The Cryogenic Target Handling System for the OMEGA Laser*

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The next series of inertial fusion experiments will approach and then achieve the conditions for ignition. These experiments are planned for the Upgraded OMEGA laser at the University of Rochester [1], and the National Ignition Facility [2] proposed to be built at Lawrence Livermore National Laboratory. To achieve sufficient density to approach ignition conditions with reasonable laser power, these experiments call for cryogenic targets with uniform fuel layer thickness and density, and a smooth inner surface finish. For DT fuel the beta decay of the tritium can provide the heat to achieve a uniform layer - a technique called "beta layering." A thick layer of DT will produce more heat than a thin layer. If the outside of the shell is maintained at constant temperature, fuel will migrate by sublimation and condensation from the thick areas to the thin, yielding a uniform layer. Experiments at Los Alamos have successfully shown that thick (~100 µm) layers of DT can achieve a high degree of uniformity [3].

Cryogenic targets must be carefully handled. A temperature change of more than 0.2 K will affect the quality of the target. Elaborate cryogenic systems will be needed to fill, layer, and characterize targets, and then insert and align them in the target chamber [4]. Bare targets can only survive ~20–100 ms in a room temperature target chamber, requiring the use of thermal shrouds that can be quickly withdrawn just prior to shot time.

General Atomics is in the process of building a cryogenic target delivery system for the OMEGA laser. This system will fill hollow ICF target capsules with DT fuel at pressures up to 1100 atm and then cool them from 293°K to approximately 20°K to condense the fuel. The targets containing the condensed DT are beta-layered to develop a uniform shell of DT on the inner surface and then inserted into the OMEGA chamber where the protective shroud is removed just 100 ms before the target is shot. The design is based on the requirement of delivering four cryogenic targets per day. A general arrangement of the process equipment is shown in Fig. 1.

As part of this effort, GA has designed, built and tested a prototype system for filling and transporting D_2 targets. The test results have demonstrated the viability of the design. The target fill system consists of the high pressure supply system, the permeation cell, the

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[1] BOEHLY, T.R., et al., "The Upgrade to the OMEGA Laser System," Proc. 11th Top. Meeting on the Technology of Fusion Energy, New Orleans, Louisiana, June 1994, Fus. Tech. V26 N3, pp. 722–729.

[2] PAISNER, J.A., CAMPBELL, E.M., HOGAN, W.J., "National Ignition Facility Design, Schedule and Cost," ibid, pp. 755–766.

[3] HOFFER, J.K., FOREMAN, L.R., MAPOLES, L.R., and SIMPSON, J.D., "Forming a 'Perfectly' Uniform Shell of Solid DT Fusion Fuel by the Beta Layering Process," Proc. 14th International Conference on Plasma Physics and Controlled Nuclear Fusion, Wurzburg, Germany, September 1992.

[4] FAGALY, R.L., ALEXANDER, N.B., MANGANO, R.A., BOURQUE, R.F., BITTNER, D.N., and GRAM, R.Q., "Conceptual Design for the OMEGA Upgrade Cryogenic Target Delivery System," Proc. 14th Symposium on Fusion Engineering, Hyannisport, Massachusetts, October 1993.

cryogenic system, and the target removal system. A high pressure intensifier compresses DT gas to pressures up to 1500 atm inside of a permeation cell with limited void volume. The permeation cell houses 4 targets on a rack and is located inside of the permeation cryostat. Filling of targets at 293°K is accomplished by increasing the pressure in the cell in small ΔP increments to allow penetration of the DT into the target through the shell wall. At pressure, the cell and target are cooled to ~20°K. The target rack holding the four targets is then picked up by the cold transfer cryostat, removed from the permeation cryostat, and placed into the transfer station. We have demonstrated all mechanical and thermal aspects of this part of the system. Targets were pressurized up to 1100 atm, the cell was cooled to 25°K, the cell lid removed, and the target was picked up and removed from the cryostat. During the pickup and removal operation the target never heated up above the burst temperature (30°K).

In the transfer station individual targets will be removed from the target rack and placed in the moving cryostat where layering is accomplished before insertion into the target chamber. When the target has been placed in the center of the target chamber, the protective shroud is removed rapidly, exposing the target for the shot.

Design of the DT system is under way. We are in the detailed design phase for the fill and transport systems with a number of equipment subunits currently undergoing DT testing at Los Alamos National Laboratory. The transfer station and target positioning device are in the late stage of preliminary design.

After fabrication of the DT equipment component testing and integrated system testing will be carried out at GA using D_2. The equipment will then be shipped to LANL for individual component and integrated system testing with DT. After successful completion of integrated system testing the equipment will be shipped to the University of Rochester Laboratory for Laser Energetics and put into operation after acceptance testing. The system is expected to be operational for cryogenic target experiments by July of 1999.

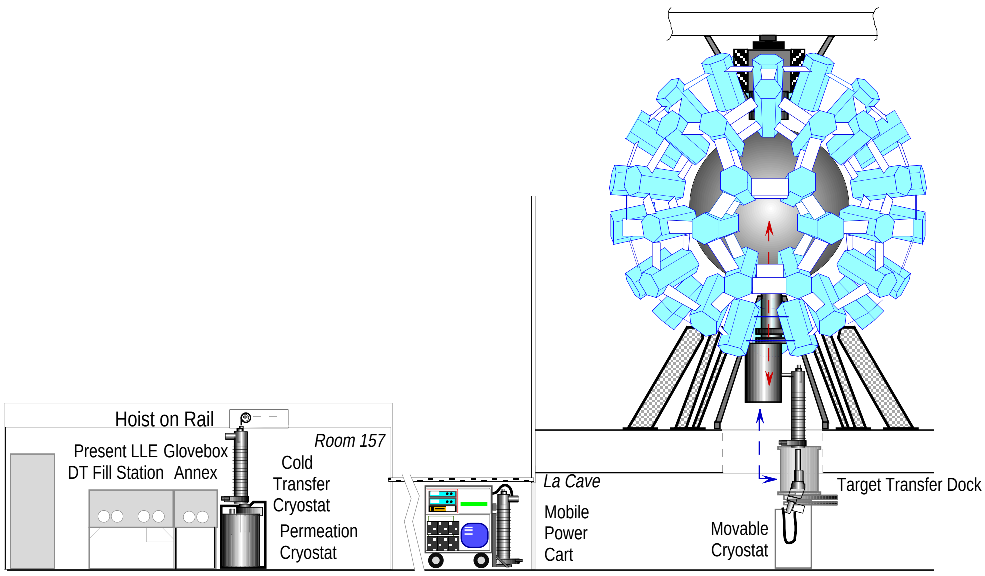

Fig. 1. OMEGA cryogenic target delivery system.