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Laser Squeeze Play A Key Step Toward Igniting Inertial Fusion

Scientists compress frozen hydrogen to a density more than five times that of gold.

ORLANDO, Florida—Researchers at the University of Rochester's Laboratory for Laser Energetics (UR–LLE) have succeeded, for the first time, in compressing deuterium to 500 times liquid density, or more than 100 grams per cubic centimeter (g/cc)—five times that of gold. Deuterium is one of the elements driving the fusion engine that powers our sun. It is also one of the most abundant elements on earth and is considered a key fuel component for long-term energy independence.

Fusion-energy concepts are based on both magnetic and inertial confinement of hot (10^8 degrees C) deuterium-rich plasmas. The primary difference between these two concepts is the density of the fuel. Inertial confinement uses large lasers to implode a shell of frozen deuterium-tritium. As this fuel shell compresses it heats up; if the density and temperature reach certain critical values, the plasma will ignite (just as a diesel engine self-ignites the fuel by compression) and create significantly more energy than was required to compress it. The density of the deuterium created at the Laboratory for Laser Energetics is close to that required for ignition to occur with deuterium-tritium fuel. These experiments are essential in preparing for ignition and gain at the National Ignition Facility (NIF).

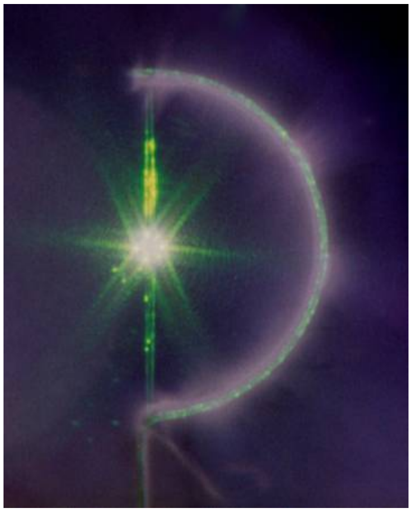

Figure 1: A photo of a cryogenic deuterium capsule being imploded on the 60-beam OMEGA laser.

The key experiment was performed using the 60-beam, 30-kilojoule OMEGA laser. A frozen shell of deuterium approximately 1 mm in diameter and less than 0.1 mm thick was imploded by symmetrically irradiating the shell with all 60 beams. A photo of the target being imploded is shown in Fig. 1. The "C"-shaped structure is used to hold the deuterium shell (the shell is actually formed inside a very thin plastic capsule) using spider silk. The silk is compliant at the cryogenic temperatures (about –425F) needed to freeze the deuterium inside the plastic capsule. The amount of energy required to compress the deuterium to >100 g/cc is much less if the starting point is deuterium ice (0.25 g/cc) rather than deuterium gas (0.00018 g/cc at room temperature); consequently, the potential energy gain is much greater when using cryogenic fuel.

The areal density of the fuel shell, crucial for inertial fusion ignition, is inferred by measuring the emitted proton spectrum and estimating the density of the fuel region using simulations and high-resolution x-ray images of the final fuel distribution. The excellent agreement between the predicted and measured spectrum (Fig. 2) demonstrated that ignition-relevant areal densities (200 mg/cm^2) can be achieved via inertial confinement and that the fuel density achieved exceeded 100 g/cc (the peak density in the simulation was 140 g/cc). It should be noted that earlier claims of high-density fuel [1] were based on a room-temperature plastic target that does not scale to ignition; the cryogenic deuterium targets imploded on OMEGA are energy scaled from the ignition designs for the NIF.

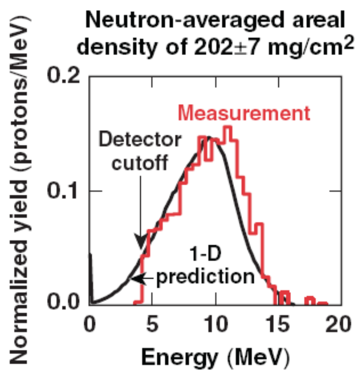

Figure 2: The proton spectrum measured from the capsule in figure 1 indicates that the D_2 areal density was in excess of 200 mg/cm^2. The black curve is the spectrum predicted by a simulation of the implosion. The excellent agreement suggests that the fuel density in the experiment was in excess of 100 g/cc.

[1] H. Azechi et al., Laser and Particle Beams **9**, 193 (1991).

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Abstract: FR1.00001

Direct-Drive Inertial Confinement Fusion Implosion Physics

Session FR1: Review: Direct-Drive Inertial Confinement

8:00 AM–9:00 AM, Tuesday, November 13, 2007
Rosen Centre Hotel - Junior Ballroom

Abstract : GI1.00001

Performance of Direct-Drive Cryogenic Targets on OMEGA

Invited Session GI1: Direct Drive Inertial Confinement Fusion and Z Pinches

9:30 AM–10:00AM, Tuesday, November 13, 2007
Rosen Centre Hotel - Junior Ballroom

Abstract:

Session JO3: Compression and Burn II

2:00 PM–5:00 PM, Tuesday, November 13, 2007
Rosen Centre Hotel - Salon 9/10