chromaticity knobs. As the optics are different at different families of sextupoles, it is not possible to group all sextupoles into the knob. Naturally for APS-U lattice (hybrid MBA lattice [3]), there are ‘similar’ optics parameters at all the focusing sextupoles SF, or at all the defocusing sextupoles SD. If using all the APS-U sextupoles for linear chromaticity knob, sextupoles strength will be continuous and smooth. However, the solution may not be optimized, even starting from a well optimized lattice.

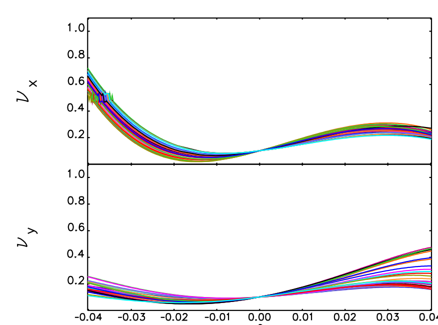

Figure 2: Chromatic detuning of optimized linear chromaticity setpoints.

On the other hand, it is possible to employ the DET method for efficiently generating a grid of linear chromaticity setpoints, as it takes much less computing time. For this approach, independent optimization is performed at each

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chromaticity setpoint, so the performance is guaranteed to be optimized. However, the resulting sextupoles strength may not be continuous and smooth. A grid of linear chromaticity covers the horizontal chromaticity from 4 to 10, and vertical chromaticity from 2 to 6, with step size of 1. DET based optimization is performed at each setpoint (a total of 500 sextupole seeds evaluated) without optics errors. The initial condition and final optimization results are shown in Figure 1, where it is observed that max tune spread penalty is reduced from 2.6 to 0.9. At each setpoint on the grid, the tune spread is optimized. The final tune spread penalty variations of these setpoints are not large, ranging from 0.6 to 0.9. The chromatic detunings of these setpoints are shown in Figure 2.

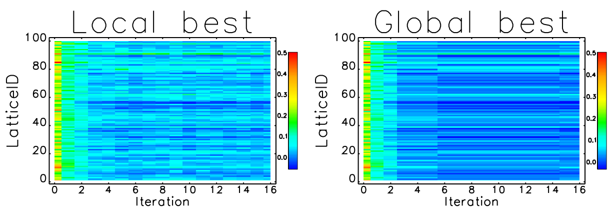

Figure 3: Local (left) and global optimum penalty of 100 lattice configurations at each iteration (color code is overall tune spread penalty).

SECOND ORDER CHROMATICITY SETPOINTS

In this section it is discussed on one way to generate second order chromaticity setpoints at fixed linear chromaticity for flexible APS-U operations, which might be useful especially in the commissioning stage. Derived with DET optimization approach, these lattice setpoints also provide solutions with possible trade-off between chromatic and geometric abberations, i.e., some solutions may have better lifetime while others have better injection efficiency.

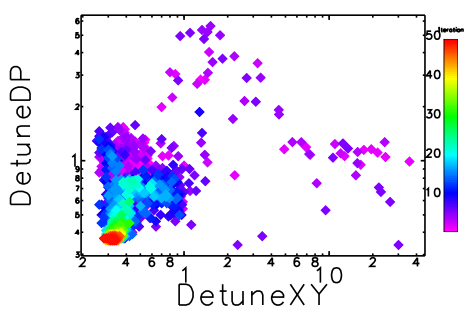

Figure 4: Pareto front and trade-off between chromatic and geometric tune spreads. Color denotes number of iterations.

For the linear chromaticity setpoint, two families out of the six families of sextupoles are employed to meet the linear chromaticity target. For second order chromaticity setpoints, it is not straightforward to directly specify the second order chromaticity targets. Instead, the linear chromaticity is fixed at (8.1, 4.7) which is the nominal value for APS-U lattice, while second order chromaticity is allowed to vary between 100 and 600. Each second order chromaticity setpoint was picked from optimized solutions with DET approach. Here, to find APS-U lattice solutions which are robust against different optics errors, all 100 commissioning [4] ensemble configurations are included in the lattice nonlinear optics optimization process [5]. These lattice configurations represent different errors (misalignment, BPM, magnets strength and tilt) and corrections.

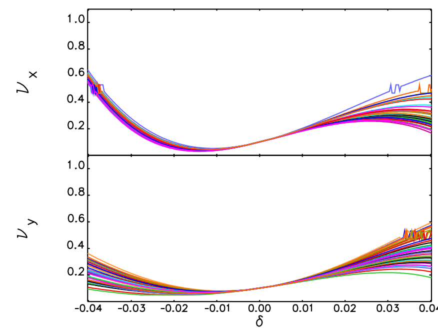

Figure 5: Chromatic detuning for optimized second order chromaticity setpoints. Linear chromaticity fixed at (8.1, 4.7) for APS-U lattice.

The local and global optimum tune spread penalty of 100 lattice configurations in the first 16 iteration are shown in Figure 3, where 30 sextupole seeds are explored for each iteration. It is observed that the average performance over 100 lattice configurations can be improved. Figure 4 shows the pareto front of the optimization, on the space of chromatic and geometric tune spreads. The chromatic detunings of these second order chromaticity setpoints are shown in Figure 5. It is observed that chromatic detunings are on average optimized, which is essential to achieve good lifetime.

