Using Machine Learning for Prediction and Optimisation in Laser Machining

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Laser materials processing can be highly nonlinear, especially with the use of short-pulse lasers, and hence is acutely sensitive to laser parameters. Because of this, simulations based on understanding and calculation of the underlying physical principles are often unable to provide an exact numerical link between such parameters. Alternative approaches for characterising the laser materials interaction process, based on trial and error, often require a time-consuming experimental exploration over the available parameter space.

Machine learning techniques, specifically Neural Networks, offer an elegant solution to these problems. Instead of incorporating the complex equations governing light-matter interactions, experimental data is used to train the network empirically. This allows the model to incorporate aspects of the process that may be unknown, even to the experimenter.

Here we apply machine learning to both parameter optimisation and predictive visualisation for laser surface texturing of micron-sized dimples. The aim is to obtain the parameters needed to machine dimples with minimal height of unwanted redeposited material, while achieving a specified minimum dimple depth. Use of artificial neural networks for parameter optimisation can provide results very quickly with relatively small amounts of training data. In this work the network was able to predict the crown height to an accuracy of within 1% of the standard deviation of the data, which demonstrates the power of using neural networks.

Predictive visualisation is a more complex task involving generative networks but has the potential to be much more versatile. Here we have created a network that can predict the appearance of the surface, based on the parameters used, with a high degree of realism and precision.

Critically, neural network approaches can greatly reduce the amount of experimental data and time required, and costs associated with laser process optimisation, without negatively impacting accuracy or performance.