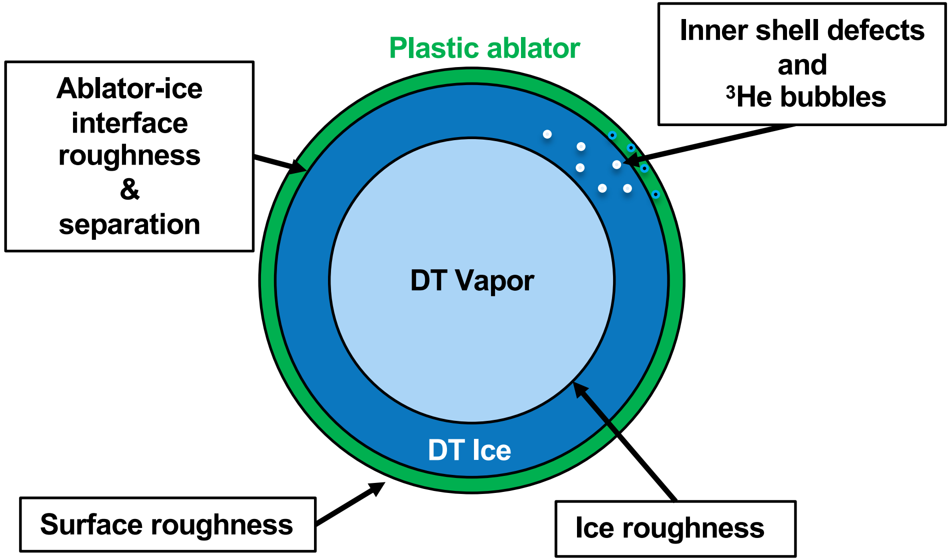
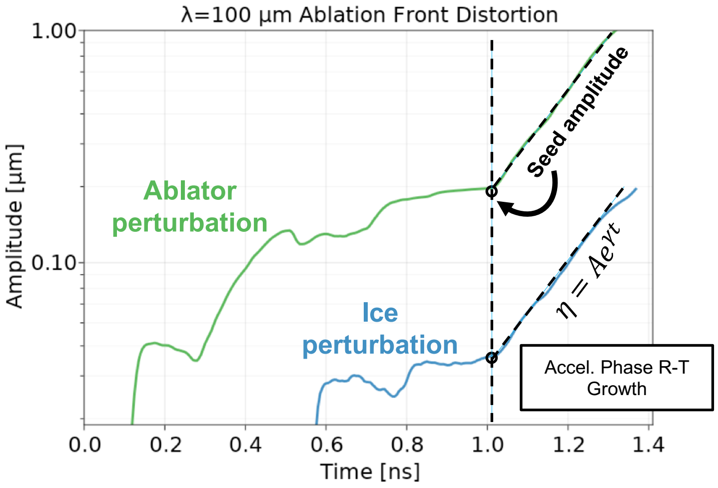
Internal Perturbation Evolution and Amplification During the Early Phase of Inertial Confinement Fusion Implosions





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63rd Annual Meeting of the American Physical Society Division of Plasma Physics
8–12 November 2021

Summary

Long wavelength perturbations in the ablator create larger acceleration phase instability seeds compared to those in the ice

- A comprehensive understanding of the impact of internal defects is needed to identify the seeds for instability growth and thereby design more robust implosions

- Internal perturbations undergo complex wave dynamics as they interact with multiple shock waves and interfaces within layered target designs

- Ablator layer perturbations experience hydrodynamic gradients during the beginning of the implosion which allow the ablation front to grow sooner and increase seed amplitudes when compared to ice

