Simulation Studies of Plasma Cascade Amplifier

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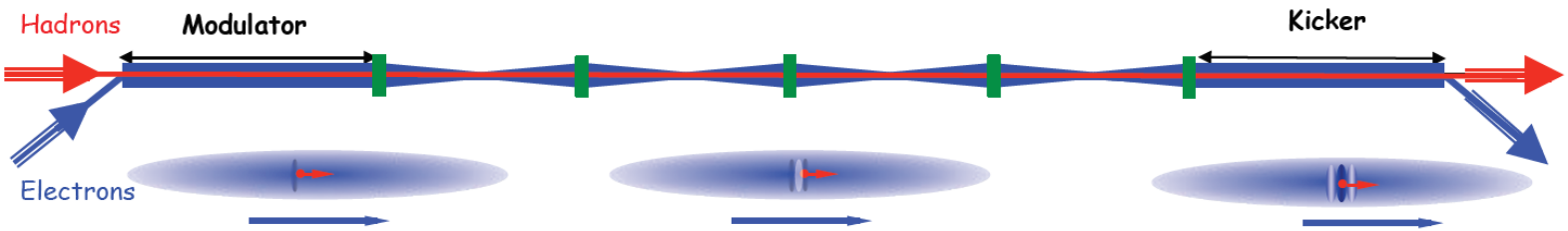
Introduction

- Coherent electron cooling (CeC) is the most promising technique for the rapid cooling of high-energy high-intensity hadron beams in the Electron-Ion Collider (EIC) at Brookhaven National Laboratory (BNL).
- Modulator, amplifier, kicker.
- Working principle of the plasma cascade amplifier (PCA) is the new plasma cascade instability (PCI).

