

From One-of-a-Kind to 500,000 Per Day: The Challenge of Mass-Produced IFE Targets*

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At present, individual targets used in inertial confinement fusion experiments are produced with considerable time and expense. In contrast, the “Target Fabrication Facility” of an IFE power plant must supply more than 500,000 targets per day, including manufacturing the spherical target capsule and other materials, filling the capsules with the DT fusion fuel, redistributing the frozen DT uniformly around the inside of the capsule (layering), and assembling the hohlraum (for indirect drive). Demonstrating a credible pathway to a reliable, consistent, and economical target supply is a major part of establishing that Inertial Fusion Energy (IFE) as a viable energy source, both for laser-driven and heavy-ion driven concepts. Here we present an overview of the development program and a discussion of recent progress in the unique materials science and chemistry associated with fueling of an IFE power system.

Leveraging the technological data base of ICF and other experimental programs, IFE target development efforts have made significant progress in recent years. IFE target fabrication research has concentrated on investigating and developing the various materials needed by the target designs and on fabrication techniques that could eventually scale to low cost and high production rate. Overall, the processes needed for supplying targets to fuel an IFE power plant have been identified and critical issues are understood. Target development plans have been established, and research teams are generating results in a focused and mission-oriented fashion.

The feasibility of fabricating specific foam capsules needed for high gain IFE targets has been shown (Fig. 1); further work is underway to improve capsule quality, reproducibility and large-scale production. In cylindrical geometry, DT ice layer formation in foams has been studied, with the results indicating that a significantly smoother ice surface finish can be obtained with the foam underlay. Furthermore, the work with DT over foam has shown that the system can be cooled down well below the DT triple point (Fig. 2). This is critical for IFE as the colder DT has more strength to withstand the acceleration during injection, and has more margin for heatup during its transit across a high temperature chamber.

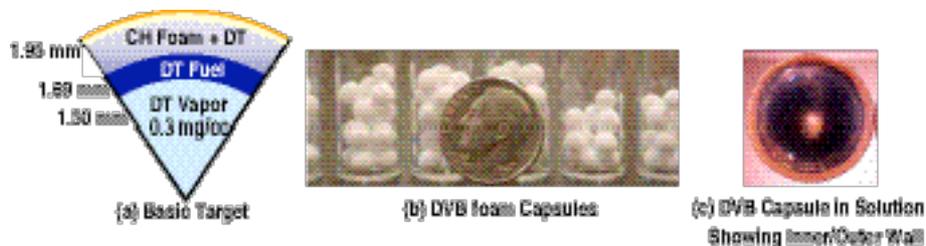


Fig. 1. Divinyl benzene (DVB) foam capsules were developed for laser IFE (direct drive) high-gain target design.

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Proof-of-principle layering experiments have been performed with multiple targets in a fluidized bed using a surrogate fuel material at room temperature to simulate DT ice. These experiments provide confidence that fluidized bed technology can be used to form DT ice layers in large numbers of capsules. The next step, now being undertaken, is to extend the fluidized bed to operation at cryogenic temperatures and with hydrogen isotopes. Processes for Heavy Ion Fusion (HIF) hohlraum production are being evaluated experimentally, and include use of laser chemical vapor deposition as a means of producing “micro-engineered” low-density metal foams for HIF hohlraums.

Targets will be injected into the target chamber at a rate of 5–10 Hz. The DT layer must survive exposure to the extremely rapid heat flux and remain highly symmetric, have a smooth inner ice surface finish, and reach the chamber center at a temperature of about 15 to 18 K. Models of the thermo-mechanical effects on the advanced materials during injection have been developed. A basic understanding of the target chamber environment is currently being determined by analyses. Fundamental measurements of the properties and response of DT under these unique conditions are being carried out in the DT facilities at Los Alamos National Laboratory. A new and versatile facility (Fig. 3) for studying target injection has been constructed and single shot room-temperature target injection experiments have begun, successfully demonstrating sabot separation needed for handling of direct drive targets. Current work is focused on upgrading this injector for rep-rated (5-10 Hz) operations and for tracking experiments under various (simulated chamber) conditions. Future work will convert the system for use with cryogenic targets injected into a high-temperature chamber at 5–10 Hz. To this end, we have defined the characteristics and requirements of such a next-stage system to validate the technology of full-scale components. Elements of the facility include mass production (in batch mode) of cryogenic targets, injection into the chamber (under simulated background gas and wall temperature conditions), and steering of a low-energy pulsed laser onto the target in flight.

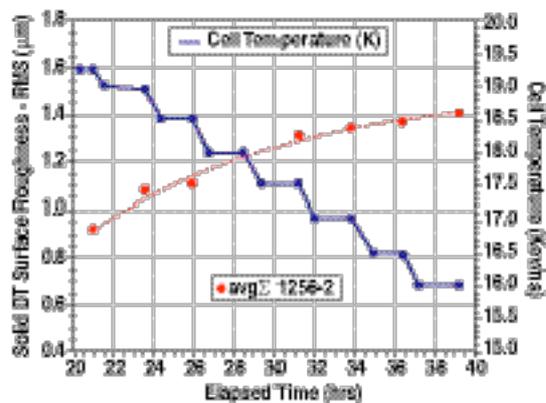


Fig. 2. Stepped-ramp cooling to 16 K resulted in RMS surface finish still ~1.4 µm.

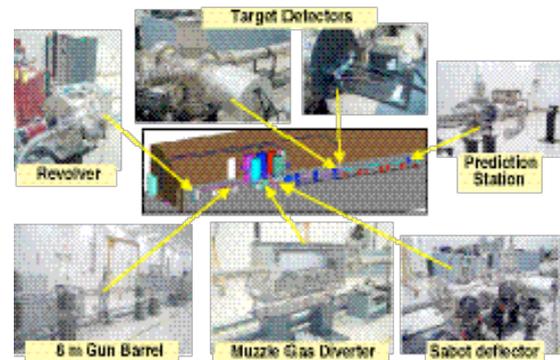


Fig. 3. The Target Injector was brought online for high-speed shots in vacuum and sabot separation demonstrations.

Because of the separability of IFE systems, a lot of progress can be – and has been – made without expensive facilities. Results are constantly fed back to target designers, as well as other parts of the program (e.g., chamber researchers) to assure self-consistency. Overall, reference target designs, issues and R&D needs have been identified and a program of concept demonstration is well underway. Progress has been made addressing unique science and technology issues for target fabrication and injection. Although much work remains to be done, our initial results are promising and suggest that a credible pathway to a reliable, consistent and economical target supply is within reach.