Collaborators

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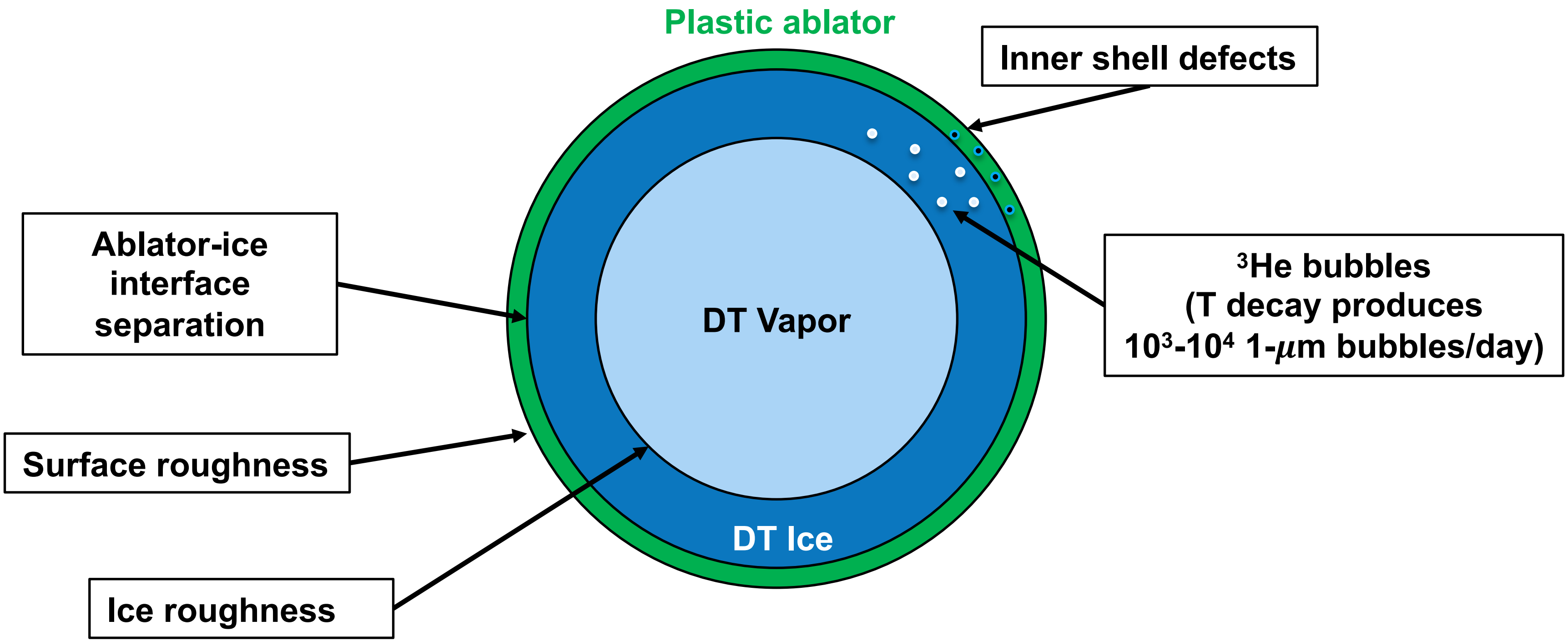
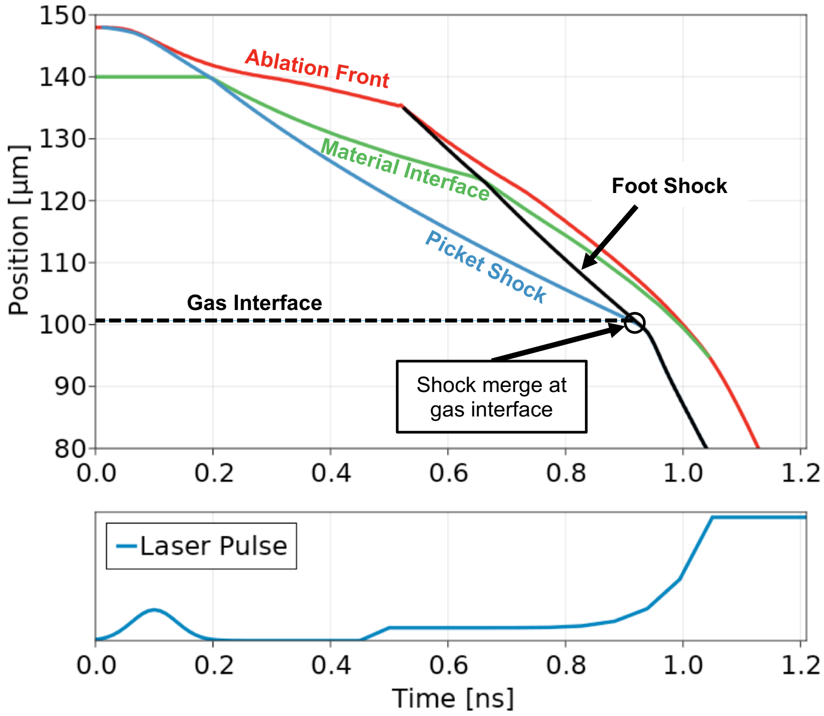
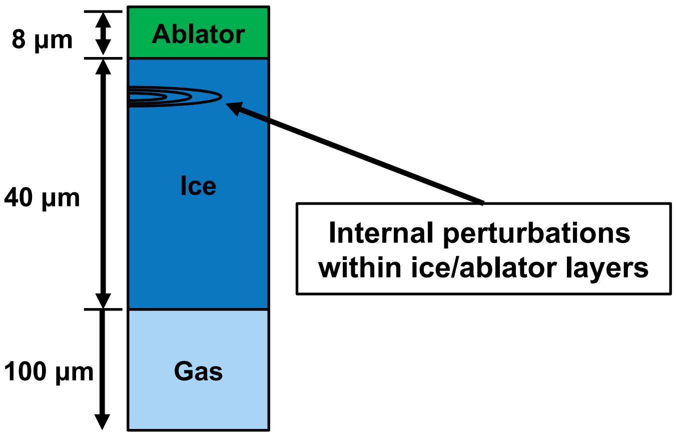
ICF target imperfections seed instability growth and can originate from various sources

