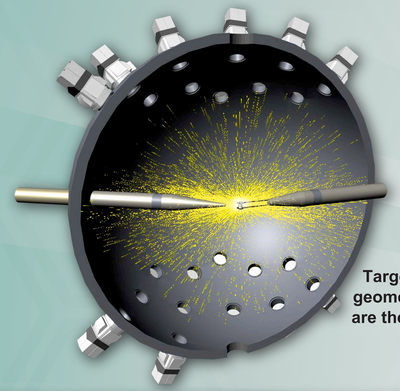
Target Design and Debris Modeling with NIF ALE-AMR

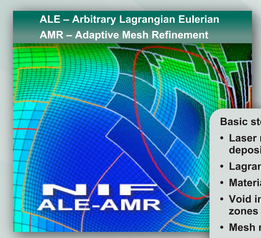
Authors: Alice Koniges,[1] D. Eder,[1] O. Landen,[1] R. Anderson,[1] A. Fisher,[1] B. Gunney,[1] N. Masters,[1] B. Maddox,[1] F. Hansen,[1] B. Brown,[1] K. Fisher,[1] T. Kaiser,[1] A. Geille,[2] J-P. Jadaud,[3] J-M. Chevalier,[2] D. Raffestin,[2] D. Benson,[4] M. Meyers,[4] H. Jarmakani,[4] B. Blue[5]

Protecting NIF Optics and Diagnostics

NIF targets must be designed to minimize damage to optics and diagnostics from target debris



Target materials, mass, geometry, and orientation are the critical parameters to understand



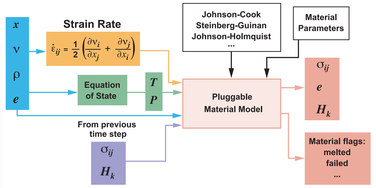
Basic steps of NIF ALE-AMR:

- Laser ray tracing and x-ray deposition
- Lagrangian hydrodynamics
- Materials update
- Void introduction for failed zones
- Mesh relaxation and advection
- Interface reconstruction
- AMR coarsening/refinement
- Radiation diffusion

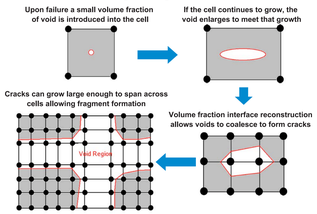
Computational Modeling and Experimental Validation

Strength and failure

Code uses flexible strength modeling framework



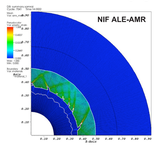
Model for fragmenting and void coalesce



Crack formation using interface reconstruction

Macroscopic verification and validation

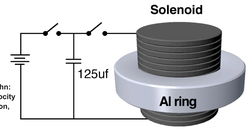
Benchmarking against industry standard



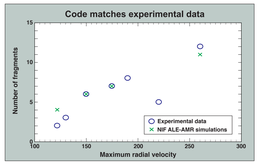
- 2- to 4-mm ring made of Al6061 surrounded by void
- Johnson-Cook strength and damage models

Plastic strain comparison shows good agreement

Electromagnetic ring expansion

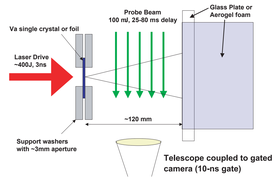


M. Altynova, X. Hu, and G. Daehn: Increased Ductility in High Velocity Electromagnetic Ring Expansion, Metall. Material Trans. A, 27A, p1837-1844, (1996)

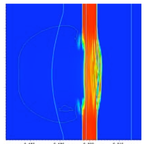


Extension of validation to micro scale

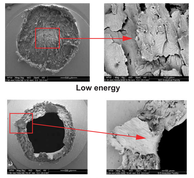
Laser loading of the foils experimental configuration



