APS/DPP 2001 Press Release

Initial Direct-Drive Cryogenic Target Implosions on OMEGA

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28 August 2001

Almost all inertial confinement fusion targets designed to achieve high gain require thick (> 100 μm) cryogenic layers of thermonuclear fuel. The point design to demonstrate ignition with modest gain on the National Ignition Facility (NIF) will use indirect drive and fusion capsules containing thick cryogenic fuel layers. Higher gains (>50) are predicted for NIF when it is configured for direct drive. For the first time, plasma researchers have carried out direct-drive laser-fusion implosions of thick D_2-filled cryogenic targets using the University of Rochester's 60 beam OMEGA laser system. (David D. Meyerhofer, 716-275-0255, ddm@lle.rochester.edu, 716-275-4973; Robert L. McCrory, rmcc@lle.rochester.edu) The initial experiments have shown exceptional performance. In direct-drive fusion, lasers from many directions deposit energy directly on a shell containing fusion fuel; the light causes the shell to implode and trigger fusion reactions.

In the experiments, the targets consisted of 3 μm wall, 940 μm diameter CH shells, filled with up to 1000 atm. of D_2 fuel and cooled 19˚K, yielding an 80~100 μm thick ice layer. The inner ice surface was smoothed using infrared laser heating. Ice surfaces with roughness of ~3 μm rms. have been measured using shadowgraphy.

The targets are transported to the center of the OMEGA target chamber using a moving cryostat that maintains the temperature and ice surface quality. The capability to handle cryogenic targets with thick fuel layers requires cryogenic handling from the time the target is filled. The cryogenic handling system demonstrated at Rochester represents the culmination of nearly 10 years of design and testing of high-pressure cryogenic target-handling capability. The cryogenic system, designed and built by General Atomics and the University of Rochester, has been undergoing testing and strict certification procedures for the past year. Half of the cryostat is removed in the last 70 msec (using a precision linear electric motor to program the acceleration profile) before the target shot. The targets are supported by four strands of 0.5 μm thick, low mass spider silk, that has acceptable cryogenic properties.

The cryogenic targets are driven with ~24 kJ of laser energy with high uniformity and have produced up to 30% of the neutron yield and ~50% of the fuel areal density predicted for by one-dimensional computer simulations. Further experiments and theoretical modeling are underway.

These results are encouraging for direct-drive ignition on the National Ignition Facility, currently under construction at Lawrence Livermore National Laboratory.

Figure Caption: X-ray pinhole camera of imploded cryogenic target core. The core diameter is approximately 100 μm.