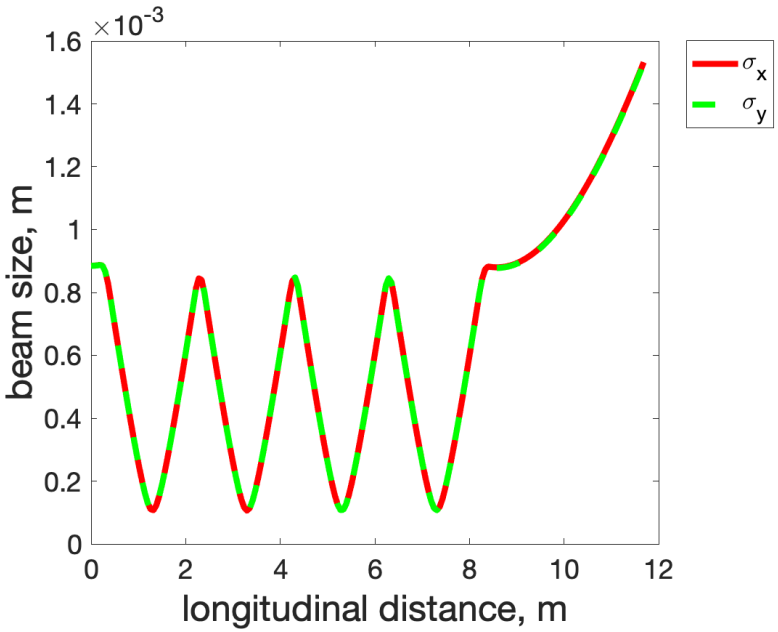


(a) CeC with PCA

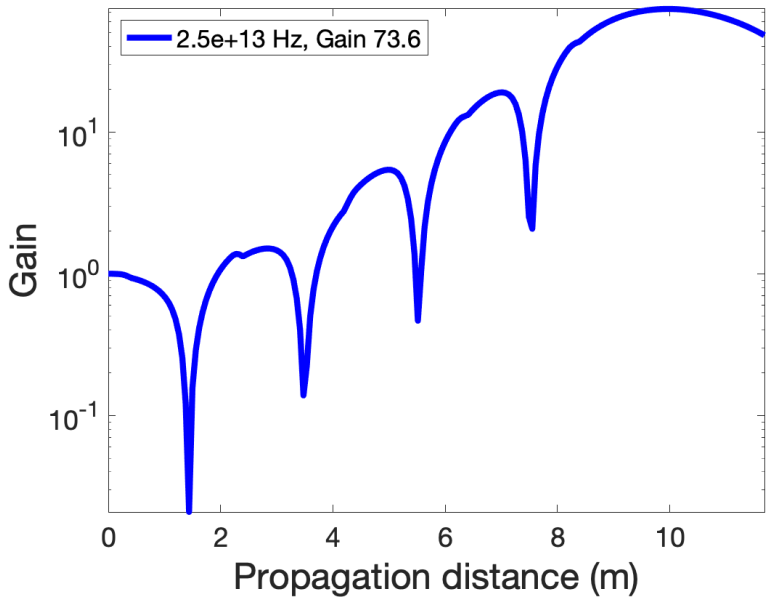
- The SPACE code is a parallel, relativistic, three-dimensional (3D) electromagnetic (EM) Particle-in-Cell (PIC) code.

Periodic PCA

- 4-cell periodic PCA with cell length 2 m.

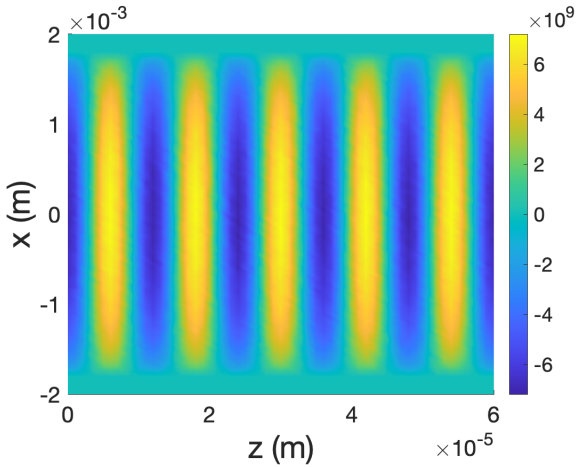


(a) Transverse beam size

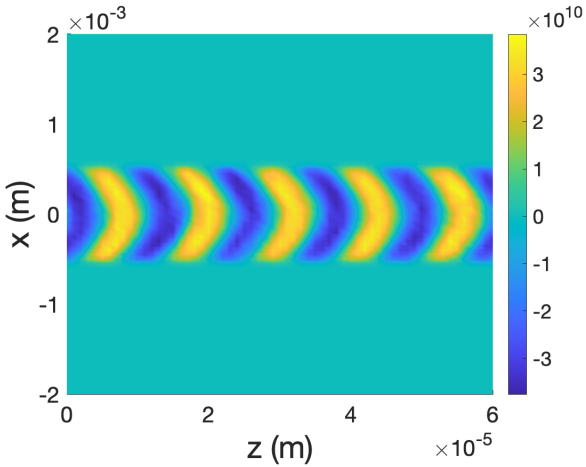


(b) Density modulation at 25 THz

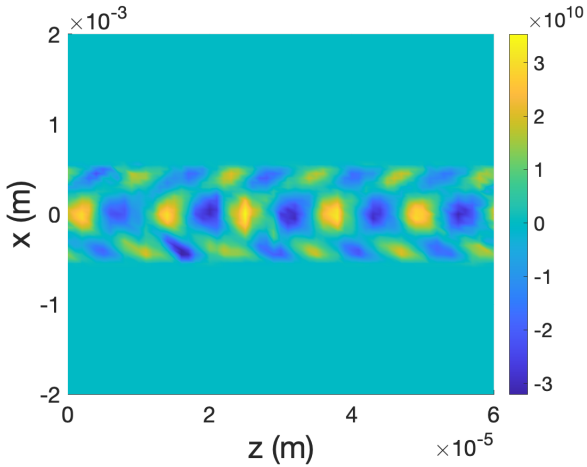
Periodic PCA, evolution of 25 THz density modulation



