OSC simulation update

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Important parameters (TT-OSC):

Cooling boundaries: $\epsilon_{max}=\frac{\mu_0^2}{k^2(\beta_p M_{51}^2-2\alpha_p M_{51}M_{52}+\gamma_p M_{52}^2)}$ $\left(\frac{\Delta p}{p}\right)_{max}=\frac{\mu_0}{k\widetilde{M_{56}}}$ $(\widetilde{M}_{56})_{max}=\frac{\mu_0}{k\,\delta E/E}$

μ_0=2.405
λ=1E-6
$\delta E/E$ = 2E-4
$(M_{56\_t})_{max}$=1.9E-3

Sample lengthening: $a_x=k\sqrt{\epsilon(\beta_p M_{51}^2-2\alpha_p M_{51}M_{52}+\gamma_p M_{52}^2)}$ $a_p=k\widetilde{M}_{56}\delta p$

The smaller, the better

Cooling rates: $\lambda_x=\frac{k\xi_0}{2}(M_{56}-\widetilde{M_{56}})$ $\lambda_s=\frac{k\xi_0}{2}\widetilde{M_{56}}$

Both λ_x and λ_s need to be positive for cooling.

Cooling decrement: $\frac{\Delta p}{p}=-\xi\sin(k\Delta s)$ corrected: $\frac{\Delta p}{p}=-\xi(1-\frac{\Delta s}{N_u\lambda})\sin(k\Delta s)$

$$\langle\Delta\epsilon\rangle=2\pi\epsilon\xi k*(M_{51}\sqrt{\frac{\beta_p}{\beta_k}}(\eta_k(\cos\varphi-\alpha_k\sin\varphi)-\eta_k'\beta_k\sin\varphi)+M_{52}\frac{\eta_k}{\sqrt{\beta_k\beta_p}}((\alpha_k-\alpha_p)\cos\varphi+(1+\alpha_k\alpha_p)\sin\varphi)+M_{52}\eta_k'\sqrt{\frac{\beta_k}{\beta_p}}(\cos\varphi+\alpha_p\sin\varphi))$$

<Δε> need to be negative for cooling.

Optical amplifier gain: $\frac{\langle\Delta\epsilon\rangle}{\epsilon}<1$

ξ is set to meet the above requirement.

Single element test: 200 particles, track for 50 turns, excitation and damping turned on
Each particle receives the energy kick based on its own (x, x', z')

Q45E: large horizontal dispersion 2.05 m in the test lattice (2.1GeV CesrTA lattice)

Initial emittance: ε_x=5E-9

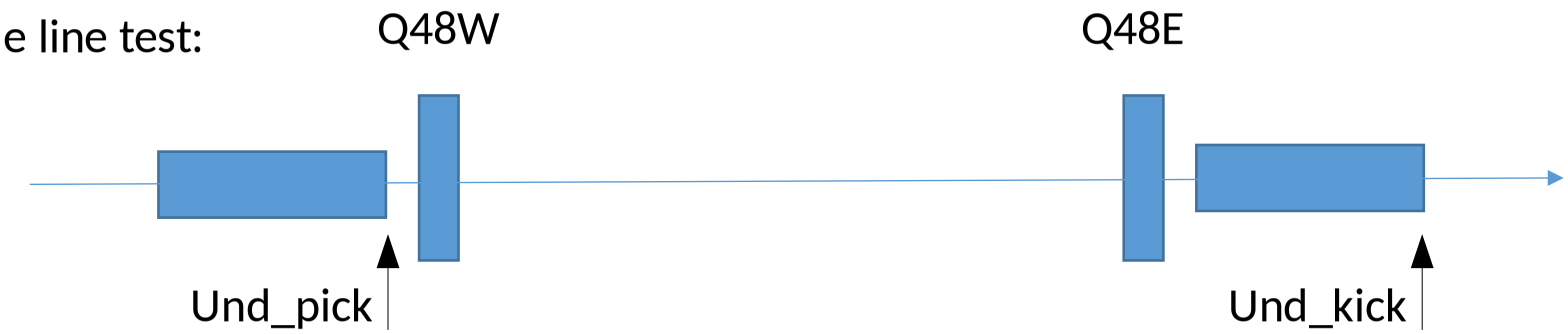
Horizontal cooling, longitudinal heating

