Design of NIF-scale double cylinder targets for study of Rayleigh-Taylor instability growth on a classically unstable interface

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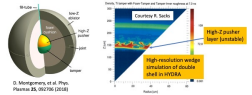
Summary

- Cylindrical implosions are useful for the study of hydrodynamic instability growth as the geometry allows for direct imaging of perturbation growth on a converging material interface
- The double cylinder experiment platform is designed as an analogue to the double shell ICF capsule in order to study hydrodynamic instability growth on the inner shell, the outer surface of which is classically Rayleigh-Taylor unstable during the acceleration phase
- We show designs for a proposed experiment at the National Ignition Facility, testing the growth of pre-seeded modes

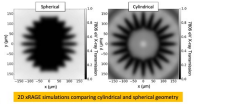
The double cylinder platform is motivated by assessment of instability growth on internal interfaces in multi shell ICF

- In multi-shell ICF concepts, a high-Z pusher is accelerated by means of a collision with the outer shell
- Internal interfaces are classically Rayleigh-Taylor unstable, without ablative stabilization



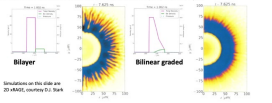
Cylindrical geometry provides a clear view of internal interfaces during implosion

- Convergence effects are retained in both spherical and cylindrical implosions
- On-axis radiographs of imploding cylinders both the outer and inner surfaces of the high-Z material

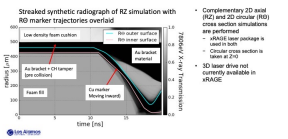


The eventual goal of the double cylinder platform is to test instability mitigation mechanisms in convergent geometry

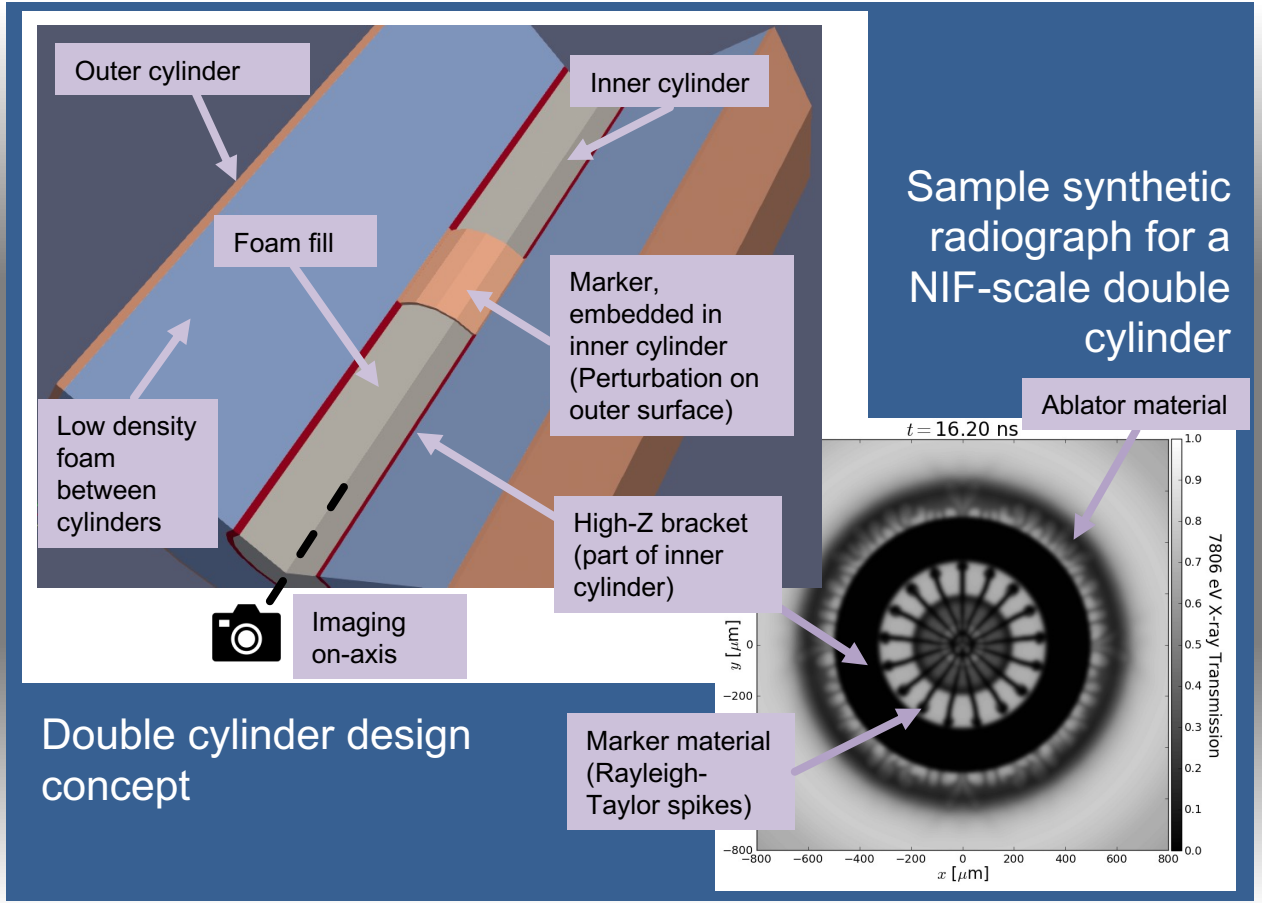
- Simulations of double shell implosions show that a graded density inner shell will be more stable than an inner shell with a conventional tamper/pusher bilayer