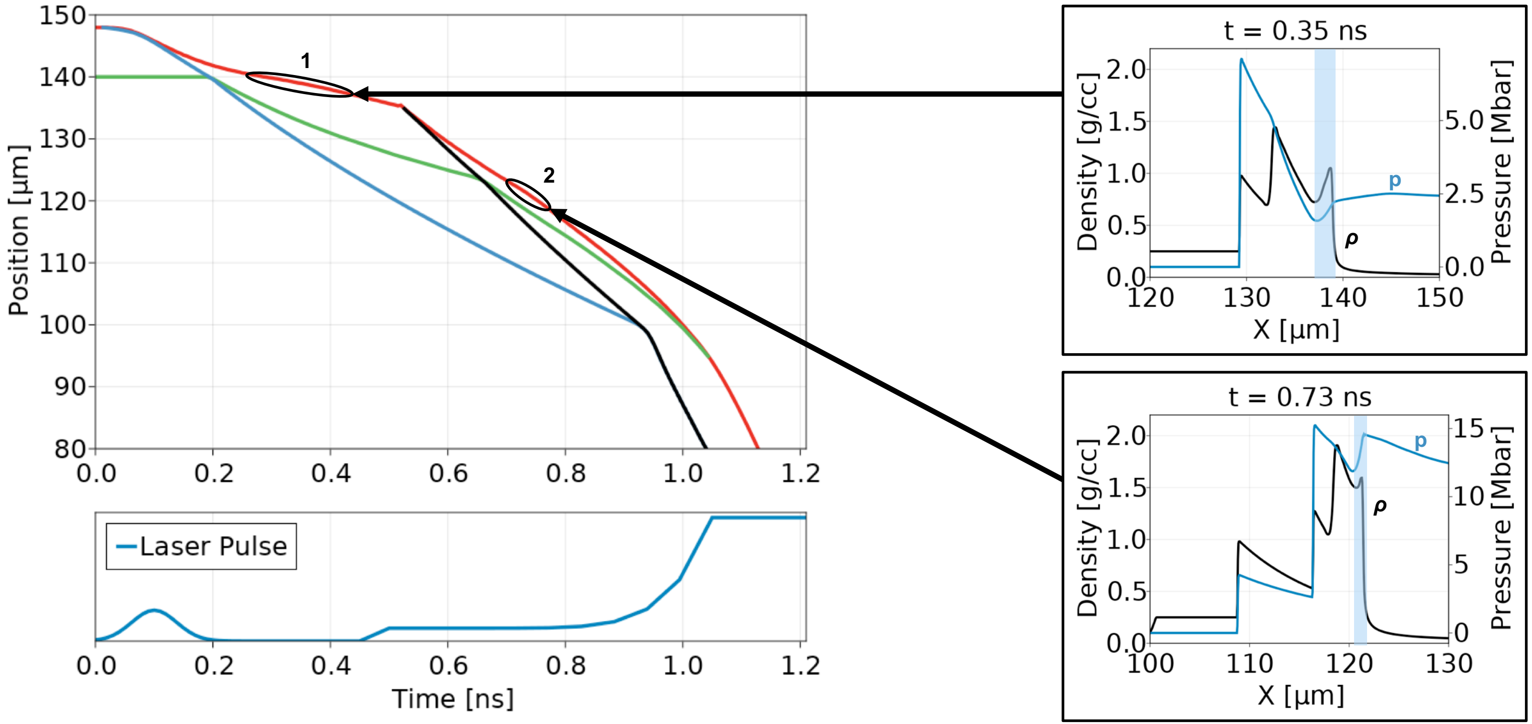


A surrogate OMEGA pulse and target helps to demonstrate the complexity of tracking internal perturbations and seeding mechanisms

