Advancing from scaled burning plasmas to hydroequivalent ignition in laser-direct-drive implosions: status, progress, and prospects

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Laser direct drive (LDD) is a viable approach to achieving high-gain, inertially confined fusion in the laboratory. It couples significantly more laser energy to the fuel capsule than its counterpart, laser indirect drive (LID), making it particularly appealing for high-gain applications. However, it faces its own set of challenges through increased sensitivity to beam quality and symmetry. In the United States, study of LDD is primarily pursued on the Omega Laser Facility at the Laboratory for Laser Energetics. Supported by data-driven modelling and state-of-the-art multidimensional simulations, DT-layered implosion experiments on the OMEGA laser now achieve conditions that, when scaled to megajoule-class facilities, extrapolate to the burning plasma regime. Using high implosion velocities (>450 km/s) and moderately high adiabats (~5), these experiments produced record scaled Lawson parameters equal to 89 ± 5% of that required for ignition with expected yields of up to 1.5 ± 0.2 MJ when projected to 2.15 MJ of laser drive. To improve this performance further and reach hydroequivalent ignition, research is now focused on improving convergence and achieving greater areal densities through advanced experimental techniques such as target subcooling, multidimensional measurements and reconstructions, and novel target and implosion designs that expand the viable parameter space. This presentation will summarize the paths taken to reach this scaled burning plasma regime, the techniques used to project this performance to megajoule-class facilities that have been supported through scaling studies at the National Ignition Facility, and the current challenges to overcome to reach scaled ignition. Finally, future directions of the field will be presented, including new target manufacturing capabilities and the development of broad-bandwidth drivers for future direct-drive facilities.

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