§12. Temperature Control in the FIREX Cryogenic Target

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i) Introduction

Fuel layering for a cryogenic target with a conical laser guide such as the FIREX target[1] is complicated because of its non-spherical symmetry appearance. To simplify the layering, a foam layer is planned to utilize as a supporting material for the fuel.[2] Ideally, the foam shell has self-fuel-layering ability at a liquid state owing to capillarity of the foam material. For stable fuel compression in laser experiments, the fuel must be solid with a lower saturated pressure. The transition to a solid state would cause random fuel crystallization and void appearances from the density difference between liquid and solid. A volumetric heat load might help to finish fuel layering even in the foam shell. Solid fuel redistribution will ignore the foam boundary. Temperature control in the target, therefore, is required during the formation of a uniform layer. Steady state temperature profiles of the FIREX target were calculated using the ANSYS code, and the heat input required for the temperature control was estimated.

ii) Model for FIREX target

Fig. 1 shows a 2D model for the FIREX target. It expresses an ideal layering resultant. No foam layer was considered because solid fuel redistribution will ignore the foam boundary. To simulate the practical FIREX target, a hydrogen and deuterium mixture fuel (20% hydrogen) was employed. The hydrogen has a function to supply volumetric heat. On the shell surface, the average heat transfer coefficient to helium gas was applied because the target should be cooled without free convection. To consider ideal cooling of the target, the radiation to the cone guide was ignored. Temperature profiles of the FIREX target with and without additional heat input to the cone guide were calculated.

iii) Calculations

Figs. 2(a) and (b) show calculated temperature profiles. The fuel temperature around the cone guide is slightly lower than that of the bottom hemisphere in the case of no heat input to the cone (Fig. 2(a)). Consequently, the layer uniformity of the FIREX target might not be achieved without the temperature control of the target. To minimize the temperature gradient in the shell, the constant and uniform heat input of 0.25×10^{-9} W was applied to the cone guide of the ideally fuel layered model. The heat input is comparable to the total heat generation of 0.75×10^{-9} W from the fuel. The temperature difference in the fuel layer can be minimized to 1 μK (Fig. 2(b)). The redistribution process using volumetric heat generation with the cone guide temperature control has the potential to finish a uniform fuel layer. Finally, according to the calculations, the temperature difference in the shell is quite small. Therefore, how much temperature difference is effective to drive fuel redistribution should be studied.

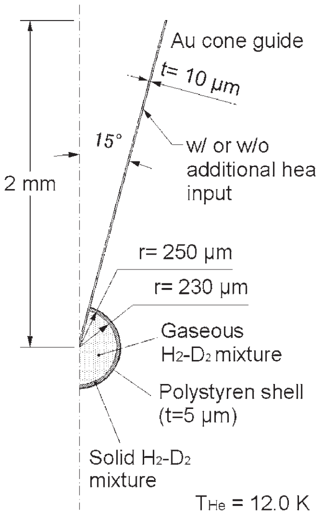
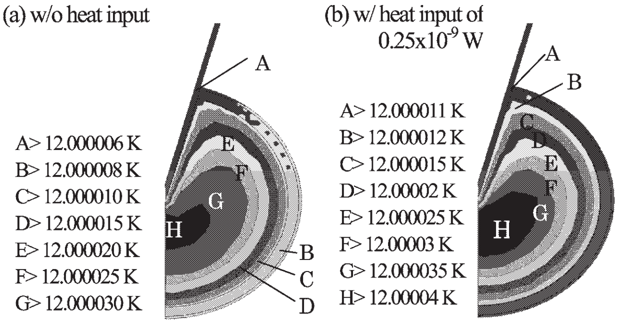


Fig. 1. 2D model of the FIREX target which is ideally layered fuel with and without additional constant heat input to the cone guide. The ortho-para conversion heat of solid H_2-D_2 mixture fuel is assumed to be 50 W/m^3. The exchange GHe temperature, T_{He} is 12.0 K. Average heat transfer coefficients on the shell and the cone are 83.4 and 6.26 W/m^{2}K, respectively.


(a) w/o heat input

(b) w/ heat input of 0.25×10^{-9} W

Figs. 2(a) and (b). Calculated temperature profiles of the FIREX target with and without heat input to the cone guide.

1) Nagai, K., Azechi, H., Ito, F., Iwamoto, A., Izawa, Y., T. Johzaki, T., et al., *Nucl. Fusion*, **45**, 1277 (2005).

2) Foreman, L. R., Hoffer, J. K., *Nucl. Fusion*, **28**, 1609 (1988).