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DUAL OCTUPOLE EMITTANCE GROWTH CORRECTION OF THE CompactLight XFEL BUNCH COMPRESSORS

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Abstract

An optimized CompactLight X-Ray Free Electron Laser (XFEL) bunch compressor design is presented. In this work, we insert an octupole into the centre of the two sequential bunch compressors (BC1 and BC2). We show how this scheme can correct the undesirable peak current profile while adjusting the compression and emittance growth.

BASELINE DESIGN

The CompactLight Collaboration [1, 2] has provided a baseline hard XRay (HXR) lattice design that ramps to 5.5 GeV and contains two standard c-shaped chicane bunch compressors (denoted BC1 and BC2) - with the current profile and the longitudinal phase space at the end of BC1 and end of BC2 shown in Figs. 1 and 2.

The bunch compressor design can significantly impact the machine performance due to Coherent Synchrotron Radiation (CSR) induced emittance growth and micro-bunching instabilities. CSR and longitudinal space charge can contribute to micro-bunching instabilities due to the fragmentation of the longitudinal phase space. This will impact FEL performance indirectly via instability induced energy spreading.

BC1 and BC2 are standard C-style 4-dipole chicanes (see the inset of Fig. 3). Figures 4 and 5 show the longitudinal phase space evolution from Linac 0 to Linac 3, respectively. Here we can see the slice energy spread which is initially small at Linac 0 (see the top Fig. 4), grows after reaching Linac 3 due to CSR and/or LSC driven instabilities (see the bottom Fig. 4).

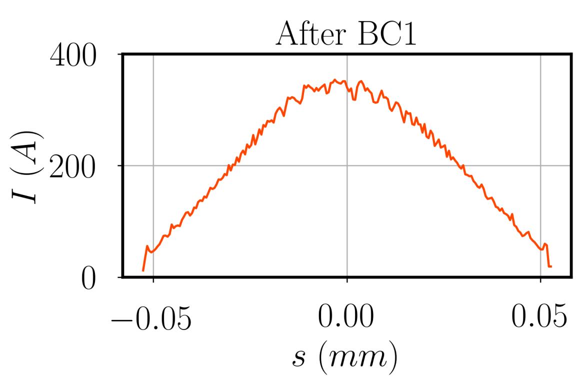

Figure 1: Current Profile of the uncorrected baseline design at the end of BC1.

DUAL OCTUPOLE DESIGN

To correct the nonlinear correlations in the longitudinal phase space shown previously, we introduce two sequentially placed octupoles; one octupole placed in the center of BC1 and one octupole placed in the center of BC2. Following the prescriptions of Sudar *et al.* [3], we fix and tune the phase advance between the two octupoles to be an integer of π – this allows us to correct for the emittance growth while simultaneously cancelling any imparted transverse kick from the first octupole. A comparision of the parameters achieved with the baseline lattice and the dual octupole scheme is shown in Table 1. The improvement of the baseline current profile using the dual octupole scheme is shown in Fig. 6. All simulations were completed using the simulation software ELEGANT [4].

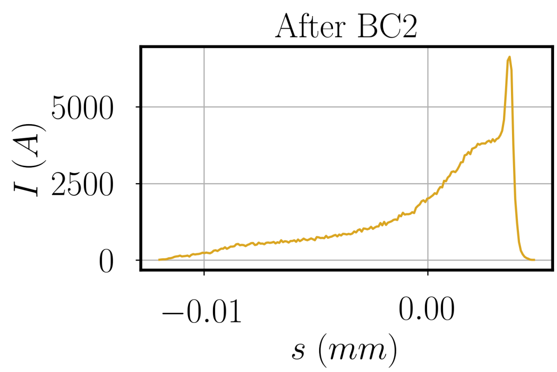

Figure 2: Current Profile of the uncorrected baseline design at the end of BC2.

Table 1: Baseline Design and Dual Octupole Design Parameters

Parameter	Baseline	Dual Octupole
σ_x	0.03 mm	0.04 mm
σ_z	3.59 µm	3.59 µm
σ_t	0.01 ps	0.01 ps
$\sigma_{\Delta p/p}$	0.04 %	0.04 %
ϵ_{nx}	0.71 mm	0.63 mm
ϵ_{ny}	0.58 mm	0.57 mm

CONCLUSION

CSR induced emittance Growth can be adjusted using binary octupoles inserted sequentially into two bunch compressors. By tuning the lattice to ensure a $n\pi$ phase advance and correct octupole strength ratio (K_3 of Octupole 1:K_3 of Octupole 2), we can correct the induced octupole kick while adjusting the longitudinal phase space as desired.

