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Automated control and optimisation of laser-driven ion acceleration

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The interaction of relativistically intense lasers with opaque targets represents a highly non-linear, multi-dimensional parameter space. This limits the utility of sequential 1D scanning of experimental parameters for the optimisation of secondary radiation. High repetition-rate (HRR) lasers augmented by machine learning present a valuable opportunity for efficient source optimisation through probing the complex interaction with higher statistical accuracy. Here [1], an automated, HRR-compatible system produced high fidelity parameter scans (1D and 2D), revealing the influence of laser intensity on target pre-heating and proton generation. For higher dimensions, Bayesian optimisation using Gaussian process regression is a tool that can be used to map the interaction and optimise chosen outputs [2]. A closed-loop Bayesian optimisation of maximum proton energy, through control of the laser wavefront and target position, produced proton beams with equivalent maximum energy to manually-optimized laser pulses but using only 60% of the laser energy. This demonstration of automated optimisation of laser-driven proton beams is a step towards deeper physical insight and the construction of future radiation sources.

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