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Measurement of Li-target thickness under high vacuum in the IFMIF/EVEDA Li Test Loop

IFMIF/EVEDAリチウム試験ループにおける高真空下Liターゲット厚みの計測

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The current design the International Fusion Materials Irradiation Facility (IFMIF) requires the liquid Li target thickness should be maintained within 25 ± 1 mm at the nominal IFMIF condition (target velocity: 15 m/s, inlet Li temperature: 250 °C, vacuum pressure: 10^{-3} Pa). In the framework of the Engineering Validation and Engineering Design Activities (EVEDA) project of IFMIF, the Li target thickness was measured at the EVEDA Li Test Loop under the nominal IFMIF condition. The result showed that the Li target was adequately stable, and satisfied the stability limit required for IFMIF.

1. Introduction

In the framework of the Engineering Validation and Engineering Design Activities (EVEDA) project of the International Fusion Materials Irradiation Facility (IFMIF) [1], the Li target thickness was measured at the EVEDA Li Test Loop (ELTL) [2] to validate the hydraulic stability of the Li target. The current IFMIF design requires the Li target thickness should be maintained within 25 ± 1 mm at the velocity of 15 m/s under a vacuum condition of 10^{-3} Pa. This paper presents the measurement results of Li target thickness under the nominal IFMIF condition (Velocity 15 m/s, Li temperature 250 °C, Vacuum pressure 10^{-3} Pa).

2. Experiment

The Li target flow can be produced in the Target Assembly (TA) of ELTL [2]. The maximum target speed is 20 m/s. The cross section of the nozzle exit is 25 mm in thickness and 100 mm in width. TA, which consists mainly of a nozzle and a concave flow channel, is drawn on the right side of Fig. 1.

To measure the Li target thickness, we used the laser probe (LP) method [3]. The method utilizes a laser distance meter (Optical Comb Absolute Distance Meter, ML-5201D1-HJ, Optical Comb, Inc.), whose measurement principle is based on the time-of-flight (TOF) measurement. Free-surface elevations measured are analyzed to obtain an average thickness and a wave height distribution by employing the zero-up crossing method [4]. Measurement uncertainty was evaluated to be 0.04 mm for measuring the Li target thickness.

Figure 1 shows the experimental setup. The *XYZ* coordinate system is defined in the figure (the origin is located at the position which corresponds to the beam center in IFMIF). The laser head, which consists of a laser interferometer, a lens assembly, and two mirrors, is mounted to a custom-made fixing base which has some positioning holes. These holes enable us to inject the laser perpendicular to the flow channel at any *X* (streamwise) positions (-50 mm ≤ X ≤ 50 mm). The fixing base is mounted on the precision stage (TAMC-30301-M6, SIGMA KOKI Co.,LTD.) to change a measurement position in the *Y* (spanwise) direction (-50 mm ≤ Y ≤ 50 mm).

Table I shows the experimental condition. We measured the target thickness under several experimental conditions, however in this paper we focus on the result of the nominal IFMIF condition (15 m/s, 250 °C, 10^{-3} Pa).

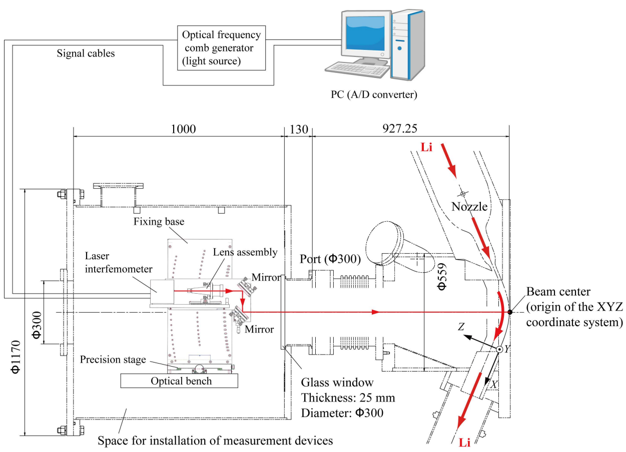

Fig.1. Experimental setup (unit: mm)

Table I. Experimental condition

Item	*Value*
Li jet speed [m/s]	10, 15, 20
Cover gas pressure [Pa]	10^{-3} - 10^{5}
Li temperature [°C]	250
Sampling frequency [kHz]	500
Data recording time [sec]	60
Laser wavelength [nm]	1550
Laser spot diameter [mm]	0.13

