Design and Commissioning of the Beam Switchyard for the SXFEL-UF

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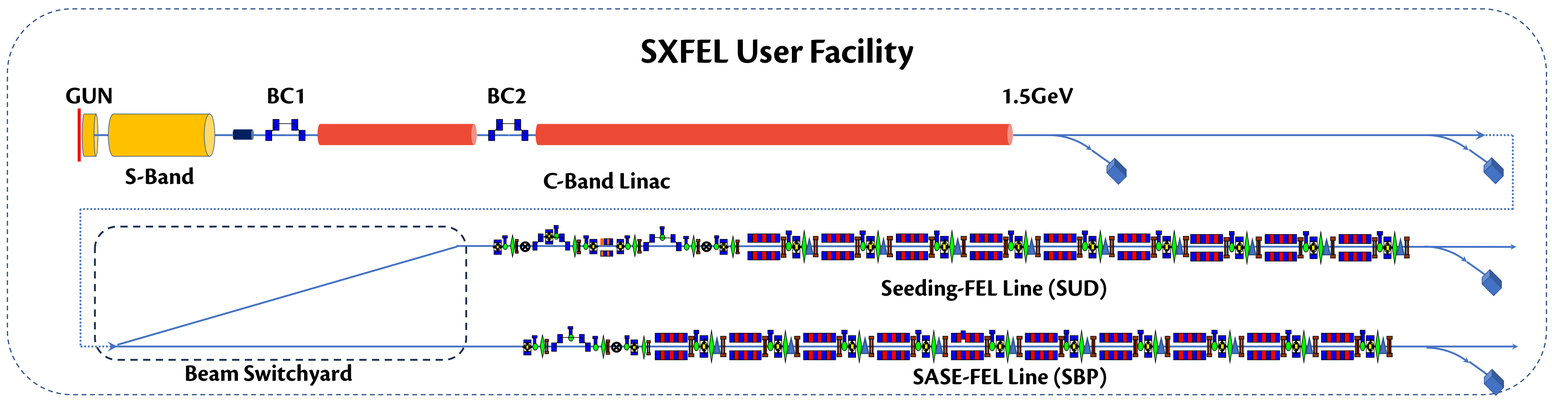
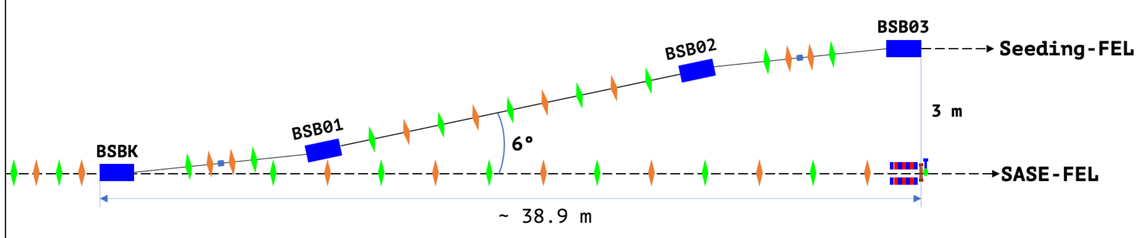
Introduction

SXFEL-UF is upgraded from the existing SXFEL-TF[1]. The beam energy is increased from 840 MeV to 1.5 GeV. Two parallel undulator lines are installed in the new undulator hall for soft X-ray radiation of 2~3 nm. For simultaneous operation of the two lines, a beam switchyard is required.