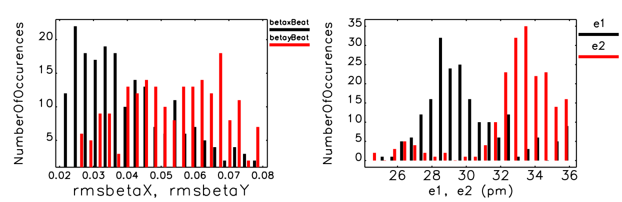

Figure 6: Histogram of beta beating (left) and beam moments of selected 200 random seeds.

EVALUATION OF PERFORMANCE

As it is impossible to evaluate all these chromaticity setpoints, using the standard APS-U commissioning/ensemble evaluation procedures (which need extremely long computing time), here a simplified evaluation procedure is employed. The quadrupole and skew quadrupoles error are generated in all 240 sextupole magnets using ELEGANT code [6].

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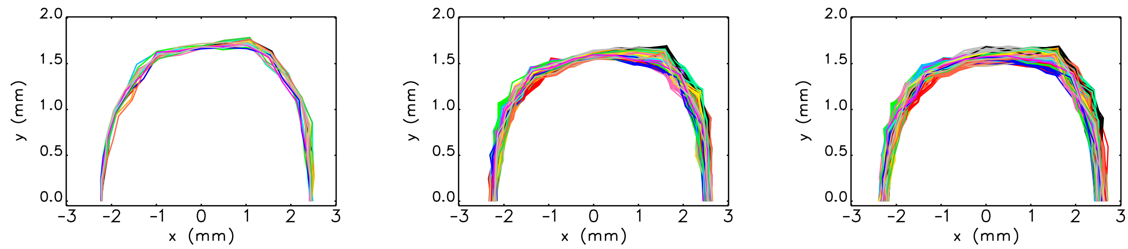

Figure 7: Dynamic acceptance (DA) of APS-U lattice (left), DA of optimized linear chromaticity setpoints (middle), and DA of optimized second order chromaticity setpoints (right).

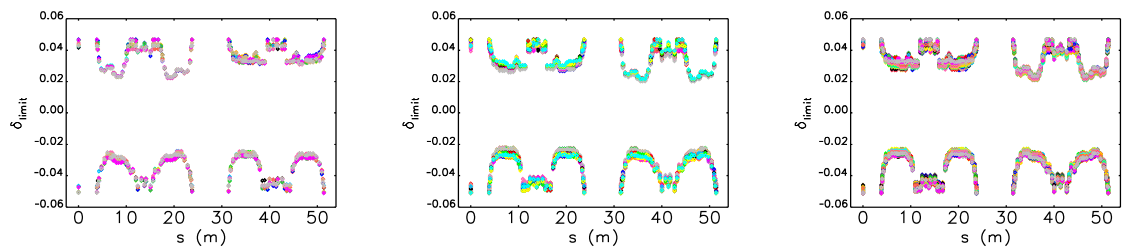

Figure 8: Local momentum acceptance of APS-U lattice (left), DET optimized linear chromaticity setpoints (middle), and DET optimized second order chromaticity setpoints (right).

Random error seeds are filtered for beta beating from 2% to 8%, plus 'same' horizontal and vertical beam moments when tunes are equal. In total 200 total seeds are collected, as shown in Figure 6.

16 Random error seeds out of the total 200 seeds are employed for simulation of dynamic acceptance and local momentum acceptance. The comparison results are shown in Figure 7 and Figure 8. The dynamic acceptance and local momentum acceptance of these linear and second order chromaticity setpoints are found to be comparable to the nominal APS-U lattice which is optimized with the LMA/DA method.

The program 'TouschekLifetime' [7] was used for calculation of Touschek lifetime, using the LMA data shown in Figure 8. The bunch charge is 15nC with full coupling, and 15mm rms bunch length. Figure 9 shows that the calculated lifetime of the linear and second order chromaticity setpoints are comparable to the nominal APS-U lattice.

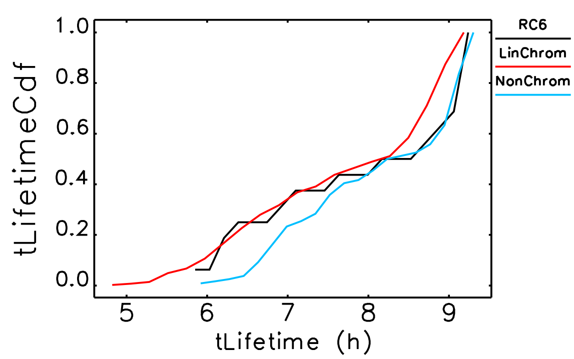

Figure 9: Comparison of Touschek lifetime cumulative distribution function. RC6 (black curve) denotes nominal APS-U lattice. Red and blue curves are for linear and second order chromaticity setpoints.

CONCLUSIONS

It is discussed on one approach for generating optimized linear and second order chromaticity setpoints for APS-U lattice, which can be useful in APS-U commissioning/operation stage. DET optimization method is adopted here as it is computationally efficient and capable to generate a set of optimized chromaticity setpoints in a relatively short time. The generated setpoints has similar performance compared with nominal APS-U lattice, under a simplified evaluation procedure.

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