§31. Generation and Fast Heating 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 2011, following progresses were made through collaboration with NIFS and other collaborators.

Target Fabrication

For current FIREX-1 project, shell targets with cone were developed by adopting various types of the advanced target components. A double cone, in which improved hot electron transport and its collimation was expected, was developed and fabricated for the integrated experiment. Also a cone made of low-Z material was developed for improvement in hot electron transport efficiency to the core plasma. A cone made of Aluminum instead of conventional Au was fabricated by laser induced CVD. Other materials such as diamond-like Carbon (DLC) were also examined. Such advanced targets will be used in the integrated experiments in 2012.

Fuel system technology for the future IFE reactor system was developed. A single-shot pellet injection system for real-size targets was developed through collaborations with Hiroshima University, Gifu University, and Ibaraki University. Fundamental researches such as on the final optics for the reactor, and tritium leakage through the heat cycle [1] were performed in 2011.

LFEX Laser Activation and Operation

Two beams among four of the LFEX laser system were activated in 2010, and the third and the fourth beams were being activated in 2011. Optical components as well as the beam monitoring equipments for the pulse-compressor system were installed inside and outside the vacuum chamber. The full system will be ready in 2012.

Many advanced technologies were introduced to the LFEX system [2]. Stability of the oscillator output was much improved by introducing mode-lock Yb fiber oscillator. Significant effort was made to reduce the prepulse component in the compressed pulse. Saturable absorbers in the spatially chirped stages and AOPF (Amplified Optical Parametric Fluorescence) quenchers were introduced to the frontend system, and the pulse contrast ratio was improved up to 3×10^8. Further improvement is expected.

The present main amplifier system has a slightly nonuniform distribution of the gain due to pumping distribution. This resulted in a rather large nonuniformity in the output beam pattern, because the amplifier has eight glass slabs and the system has a four-pass configuration. Modified structure of the pumping system was developed for much reduced beam nonuniformity down to 1%. Wavefront distortion during the pumping was compensated with feed-forward control of the deformable mirrors by using separately measured Zernike components.

Plasma Experiment and Diagnostics Development

Results of the integrated experiment of Fast Ignition in 2010 were carefully analyzed in 2011. Experiments were 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 to 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 confirmed. The maximum neutron yield was 3.5×10^7 [3]. Figure 1 shows neutron yield vs heating laser energy. The estimated heating efficiency (= thermal energy increase in the fuel core plasma / injected heating laser energy) was 10-20%. The heating condition has not yet been optimized, and we will try to further improve the efficiency in 2012. We will increase the heating laser energy up to 10 kJ in four beams to achieve fast heating up to 5 keV.

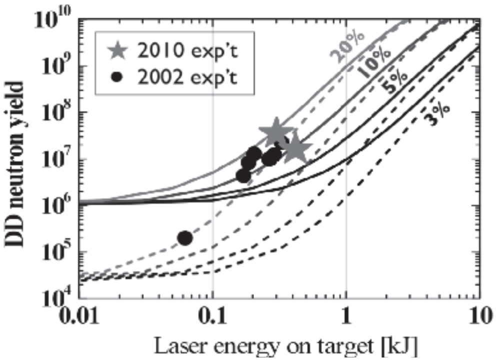

Fig. 1. Enhanced neutron yield by heating laser injection.

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. Scattering by Au ions was found to reduce the transport efficiency, ans use of low-Z material was recommended. Also it was found that by using solid "TONGARI" cone made of DLC, one can expect better transport efficiency due to electron beam collimation by self generated magnetic fields [4].

[1] T. Norimatsu, *et al.*, Fusion Sci. Tehnol. **60,** 893 (2011).

[2] N. Miyanaga, *et al.*, IQEC/CLEO Pacific Rim 2011.

[3] H. Shiraga, *et al.*, Plasma Phys. Control. Fusion **53,** 124029 (2011).

[4] H. Cai, *et al.*, Phys. Plasma **18**, 023106 (2011).