§54. Evaluation of Liquid Metal Mirror for the Final Optics of Fast Ignition, Laser Fusion Reactor

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Introduction

In a case of laser fusion, final mirrors are directly irradiated with neutrons. When optical glass is exposed with neutrons, Si atoms are scattered and make defects called "color center" that absorb laser energy. In the KOYO-F case, the neutron load at 30m from the chamber center is estimated to be 0.7 dpa/year. Conventional transmitting optics can be used only few minutes if we estimate the life time using reported experimental values under 0.1 dpa fission neutrons.[1] Under such sever condition, the reflectivity can keep, however, high values because the reflection takes place just on the surface.

In the KOYO-F case, the life time of the final mirrors for compression beams is estimated to be 2 - 4months. So, if we can replace the mirrors every 2 to 4 month in a short time, the plant can be continuously operated. The cost for mirrors is estimated to be 1% of fuel const. In the case of heating laser whose pulse width is 30ps, damage threshold is low and the size of the final optics become large. Technology to make the large mirrors with allayed small mirrors exists but there is no space at the busy chamber area to make an automated replace system.

A gracing-angle-incidence, metallic-mirror (GIMM) and that coated with thin liquid metal are proposed for the final optics.[2, 3] These candidates seem, however, hard to survive under high 14 MeV neutron load because swelling of base metal due to nucleation of He makes the base board warped.

We propose a liquid metal mirror with shallow pool. This concept can equalize the curvature of the base board. A large, parabolic mercury mirror was developed in a field of astronomy[4]. There is no optical data for the liquid metal mirror to design the final mirror system for the heating beam. In this project, the reflectivity, the damage threshold, and damping of liquid surface wave will be measured to enable the design of the final optics for the heating laser.

2 Experimental equipment

In 2012, we designed experimental equipment to measure the damage threshold of liquid metal mirror. Figure 1 illustrates the system to measure the damage threshold of liquid metal mirror. Since the no damage remains on the surface, we will measure the reflectivity using a focusing beam. When small plasma is created on the surface, which causes damage on the conventional metal mirror, the reflectivity decrease rapidly since the plasma absorbs laser energy.

Figure 2 shows a system to measure small vibration on a reflective surface using a dynamic hologram crystal that can eliminate stable speckles in the beam.

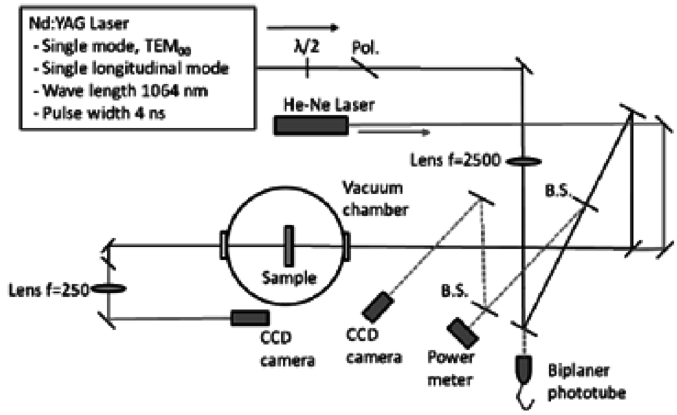

Fig 1 Experimental equipment to measure damage threshold of liquid metal mirror

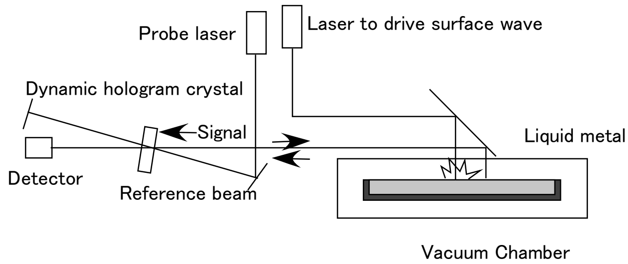

Fig. 2 Equipment to measure propagation of surface wave on a shallow liquid metal mirror

Reflectivity measurement

Figure 3 shows time dependence of the reflectivity of a gracing angle liquid metal mirror measured in a Ar-filled grove box. The highest reflectivity was 98% that is sufficiently high to use as a laser mirror but the repeatability was poor. We attribute this degrade to moisture in the grove box.

In the KOYO-F case, liquid first wall will be used. So impurities will be absorbed and removed as slag. This quick degrade in the reflectivity is not important in the power plant.

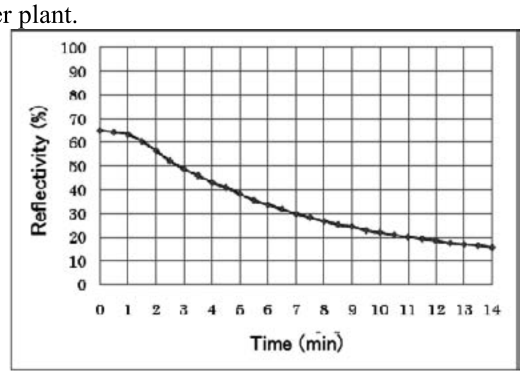

Fig. 3 Time dependence of reflectivity of He-Ne on liqud Pb in Ar gas. Oxidization of the surface degraded the reflectivity.

1) Snead, L. L et al., Fusion Sci. Technol. **56** (2009) 1069
2) Sawan, M. E. et al, Fusion Sci. Technol., **52**, (2007) 938.
3) Moir, R. W., Fusion Eng. Design, **51** (2000) 1121.
4) Potter, A. E., Adv. Space Res., 19 (1997) 213.