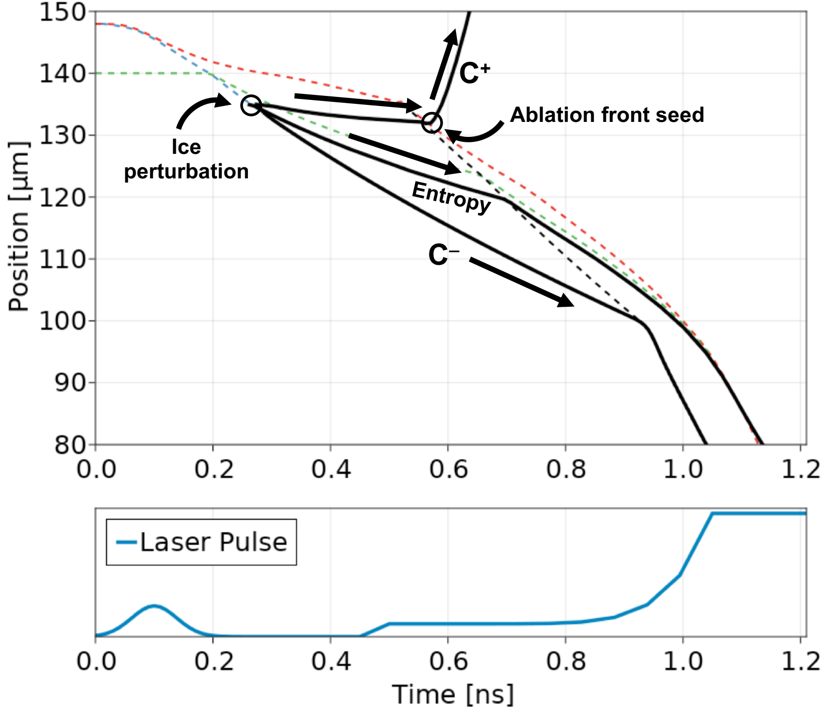




Reflected rarefaction waves from the material interface carry perturbation information out to the ablation front and relax the density of the outer surface



When the first shock hits a perturbation, three primary waves are created that carry information about this event throughout the target



Wave Definitions:

