23P156-P

Recent progress of cryogenic target fabrication technique for FIREX project

高速点火実証実験（FIREX）用極低温燃料ターゲット開発
－　フォーム層への燃料充填率の改善　－

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Unique design of the cryogenic target with a gold conical guide and a fuel feeding capillary has been developed for the Fast Ignition Realization Experiment (FIREX) project at the Institute of Laser Engineering (ILE), Osaka University. In the scheme, the deuterium gas is to be fed in a foam layer of the shell and solidified. In the case of a foam shell filled with solid fuel, it is worried that bubble-like void may remain in the cell after the liquid-solid transition. Filling fraction of solid fuel in the Resolcinol-Formalehyde foam of a surrogate target was investigated by using an interference imaging technique. It was shown that the optimization of cooling speed and temperature gradient was quite promising to make a uniform solid layer with a low void fraction.

1. Introduction

In the Fast Ignition Realization Experiment (FIREX) project, pellets with cryogenically cooled fuel are to be used to demonstrate the heating of the compressed deuterium/tritium plasma up to 10 keV by a PW-laser beam. In order to achieve the required high density compression by implosion, the initial target spatial perturbation must be within a certain level in order to restrict the perturbation growth during the implosion process. Fabrication of the uniform layer of pure deuterium/tritium fuel is, however, a difficult task. Application of a foam layer as structuring body is expected to be a promising remedy to make a uniform fuel layer. A proposed target of the project under development has a unique design of the structure which consists of a low density plastic foam shell covered with a plastic overcoat as a gas barrier, a hollow cone to guide a heating laser beam, and a fine tube to feed the shell with liquid fuel. Liquid deuterium/tritium is fed to fill up the foam layer through the fine feeder and is cooled down to solid without handling a high pressure apparatus [1].

Key issues to be developed are 1) fabrication of the low density foam shell and 2) cryogenic cooling system and fuelling procedure. Although foam materials with the density lower than 10 mg/cm^3 are successfully developed, fabrication of a shell with those materials is another difficult task. We started the fabrication of the target with using a resolcinol-formaldehyde (R/F) foam shell [2] which is rather heavy with typical densities of about 100 mg/cm^3 but has been well developed in USA. Recently we succeeded to fabricate the R/F foam shells with lower density than 100 mg/cm^3 developing the gelation process.

As for the fueling techniques, a bilateral collaboration between Osaka University and National Institute of Fusion Science (NIFS) was initiated at the fiscal year 2003 to accelerate the development of cryogenic target system for the FIREX project. In this collaboration, fuelling procedure and the material properties of the pellets under the cryogenically cooled condition have been investigated using a newly developed test apparatus at NIFS [3]. A difficult point of this foam method is to realize high filling fraction of the foam tissue with solid fuel because of the density difference between the liquid and solid fuel. Rapid cooling of the liquid fuel into solid may leave bubbles in the porous structure of the foam shell. Here we describe the interference method to investigate this filling ratio of the fuel and the result which shows the optimization of cooling speed and temperature gradient is quite promising to make a uniform solid layer with a low void fraction.

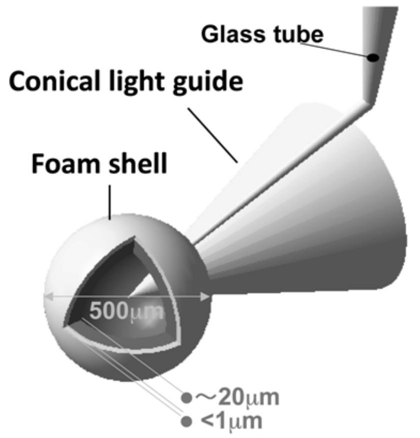

Fig. 1. Typical design of the cryogenic fuel target with a plastic foam shell for the FIREX project.

2. Masurement of refrctive index of hydrogen

In order to measure the filling ratio of solid fuel in the foam and demonstrate the fueling procedure, a wedge-shaped sample schematically shown in Fig.2 was used. A hollow glass wedge was sandwiched between copper heat sinks. Hydrogen was fed through a fill tube (fuel feeder). Each copper sink has a calibrated Cernox sensor and a strain gage as a heater glued by epoxy resin. Optical system for the interference microscopy was consist of a telemicroscope and a sheering interference unit. A 5-mW He-Ne laser with the wavelength of 632.8 nm and a 2-mW He-Ne laser with 594.1 nm wavelength were utilized to see the wavelength dependence of the refractive index.

It is very difficult to measure the absolute refractive index directly from the interference data since the geometrical size of the sample could not be measured due to the shrinking by cooling. We measured the relative change of the refractive indexes of the solid hydrogen from those of liquid and evaluated the absolute value at each different temperature as shown in Fig. 2 from those values of liquid hydrogen by D. E. Diller [4].

3. Measurement of fuel-filling ratio

Similar technique was applied to measure the fuel filling ratio. R/F foam was filled in the hollow wedge of the sample. Change of the optical path due to solidification was measured and effective refraction index of the solid hydrogen in the foam was inferred. It was shown that high filling ratio of 99% was achieved by slow cooling with cooling rate of about 0.03 degrees/min. as in Fig. 4.

Acknowledgments

Authors gratefully acknowledge the support of the target and material groups of the ILE,

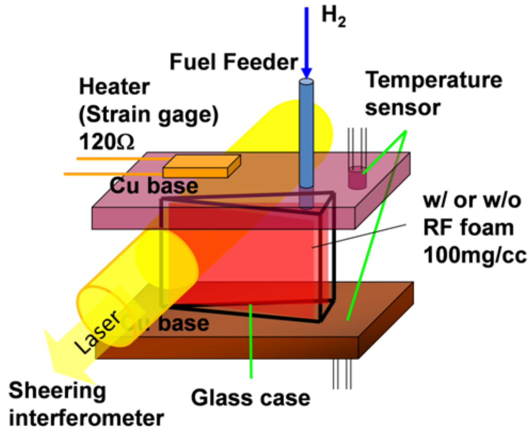

Fig.2. A schematic image of the sample to measure the refractive indexes of hydrogen.

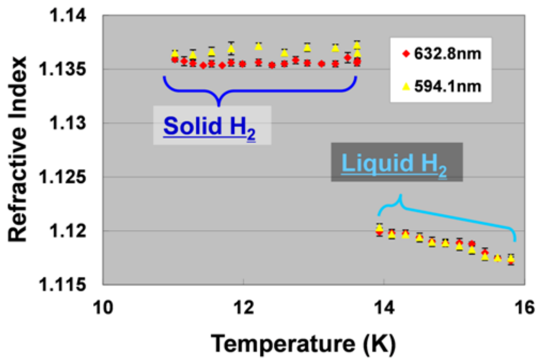

Fig. 3. Refraction index of solid hydrogen.

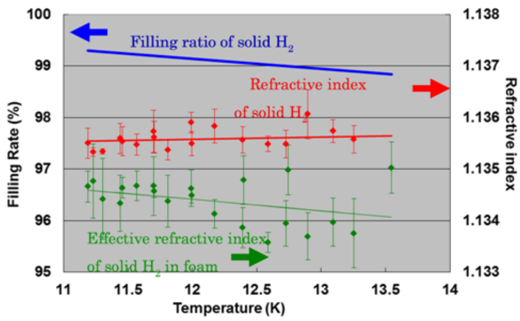

Fig. 4. Effective refractive index in the foam and inferred filling ratio.

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