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Diagnosis and optimisation of laser pulse shaping for laser-plasma accelerators

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Laser-plasma accelerators (LPAs) still trail conventional accelerators in terms of their ability to generate high-quality electron beams with low shot-to-shot variation. But with higher repetition rates and longer-term operation, the use of machine learning techniques is becoming increasingly viable as a control tool for improving the stability and reliability of LPAs.

In this context, machine learning techniques have previously been used to identify promising working points [1] and to tune laser-plasma accelerators during operation [2],[3],[4]. A key challenge is that the high-intensity laser pulse used to drive the accelerating wakefield is often subject to unexpected variations. These variations have a significant impact on the properties of the accelerated electron bunches, so correlating, predicting [5] and compensating these deviations using active feedback mechanisms is crucial for improving beam quality and the stability of the LPA, particularly for proposed projects to utilise LPAs as frontends for conventional machines [6]. As part of this, it is necessary to have a fast and verifiable analysis of the laser pulse that informs the operator or machine controls about which optical component to tune.

Here we present machine learning and simulation techniques implemented to diagnose and optimise laser systems for laser plasma acceleration at DESY. A neural network which takes a few minutes to train on CPU has been used to identify complex laser mode coefficients with a high degree of accuracy in $\sim$ 10ms. This leverages LASY, a simulation tool which models beam propagation through the laser system.

[1] https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.26.084601
[2] https://www.nature.com/articles/s41467-020-20245-6
[3] https://link.springer.com/book/10.1007/978-3-031-88083-4
[4] https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.126.104801
[5] https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.126.174801
[6] https://bib-pubdb1.desy.de/record/615183

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