Imaging femtosecond laser ablation using plasma emission and deep learning

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Lasers have a broad range of applications in in the modern world, especially in manufacturing, including cutting, 3D printing and welding. However, real-time control presents a significant challenge because the workpiece is typically not directly observable due to the intense light from plasma emission at the laser's point of interaction with a material. Therefore, there is a considerable interest in developing methods for indirect imaging of the sample during laser machining. The plasma generated from femtosecond laser machining results from the ionisation of the target material by the extremely high peak power of the laser pulses [1]. The plasma plume's shape is dependent on a variety of factors, such as the laser parameters and the sample surface, meaning the plasma contains information regarding the surface of the sample and hence could contain the necessary data for indirect imaging of the sample. However, there is currently no mathematical method that can reconstruct the sample's appearance from the plasma due to the complex physical principles governing plasma generation, and as such, a data-driven technique like deep learning is required.

A type of artificial intelligence that utilises neural networks is deep learning, which has become increasingly popular in recent years due to advancements in graphics processing unit capabilities and its ability to identify patterns in data that may not be apparent to humans. Therefore, deep learning has the potential to discover innovative solutions to many problems simply by processing experimental data. In this work, neural networks are used to transform plasma images recorded during femtosecond laser machining into predictions of the sample's appearance, enabling real-time control of the laser to prevent it from scanning over a material boundary.

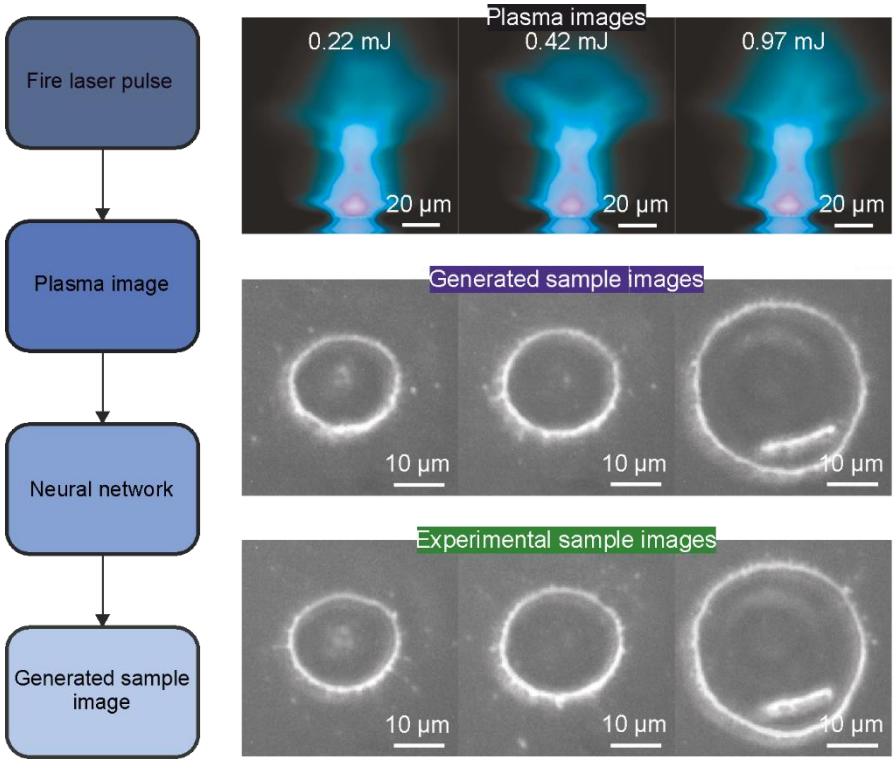

Figure 1. Showing (left) a flowchart that illustrates how deep learning is used to predict the sample's appearance directly from the plasma and (right) images of the plasma (false colourmap used) and the corresponding predictions.

References

[1] Grant-Jacob J A, Mills B and Zervas M N 2023 Visualizing laser ablation using plasma imaging and deep learning *Opt. Continuum* **2** 1678–87