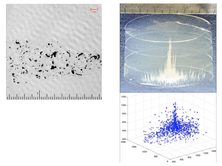
Simulation shows back plane spall



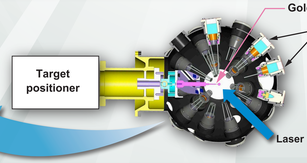
Foil post shot



Experimental results



Foil samples inside sphere

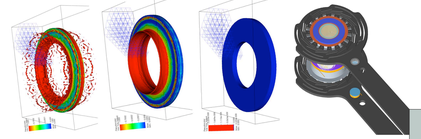


Sphere in CEA chamber

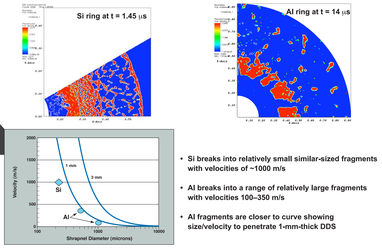
Dedicated joint LLNL/Commissariat à l'Énergie Atomique (CEA) x-ray driven fragmentation experiments are ongoing

Application to NIF/NIC

Simulations show that fragments from Si have a greater safety margin than Al rings



Time progression of cooling ring disintegration allows us to determine particle size/velocity

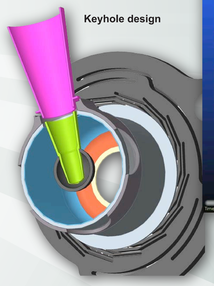


- Si breaks into relatively small similar-sized fragments with velocities of ~1000 m/s
- Al breaks into a range of relatively large fragments with velocities 100–350 m/s
- Al fragments are closer to curve showing size/velocity to penetrate 1-mm-thick DDS

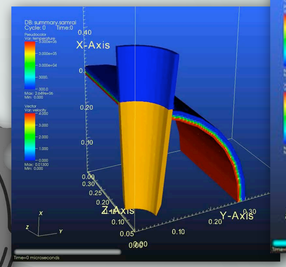
Cryogenic cooling ring simulations

Shock timing campaign simulations

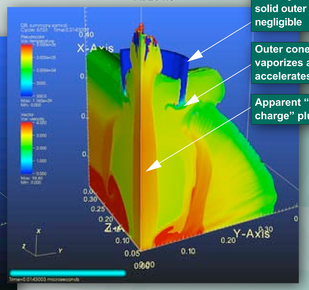
Keyhole design



3D simulation setup

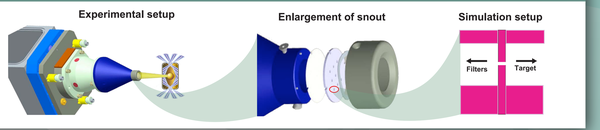


At 26 ns



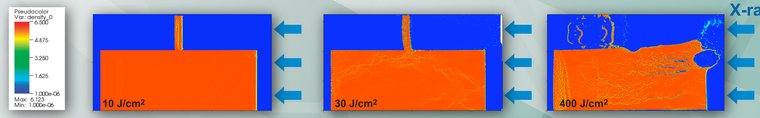
- Velocity of remaining solid outer cone is negligible
- Outer cone melts/ vaporizes as it accelerates
- Apparent "shaped charge" plume

Re-emit capsule experimental design



Requirements on shrapnel size and velocity depend on filter material and thickness

NIF ALE-AMR simulations

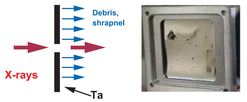


For re-emit at 10 J/cm², pinholes don't get launched. Higher energies do.

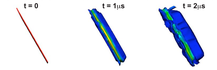
NIF Early Light (NEL) experiments demonstrated effectiveness of tilting diagnostic components to redirect debris

NEL

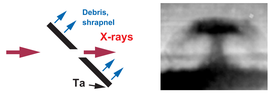
Configuration and damage prior to tilting



Simulation → blow-off in normal direction



Configuration and image after tilting



OMEGA

Two shrapnel jets before tilting

Redirection of one jet following tilting

Summary

- NIF ALE-AMR is unique in its ability to model hot plasmas and cold fragmenting solids
- NIC targets are analyzed; results help guide NIC target design
- Improvements to physics models are ongoing

Author affiliations: [1]LLNL, Livermore, CA, USA; [2]CEA/CESTA, France; [3]CEA/DIF, France; [4]University of California, San Diego, CA, USA; [5]General Atomics, San Diego, CA, USA

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