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Efficient designing laser-driven fusion targets by combining random walk and Bayesian optimization

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Laser-driven inertial confinement fusion is an important approach to achieve controllable nuclear fusion, which applies high-power laser pulses or X-rays to ablate outer surface of a spherical shell containing the fusion fuel, leading to a centripetal implosion and an increase in pressure and temperature of the fuel. In order to reach the Lawson criterion and thus realize a self-sustaining burning plasma, we have to compress the fuel to several hundred times of the solid density and rise the target temperature to over 5 keV. Such high-density compression can only be achieved through isentropic compression.

Firstly, in order to realize an efficient implosion, the driven laser pulse and target structure are designed using a random walk method for a given laser energy. It can quickly optimize the laser pulse and target structure parameters for an efficient isentropic compression of the target, leading to an areal density 9.3% higher than that given by the hydrodynamic scaling. A correlation matrix can also be constructed to analyze the correlation between the parameters. This provides a reference for further optimizations and improvements.

Secondly, we combine the random walk method and the Bayesian optimization method to further improve the optimization efficiency. The series of laser pulses and target structures with relatively high areal density obtained by the random walk optimization are used as the basic sampling data of the Bayesian optimization, which greatly reduces the desired number of samples for Bayesian optimizations. At the same time, the Bayesian optimization also makes up for the small step size and low efficiency of the random walk method in the later stage of optimization, and reduces the randomness in the optimization process. The combination of the two algorithms greatly improves the optimization efficiency. At present, our method has been applied to the experiment of the double cone collision ignition scheme, and it is believed that it will play a greater role in future laser fusion experiments.

References

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