3. Result

3.1 *Average thickness*

Figure 2 shows the three-dimensional plot of the average Li target thickness at 15 m/s at 2 Pa. As shown in the figure, the target was very smooth. No pressure dependence was obtained. Average thickness was 26.06±0.08 mm at the beam center of (X,Y) = (0,0) under the nominal IFMIF condition. The ununiformity, defined as the distance between the maximum and the minimum, was just 0.17 mm inside the corresponding IFMIF beam footprint. The smooth free surface was also observed by still photos taken with a relatively long exposure time. In the vicinity of the side walls, the thickness rose toward the side walls. This means Li well wetted to the side walls made of stainless steel type 316L.

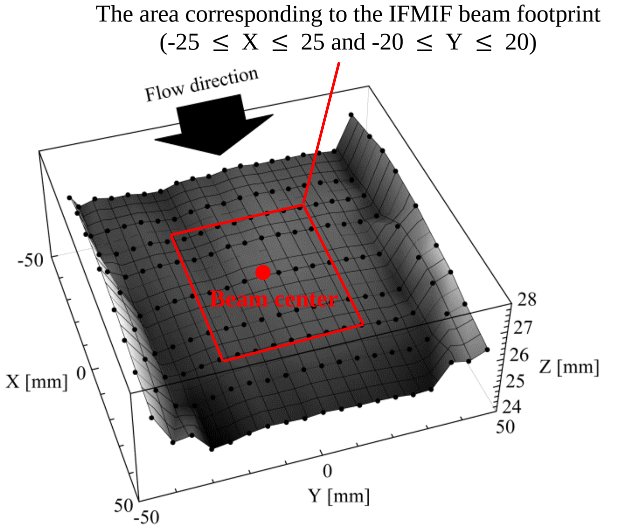

Fig.2. Three-dimensional plot of the average thickness of the Li target at 15 m/s, 250 °C, 2 Pa
(Black symbols denote measurement data)

3.2 *Wave height*

Figure 3 shows a wave height distribution at (X,Y) = (0,0), beam center, under the nominal IFMIF condition, where "wave" was defined from the time-series Li level data by the zero-up crossing method [4]. The stability limit of the Li target specified under the current design is 1 mm in amplitude, in other words, 2 mm in wave height (wave height is double amplitude). As clearly shown in Fig. 3, almost all of the wave components, 99.7 % of total, are within the stability limit and average wave amplitude was 0.26 ± 0.02 mm. These facts mean very small waves are the dominant fluctuation of the target thickness. The maximum wave amplitude was slightly over the stability limit, but its probability is extremely small and even when such a wave travels in the beam footprint the minimum target thickness satisfied the required minimum thickness of 24 mm since the average thickness measured was 26.06 mm.

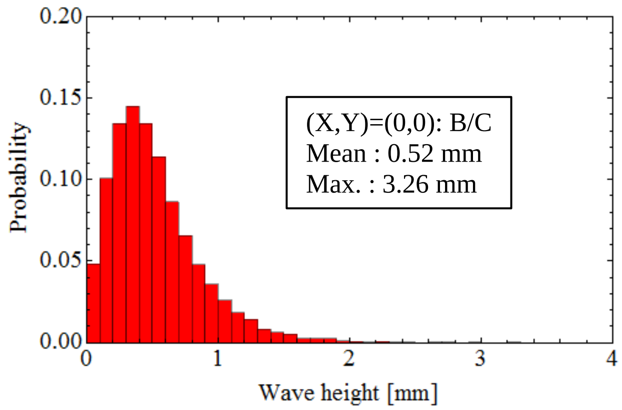

Fig.3. Wave height distribution at the beam center under the IFMIF condition: 15 m/s, 250 °C, 10^{-3} Pa

4. Summary

This paper presents the measurement results of the Li target thickness under the nominal IFMIF condition (15 m/s, 250 °C, 10^{-3} Pa). The Li target was found to be adequately stable, and satisfied the stability limit required for IFMIF.

Acknowledgments

The authors express their gratitude to Drs. M. Kourogi and K.Imai of Optical Comb Inc. for their support to conduct the present experiment. Appreciation is also extended to Dr. J. Knaster, the leader of the IFMIF/EVEDA project, and Drs. F. Groeschel and F. S. Nitti, the former IFMIF/EVEDA project team members, for their support of this task.

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