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Simulation advances in Coherent Synchrotron Radiation modeling

Thursday, 3 October 2024 16:00 (30 minutes)

A unique particle beam dynamics simulation code, CoSyR [1], has been developed using MPI + Kokkos to exploit exascale computing and multi-GPU acceleration. This new simulation code tackles a fundamental problem of beam nonlinear dynamics from its radiation self-fields, which underpins many accelerator design issues in high brightness beam applications as well as those arising in the development of advanced accelerators. CoSyR, together with other state-of-the-art codes dedicated for coherent synchrotron radiation (CSR) study, such as LW3D and CSRtrack, are a unique suites of complementary simulation capability employing first-principle models but with a hierarchy of model complexities and assumptions, which are ideal for the understanding of the CSR effects in increasingly high-brightness beams. In this work, we will present the design and benchmark of CoSyR with other CSR simulation codes and the widely used static-state analytic models in applicable beam conditions. We will highlight the understanding of the interplay of the longitudinal and transverse CSR effects, which is generally not captured in 1D CSR models. Detailed study with experiment validation to elucidate CSR model differences and applicability to complex beams is being explored for future accelerator designs. We will also discuss plan to include the accelerator channel or magnetic dipole shielding effect by making use of the cavity Green's functions. Finally, we introduce a pilot work to develop and train a class of phase space structure-preserving neural networks — Henon Neural Networks (HenonNets) [2], as a fast surrogate of radiative collective effects for nonlinear beam dynamics problems.

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[1] C.-K. Huang et al., "CoSyR: A novel beam dynamics code for the modeling of synchrotron radiation effects," Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip., vol. 1034, no. April, p. 166808, Jul. 2022, doi: 10.1016/j.nima.2022.166808; https://github.com/lanl/cosyr.

[2] C.-K. Huang et al., "Symplectic neural surrogate models for beam dynamics," J. Phys. Conf. Ser., vol. 2687, no. 6, p. 062026, Jan. 2024, doi: 10.1088/1742-6596/2687/6/062026.

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