# §31. Fast Ignition of Super High-Dense Plasmas

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At ILE Osaka University, elemental researches to develop fast plasma heating applicable to fusion reactor technology development have been conducted using the fast ignition of deuterium targets. The researches consist of laser development, target fabrication, simulation technology and integrated implosion experiments. In 2012, following progresses were made through collaboration with NIFS and other collaborators.

**Target Fabrication**

Many advanced target designs were proposed to increase the coupling efficiency between laser energy and that of a compressed core. A guide cone made with diamond-like carbon (DLC) is expected to improve the coupling efficiency because of its low scattering coefficient of hot electrons. We successfully fabricated a 20μm-thick DLC cone using a brass mandrel coated with a thin gold layer that enables stable growth of DLC on the mandrel (Fig. 1). This DLC cone was used in hot electron transport experiment.

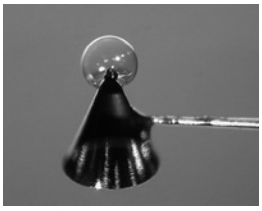

Fig.1 A shell target with a DLC cone. Inner surface of the cone is coated with gold.

Injection of fast ignition target is another interest in future reactor technology because the cone of the fast ignition target must face to the heating laser. In 2012, we started injection of real-size targets to know the stability of the target after the sabot release. We achieved the goal for the injection speed (90+/-5 m/s) and the pointing (+/- 1 mrad) but "tumbling" of target was almost 5 times larger than designated 2 degrees. We are now going to use a helical allay of permanent magnets to spin the target.

**LFEX Laser Tuning and Operation**

Two beams among four of the LFEX laser system were operated in 2010. Optical components as well as the beam monitoring equipments for the pulse-compressor system were being installed inside and outside the vacuum chamber, and the system performance was much improved in 2012 [1]. The full system will be ready in 2013.

Pulse contrast ratio was improved by adding AOPF (amplified optical parametric fluorescence) quencher to the first-stage OPCPA. Also a saturable absorber ($Cr^{4+}$:YAG) was introduced at a spectrally dispersed stage. These made the contrast ratio to be $4 \times 10^8$. Another stage of a saturable absorber will be installed to further improve the contrast ratio to be $2 \times 10^{10}$ in 2013.

Oscillation of the beam pointing has been a serious problem in LFEX focusing. Structure and vibration of the optical component holders and actuators were analyzed, and the stabilizing component was introduced, resulting in a much improved pointing stability down to 5 μrad, which is close to the required value.

Contamination of the optical elements inside the vacuum pulse-compressor chamber with oily material has also been a serious problem in LFEX operation. Mechanisms of the contamination and the physics to solve the problem were clarified. It was found that placing sufficient amount of separate absorbers inside the vacuum chamber can solve the problem. Also a scheme to further improve the cleanness and the laser-damage threshold of the components was invented based on this knowledge.

**Plasma Experiment and Diagnostics Development**

Although an efficient enhancement of the neutron yield from the imploded fuel plasma by injection of the LFEX as a heating beam was demonstrated in 2010, details of the physical processed related to the fast heating still have not been clearly known. Fundamental physics including the hot electron generation, transport through the cone and the plasma surrounding the fuel core, energy deposition to the fuel plasma have been studied by using newly designed fundamental experiment plat form targets. Also many advanced plasma diagnostics such as many kinds of absolutely calibrated hard x-ray spectrometers and neutron detectors guarded with high-performance collimators and shielding were developed.

Figure 2 shows hot electron generation efficiency estimated from the measured hard x-ray spectra by using such new hard x-ray detectors. It was found that the hot electron generation was four-times improved in the platform target, which has a cone and low-density plasmas at its tip than in a simple plane target [2].

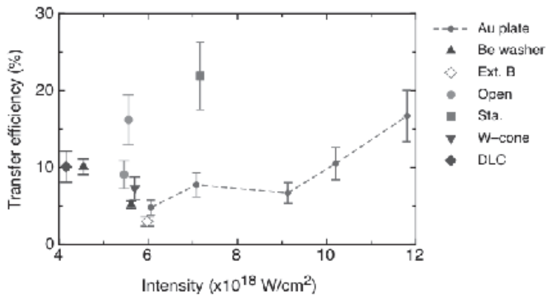


Fig.2 Transfer efficiency from the heating laser energy to the hot electron energy estimated from the measured hard x-ray absolute spectra.

A scheme to guide the hot electron flow to the fuel plasma by using external magnetic field was proposed, and a fundamental experiment was performed by using a capacitor target with a one-turn coil irradiated with separate laser beams. A strong magnetic field up to 1 kT was demonstrated [3].

**Theory and Simulation, Target Design**

Hot electron transport through the cone to the compressed fuel was intensively investigated with various simulation codes interconnected as $FI^3$ system. It was found that one can expect better transport efficiency due to electron beam collimation by self generated as well as externally applied magnetic fields [4]. Slow implosion scheme was examined as a high-density implosion scheme.

[1] Y. Nakata, *et al*., presented at IICUIL2012.

[2] Z. Zhang, *et al*., Rev. Sci. Instrum. **83**, 053502 (2012).

[3] S. Fujioka, *et al*., Sci. Reports **3**, 01170 (2013).

[4] T. Johzaki, *et al*., to be published in European Physical Journal.