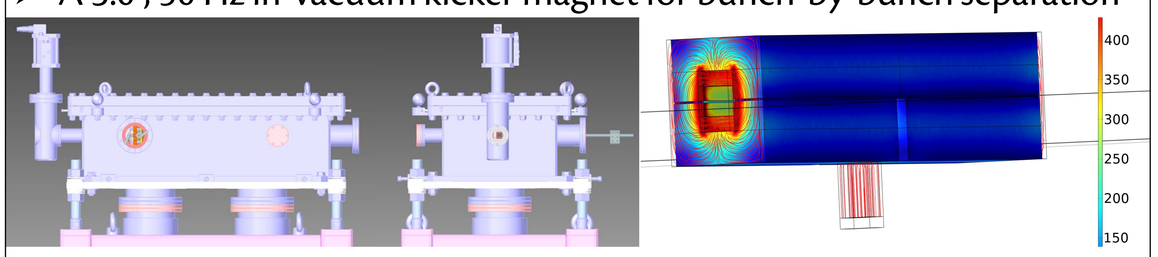
Parameters	*SXFEL-UF*
E_{beam} (MeV)	1500
σ_E/E_0	$<1\times10^{-3}$
$\varepsilon_{n,rms}$ (mm·mrad)	≤1.5
I_{pk} (A)	>700
f_{bunch} (Hz)	50
λ_r (nm)	2(SBP) & 3(SUD)



General Layout and Kicker Magnet

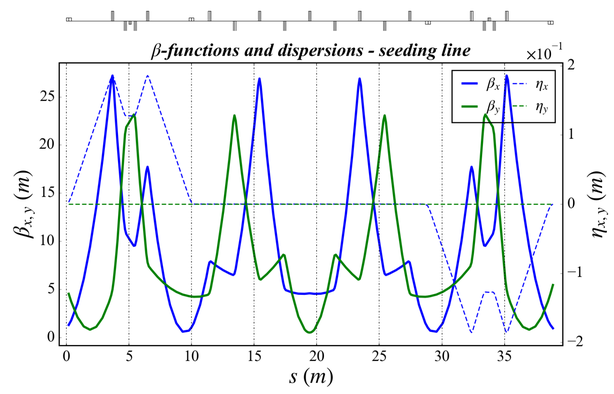


- 3 m horizontal distance by a dual-DBA dog-leg of 6° total angle;
- Small reverse angle bends inserted in DBAs for isochronous;
- A 3.0°, 50 Hz in-vacuum kicker magnet for bunch-by-bunch separation

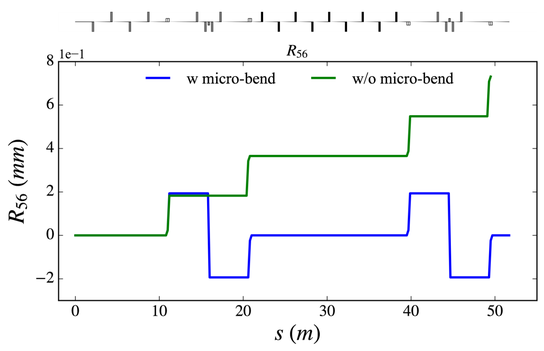


pulse repetitive jitter < 100 ppm; Programmable for arbitrary pattern[3]

Lattice Design with CSR & MBI suppressing



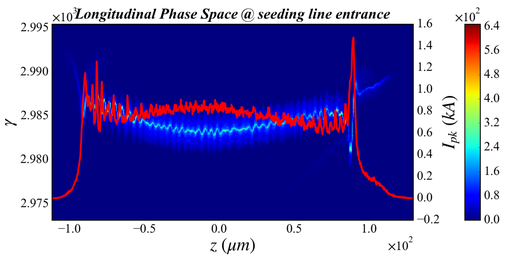
β functions and dispersion functions



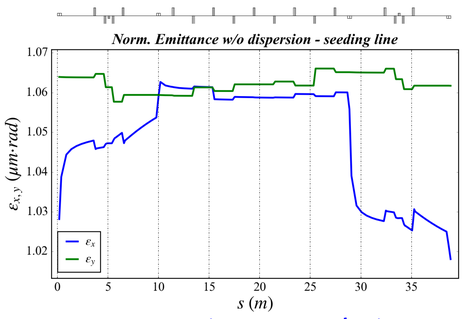
comparison of R_{56} evolution w/wo micro-bend

