# §40. Design of Final Optics on Dry-wall Fast-ignition Laser Fusion Reactor FALCON-D

Ogawa, Y. (Graduate School of Frontier Sciences, Univ. Tokyo),
Someya, Y. (Tokyo City Univ.),
Okano, K., Hiwatari, R. (CRIEPI)

A new concept of the laser fusion reactor that utilizes the property of the fast ignition has been proposed. Numerical simulations by 1-D/2-D hydrodynamics codes showed the possibility of the achievement of the sufficient fusion gain (~100) with a 40 MJ fusion yield by optimizing the pellet design and the laser pulse shaping. Thermomechanical analysis and considerations about the several threatening effects of energetic particle irradiation showed that the design of a compact dry wall chamber (radius of 5-6 m) is possible with the use of some highly-engineered materials for the first wall armor. Neutronics analysis showed the feasibility of consistent design of the blanket system. This compact dry wall chamber enables a simple cask maintenance method. By separating the blanket system and vacuum vessel, the cask can access the upper port of the vacuum vessel without interference with multiple laser beam ducts. It can reduce maintenance time and increase plant availability, which lowers the cost of electricity of the plant system.

The locations of the final optics for implosion beams are divided into 6 groups by the polar angle of the beam lines, and we proposed the build-in style module in the shield for the final optics of implosion beams, as shown in Fig. 1.

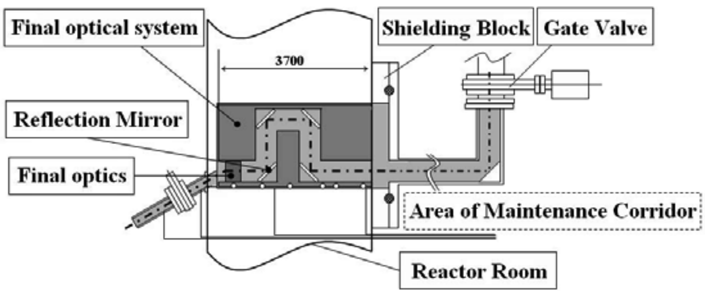


Fig. 1. The final optics system for FALCON-D.

To access the final optical modules, 6 access corridors are placed along to the shield, and all final optical modules for implosion beam is withdrawn and replaced through those corridors by a remote handling device. There is neutron streaming through the final optical module, and the total neutron flux just behind the final optical module is estimated at $2.4 \times 10^7$ n/(cm$^2 \cdot$s). This is 10 times less than that just behind the shield of the tokamak reactor concept such as CREST. Hence, the radiation resistant performance of remote maintenance system similar to tokamak reactor concepts is sufficient, and the remote maintenance system considered for several tokamak reactor concepts is also applicable to the replacement of the final optical module for the implosion beam of FALCON-D.

The shortest distance from reactor core to final optics is about 15 m near the equatorial plane of the reactor core, and the neutron flux above 100 keV in front of that final optical module is $1.55 \times 10^{13}$n/(cm$^2 \cdot$s). What kind of the optical device is suitable for the final optics of FALCON-D depends on its neutron irradiation resistance from the view point of plant availability and maintenance. For example, a transmission diffraction grating has been proposed as the condensing lens in KOYO-Fast [1]. On the other hand, a grazing incidence metallic mirror (GIMM), which prevents the condensing lens or mirror from the direct exposure the high energy neutron, has also been proposed in the HAPL program [2]. To apply such final optics, the neutron irradiation resistance up to about $10^{21}$n/cm$^2$ of the neutron fluence is required for one-year full-power operation.

It should be noted that the location where those maintenance corridors exist is outside the vacuum vessel, that is, outside the primary tritium boundary for the reactor core. Therefore, a replacement area behind the final optical module is required to minimize the tritium diffusion to the maintenance corridors, and the small cask for transfer of the old and new optical modules is also required.

The final optics of the heating beam is located at 30 m distance from the reactor core in the heating beam room. That final optics is also directly exposed to the neutron from the reactor core. In addition, the target injector room is in the same condition as for neutron streaming. Hence, the heating beam room and the target injection room also require the neutron shield.

The 30 m distance from reactor core to the final optics of the heating beam is kept to reduce the neutron flux. The neutron flux at the entrance of the heating beam room is estimated at $2.25 \times 10^{11}$n/(cm$^2 \cdot$s), which is 10 times smaller than that of KOYO-fast [1]. The remote handling device is also required for the replacement of final optics of the heating beam. The radiation dose rate in the heating beam room is supposed to be higher than that of the maintenance corridor for implosion beams due to this neutron flux. This fact implies that the handling device for the final optics of the heating beam probably needs to be equipped with the highly radiation resistant system, and the replacement time of the final optics of the heating beam is restricted to as short period as possible. In order to figure out the effective maintenance method for the final optics of the heating beam, the detailed design of final optics and the effect of neutron damage on the heating performance have to be made clear.

The neutron load on the blanket system is about 2 MW/m$^2$, and the blanket sectors have to be replaced by every several years. On the other hand, the final optics for both implosion and heating beams also have to be replaced periodically in the present FALCON-D concept. Hence, the lifetime of the final optics will determine the required maintenance frequency and the plant availability. Thus the experiment on neutron irradiation damage of the final optics are eagerly expected to establish the feasible IFE power plant concept with the fast ignition method.

[1] Miyanaga N *et al.*, *J. Plasma Fusion Res.* **83** 3 (2007).
[2] Sethian J D *et al.*, *Nucl. Fusion* **43** 1693 (2003).