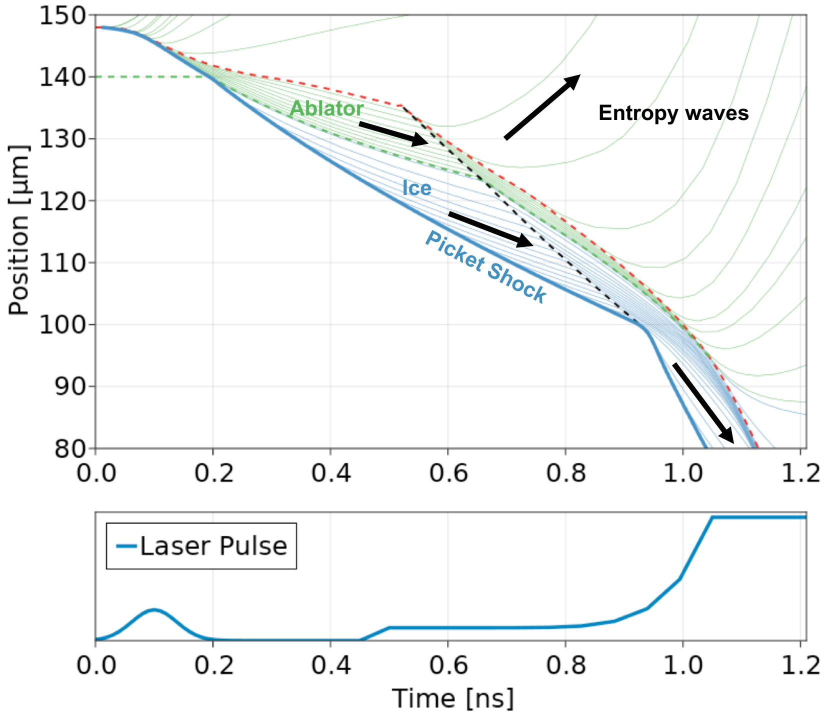
$$\text{Entropy}: \frac{dx}{dt} = U$$

$$\text{C}^+: \frac{dx^+}{dt} = U + c_s$$

$$\text{C}^-: \frac{dx^-}{dt} = U - c_s$$

U: Velocity
c_s: Sound speed

As the shock wave moves inward, it is a continual source of oscillation and vorticity which propagate along entropy waves



Wave Definitions:

$$\text{Entropy}: \frac{dx}{dt} = U$$

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U: Velocity
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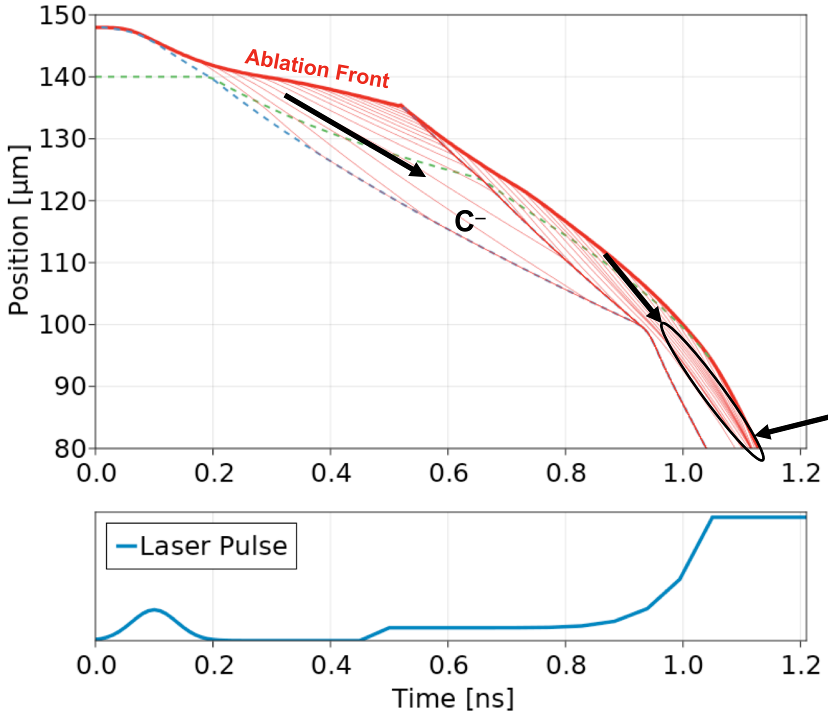
The rise in the main pulse launches a compression wave and converging C^- characteristics that will amplify velocity perturbations

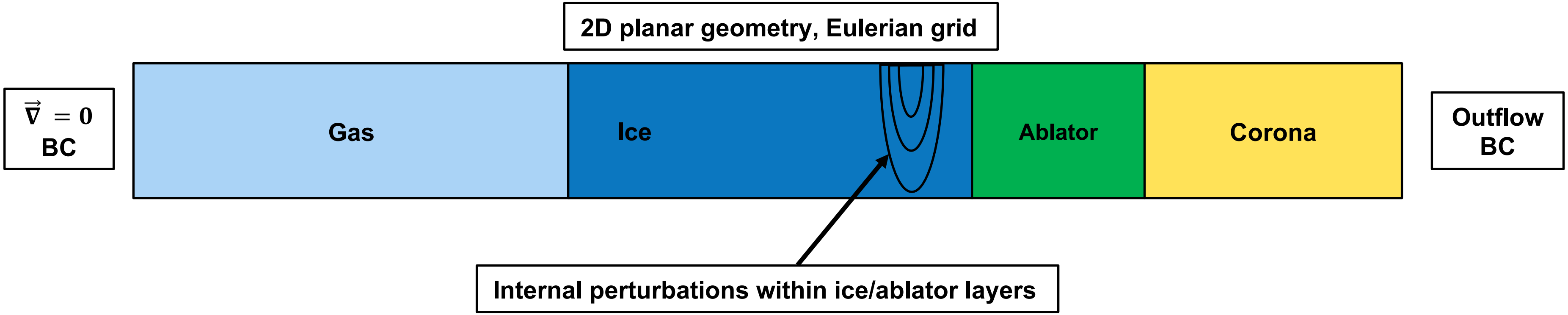


Velocity perturbations from the ablation front traveling along converging characteristics will experience amplification[1,2]