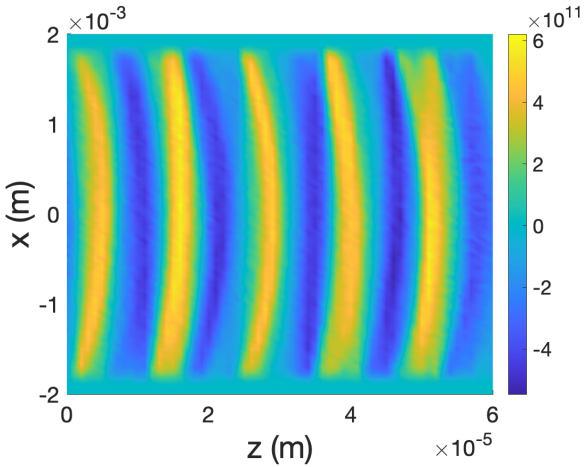
(a) Entrance



(b) Before 2nd cell waist



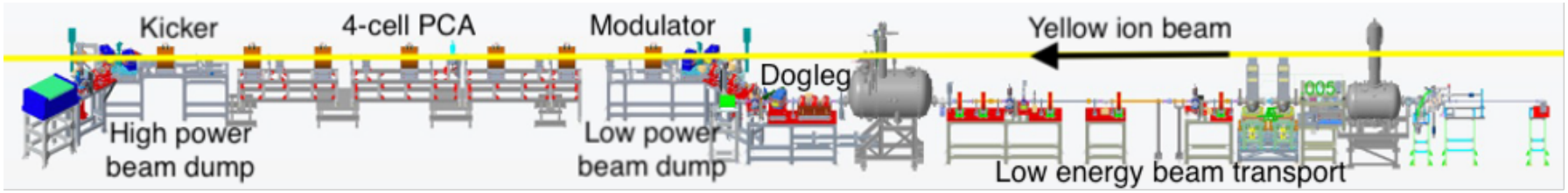
(c) After 2nd cell waist



(d) Exit

Realistic PCA

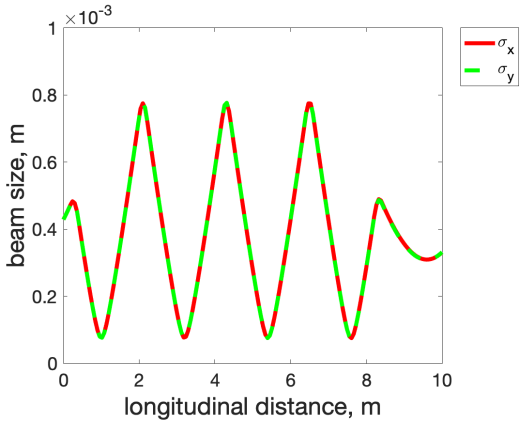
- 4-cell PCA with cell length 1.8 m, 2.2 m, 2.2 m, 1.8 m.



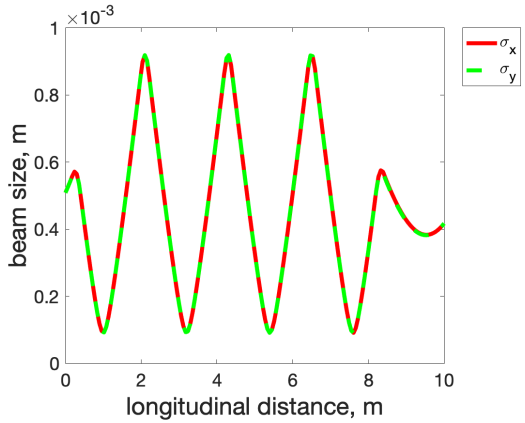
(a) PCA-based CeC system installed at BNL RHIC

- Beam energy γ=28.5
- Case 1: peak current 50 A, normalized KV emittance 5 mm mrad.
- Case 2: peak current 75 A, normalized KV emittance 7 mm mrad.
- Case 3: peak current 100 A, normalized KV emittance 8 mm mrad.
- Kapchinsky-Vladimirsky (KV) emittance is 4 times of the traditionally defined root mean square (RMS) emittance.

