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Performance Enhancement of Direct-Drive Shock Augmented Ignition Inertial Fusion Implosions through Shock Timing Optimisation

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The Shock Augmented Ignition (SAI) [1] approach to inertial fusion aims to assemble high areal density fuel using moderate implosion velocities, where ignition is triggered with a late-timed shock, similar to Shock Ignition [2]. This favourable fuel assembly is predicted to enable high gains while maintaining hydrodynamic stability. The resulting sub-ignition hot spot is pushed beyond the ignition threshold by the supplementary energy of the augmenting shock. Unlike Shock Ignition, SAI is able to launch this shock using significantly lower laser intensities, reducing the excitation of detrimental laser-plasma instabilities. This is achieved by first decreasing the laser power before rapidly increasing it again. The shock generation effectiveness is further enhanced by plasma preconditioning from the initial power reduction.

This talk presents the results from a series of direct-drive implosions performed at the OMEGA Laser Facility. The experiment was designed to demonstrate the efficacy of the augmenting shock through the resulting performance increase from an optimised shock launch timing. Using energy-equivalent laser pulses, the timing of the shock launch was varied by changing the timing of the dip and increase in power. Key performance metrics improved substantially when the timing was optimised; areal density and hot spot pressure increased by 50% and 112%, respectively. The optimal range of shock launch timings and the associated trend in implosion performance were closely matched by simulations.

The critical design feature for SAI that is suggested by the results from this experiment and ignition-scale simulations is the timing of the shock arrival at the hot spot centre relative to the peak in compressive yield. It was found that the maximum benefit of the augmenting shock occurred for arrivals marginally before this peak, with ignition-scale simulations predicting an ignition cliff for shocks arriving after this.

[1] R. Scott, D. Barlow, W. Trickey, A. Ruocco, K. Glize, L. Antonelli, M. Khan, and N. Woolsey, Shock-augmented ignition approach to laser inertial fusion, Physical Review Letters 129, 195001 (2022).

[2] R. Betti, C. Zhou, K. Anderson, L. Perkins, W. Theobald, and A. Solodov, Shock ignition of thermonuclear fuel with high areal density, Physical Review Letters 98, 155001 (2007).