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Optimization of a TBA with Stable Optics and Minimal Longitudinal Dispersion and CSR-Induced Emittance Growth*

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Abstract: In the beam transfer line which often consists of dipoles to deflect the beam trajectory, longitudinal dispersion effect and emission of coherent synchrotron radiation (CSR) will lead to beam phase space distortion, thus deteriorating the machine performance. In this study, optimizations of a **TBA cell** are conducted using the multi-objective particle swarm optimization (**MOPSO**) method to **suppress the CSR-induced emittance growth and minimize the longitudinal dispersion functions up to high orders**, simultaneously. For the longitudinal dispersion function, results of three optimization settings are reported, which makes the TBA design first-order, second-order, and higher-order isochronous. Furthermore, we study the shortest possible beamline length of the higher-order isochronous TBA design, which may pave the way to designing a more compact beam transfer line.

Introduction

CSR

- In transverse direction: CSR causes energy deviation and brings about dilution of the transverse emittance
- In longitudinal direction: CSR can give rise to the microbunching instability (MBI).

Longitudinal dispersion

- the particle's momentum deviation δ is correlated to the longitudinal bunch coordinate z via R_{56}, T_{566}, U_{5666}, etc.

$$z_f = z_i + R_{56}\delta_i + T_{566}\delta_i^2 + U_{5666}\delta_i^3 + O\left(\delta_i^4\right)$$

- results in undesirable bunch length variation.

TBA cell layout & Optimization method

TBA cell layout

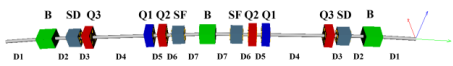


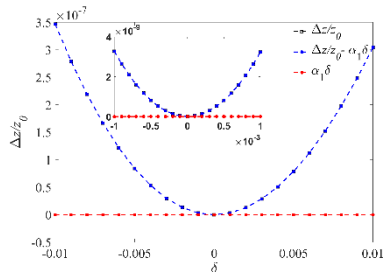
Figure 1: The lattice structure of TBA design and the magnet layout. The green cuboids represent dipoles, the red ones and the blue ones represent focusing quadrupoles and defocusing quadrupoles, respectively, while the indigo blue ones represent sextupoles.

MOPSO optimization

- Objective functions: weighted α_1, weighted $\Delta\varepsilon_n$
- Variables: 8 variables——6 drift lengths, 2 quadrupole strengths
- drift length [0.1m, 2m], quadrupole strength [-30m^{-2} , 30m^{-2}]
- Dipole parameters: L_B=0.4m, θ =4°

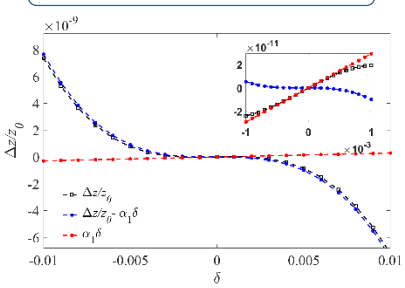
MOPSO optimization and results

Optimization of $\Delta\varepsilon_n$, α_1



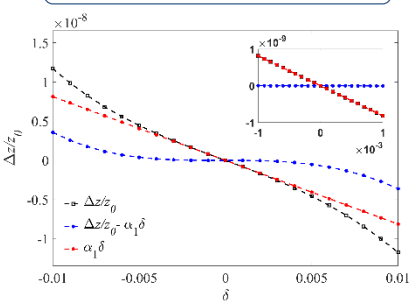
Optimization of $\Delta\varepsilon_n$, α_1, α_2

add weight factor $|\alpha_1\delta| > 5|\alpha_2\delta^2|$.



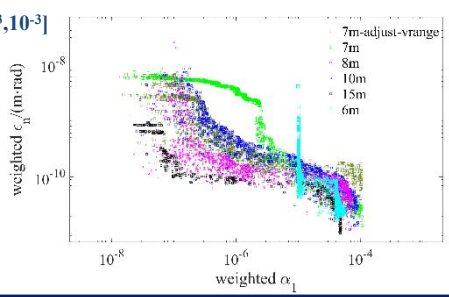
Optimization of $\Delta\varepsilon_n$, α_1, higher orders

add weight factor $|\alpha_1\delta| > 2|O(\delta^2)|$

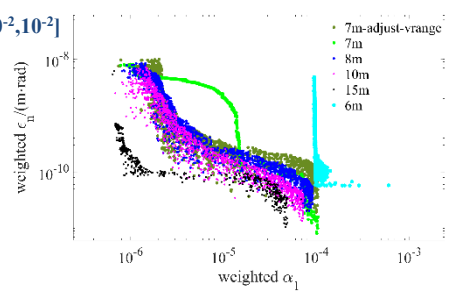


Comparison of the TBA length

δ= [-10^{-3},10^{-3}]



δ= [-10^{-2},10^{-2}]



It is feasible to compress the TBA length to 8m in the current parameter range.

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