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Accessing ultra-high pressures and strain rates in the solid state: An experimental path to extreme materials science on the Omega and NIF lasers[1]

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A new approach to materials science at extreme pressures and strain rates has been developed on the Omega laser, using a ramped plasma piston drive. The laser drives a shock through a solid plastic reservoir that unloads at the rear free surface, expands across a vacuum gap, and stagnates on the metal sample under study. This produces a gently increasing ram pressure, compressing the sample nearly isentropically. The peak pressure on the sample, diagnosed with VISAR measurements, can be varied by adjusting the laser energy and pulse length, gap size, and reservoir density, and obeys a simple scaling relation.[1] This has been demonstrated at OMEGA at pressures to 200 GPa in Al foils. In an important application, using in-flight x-ray radiography, the material strength of solid-state samples at high pressure can be inferred by measuring the reductions in the growth rates (stabilization) of Rayleigh-Taylor (RT) unstable interfaces. RT instability measurements of solid Al-6061-T6 and vanadium, at pressures of 20-100 GPa and strain rates of 10^6 to 10^8 s^{-1}, show clear material strength effects. High-pressure experimental designs based on this drive have been developed for the NIF laser, predicting that solid-state samples can be quasi-isentropically driven to pressures an order of magnitude higher than on Omega - accessing new regimes of dense, high-pressure matter. [1] J. Edwards et al., Phys. Rev. Lett., 92, 075002 (2004).

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