§40. 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 target fabrication, laser development, integrated implosion experiments, and simulation technology and reactor target design. In FY2013, following progresses were made through collaboration with NIFS and other collaborators.

Target Fabrication

Fast ignition targets need new technologies such as cryogenic technique to fabricate uniform solid layer in non-isothermal environment, and to increase the coupling efficiency between laser energy and that of a compressed core. A guide cone made with diamond-like carbon (DLC), double cone, and low-Z cone with sharp tip are expected to improve the coupling efficiency. These examples are near term goal. For future fusion reactor technology, we engaged in injection of real-size target at single shot scheme to identify technical issues toward a fusion power plant.

In the cryogenic technology, we take two approaches to make uniform solid hydrogen layer in a non-spherically symmetric target. One is foam method and the other is infrared heat method. In 2013, we improved reproducibility of a foam shell that supports the solid hydrogen layer. For the infrared method, we numerically evaluated the intensity of infrared in an integrated sphere and prepared laser system for the demonstration.

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 2013, we improved the repeatability but we still need effort in "tumbling" of target. We are now going to use a helical allay of permanent magnets to spin the target.

LFEX Laser Tuning and Operation

Three beams among four of the LFEX laser system were operated in 2013. Optical components as well as the beam monitoring equipments for the pulse-compressor system were being installed inside and outside the vacuum chamber. The full system with four beams will be ready in 2014.

Pulse contrast ratio was improved by adding AOPF (amplified optical parametric fluorescence) quencher to the first-stage OPCPA. Also two saturable absorbers (Cr^{4+}:YAG) were introduced at a spectrally dispersed stage to further improve the contrast ratio to be >>8x10^8 in 2013.

Beam patterns have been improved by modifying the shape of reflectors in the main amplifier houses resulting in improved flatness in the amplifier gain distributions. The filling factor in NFPs was improved to be 47% in 2013 from 37% in 2012. Also FFPs were improved by feed-forward controlling of the two-stage deformable mirrors taking into account of the thermal wave-front distortion due to the pumping by the flash lamps. Nearly diffraction-limited beam quality was achieved for all of three operating beams.

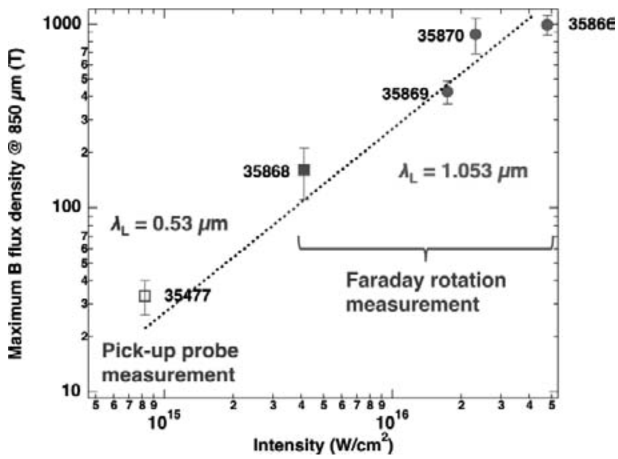

Figure 1 Generation of 1 kT of magnetic field was demonstrated with laser-driven capacitor-coil targets.

Plasma Experiments

A series of fast-ignition laser-driven inertial fusion researches has been performed to understand energy coupling efficiency from a heating laser to a fuel core. All plasma and beam parameters, which determine the efficiency, were measured to identify the critical ones for increasing the efficiency to 10%. The experimental result clarifies that still there are two difficulties in the fast-ignition scheme, "unstoppable" and "diverging" of a relativistic electron beam (REB) generated by an intense laser pulse. Guiding of the REB by > 1 kT magnetic field produced by a laser-driven capacitor-coil target [1,2] is essential to overcome these difficulties.

Generation of 1 kT of magnetic field was demonstrated by using capacitor-coil targets as shown in Fig. 1. Enhancement of the heating efficiency is expected by implementing this external magnetic field in the future fast-ignition experiment.

Theory and Simulation, Target Design

The control of the high energy electron beam toward a high dense core plasma is the effective way to increase the heating efficiency in fast ignition. The quantitative analyses are made for magnetic field generation [3] and high energy electron transport as follows. Using PIC simulation it is shown that the hot electrons generated by the intense laser of 10^{18}-10^{20} W/cm^2 are collimated by the strong magnetic field of 1-10kT [4]. Such a strong magnetic field can be achieved by the compression of the implosion as the result of radiation hydro simulation with magnetic field transport.

[1] S. Fujioka *et al.*, Sci. Rep., 3, 1170 (2013).

[2] S. Fujioka *et al.*, Plasma Phys. Control. Fusion, 54, 124042 (2012).

[3] H. Nagatomo *et al*., Nucl. Fusion **53** 063018 (2013).

[4] T Johzaki, *et al*., J. Plasma Fusion Res. **89**, No.7, 456, (2013).