§31. Fast Ignition of Liquid Deuterium Targets

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At ILE Osaka University, elemental researches to develop fast plasma heating applicable to reactor technology development have been conducted basing on the fast ignition of liquid deuterium targets. The researches consist of laser development, target fabrication, simulation technology and integrated implosion experiments using developed elemental researches. In 2010, following progresses were made through collaboration with Kyushu University, Hiroshima University, Gifu University, NIFS and other collaborators.

Target Fabrication

To make a spherical solid fuel layer inside a non-symmetric target with a cone guide, two approaches are investigated. One is conventional foam technology which is a reliable pathway toward the fusion power plant including a scenario for mass production. The critical path of this technique is fabrication of low density foam layer to support the fuel layer. In 2010, the foam density of 100 mg/cc was achieved. The other is dynamic layering technique that needs precise temperature control around the melting point.

Figure 1 shows a test cell for controlling the solidification of liquid deuterium fuel and filling measurement. By careful control of the temperature gradient, high filling up to 98% was achieved.

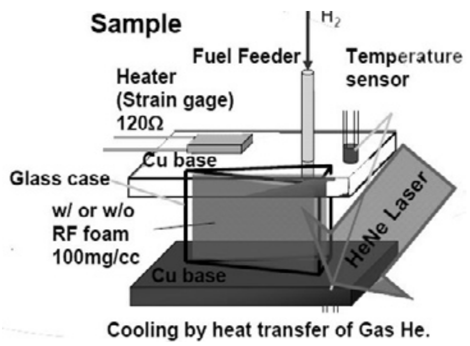

Fig. 1 Wedged cell of liquid/solid deuterium for fuel filling measurement.

LFEX Laser Activation and Operation

The second arm of the LFEX laser system became operational in pulse-compressed mode, and was utilized with the first beam in the integrated Fast Ignition experiment. Figure 2 shows gratings for two beams. A 2.2-ns amplified chirped pulse was compressed with large grating system down to 1.5 ps. The compressed beams were focused onto targets with an off-axis parabola mirror. Overlapped focal spot size of 30-60 μm, about twice the diffraction limit, was achieved. Maximum output energy was 2 kJ in two beams.

Significant effort was devoted to reduce the prepulse component in the compressed pulse. Saturable absorbers and AOPF (Amplified Optical Parametric Fluorescence) quenchers were introduced to the frontend system, and the pulse contrast ratio was improved up to 10^8.

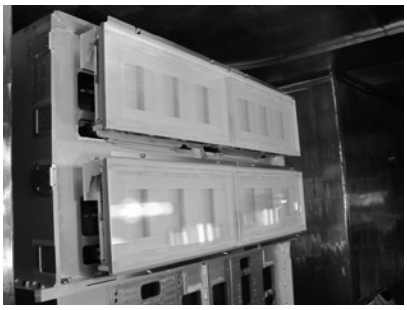

Fig. 2 Multiple gratings for two beams mounted on the lack in the pulse compressor system.

Plasma Experiment and Diagnostics Development

Integrated experiment of Fast Ignition was performed by using Gekko-XII laser (0.53 μm, 9 or 12 beams, up to 3 kJ in total / 1.5-ns pulse) for implosion of the target (deuterated polystyrene shell, 500 μm in diameter, 7 μm in thickness) and LFEX laser (1.05 μm, up tp 2 kJ/1.5 ps) for fast heating of the imploded core plasma. Variety of neutron diagnostics was developed and introduced to the experiment, which enabled us to accurately measure the enhanced neutron yield even in the intense hard x-ray harsh environment. Heating beam injection time was monitored with non-imaged signal in x-ray streak camera images within an accuracy of better than 10 ps.

Enhancement of the neutron yield due to LFEX heating by a factor of up to 30 was observed. The maximum neutron yield was 3.5×10^7, which exceeded the record in 2002 experiment[1]. Figure 3 shows comparison of neutron yield obtained in 2010 with previous 2002 experiment. The estimated heating efficiency (= thermal energy increase in the fuel core plasma / injected heating laser energy) reached to 20%. The heating condition has not yet been optimized, and we will try to further improve the efficiency. We will increase the heating laser energy up to 10 kJ in four beams to achieve fast heating up to 5 keV.

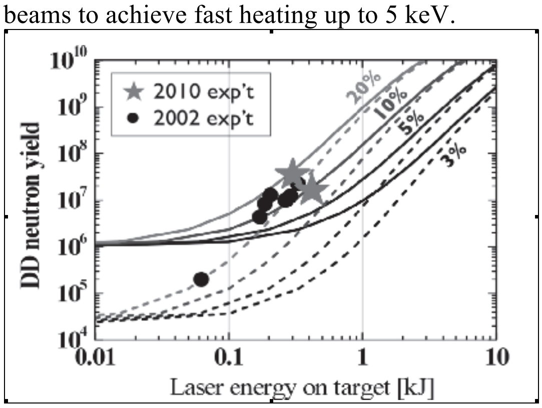

Fig. 3 Enhanced neutron yield by heating laser injection.

Theory and Simulation, Target Design

For investigation of physical processes of fast heating and improvement of the heating efficiency, various codes have been developed and used. Effect of the prepulse to degradation of the heating was intensively studied, and the experimental results were analyzed. Also new concepts for advanced targets were investigated.

[1] R. Kodama, et al., Nature **418** 933 (2002).