[1] V. N. Goncharov, APS DPP 2019 PO7.001
[2] S. C. Miller, APS DPP 2019 PO7.002

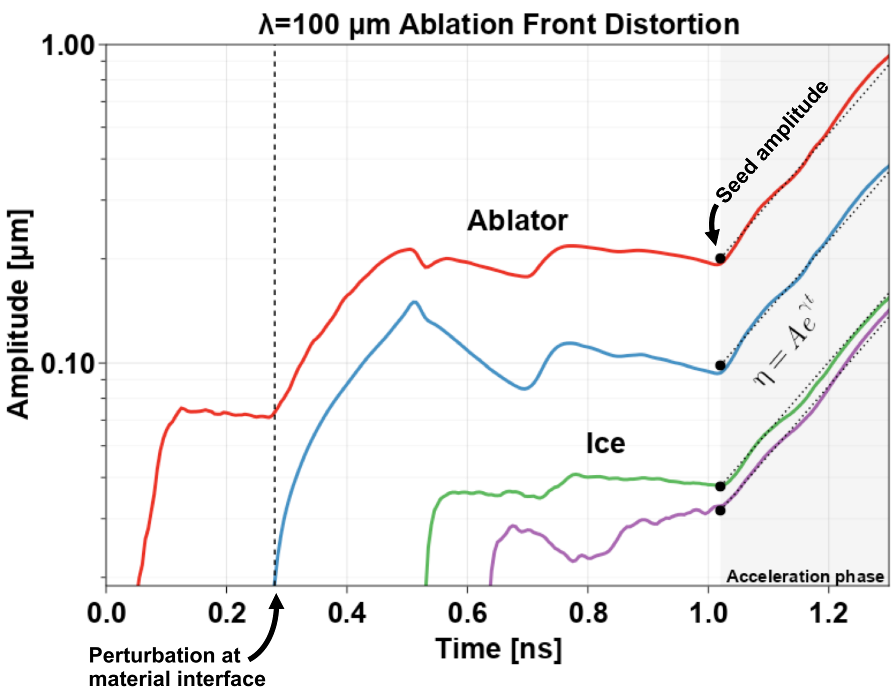
Internal perturbation evolution and instability seeding was studied using a simplified multi-physics code that couples hydrodynamics with thermal conduction

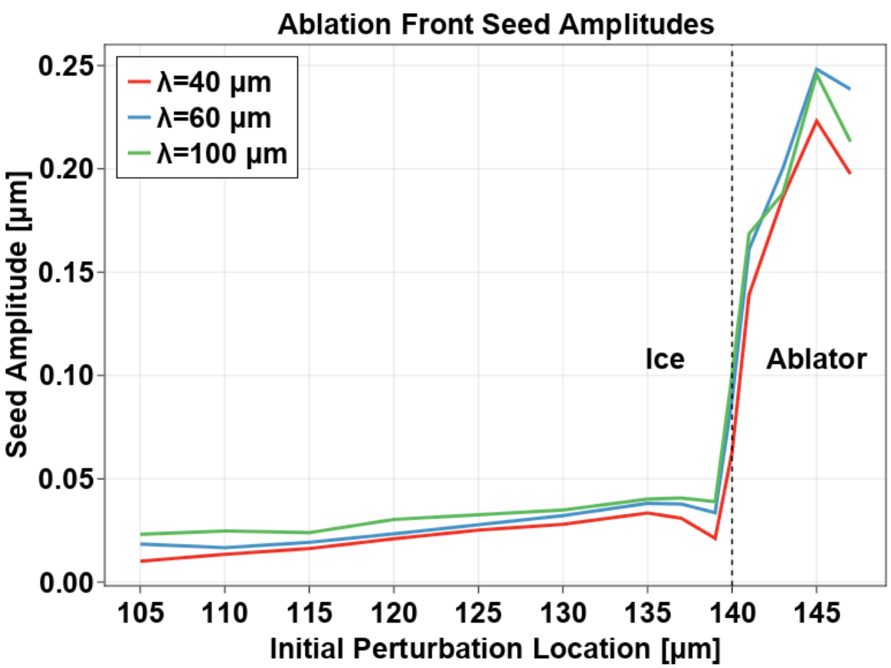
- Single-material, low-dissipation 2D finite volume Riemann solver(1) with 5th order spatial reconstruction(2)
- 2D ADI thermal conduction solver with Spitzer conductivity
- Energy deposition via thermal source term
- Internal density perturbations: single-mode, isolated void, etc.



