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Investigations into the Seeding of Instabilities due to X-ray Preheat in Beryllium-Based Inertial Confinement Fusion Targets

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The geometry of inertial confinement fusion (ICF) capsules makes them susceptible to various types of hydrodynamic instabilities at different stages during an ICF implosion. From the beginnings of ICF research, it has been known that grain-level anisotropy and defects could be a primary source of instability seeding in solid capsules. This has steered ICF designs to include amorphous materials such as plastic; however, the benefits of low-Z metallic materials, i.e. beryllium, has kept these materials the focus of much research. Recently, experiments were conducted at the Trident laser facility to measure dynamic surface roughening from hard x-ray preheat. M-band emission from laser produced gold plasma was used to heat beryllium targets with different amounts of copper doping to temperatures comparable to National Ignition Facility (NIF) preheat levels. Temporal and spectral x-ray diagnostics were used to estimate the target heating, which was also predicted by multi-dimensional radiation hydrodynamics calculations. Wave profiles of varying complexity due to differences in copper doping were observed with free surface line imaging velocity interferometry. Dynamic roughening measurements were made on the surface away from the plasma at discrete times up to 8 ns after the beginning of the drive pulse using a surface displacement interferometer with nanometer scale sensitivity. Undoped, large-grained targets were measured to roughen between 15 and 50 nm rms depending on variations in x-ray absorption through the target thickness. Fine-grained, copper-doped targets were observed to roughen near the sensitivity limit of the interferometer and approached the Rev2 NIC design point of 0.9 nm. The results of this combined experimental and modeling effort have shed light on the effects of high-Z doping and microstructural refinement on the dynamics of differential thermal expansion and have shown that current NIF capsule designs using beryllium are very effective in reducing preheat related roughening ahead of the first shock. These experiments have raised additional questions, however, such as the possibility of spallation from intense thermal expansion, which will also be discussed.