M_{51}: -3.98E-7, M_{52}=2.46E-6, M_{56}= 3.61E-8, M_{56_T}= -2.12E-7,
undulator light wavelength: λ=1 μm, gain: ξ_0=2E-2
Cooling range: ε_{max}=1.02E-1, $(\Delta p/p)_{max}$= -1.8
Cooling rates: λ_x=1.56E-02, λ_s= -1.334E-02
Change emittance per turn: $\Delta\varepsilon$= -9.81E-10, Δs= ~1E-9 → 1E-11
a_x=5.3E-4

Horizontal cooling, longitudinal cooling

M_{51}: -3.98E-7, M_{52}=2.46E-6, M_{56}= 1.6E-6, M_{56_T}= 7.51E-7,
undulator light wavelength: λ=1 μm, gain: ξ_0=2E-2
Cooling range: ε_{max}=1.02E-1, $(\Delta p/p)_{max}$= 0.51
Cooling rates: λ_x=1.56E-02, λ_s= 4.72E-2
Change emittance per turn: $\Delta\varepsilon$= -9.81E-10, Δs= ~1E-9 → 1E-11

Simple line test:



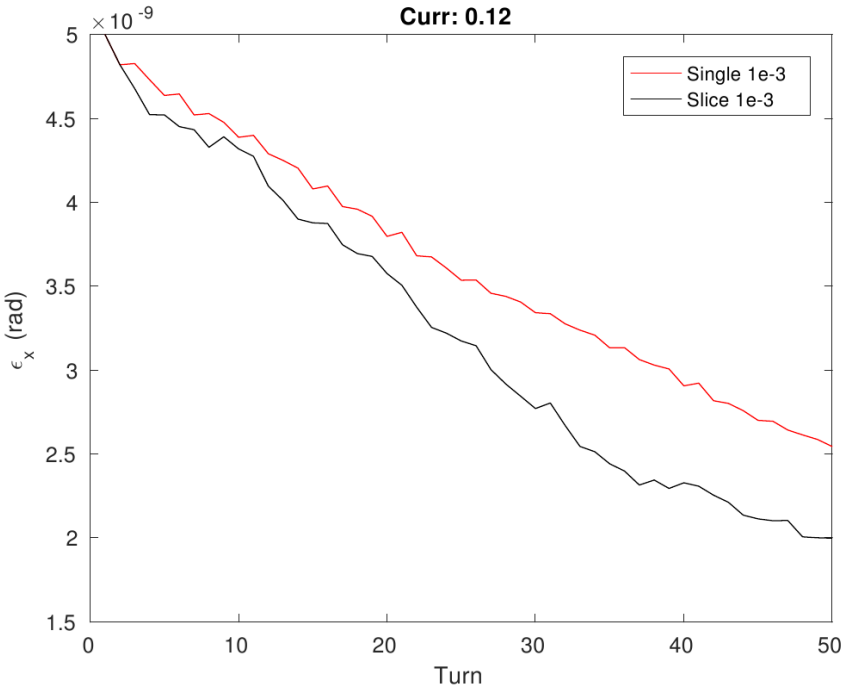
In tracking simulation at each turn:

- Record the particle distribution in z at the end of Und_pick
- Particle receive the energy kick at the end of Und_kick

