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Modeling the 3D structure of ignition experiments at the NIF[1]

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Inertial confinement fusion ignition experiments at the National Ignition Facility (NIF) have shown strong self-heating and are approaching the burning plasma regime. However, detailed experimental diagnostics show a variety of limiting degradations that must be removed on the push for ignition. These limiters have both axisymmetric (2D) or fully three-dimensional (3D) characteristics as revealed by a host of spatially resolved x-ray and neutron diagnostics. To understand these limiters, researchers routinely use two complementary approaches one using forward modeling and a limited number of high-fidelity 3D simulations, another using inverse modeling and large numbers of moderate-fidelity 2D simulations.

We introduce here a new, 3D inverse technique that uses the full complement of spatially resolved NIF data to estimate the low mode number 3D implosion structure. Our goal is to reproduce a heavily coupled set of diagnostic measures including multiple x-ray images, neutron images, and other spectrally resolved neutron diagnostics. We begin by developing a large ensemble of 3D HYDRA simulations perturbed by long wavelength x-ray drive asymmetries as are likely produced by imbalances in the laser and target. Then, using a machine learning surrogate for our simulations and a companion optimizer, we select simulations whose diagnostic outputs are near matches for experimental observations. Our end product is both a candidate radiation drive model and an associated 3D implosion structure that replicates the experimental observations.

We detail in our talk the results garnered from application of this technique to a high-yield NIF ignition campaign. We explore the implications of the findings, including a characterization of the perturbations, their impacts, and the potential benefits of their mitigation. We also place the results in the context of the previous approaches and carefully sketch the conditions under which our techniques are applicable.

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