

Automated target and pulse design for laser direct drive using multi-fidelity and differentiable optimisation schemes

A Crilly ⁽¹⁾, P Moloney ⁽¹⁾, A Joglekar ⁽²⁾, J Brodrick ⁽²⁾, J Coughlin ⁽²⁾

⁽¹⁾ *Centre for Inertial Fusion Studies, Imperial College London, UK*

⁽²⁾ *Pasteur Labs, USA*

Presenter email: ac116@ic.ac.uk

The design of Inertial Confinement Fusion (ICF) experiments strongly relies on simulation due to the expense and rep-rate of current ICF facilities. While the design process for maximising fusion gain through simulations is time-intensive, its systematic input-output structure lends itself to automation. Any automated design scheme for ICF must be able to (a) simulate the relevant physics, (b) explore the large design space (10s to 100s parameters) and (c) converge to an optimal design efficiently. In this talk, we explore two modern machine learning techniques for optimisation with the aim of automating the design of laser direct drive targets and pulse shapes.

Firstly, we use gradient-free methods, namely Bayesian optimisation, coupled to the state-of-the-art multi-dimensional radiation-magnetohydrodynamics code Chimera. We use this novel capability to explore designs in increasing dimensionality with a multi-fidelity approach. Hydrodynamic instabilities can only be modelled in > 1 spatial dimension. Therefore, we will observe how designs must be modified to be robust to these instabilities.

Secondly, we explore gradient-based methods for ICF design. Legacy codes are not differentiable by construction. Instead, here we present work on the construction of a new differentiable 1D Lagrangian radiation-hydrodynamics code for laser direct drive simulations, lagradept. In this novel code, gradients with respect to design parameters are obtained via Automatic Differentiation (AD). The lagradept code is written in JAX with use of various packages (diffirax, lineax) which allows for computation of accurate gradients through the coupled PDEs' solution. JAX code is also performant due to Just-In-Time compilation and can be natively run on accelerators such as GPUs. We show some examples of capsule simulations run using lagradept and showcase its AD capabilities for inverse design.

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