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Efficient 6-dimensional phase space measurements using generative machine learning and applications to autonomous beam monitoring at LCLS-II

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Enhancing the performance and capabilities of free electron lasers, such as LCLS-II, hinges on our ability to precisely control and measure the 6-dimensional phase space distribution of the beam. However, conventional diagnostic techniques necessitate a substantial number of measurements and computational resources to characterize a single beam distribution, using many hours of valuable beam time. In this work, we present a novel approach to analyzing experimental measurements using generative machine learning models of 6-dimensional beam distributions and differentiable beam dynamics simulations to substantially reduce the number of measurements needed to reconstruct detailed phase space distributions. We demonstrate in simulation and experiment that using our analysis technique can reconstruct detailed 6-dimensional phase space distributions using as few as 20 beam measurements with no prior training or data collection. We also discuss plans for combining this work with advanced accelerator control algorithms and parasitic beam measurements to autonomously monitor the 6-dimensional phase space distribution of the beam at LCLS-II during accelerator operations.

Footnotes

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