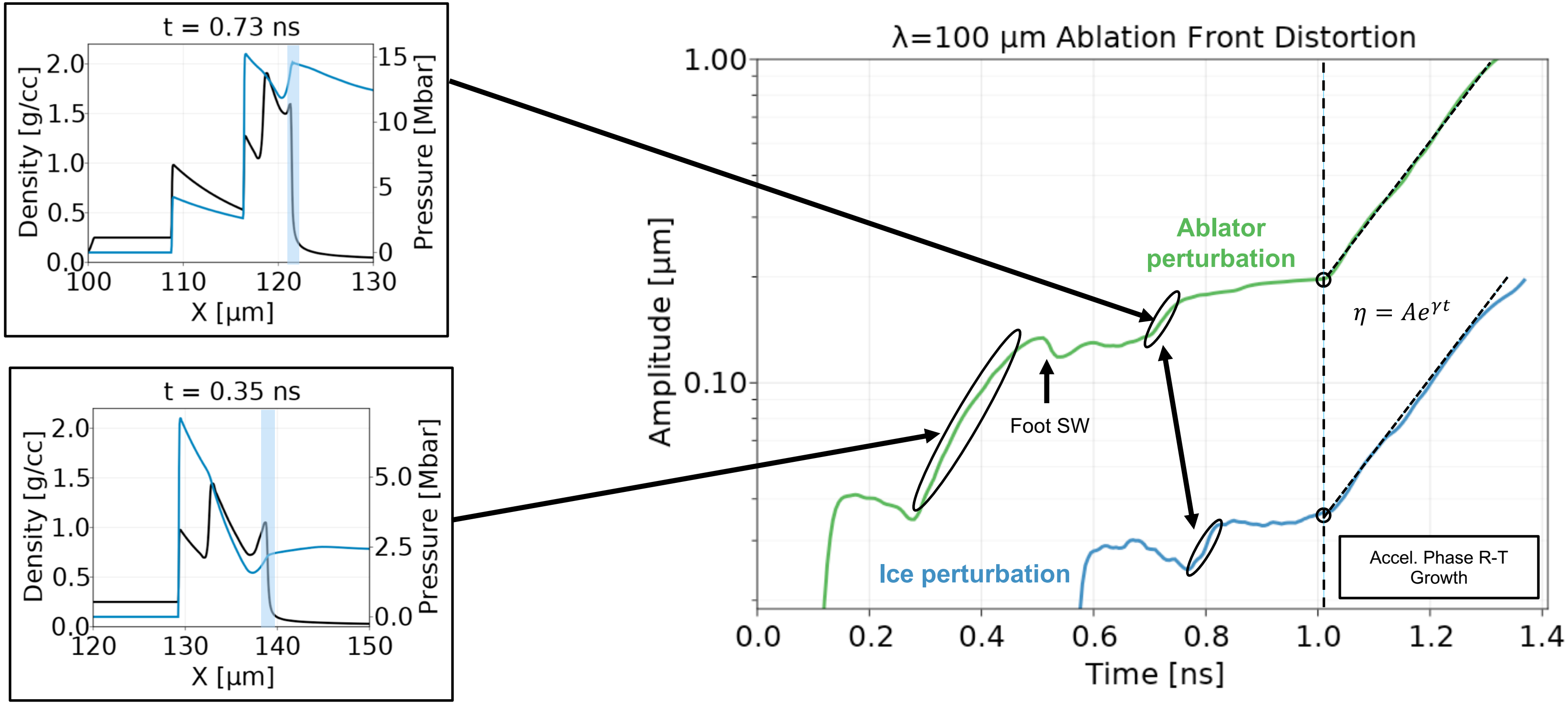
1 Kim, K. H., Kim, C. & Rho, O.H. *Journal of Computational Physics* **174**, 38–80 (2001)
2 Kim, K. H. & Kim, C. *Journal of Computational Physics* **208**, 570–615 (2005)

