Frequency Map Studies for the OCS6 Lattice

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Overview

- Frequency Maps
- Results for nominal lattice
- Results for OCS5 lattice
- Results for higher chromaticity
- Results for different tunes
- Conclusion
Frequency Maps

- track a set of particles for $N$ turns
- record position and angle every turn
- calculate tune for first $N/2$ and second $N/2$ turns
- calculate tune diffusion rate; the smaller it is, the more stable the particle
- plot diffusion rate color coded as function of amplitude and initial tune
Results for Nominal Lattice

- Vertical fourth order resonance clearly visible
- Strong cross detuning with amplitude
- Footprint frayed
Nominal Lattice (off-momentum)

\[ \frac{\Delta p}{p} = -0.5\% \]

\[ \frac{\Delta p}{p} = -1.0\% \]

\[ \frac{\Delta p}{p} = +0.5\% \]

\[ \frac{\Delta p}{p} = +1.0\% \]

- horizontal third order resonance is strong
- footprint frayed
Nominal Lattice (off-momentum)

\[
\frac{\Delta p}{p} = -0.5\%
\]

\[
\frac{\Delta p}{p} = -1.0\%
\]

\[
\frac{\Delta p}{p} = +0.5\%
\]

\[
\frac{\Delta p}{p} = +1.0\%
\]

- Large diffusion rates at large vertical amplitudes for negative \(\frac{\Delta p}{p}\).
- Dynamic aperture reduced compared to on-momentum.
Results for different chromaticities

\[ \xi_x = \xi_y = 1 \]

\[ \xi_x = \xi_y = 3 \]

- more particles are pushed over horizontal third order resonance
- more particles with large diffusion rates
Results for different chromaticities

\[ \xi_x = \xi_y = 1 \]

\[ \xi_x = \xi_y = 3 \]

- dynamic aperture reduced for larger chromaticity
- vertical fourth order resonance crossed at smaller amplitude
\[ \xi_x = \xi_y = 3 \text{ (off-momentum)} \]

\[ \frac{\Delta p}{p} = -0.5\% \quad \frac{\Delta p}{p} = -1.0\% \]

\[ \frac{\Delta p}{p} = +0.5\% \quad \frac{\Delta p}{p} = +1.0\% \]

- horizontal third order resonance reduces dynamic aperture for negative \( \frac{\Delta p}{p} \)
- many particles have large diffusion rates
\( \xi_x = \xi_y = 3 \) (off-momentum)

- \( \frac{\Delta p}{p} = -0.5\% \)
- \( \frac{\Delta p}{p} = -1.0\% \)
- \( \frac{\Delta p}{p} = +0.5\% \)
- \( \frac{\Delta p}{p} = +1.0\% \)

- vertical dynamic aperture clearly reduced for negative \( \frac{\Delta p}{p} \)
- large diffusion rates occur at small amplitudes

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Comparison between OCS5 and OCS6

- Lattices have different number of short straight sections
- Arc cells are identical
- Tunes are different
Comparison between OCS5 and OCS6

- different tunes
- cross detuning smaller for OCS5 leading to a smaller footprint
Comparison between OCS5 and OCS6

- particles at large amplitude are more stable for OCS5
- dynamic aperture reduced for OCS6
What changed from OCS5 to OCS6?

- Different number of straight sections
- Different tunes

Try to change tune of OCS6 to the values of OCS5:
- Using one straight section as a tune trombone
- Changing the phase advance in the arc cells slightly
Using OCS5 tunes (tune trombone)

vertical third and horizontal fourth integer resonance are strong
footprint frayed
Using OCS5 tunes (tune trombone)

- vertical dynamic aperture reduced drastically
- horizontal fourth order resonance cutting into dynamic aperture

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Using OCS5 tunes (arc)

OCS6

- some horizontal fourth and fifth order resonances visible
- vertical detuning reduced
- part of footprint still frayed
Using OCS5 tunes (arc)

- Dynamic aperture about comparable, better in the vertical plane
- Dynamic aperture restriction mainly caused by horizontal fifth order resonance
Tune scan

- scan tunes and calculate 10x10 frequency maps
- sum diffusion rates
- select tune at lowest diffusion rate (0.300, 0.275)
New tune (0.300, 0.275)

- footprint is small (i.e. detuning is reduced) but still a little bit frayed
- some resonances visible
New tune (0.300, 0.275)

- almost no particle losses
- some resonances clearly visible at small amplitudes
\[ Q = (0.300, 0.275), \text{ off-momentum} \]

\[ \frac{\Delta p}{p} = -0.5\% \]

\[ \frac{\Delta p}{p} = +0.5\% \]

- footprint somewhat frayed due to some resonances
- very few particles lost
- some resonances at small amplitudes
- worse, but not significantly so, than on-momentum
Conclusion

- Dynamic aperture problems caused by combination of tune values and large cross detuning with amplitude
- Choosing a different tune can increase the dynamic aperture significantly
- Harmonic sextupoles might increase the dynamic aperture further