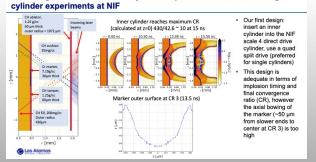
2D xRAGE simulations are used to model the implosion for our proposed proof-of-concept experiment on NIF



- Complementary 2D axial (RZ) and 2D circular (R0) cross section simulations are performed
  - xRAGE laser package is used in both
  - Circular cross section is taken at Z=0
- 3D laser drive not currently available in xRAGE

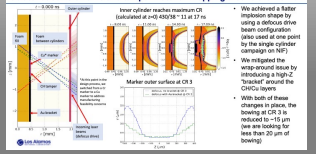


Our design for the NIF double cylinder experiment builds off of single cylinder experiments at NIF



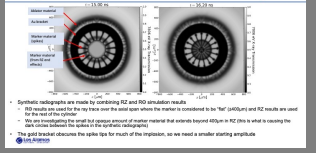
- Our first design: insert an inner cylinder into the NIF scale 4 direct drive cylinder, use a quad split drive (preferred for single cylinders)
- This design is adequate in terms of implosion timing and final convergence ratio (CR), however the axial bowing of the marker (~50 μm from slower ends to center at CR 3) is too high

We identified two contributing factors to marker bowing– the shape of the ablator at collision time and tamper material wrapping around the marker



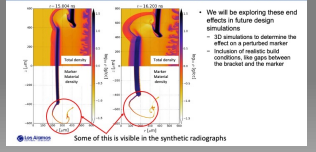
- We achieved a flatter implosion shape by using a defocus drive beam configuration (also used at one point by the single cylinder campaign on NIF)
- We mitigated the wrap-around issue by introducing a high-Z "bracket" around the CH/Cu layers
- With both of these changes in place, the bowing at CR 3 is reduced to ~15 μm (we are looking for less than 20 μm of bowing)

Synthetic radiographs show that spikes will be visible, though we need to investigate end effects and start with a smaller perturbation amplitude



- Synthetic radiographs are made by combining RZ and R0 simulation results
  - R0 results are used for the ray trace over the axial span where the marker is considered to be "flat" (±400μm) and RZ results are used for the rest of the cylinder
  - We are investigating the small but opaque amount of marker material that extends beyond 400μm in RZ (this is what is causing the dark circles between the spikes in the synthetic radiographs)
- The gold bracket obscures the spike tips for much of the implosion, so we need a smaller starting amplitude

Small amounts of marker material extend past the region where the implosion is axially uniform, complicating the synthetic radiographs



- We will be exploring these end effects in future design simulations
  - 3D simulations to determine the effect on a perturbed marker
  - Inclusion of realistic build conditions, like gaps between the bracket and the marker

Future work

- The first double cylinder shot day is at OMEGA in May 2022; this shot day will inform our ongoing NIF double cylinder design process
- The NIF design is not complete. Our goals include:
  - Still trying to understand the axial end effects
  - Working out what initial perturbation amplitude will work in order to see the Rayleigh-Taylor spike tips throughout the acceleration phase
  - Iterating on the design with target engineers, for a target that will meet our scientific goals and will be feasible to build

LA-UR-22-20802

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This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.