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Photoinjector transverse phase space linearization with sacrificial charge

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Compensating the emittance growth due to linear and nonlinear space charge effects in photoinjectors is critical for high-brightness electron beam applications ranging from XFELs to various ultrafast electron probes. While linear emittance compensation is extremely robust, nonlinear emittance compensation depends on the detailed nature of the charge distribution, and in general, producing simultaneous compensation of linear and nonlinear space charge effects is an ongoing challenge. This challenge will grow in importance as intrinsic emittance from photocathodes is further improved.

In this work, we will show results discovered via multiobjective optimization of various high-brightness photoinjectors equipped with scraping apertures. We find a new class of robust nonlinear emittance compensation that uses the space charge field of the sacrificial component of the beam to linearize the transverse slice phase space of the surviving component. We study this effect analytically and show excellent agreement with space charge simulation and extremely low emittance for charges relevant for XFEL injectors.

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