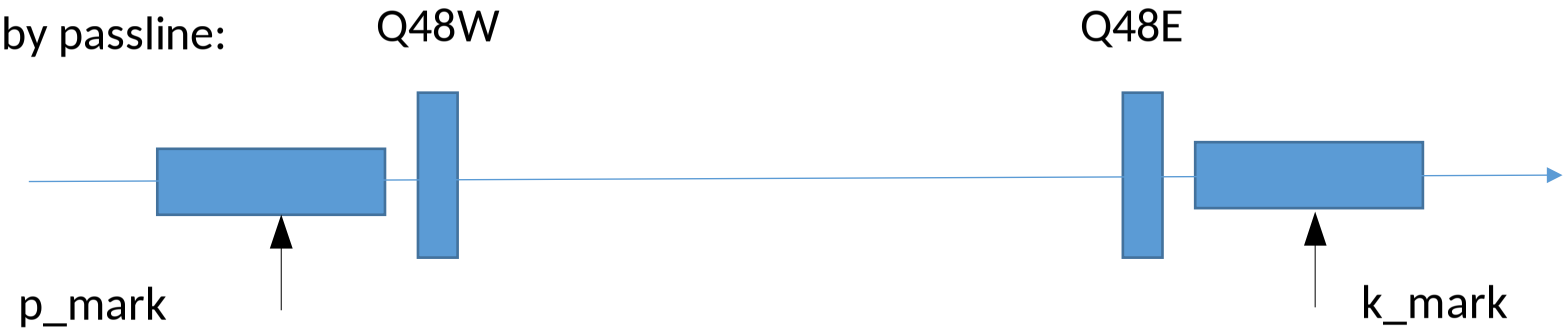
M_{51}: -1.02E-4, M_{52}=3.14E-4, M_{56}= 7.7E-7, M_{56_T}= -1.52E-6,
undulator light wavelength: λ=1 μm, gain: ξ_0=1E-3
Cooling range: ε_{max}=1.15E-6, $(\Delta p/p)_{max}$= -0.25
Cooling rates: λ_x=7.21E-3, λ_s= -4.77E-3
Change emittance per turn: $\Delta\varepsilon$= -4.53E-10,
Path length delay: Δs= ~5E-8 → 1E-8, $k\Delta s \sim 0.3$
a_x = 0.16

Increase M_{56}= 5E-6, M_{56_T}= 2.70E-6,
undulator light wavelength: λ=1 μm, gain: ξ_0=1E-3
Cooling range: ε_{max}=1.16E-6, $(\Delta p/p)_{max}$= 0.14
Cooling rates: λ_x=7.23E-3, λ_s= 8.48E-3
Change emittance per turn: $\Delta\varepsilon$= -4.55E-10
Both horizontal and longitudinal cooling

Initial emittance: ε_x=5E-9
In a 2.1GeV CTA lattice



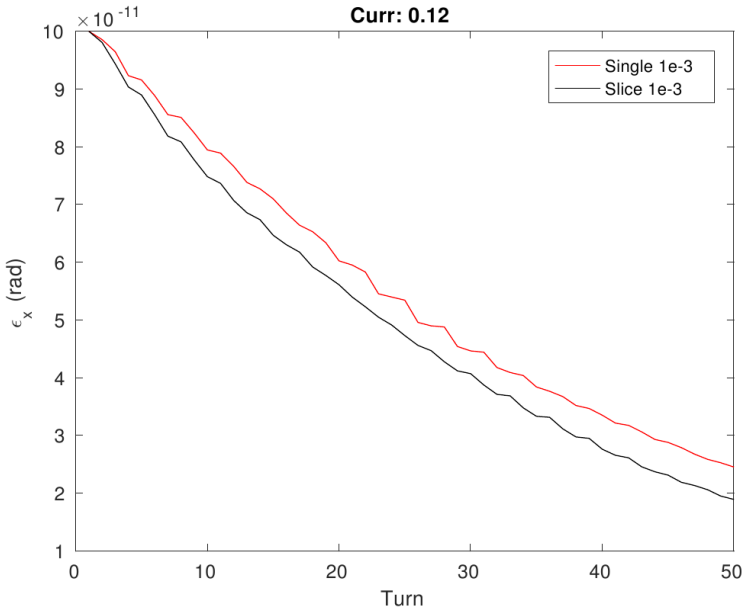
MPE's by passline:



