Simulating and Diagnosing Shell ρR Perturbations and Hot-Spot Mix in NIF Capsule Implosions

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The growth of perturbations in ICF capsules can lead to significant variation in in-flight shell areal density (ρR), and result in mixing of dense material into the hot-spot (H-S). Experiments on the National Ignition Facility (NIF) have provided clear evidence of ablator mix, consistent with simulation predictions,[1] however a detailed understanding of the individual sources of perturbation growth and their relative contribution to H-S mix remains a challenge.

Seeds for perturbations include "isolated defects" on the capsule, the fill-tube (10-μm-diam, for filling capsule with gas), and the "tent" (~ 50-nm-thick plastic which supports the capsule). These seeds are high-mode number, making both the simulations and experimental measurements challenging.

As the capsule is accelerated inward, the perturbation growth results from the initial shock-transit phase and then amplification by Rayleigh-Taylor (R-T). Measurements of capsule ρR perturbations, after inward acceleration is complete (i.e. at peak velocity), are a stringent test of our understanding. They inform us of the "integrity" of the shell while it is still large enough to resolve the most unstable modes. To achieve this we employ a "self-backlighting" method, where emission from the H-S is enhanced prior to peak compression by adding high-Z gas to the fill, producing a bright continuum x-ray source.[2] From images of the transmitted x-rays, above and below the K-edge of an internally doped high-Z layer (Cu), we infer the growth of various seeds, resolving up to mode ~60.

As the capsule decelerates, shell ρR perturbations result in jets entering the H-S, including ablator material (e.g. C, Be), or "payload" (DT fuel or extra ablator as "surrogate fuel" for non-cryo targets). In symcaps, we dope the inner most region of the shell with high-Z (e.g. Cu, W), and image the characteristic emission, allowing us to visualize the jets as they enter the H-S. For a DT layered target, simulations indicate we can "tag" the fuel, and visualize jets, if the DT layer is formed on a high-Z doped foam. Alternatively, jets could be measured in a hybrid target using a thin DT layer (~5 μm) and doped "surrogate fuel" ablator layer. Using localized doping, the relative contributions to mix from different seeds can be determined by using different high-Z materials - allowing an estimate of mixed mass (spectroscopy) and identification of the sources of mix (imaging).

[1] B.A. Hammel et al., HEDP, 6 (2010)
[2] L.A. Pickworth, B.A. Hammel, et al. PRL (2016)
[3] B.A. Hammel et al., POP 18, 056310 (2011)

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