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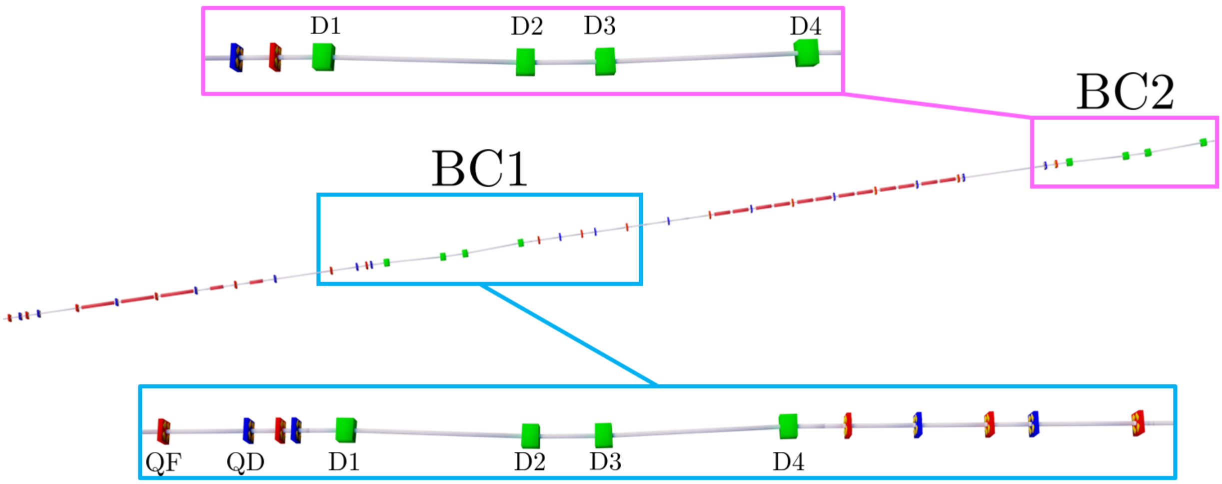

Figure 3: CompactLight Baseline Lattice Design from September 2020 showing the bunch compressors, BC1 and BC2 as indicated. Note, QF denotes the focusing quadrupoles, QD denotes the defocusing quadrupoles. Also note that D1 is the first dipole within the chicane, D2 is the second, D3 is the third and D4 is the fourth dipole within the chicane.

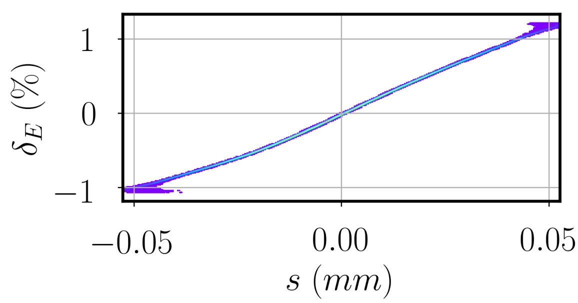

Figure 4: Longitudinal Phase Space evolution of the uncorrected baseline design at the end of BC1.

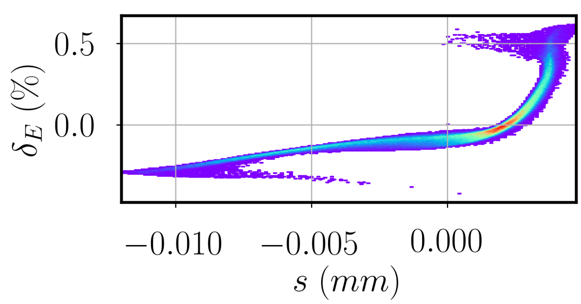

Figure 5: Longitudinal Phase Space evolution of the uncorrected baseline design at the end of BC2.

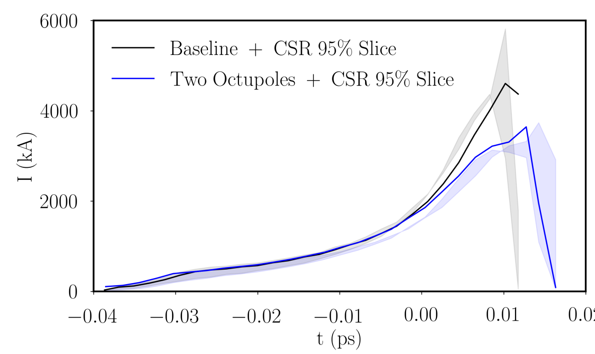

Figure 6: Current profile slice comparison between the original baseline (black) and the dual octupole scheme (blue).

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REFERENCES

[1] CompactLight Collaboration, `http://www.compactlight.eu/`.

[2] M. Aicheler *et al.*, "Status of the CompactLight Design Study", in *Proc. 39th Int. Free Electron Laser Conf. (FEL'19)*, Hamburg, Germany, Aug. 2019, pp. 738-741. doi:10.18429/JACoW-FEL2019-THP078

[3] N. Sudar, Y. Nosochkov, K. Bane, Z. Zhang, and Y. Ding, "Octupole based current horn suppression in multistage bunch compression with emittance growth correction", *Phys. Rev. ST Accel. Beams*, vol. 23, p. 112802, 2020. doi:10.1103/PhysRevAccelBeams.23.112802

[4] M. Borland, "ELEGANT: A flexible SDDS-compliant code for accelerator simulation", Technical Report, Argonne National Laboratory, Illinois, USA, LS-287, Aug. 2000. doi:10.2172/761286