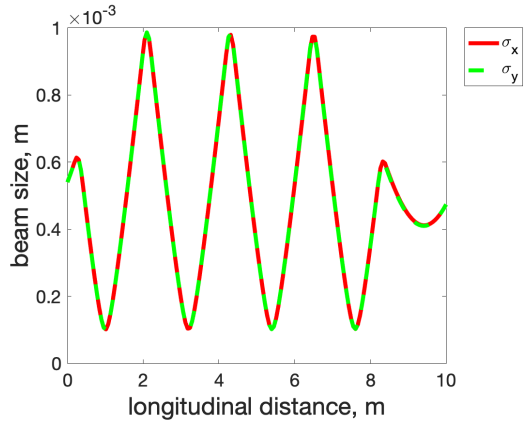
Realistic PCA



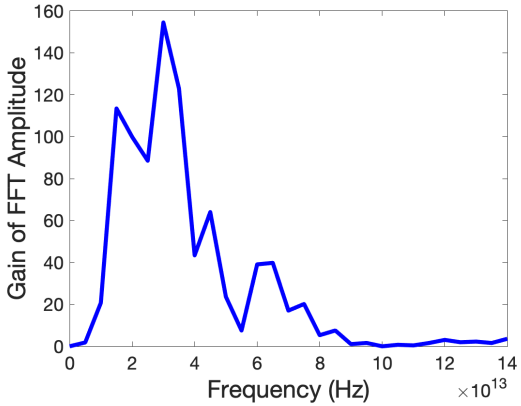
(a) Case 1



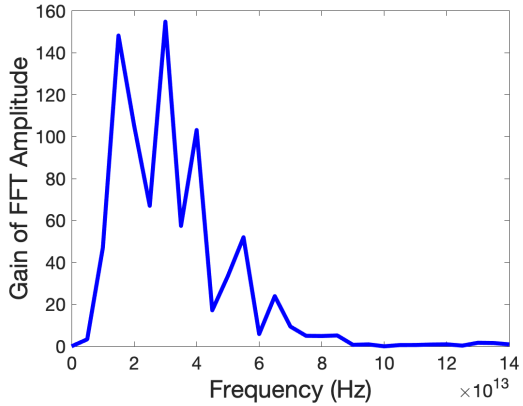
(b) Case 2



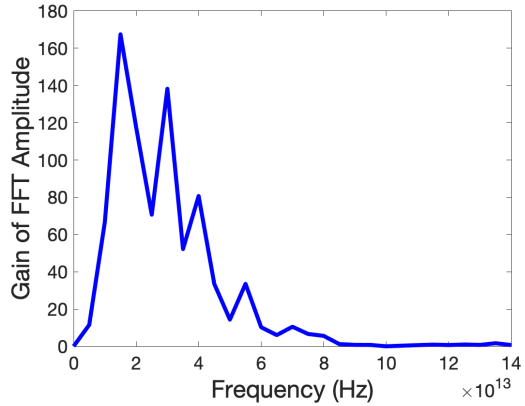
(c) Case 3



(d) Case 1



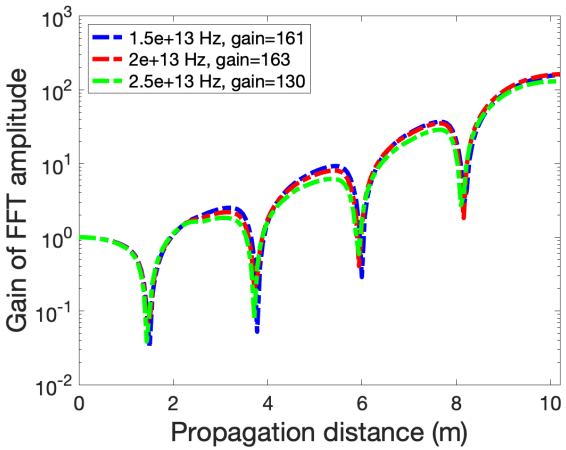
(e) Case 2



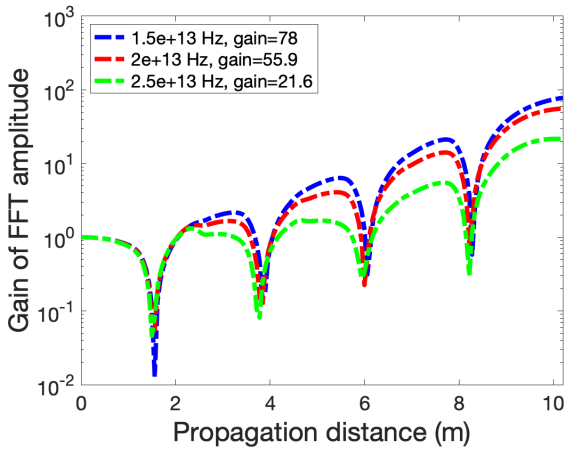
(f) Case 3

Realistic PCA, sensitivity study on emittance

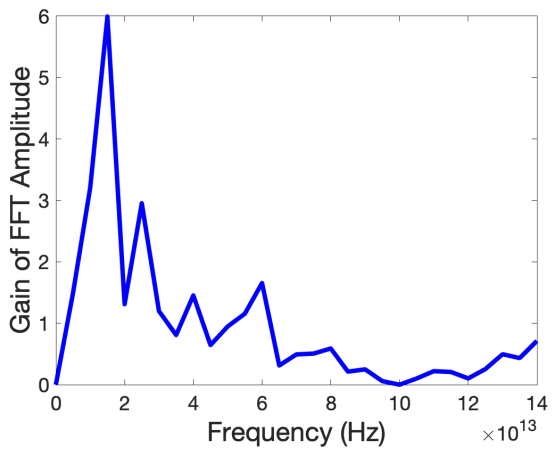
- Peak current 75 A
- Normalized KV emittance 7, 10, 20 mm mrad