- Symmetrical optics of the dog-leg;
- Optics measures for suppressing CSR induced emittance growth[2]:
  - Matching for a small β_x (<2 m) at the kicker and dipoles;
  - Optics balance: π phase advance between the two DBA cells;
- Micro-bends in DBAs for suppressing micro-bunching instability

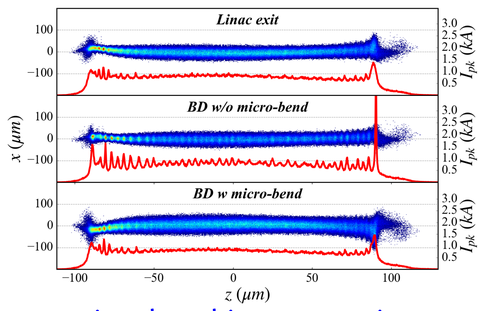
S2E Tracking Simulation



longitudinal phase space



norm. emittance evolution



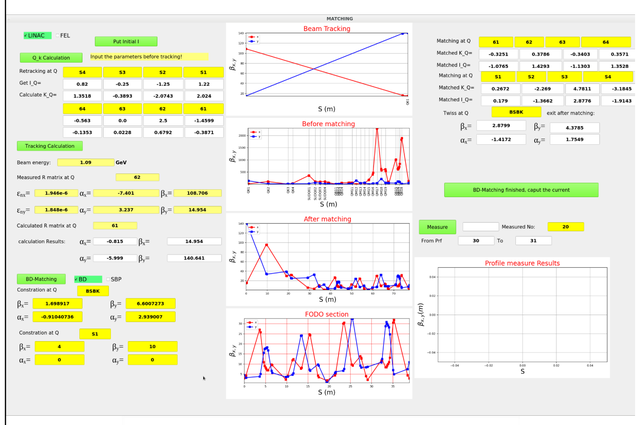
micro-bunching suppression

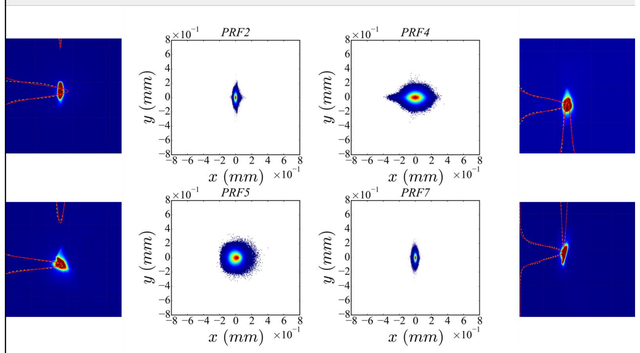
- 1 million electron population; from linac exit to the end of dog-leg; elegant[4]
- CSR introduced emittance growth well suppressed by the optics design
- Barely visible micro-bunching gain with R_{56} ~ 0 by micro-bend

Installation

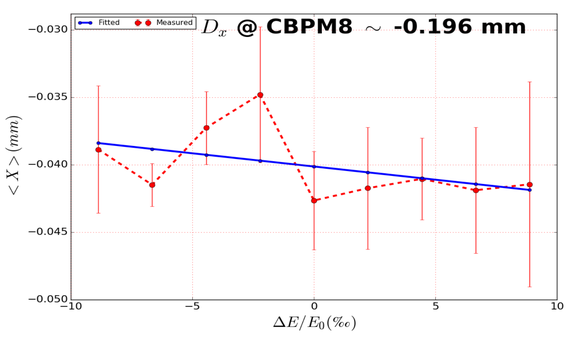
- Beam switchyard installed in late 2020
- Commissioning started in late 2021 without kicker
- Kicker available with required stability in late 2022

