Richtymer-Meshkov (RM) Instabilities in Clyindrical and Planar Geometries on Z

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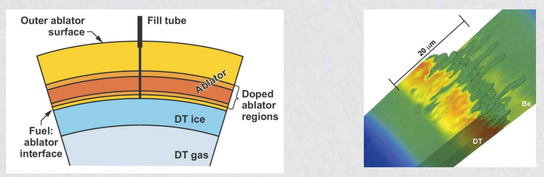
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Early Career R&D Program

Problem

- In many high-energy-density (HED) plasmas turbulent mixing occurs between different material layers as a result of the initial surface roughness and hydrodynamic instabilities such as the Richtmyer-Meshkov (RM) instability.



Left: Schematic of a layered fuel capsule for inertial confinement fusion experiments on the National Ignition Facility.
Right: 3D HYDRA simulations of the layered capsule that show mixing between the different materials. Both images taken from B.A. Hammel, et. al., High Energy Density Physics 2010.

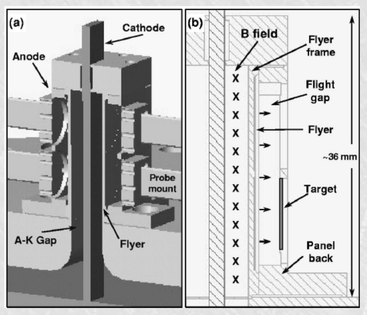
- Simulations struggle to accurately model the turbulent mixing and so benchmark quality experiments are needed.

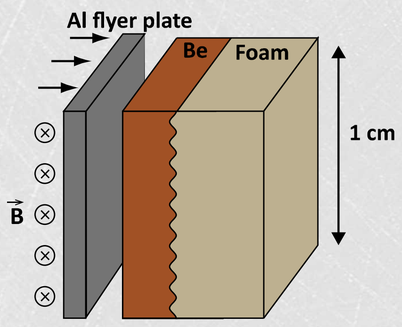
- However, only a few laboratory experiments exist that can produce benchmark quality data, and even fewer produce an observable turbulent transition.

Approach

- The primary objective is to measure the growth of a shocked rippled interface and compare the observations to simulation and theory.

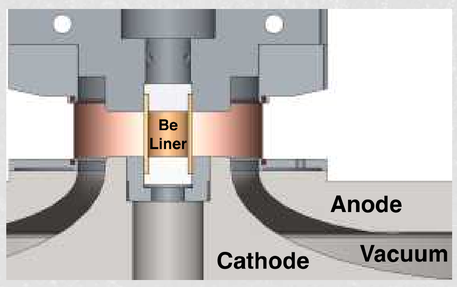
- A flyer plate launched by the large magnetic pressure produced by the Z machine can be used to shock a target.

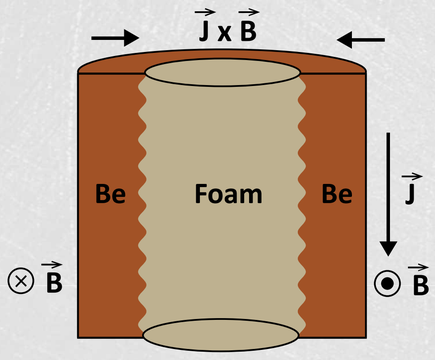




Left: Z machine load hardware used to launch high-velocity slabs of metal known as "flyer-plates." Image from Knudson et. Al. JAP 2003.
Right: Proposed Be/foam target for generating benchmark quality mixing data.

- Mix experiments can also be performed using a cylindrically converging geometry in which the magnetic pressure drives an inward-propagating shock.



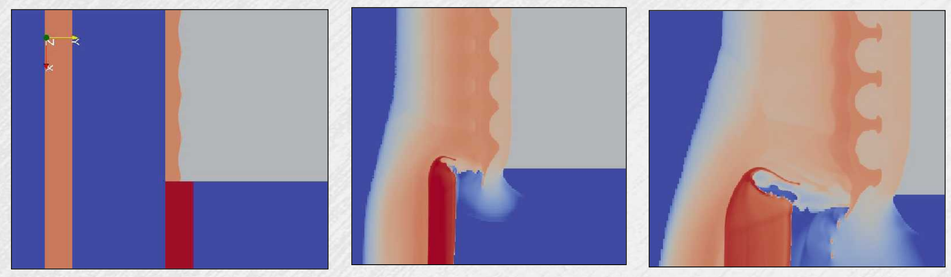


- In both geometries the evolution of the initial perturbations will be captured by radiographs formed from backlighting the target with 6 keV x-rays.

Results

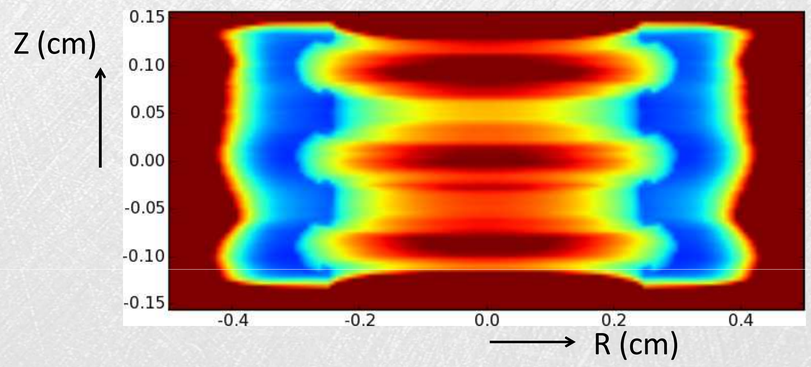
- ALEGRA modeling of the planar case predicts the interface can be driven for 100 ns at 3 Mbar. **This is 4x longer than any previous HED RM experiment.**

- 2D ALEGRA modeling of the planar case predicts that there is observable RM growth.

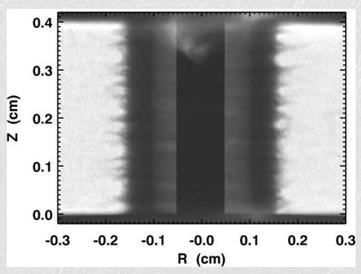


Simulation of an Al flyer impacting a Be/foam interface with a perturbation (λ = 250 μm, amplitude = 25 μm).

- 2D ALEGRA modeling of the cylindrical case predicts that there is observable RM growth, yet it is more difficult to observe than the planar case.



Simulation of an imploding Be cylinder filled with foam.



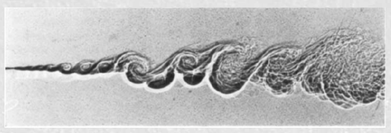
Recent experimental data from smooth cylinders showed that high-quality images can be obtained.

Significance

- Predictive drive simulations using the highly validated ALEGRA code demonstrate that HED RM data of unprecedented quality is attainable through Z experiments.

- With Z's unique pulse shaping capability the growth of the RM instability can be studied in regimes that are sensitive to material strength and phase changes.

- Furthermore, for the first time in the HED regime, this platform has the potential to produce an observable turbulent transition.



Brown and Roshko, *J. of Fluid Mech.* (1974)

- All of the above points are important for validating simulations that support the Inertial Confinement Fusion Program.

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