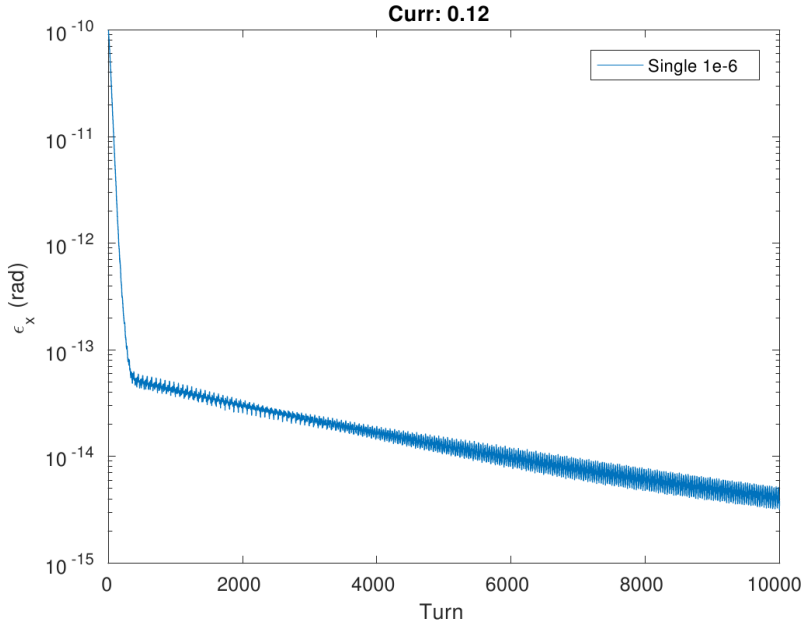
1. $\varepsilon_{init} > \varepsilon_{max}$, no horizontal cooling and a_x>2.3 large

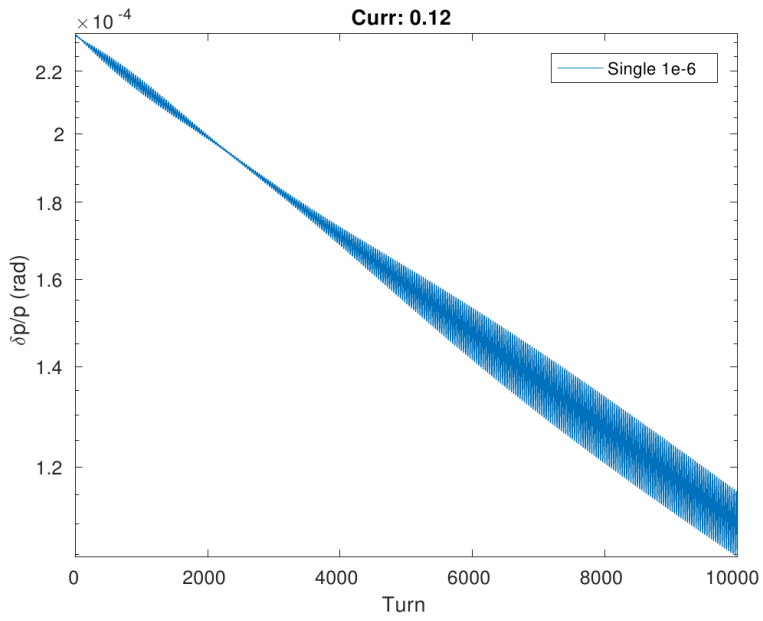
2. $\varepsilon_{init} < \varepsilon_{max}$, horizontal cooling but slow longitudinal cooling
   ε_{init}=1E-10, a_x=0.77

M_{51}= 1.89E-3, M_{52}= -4.09E-2, M_{56}= 1.176E-2, M_{56_T}= 5.35E-5,
undulator light wavelength: λ=1 μm, gain: ξ_0=1E-6
Cooling range: ε_{max}=9.835E-10, $(\Delta p/p)_{max}$= 7.16E-3
Cooling rates: λ_x=3.68E-2, λ_s= 1.68E-4
Change emittance per turn: $\Delta\varepsilon$= -4.62E-11,
Path length delay: Δs < 3E-7 ($k\Delta s$ ~ 1.88)



MPE's bypass line





Horizontal: two cooling rates
1-500 turn: t_x= 32.6 turns
>500 turn: t_x=3806 turns

Energy cooling rate:
t_s=13390.06 turns

Theoretical cooling rate ratio: λ_x/λ_s=3.68E-2/1.68E-4 = 219

Tracking: t_s/t_x= 410.7