Long wavelength, single-mode perturbations in the ablator create larger acceleration phase instability seeds compared to those in the ice

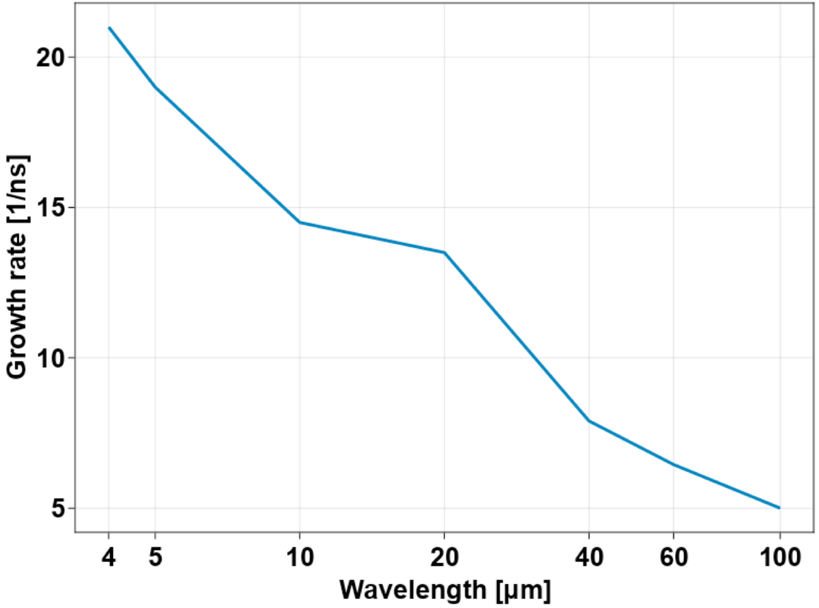


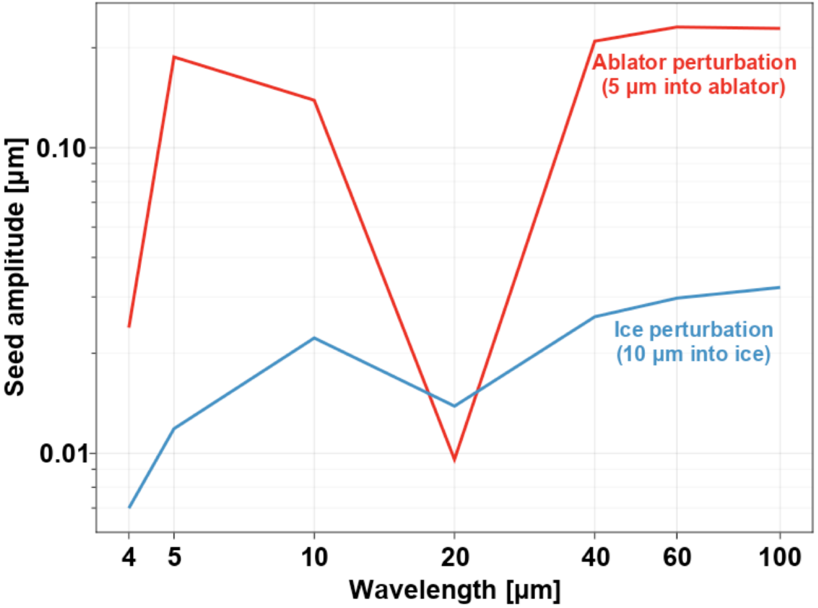


Growth at the ablation front prior to acceleration is dictated by the pressure and density gradients created by shock and material interface interactions



Short wavelength ablator perturbations are influenced more by oscillation and the distorted material interface compared to long wavelengths and those in ice





Ablator thickness can be optimized to reduce amplitudes of the most dangerous modes

Long wavelength perturbations in the ablator create larger acceleration phase instability seeds compared to those in the ice

- **A comprehensive understanding of the impact of internal defects is needed to identify the seeds for instability growth and thereby design more robust implosions**
- **Internal perturbations undergo complex wave dynamics as they interact with multiple shock waves and interfaces within layered target designs**
- **Ablator layer perturbations experience hydrodynamic gradients during the beginning of the implosion which allow the ablation front to grow sooner and increase seed amplitudes when compared to ice**
- **Future work will study optimal ablator thickness designs based on the findings of both long and short wavelength internal perturbations**