Rings, pickets, spiders and frozen fuel drive hot fusion targets

Innovative target irradiation geometries that make use of rings of beams coupled with successes in cryogenic target and picket pulse experiments at the University of Rochester's Laboratory for Laser Energetics (LLE) significantly advance the prospects of achieving direct-drive ignition on the National Ignition Facility (NIF).

Contacts: Robert L. McCrory (rmcc@lle.rochester.edu; 585-275-5286) and David D. Meyerhofer (ddm@lle.rochester.edu; 585-275-0255)

The direct-drive approach (where laser beams uniformly illuminate a spherical capsule) offers the potential of very high fusion gain on NIF – NIF will become the nation's premier fusion laser later in this decade. Carrying out direct-drive experiments on NIF, however, is made potentially difficult due to the NIF baseline irradiation geometry (it is optimized for two sided illumination of targets using x-ray drive). LLE scientists have made spectacular progress during this year in several areas of research that bode well for the early demonstration of ignition and gain on NIF using the direct-drive approach.

First, high fusion yield and fuel density were demonstrated on direct-drive spherical implosions of cryogenic capsules on the OMEGA 60-beam laser. These capsules were energy-scaled from the designs that have been developed to demonstrate ignition on NIF. Thin-walled (3- to 4-μm) CD polymer shells, just less than a millimeter in diameter and filled with approximately one thousand atmospheres of deuterium gas frozen to the freezing point of the heavy hydrogen were used for these experiments. The shells were supported by means of spider silk in specially shaped mounts. OMEGA experiments that were carried out with these capsules yielded the highest fusion yields and fuel areal densities (product of fuel mass density and fuel radius) recorded to date in cryogenic-fuel laser fusion experiments. Sophisticated multi-dimensional hydrodynamics code simulations (using the code DRACO) show good agreement with the experimental observations.

Second, OMEGA experiments confirmed that significant improvement in fusion capsule performance could be achieved by using specially designed laser pulses that have high intensity "pickets" prior to the main high-energy pulse.

Finally, polar direct drive (PDD), an innovative NIF target concept, was tested on OMEGA to make use of the existing NIF two-sided beam geometry to directly drive capsules to ignition and gain. The idea uses the four "rings" of NIF beams, placed at angles ranging from 23.5 to 50 degrees from the vertical, and the four corresponding rings in the lower hemisphere, aimed towards the equator rather than the capsule center. This compensates for the enhanced refractive energy loss expected due to the off-normal incidence of beams near the equator. In addition, the concept uses a "ring" of material placed at some distance from the capsule (see Fig. 1) to provide additional concentration of the laser beams towards the target. Initial PDD experiments on OMEGA, along with simulations using the hydrodynamics code DRACO, indicate that the prospects of achieving ignition with PDD are very good.

Invited papers describing this work will be presented by:

F.J. Marshall (BI2.001) – *Direct-Drive, Cryogenic Target Implosions on OMEGA* (category 4.4.0)
R.S.Craxton (BI2-002) – *Polar Direct Drive – Proof-of-Principle Experiments on OMEGA and Prospects for Ignition on the NIF* (category 4.4.0)
J.P. Knauer (BI2-003) – *Improved Target Stability Using Picket Pulses to Increase and Shape the Ablator Adiabat* (category 4.4.0)
P.B. Radha (BI2-004) – *Multidimensional Analysis of Direct-Drive Plastic-Shell Implosions on OMEGA* (category 4.4.0)

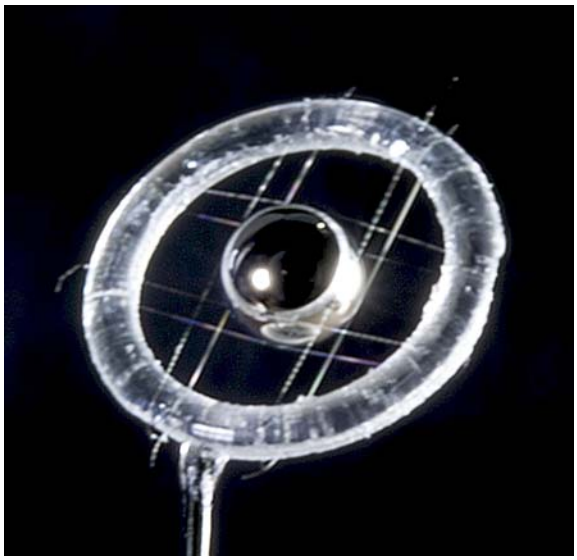

Fig. 1 Photograph of a capsule in a configuration dubbed the “Saturn target” that was devised to test the NIF polar direct drive concept on OMEGA. The ring placed around the fusion capsule at the center is partially ablated during the implosion and forms a plasma that refracts the incoming laser beams towards the capsule. Several spider silk strands attached to the ring support the capsule.