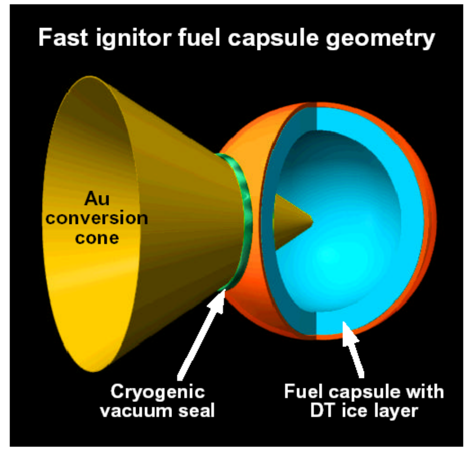
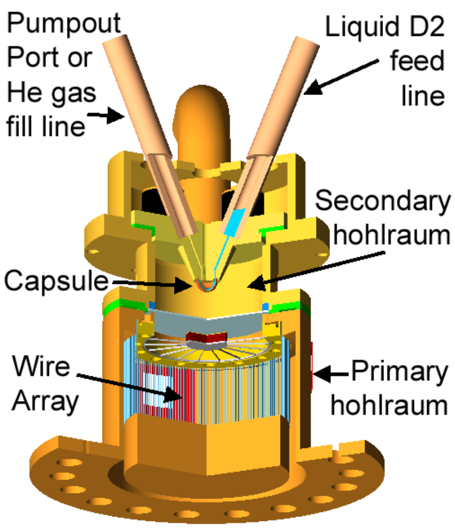
1673 News Notes: September 2002 Edition



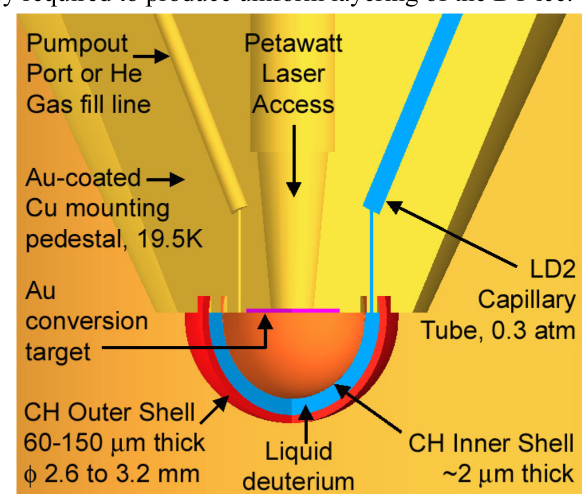
Cryogenic liquid target designs for fast ignition research

One of the uses for the proposed Petawatt laser at Sandia (see April 2002 News Notes) is the study of fast-ignition capsule implosions on the Z/ZR-machine (see July 2002 News Notes). In fast ignition experiments, a fusion capsule is first compressed by radiation from a wire-array z-pinch and then a portion is rapidly heated using a Petawatt laser to about 100 million °C (the temperature at which deuterium-tritium fusion reactions occur). This approach is attractive because it may reduce the symmetry, energy and temporal pulse-shaping requirements of the main radiation drive if it is successful.



For this approach to succeed, the Petawatt laser pulse must have a plasma-free path close to the densest region of the compressed capsule. Several groups investigating this problem have proposed the use of a gold cone inserted into a spherical capsule, as shown in the figure in the upper right. The apex of the cone is located near the center of the capsule, providing a clear path for the Petawatt laser to this point. This approach, while conceptually simple, is not trivial to implement with capsules containing frozen deuterium-tritium mixtures.

Traditional spherical capsule implosions use plastic shells filled to high pressure by diffusion with a deuterium-tritium mixture that is frozen in a uniform layer on the inside surface of the sphere. To keep the DT ice frozen and prevent bursting, the capsule must be stored and transported to the experiment at temperatures below 19 K (-254 °C). The cost of building a facility at Sandia capable of doing this is estimated to be of order $50 million. An alternative approach would be to use beryllium metal in place of the plastic shell. Beryllium capsules can be sealed, stored, and transported at room temperature without bursting. However, the insertion of a gold cone into a spherical capsule requires the use of a cryogenic vacuum seal, which would severely limit the pressure the capsule could withstand before it failed (negating the advantage in using Be over plastic). Furthermore, the gold cone would disrupt the thermal symmetry required to produce uniform layering of the DT ice.



David Hanson (dlhanso@sandia.gov) is now investigating a new method for constructing fast-ignitor capsules containing liquid deuterium. David has already built the infrastructure at Sandia to handle liquid D_2 for isentropic compression experiments on the Z-machine [M.D. Knudson *et al.*, "Equation of state measurements in liquid deuterium to 70 Gpa", Phys. Rev. Lett. **87**, 225501 (2001)]. In his approach, the cone angle is 180°, so that the spherical capsule becomes a hemisphere, as seen to the right. This geometry is well suited to a single-sided radiation driver (i.e., a single wire-array z-pinch) and allows for flexible Petawatt target designs that optimize the fast ignition drive. The geometry also allows the capsule to be constructed on a flat, solid platform capable of supporting external gas lines. Thus, to supply the requisite number of hydrogen molecules for fusion reactions, the small-volume, high-pressure (400-1200 times atmospheric pressure) gas reservoir inside spherical capsules can be replaced by a very large gas reservoir operating at near atmospheric pressure. A liquid volume of D_2 (or DT) fills the space between two plastic shells, and the dimensions, thickness, uniformity, and surface finish of the liquid layers are entirely determined by the parameters of the hemispherical shells, which can be easily measured beforehand and during experiments. The initial density of D_2 ice is only 14% greater than liquid D_2, so little difference in performance is expected. Experiments to test this concept are being planned.

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