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Real-Time Programmable Shaping for Electron and X-Ray Sources

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The next generation of augmented brightness XFELs, such as LCLS-II, promises to address current challenges associated with systems with low X-ray cross-sections. Typical photoinjector lasers produce coherent ultraviolet (UV) pulses via nonlinear conversion of an infrared (IR) laser. Fast and active beam manipulation is required to capitalize on this new generation of XFELs, and controlling the phase space of the electron beam is achieved by shaping the UV source. However current techniques for such shaping in the UV rely on stacking pulses in time, which leads to unavoidable intensity modulations and hence space-charge driven microbunching instabilities [1]. Traditional methods for upconversion do not preserve phase shape and thus require more complicated means of arriving at the desired pulse shapes after nonlinear upconversion [2]. Upconversion through four-waving mixing (FWM) allows direct phase transfer, convenient wavelength tunability by easily changeable phase matching parameters, and also has the added advantage of greater average power handling than traditional $\chi(2)$ nonlinear processes [3, 4,]. Therefore, we examine a possible solution for e-beam shaping using a machine learning (ML) implementation of real-time photoinjector laser manipulation which shapes the IR laser source and then uses FWM for the nonlinear upconversion and shaping simultaneously. Our presentation will focus on the software model of the photoinjector laser, the associated ML models, and the optical setup. We anticipate this approach to not only enable active experimental control of X-ray pulse characteristics but could also increase the operational capacity of future e-beam sources, accelerator facilities, and XFELs.

References:

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