Contribution ID: **212** Type: **Contributed Oral**

Electron source bunch length characterization based on chicane-decompressed coherent transition radiation emission

Thursday, 10 November 2022 11:30 (20 minutes)

Laser plasma accelerators (LPAs) are capable of producing electron bunches as short as a few femtoseconds at percent-level energy spread. However, measuring the bunch length is not straightforward, let alone unraveling source correlations between the longitudinal position and momentum distribution. Here we present the theoretical framework and preliminary experimental demonstration of a multi-shot technique that applies a chicane decompression scan and records the emitted Coherent Transition Radiation (CTR) pulse energy. Comparing the measurement of CTR energy vs chicane R56 to accurate modeling of CTR generation allows us to diagnose the longitudinal emittance in a manner that is analogous to retrieving the transverse emittance from a quadrupole scan. The combination of chicane-decompressed CTR emission and chromatic transport of energy-spread electron beams yields CTR emission in a regime where the longitudinal and transverse coherent radiation form factors are not separable, thus forcing a more rigorous treatment to match experimental data to the theory and simulations. Analytic expressions in a simplified scenario are presented, highlighting the diagnostic sensitivity to position-momentum source correlations. The experimental demonstration was performed at the BELLA Center 100 TW HTU laser plasma accelerator, producing electron beams at 100 MeV, coupled into a beam line consisting of a quadrupole triplet, chiance, CTR screen, and CTR energy detector.

Acknowledgments

The work at LBNL was supported by the U.S. Department of Energy (DOE), Office of High Energy Physics under Contract No. DE-AC02-05CH11231, while efforts at LANL were performed under DOE Contract No. 89233218CNA000001.

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Session Classification: WGs 5+7 Joint Session

Track Classification: Working Group Parallel Sessions: WG5 Oral: Beam Sources, Monitoring, and Control