Commissioning Results

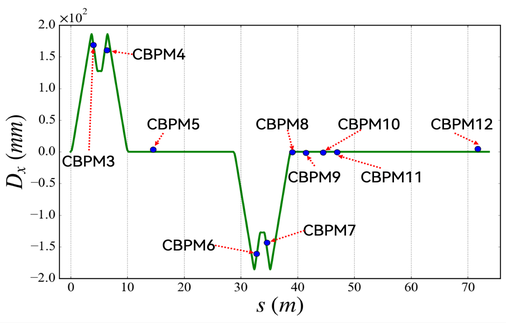


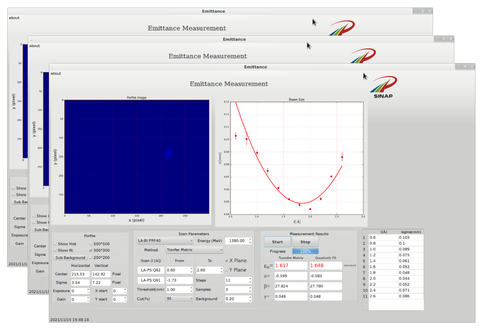


automatic matching tool based on ocelot[5]



dispersion measured by fitting BPM data while varying beam energy (varying dipole current as equivalent)

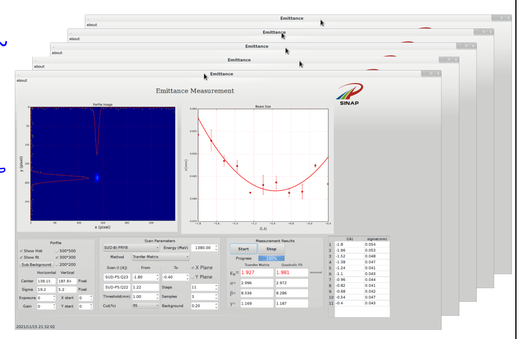


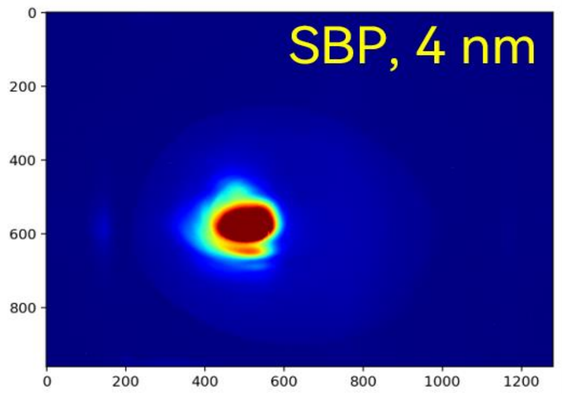


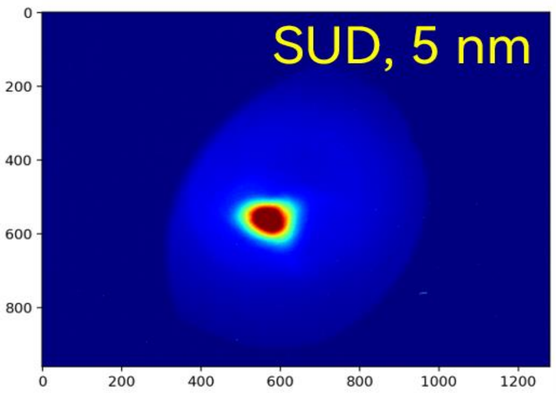
ε_x @ linac exit ~ 1.83 mm·mrad

ε_x @ BSY exit ~ 1.89 mm·mrad

emittance growth well suppressed







two undulator lines lasing simultaneously and saturated

References

[1] Bo Liu, et al., Appl. Sci. 2022, 12, 176
[2] S. Di Mitri, et al., PRL 110, 014801 (2013)
[3] thanks to R.P. Wang & Y.F. Liu for the design of the kicker
[4] M. Borland, Advanced Photon Source LS-287, September 2000.
[5] https://github.com/ocelot-collab/ocelot

Acknowledgement

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