(a) 7 mm mrad



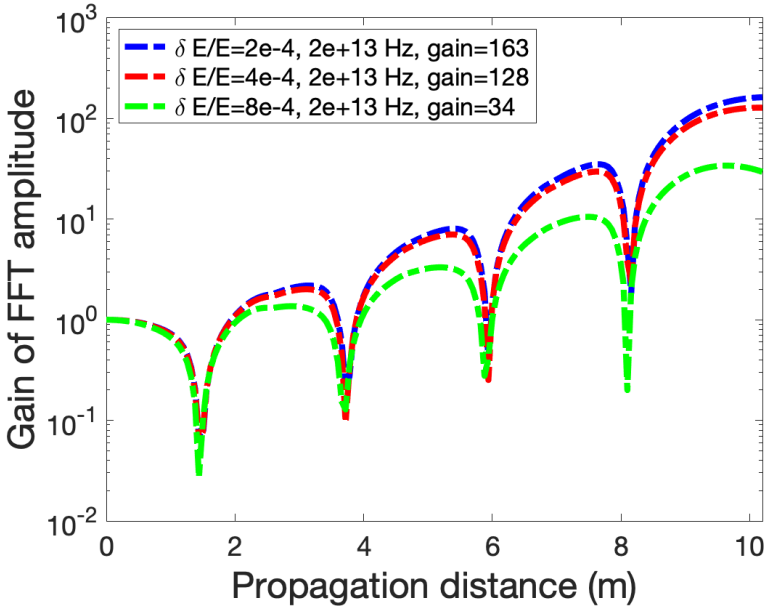
(b) 10 mm mrad



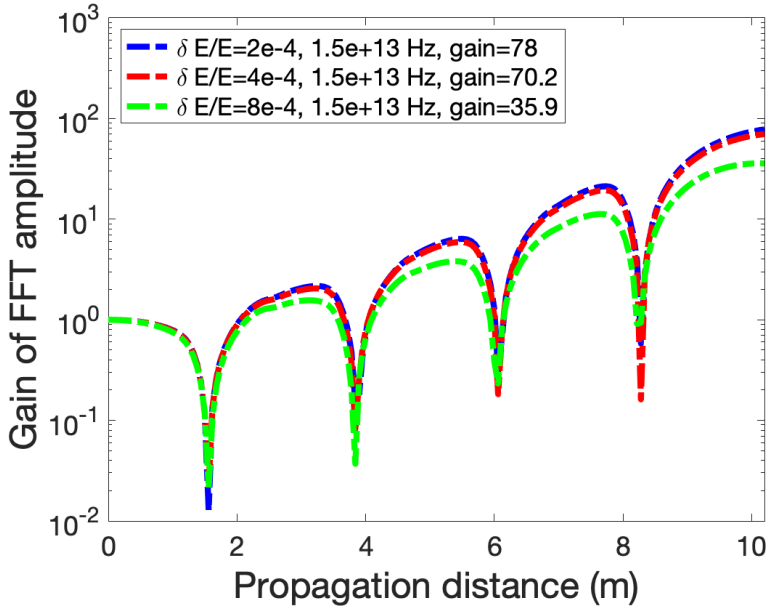
(c) 20 mm mrad

Realistic PCA, sensitivity study on energy spread

- Peak current 75 A, Normalized KV emittance 7, 10 mm mrad
- Energy spread 2e-4, 4e-4, 8e-4



