Implosion of Double Shell targets for fusion plasma studies

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Implosions of Double Shell targets offer an alternative path to significant alpha-heating and high neutron yields at the National Ignition Facility (NIF)[1]. Current Double Shells are imploded inside Au hohlraums with approximately 5 ns long, 1 MJ (and above) laser pulses with less than 2% backscatter and low hohlraum wall motion. An Al outer shell (two joined hemi-shells) implodes inward compressing a low-density foam buffer shell that impacts and transfers its kinetic energy to an inner high-atomic-number metal shell. With enough kinetic energy the inner shell will then compress liquid DT to densities and temperatures sufficient to induce thermonuclear reactions and stop alpha-particles in the fuel. Using a heavy metal inner shell on DT results in a ‘volume’ burn condition since the entire fuel region compresses to the same density and temperature (in the ideal case). The inner shell also becomes a radiation cavity greatly reducing radiation losses resulting in a lower required fuel ion temperature for ignition.

For Double Shells there are numerous physics and engineering challenges that differ from single shell hot spot inertial confinement fusion (ICF). From a one-dimensional (1D) perspective, experimental data is needed to evaluate competing design strategies available to double shell targets, such as velocity multiplication, ‘fall-line’ optimization, and payload-pusher mass matching. These designs typically trade-off between high 1D yield performance and 3D performance when high-Atwood number, high-mode Rayleigh-Taylor growth on the inner shell is included. To prepare for these full-scale, high-yield experiments we are currently conducting impact symmetry tuning campaigns while developing the target fabrication methods needed to meet full-scale specifications.

In this presentation we will report on our current design efforts and experimental progress at the NIF and OMEGA laser facilities. We have completed the first set of double shell radiography experiments on NIF where the inner shell was replaced with a surrogate low-density (SiO_2) inner shell so that it could be imaged with a Zr (16.3 keV) x-ray backlighter. These experiments showed implosion symmetry that was close to predictions by the LLNL code HYDRA. They also showed evidence of a growing disk-like feature we associate with the step joint from assembly of the outer Al hemi-shells. We will also present future directions for double shells and considerations for optimizing targets and designs.

References

[1] E.I. Moses, Nucl. Fusion 49, 104022 (2009).