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Abstract Title: Inverse Methods for Beam Profile Optimization to Mitigate Coherent Synchrotron Radiation

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Increasing the 'brightness' of an electron beam – defined as the particle density per unit area and time – is essential to developing colliders of increasing energy for future high energy physics experiments. A significant impediment to increasing brightness is found in the self-interactions by individual particles within the beam. In particular, when a beam of high energy is bent into a curved trajectory, the low-frequency spectra of the resulting synchrotron radiation (referred to as coherent synchrotron radiation or CSR) can have detrimental effects on beam quality. As a result, several mitigation approaches have been proposed, with shielding by conducting parallel plates showing promise in both theoretical and experimental studies [1], albeit at small shielding gaps for beams of relatively low charge.

In this work, we expand on the existing body of work by considering larger shielding gaps, for high-charge beams in practical accelerator designs. Due to weaker direct shielding effects at large gap separations, effective CSR mitigation necessitates leveraging careful optimization of the beam profile on top of shielding. To this end, we have developed a 3D simulation method (that generalizes existing 1D tools in the literature) to model both the CSR radiated by the beam and the reflections caused by the shielding walls. We then devise an inverse problem to compute optimal profile shapes for different gap separations using our method to construct a cost function. Our results indicate novel profile shapes that differ from existing results that were derived without shielding in the literature [2]. Our talk at the symposium will go into the specifics of the inverse formulation, the highly nonlinear search space and the convergence properties of different optimization methods. This work is part of a collaboration that explores the effects of CSR on a beam both theoretically and through ongoing experiments at the Argonne Wakefield Accelerator.

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References

1. Yakimenko et al., Experimental Observation of Suppression of Coherent-Synchrotron-Radiation–Induced Beam-Energy Spread with Shielding Plates, Phys. Rev. Lett. 109, 164802

2. Mitchell et al., Longitudinal pulse shaping for the suppression of coherent synchrotron radiation-induced emittance growth, Phys. Rev. ST Accel. Beams 16, 060703