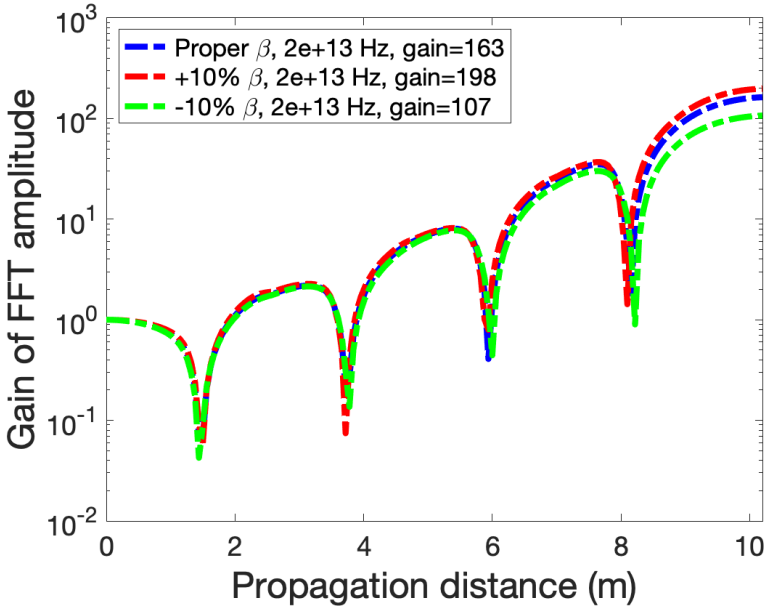
(a) 7 mm mrad



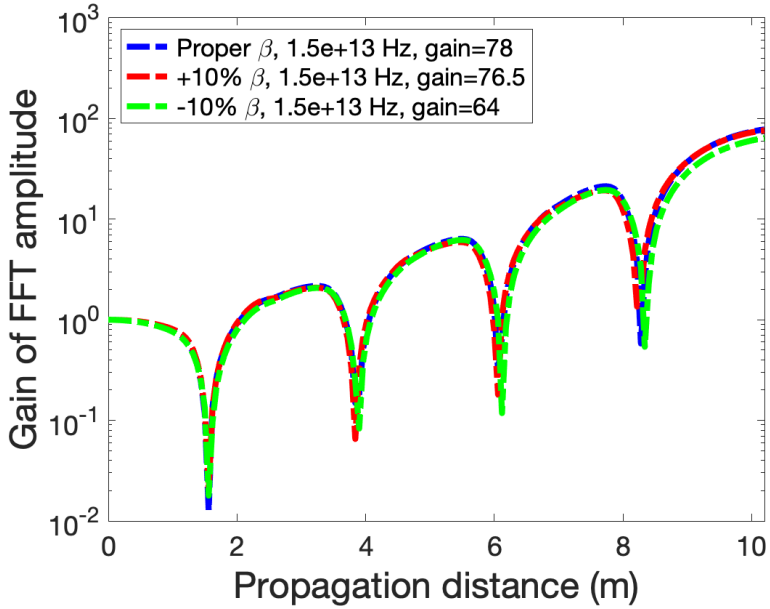
(b) 10 mm mrad

Realistic PCA, sensitivity study on initial β function

- Peak current 75 A, Normalized KV emittance 7, 10 mm mrad
- Initial β function $\pm 10\%$



