Present Status of Fast Ignition Research and Prospects of FIREX Project

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We have been studying the fast ignition scheme of laser fusion by the GEKKO XII and PW lasers. In the 2002 IAEA FEC, it was reported that the neutron yield increased from 10^4 without heating to 10^7, when a 400 J/0.6 ps PW laser was injected into a compressed CD shell. This indicates that the core plasma temperature increases by 500 eV and the energy coupling efficiency between heating laser and core plasma is 20-25% [1]. According to these results, we started the FIREX (Fast Ignition Realization Experiment) project toward demonstrating the fast ignition with a new high energy PW laser, LFEX (Laser for Fast Ignition Experiment) which is currently under construction. In this paper, the progresses in the experimental research on scientific and technological issues related to fast ignition and the integrated code development toward the FIREX will be reported.

The new heating laser LFEX has been designed to deliver 10kJ energy in 10ps with 1ps rise time. It consists of 2x2 segment amplifiers with a size of 40 cm x 40 cm in each beam. After pulse compression, 4 laser beams are combined into 1 beam for obtaining a single focal spot without reducing the encircled energy. In the pulse compressor, the segmented gratings will be used because of the limited size of the dielectric grating. In the preliminary experiment by Ti:sapphire laser no significant changes in compressed pulse width and far-field pattern were observed between the segmented gratings and a monolithic grating. One of the critical technical issues of the LFEX is the coherent combining of 4 segmented beams. A precise phase control system in beam and among beams is introduced. The LFEX is under construction and the FIREX-I experiment will start before 2007 .

In the fast ignition scheme using cone-shell target, it is important to understand the physics of ultra-intense laser absorption, relativistic electron generation and transport in the cone and the compressed plasma, as well as non-spherical cone-shell target implosion. As interpretation of the cone-shell-target experiment, the relativistic electron propagation in dense plasmas has been widely investigated by experiment, simulation and theory. Further analysis of the cone target experiments has been carried out by the integrated simulation combining PIC, 2D hydro PINOCO and Fokker Planck (F.P.) codes[2]. We found that the unique interaction of heating laser with cone contributes to enhancing the coupling efficiency of short pulse laser to core plasmas. Namely, the energy distribution of relativistic electron has a low energy component, which contributes to the efficient heating. The non-spherical cone-shell target implosion was investigated by experiments with the GEKKO XII laser[3]. The experiments indicate that the imploded plasma ρr is not smaller than that of the corresponding spherical CD shell implosion.

The heated plasma parameters and the gain for the FIREX-I were evaluated to be ρr = 0.15g/cm^2, = 20 μm, T = 8 keV, and Q = 0.1 by the integrated simulation with 0.5 MeV slope temperature for the 10kJ heating pulse energy. When the above expected plasma parameters are achieved, we plan to start the FIREX-II project in which both implosion and heating lasers are up-grated to 50 kJ. In this case, the gain will reach higher than unity and the ignition will be achieved. Toward the FIREX-I experiment, we also started research and development for fabricating cryogenic foam shell cone target as the collaboration work with NIFS (National Institute of Fusion Science). A cryogenic target will be imploded in a year.

[1] R. Kodama, et al., Nature **412**, 798 (2001), R. Kodama, Nature **418,** 933 (2002).

[2] T. Johzaki, et al., ibid, Wpo3.16.

[3] H. Shiraga, et al., ibid, WP3.4.