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Beam emittance optimization as an inverse problem

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The European XFEL at DESY is a world-leading research infrastructure in Hamburg, enabling scientists to observe and investigate microstructural processes with resolutions on the atomic and femtosecond scale. To improve the performance of the accelerator, it is essential to optimize the EuXFEL for operation in continuous-wave (CW) mode. Despite its advantages, an operation in CW mode requires a reduction of the beam energy and is associated with an increase in the geometric beam emittance. Within the OPAL-FEL project, we pursue a data-driven optimization of the beam emittance to ensure the delivery of high quality beams in CW mode. Central to our approach is the use of deep learning techniques to implement an inverse model, predicting the optimal state of the photoinjector for achieving a desired optimal emittance. We detail our methodology and present initial results from a neural network trained on synthetic data generated using the beam dynamics simulation code ASTRA. Additionally, we explore the theoretical aspects of the forward model's invertibility, drawing on Whitney's embedding theorem within the context of attractor reconstruction.

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