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Multitask optimization of laser-plasma accelerators using simulation codes with different fidelities

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Laser-plasma accelerators can generate GeV electron beams in an ultra-compact, cm-scale setup, but have yet to demonstrate sufficient beam quality and stability for demanding applications. To overcome this challenge, broad optimization of the accelerator design with numerical simulations is essential. However, due to the high computational cost of general particle-in-cell simulations, optimization over a large parameter space is prohibitively expensive. Here, we show that cheaper simulations based on reduced physical models can be effectively incorporated into an optimization to strongly reduce the need for fully-detailed simulations. This is enabled by a Bayesian optimization algorithm using a multitask Gaussian process, where two tasks corresponding to the output of each simulation code are defined. The algorithm identifies correlations between both tasks, allowing it to learn from inexpensive evaluations and perform only a few, well-targeted simulations of high fidelity. By means of a proof-of-principle study combining the FBPIC and Wake-T codes, we demonstrate an order-of-magnitude reduction in computing time and cost, paving the way towards cost-effective optimization over wide parameter spaces.

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