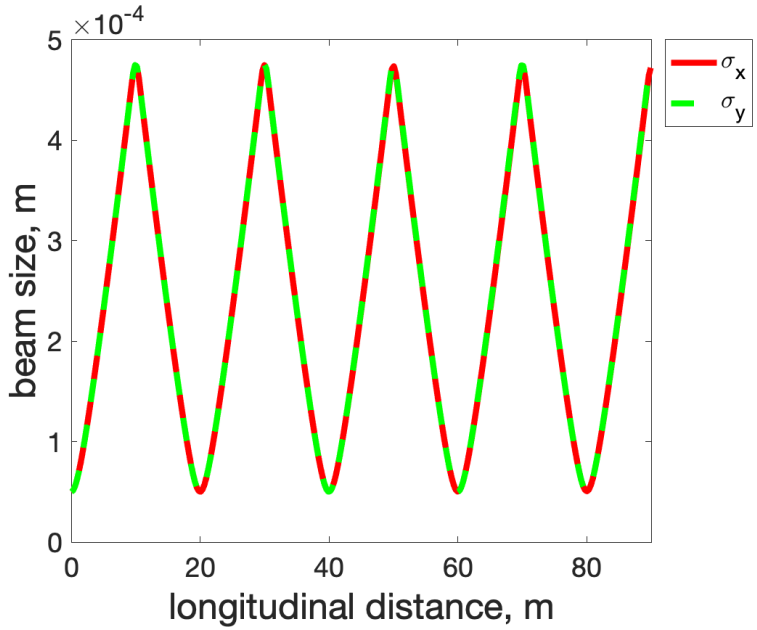
(a) 7 mm mrad



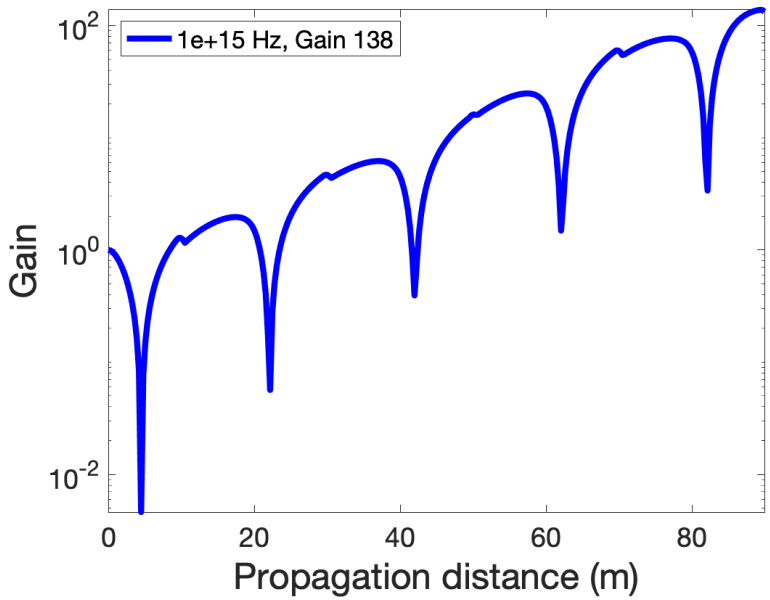
(b) 10 mm mrad

EIC PCA

- PCA design for the Electron-Ion Collider (EIC) at BNL.
- Beam energy γ=275, Peak current 250 A, Normalized KV emittance 2 mm mrad
- 4-cell periodic PCA with cell length 20 m.



(a) Transverse beam size



(b) Density modulation at 1 PHz

Conclusion

- Present the simulation studies of the PCA for the CeC system, including the periodic PCA, the realistic PCA, and the EIC PCA.
- Perform sensitivity study to characterize the dependence of PCA performance on various beam parameters.
- Demonstrate sufficiently high gain from PCA with proper setup.

Thank You