§36. Simulation of Fast Ignition by Using 1-D Hydrodynamic Code ILESTA-1D

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A new conceptual design of the laser fusion power plant FALCON-D (Fast ignition Advanced Laser fusion reactor CONcept with a Dry wall chamber) has been carried out. A fast ignition scheme can achieve the sufficiently high pellet gain with a small fusion yield. To make full use of this property, the FALCON-D aims at designing with a compact dry wall chamber (5~6m radius) and a high repetition of laser pulse (30Hz), which enable a simple cask maintenance method and an electric output power of ~400MWe with a moderate construction cost.

To realize a dry wall chamber, a fusion yield needs to be minimized with keeping sufficiently high gain. Then we performed implosion and burning simulations by using 1-D/2-D hydrodynamic codes[1]. Figure 1 shows 2-D simulation result, where a cylindrical region with a radius r_h and length L_h is artificially heated for a compressed pellet to simulate a fast ignition.

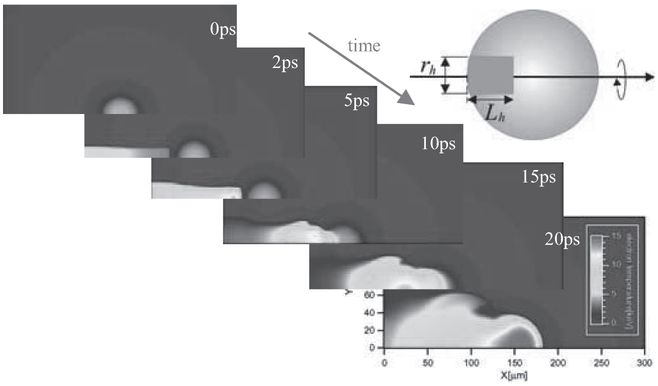

Fig. 1 2-D burning simulation to simulate a fast ignition.

Figure 2 shows the fusion gain as a function of core heating energy for various pulse shapes of the implosion laser with 350 kJ. We can see that the threshold heating energy strongly depends on the pulse shape of the implosion laser which determines the core density profile. It is also found that the fusion gain of 100 is achievable with the heating energy of 10 kJ. If the coupling efficiency of heating laser to a compressed core would be expected to be 20 %, the heating laser energy of 50 kJ might be sufficient for this compact reactor.

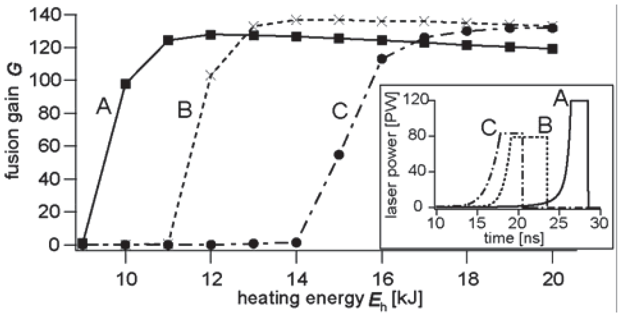

Fig. 2 Fusion gain G versus heating laser energy for various waveform of the implosion laser.

The dry wall chamber undergoes several threatening effects due to the high heat and particle load. Here we employed the ferritic steel covered with a 1mm-thick tungsten for the first wall and 623K supercritical water for the coolant, and carried out thermo-mechanical analysis.. The maximum temperature at the surface of the tungsten armor is around 1400 K, and for a repetitive irradiation of 30Hz this surface temperature is saturated around 1600K, which is much less than tungsten melting point (3680K) and the threshold temperature of roughening (2400K). While, The surface region undergoes large plastic deformation. To avoid a fatigue problem due to this cyclic plastic deformation, the enhancement of the yielding strength is indispensable for the tungsten. A highly-engineered material such as an ultra fine grained tungsten (UFG-W) might be a candidate, because the yielding stress of the UFG-W is much higher than that of the standard tungsten[2]. In addition, by taking the fast strain rate (~10^4/s) into account, the first wall design with no plastic deformation could be available. Among the effect due to high energy particle irradiation, blistering and exfoliation due to helium accumulation is quite severe. The loss rate of the surface layer is estimated to be a few millimeters or more in one year, based on the experimental studies on helium irradiation to the tungsten[3]. The UFG-W has an advantage for helium retention, as well, because the UFG-W could drastically suppress the concentration of helium[2], resulting in the remarkable reduction of the loss due to the exfoliation.

In FALCON-D, the cask method, using a large cask with a large maintenance port for replacement, is adopted for a maintenance scenario[4]. The first wall and blanket system is divided into 20 sectors so that all beam lines cross the edge between blanket sectors. The vacuum vessel (VV) is located outside the blanket system, and 20 maintenance ports exist on the upper side of the VV. The cask accesses to those maintenance ports on the upper side of the VV. The VV serves as a role of the first tritium boundary, and the wall of the reactor room serves as that of the neutron shield. To replace the final optical device, 6 access corridors are placed along the reactor room. Final optics system, which consists of a final optics and some controllable reflection mirrors, is built into the reactor room wall.

[1] T. Goto, *et al.*, *Fusion Science and Technology*, **52**, 953-957 (2007).
[2] H. Kurishita, *et al.*, *J.Nucl.Mater*. **367-370**, 1453-1457 (2007).
[3] S. B. Gilliam, *et al.*, *J. Nucl. Mater.*, **347**, 289-297 (2005).
[4] R. Hiwatari, *et al.*, *Fusion Science and Technology*, **52**, 911-915 (2007).