FEEDTHRU OF RIPPLED SHOCKS FROM ABLATIVELY-DRIVEN RICHTMYER-MESHKOV IN METALS ACCOUNTING FOR MATERIAL STRENGTH

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Hydrodynamic instabilities are a dominant feature of most High-Energy-Density (HED) systems. The growth of these instabilities depends on the material phase and intrinsic fields that perturb the hydrodynamics away from an ideal fluid flow. For example, many materials can retain significant resistance to shear deformation up to Mbar pressures in the solid-state. This strength is known to decrease Rayleigh-Taylor (RT) growth rates relative to those predicted and observed under ideal hydrodynamic conditions. Little is known, however, about the effects of material strength as phase boundaries (solid-solid, solid-liquid, etc.) are approached. Specifically, the behavior of shock and release waves undergo sharp changes near these boundaries, suggesting that significant changes to the growth rate of instabilities at material boundaries, i.e., Richtmyer-Meshkov (RM), may occur at perturbed solid-state interfaces. It is also likely that this material strength could be useful in mitigating instability growth in inertial confinement fusion (ICF) capsules using metal ablators.

In the experiments and simulations we present, a rippled shock is created by laser-ablation of a sinusoidal perturbation in a metal target. The strength of the shock can be tuned to access phase transitions in metals such as iron or simply to study high-pressure strength in isomorphic materials such as copper. Simulations show that the oscillation frequency and decay rate of the shock front ripple is strongly affected by material strength. To validate these and future models of phase-aware strength we have performed experiments at the TRIDENT Laser (Los Alamos National Laboratory) to measure the feedthru of ablative RM shock fronts. These experiments directly measure the surface height amplitude imposed by the shock ripple at the opposite free surface with 50 nm precision using a diagnostic called Transient Imaging Displacement Interferometry (TIDI). With multiple frames of data on each shot at 8 ns pulse separation, the evolution of the free surface ripple is measured allowing us to better constrain model parameters.

Simulations predict that the free surface ripple grows about 3 times more without the use of a strength model (Preston-Tonks-Wallace [1]) in copper for an initial 5 micron amplitude, 50 micron wavelength sinusoid driven to a free surface velocity of 600 m/s. By increasing the perturbation wavelength we can slow the shock oscillation frequency and decay rate to increase the free surface ripple amplitude. In polymorphic materials the shock pulse can be adjusted to cross a phase boundary inside the target, potentially allowing for the observation of oscillation frequency change due to the difference in strength of the new phase.

[1] D. Preston, D. Tonks, D.C. Wallace, J. Appl. Phys. 93 (2003).