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Longitudinal Profile Reconstruction of Ultrashort Electron Bunches with Coherent Transition Radiation Images and Ensemble Deep Learning Models

Thursday, 3 October 2024 11:50 (20 minutes)

Ultrashort bunch length measurements are essential in modern accelerator experiments like high-gradient plasma-based accelerators and free electron lasers. These require quality electron bunches in the femtosecond-length scale and thus pose significant challenges for developing novel beam instrumentation and diagnostics. This contribution presents current results on the development of a shot-to-shot bunch-length monitor with femtosecond resolution using broadband imaging of coherent transition radiation (CTR) that will operate online and minimally invasively as a virtual diagnostic. The implemented method successfully reconstructed the longitudinal bunch profiles from simulated CTR images by using ensemble methods and deep learning models like convolutional neural networks (CNNs). The CTR images were simulated using Zemax OpticStudio for different bunch profile lengths and shapes below 200 fs. The ensemble learning models accurately reconstructed bunch profiles with resolution in the few femtosecond ranges. Uncertainty measures for the reconstructions were calculated to study the reliability and precision of the results. The results and observed resolution confirm the suitability of the proposed diagnostic for plasma accelerator applications and highlight the potential of machine learning for producing high-resolution virtual diagnostics for these and other short-pulse accelerator experiments. The next stage in the research will include testing the ensemble learning models with more realistic electron bunches and plasma accelerator-specific datasets combining both simulated and experimental data while further exploring relevant models to develop reliable virtual diagnostics.

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