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Beam dynamics study on low-emittance electron beams generated via a combined transverse and temporal photocathode laser shaping approach at the European XFEL

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Low-emittance electron beams play an essential role in improving the machine performance and extending the capabilities of existing free-electron lasers. The generation of such high-quality electron bunches relies on an overall optimization of the photoinjector, and most importantly, on the desired properties of the cathode drive laser. Appropriate shaping of the drive laser, namely, controlling the laser intensity distribution both temporally and spatially, has emerged as a promising technique to reduce the emittance of electron beams. A strategic combination of two-dimensional (2D) transverse and one-dimensional (1D) temporal shaping of the drive laser pulse may efficiently bring down the overall bunch emittance very close to its fundamental limit. In this work, we present beam dynamics simulations conducted for the European XFEL photoinjector so as to optimize the transverse projected and sliced emittance of the bunch under various transverse and longitudinal laser pulse configurations. The obtained results confirm the impact of lengthening the cathode drive laser pulse on both the projected and sliced emittance of the optimized bunches, and demonstrate the advantage of a longitudinal flat-top shaping over a conventional Gaussian pulse. It is also shown that a combined 2D spatial and 1D temporal shaping technique can minimize the central slice emittance of the bunch to the level of the cathode thermal emittance.

Footnotes

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