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Fast surrogate models for dielectric laser accelerator diagnostics

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Dielectric Laser Acceleration (DLA) is an advanced electron accelerator concept reaching gradients significantly larger than conventional RF cavities. DLAs contain dielectric nanostructures to modulate the electrical near-fields of ultrashort laser pulses. The experimental complexity of DLA experiments in the subrelativistic as well as in the relativistic regime increases with increasing structure length and the utilization of more complex laser pulse shapes, such as pulse front tilts. Consequently, the experiments involve many parameters demanding careful control and optimization. Previous studies have demonstrated the efficacy of machine learning in enhancing the performance of conventional accelerators. In this presentation, we introduce our BMBF research project, which aims to implement a machine learning-based control system. This system is designed to reconstruct, analyze and optimize the laser pulse shape used for DLA experiments at ARES, leveraging electron beam diagnostics after the DLA interaction. For reconstructing the experimental parameters from measurements a deep neural network is implemented using the framework PyTorch. Simulation data by the tracking code DLAtrack6D serves as training data and initially also for validation as long as the laser pulse shaping optics are being set up. We verified these simulations by comparing tracking results to experimental data. We optimized the hyperparameters to get the best accuracy in the reconstruction and studied possible experimental parameter sets, dedicated DLA structures and additional diagnostics to reduce potential issues due to the non-uniqueness of the numerical reconstructions. This is the basis to use the neural network as virtual diagnostics of laser pulse and electron beam in order to active control and optimize DLA experiments.

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