8. Bilateral Collaboration Research Program

Osaka University

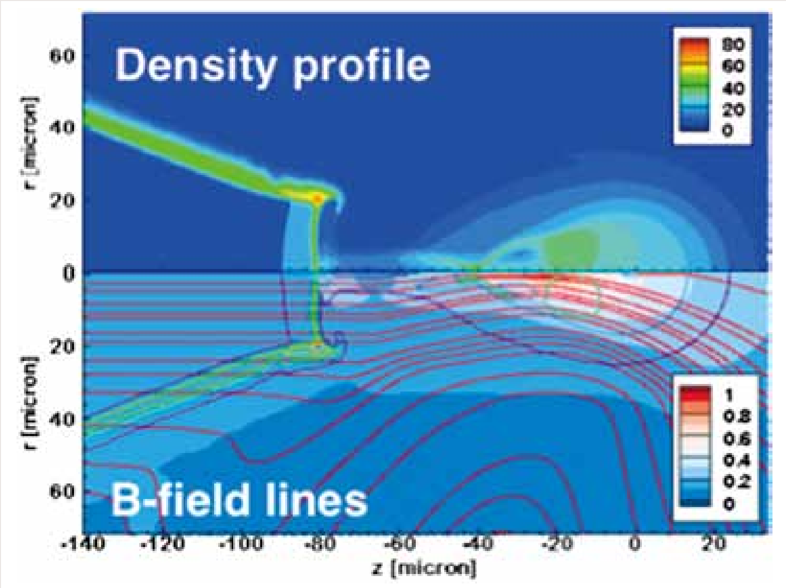

Fig. 1 Calculated plasma density profile of the imploded solid sphere target (upper) and the applied magnetic field distribution (lower).

Highlight

Plasma Heating by Fast Ignition Scheme

In FY 2015, three scientific challenges to achieve high heating efficiency of the fast ignition (FI) scheme with the current GEKKO and LFEX systems: (i) suppression of high energy tail of relativistic electron beam (REB), (ii) guiding and focusing of REB to a fuel core, and (iii) formation of a high areal-density core were successfully solved. In FY2016, integrated experiments of fast ignition based on such achievements were successfully performed by using reduced electron beam temperature for improvement of the beam energy deposition, kT-class applied magnetic field to collimate the electron beam, and solid sphere target for stable implosion. The target was imploded by irradiation of the Gekko-XII laser beams, and the LFEX beam was injected into the cone attached to the spherical fuel target. Density of the imploded target was measured by x-ray backlighting with 4.7-keV Kα-rays generated by irradiation of a Ti plane with a high-intensity laser beam. From the observed x-ray spectrum emitted from the doped Cu ions, a fast-heated temperature of the imploded solid sphere target was found to be raised up to 20 million degrees.

Fast Ignition of Super High-Dense Plasmas

Laser-driven inertial confinement fusion by the Fast Ignition scheme has been intensively studied as the FIREX-1 project at the Institute of Laser Engineering, Osaka University. The research consists of target fabrication, laser development, fundamental and integrated implosion experiments, and simulation technology and reactor target design. In FY2016, the following progress was made through Bilateral Collaboration Research with NIFS and other collaborators (2016NIFS12KUGK057).

Fundamental and Integrated Plasma Experiments

Integrated experiments of fast ignition by using reduced electron beam temperature, applied magnetic field, and solid sphere target were performed. From the observed x-ray spectrum emitted from the doped Cu ions, a fast heated temperature of the imploded solid sphere target was found to be raised up to 20 million degrees. Fundamental experiments of laser-plasma physics related to fast ignition, such as fast ion generation, were also performed.

Theory and Simulation, Target Design

Performance of the electron beams generated by high-intensity laser irradiation, such as beam divergence, slope temperature, and the control of those, which are the most important issues in fast ignition research, were intensively studied. In particular, the slope temperature of the hot electrons was found to be dependent not only on the laser intensity but also on the pulse length resulting in increased temperature at a pulse length longer than 1 ps. The electron beam transport as well as the implosion hydrodynamics under the applied magnetic field also were investigated. For design study of the ignition/burning-scale experiments, the scheme for integrated simulation was improved, including data coupling schemes between codes to enable such large calculations with current-level computers.

Target Fabrication and Reactor Technology

Solid sphere fuel target is expected to give favorable performance as a fast ignition target. It is robust against Rayleigh-Taylor instability since implosion is achieved by spherically converging shock waves instead of acceleration of a thin shell. One practical scheme to realize the concept is filling an empty plastic shell target with liquid DTO. A small inventory liquid filling system was developed, and a plastic sphere 360 mm in diameter was successfully filled with liquid D2O without generating voids. Targets filled with DTO liquid will be introduced to implosion experiments in 2017. Target injection experiments were performed on a real-sized target injector apparatus. By improving the stiffness of the accelerator tube and by adding slippery coating on the surface of the injector sabot, angular stability of the sabot after injection was reduced to 2/3 of the previous results.

LFEX Laser with All Four-Beams in High-Power Shots

In FY2016, the LFEX laser system performance was further improved in many aspects. The beam diagnostic system after the amplification and pulse-compression was upgraded. A single-shot auto correlator to accurately measure the pulse shape was carefully tuned in order to avoid nonlinear optical effects in the optical components. The focal pattern monitor to observe the focused beam at the target chamber center was renewed to have a full aperture observation capability.

Individual Collaborations

In parallel to the main project described above, twenty-one other collaborations by individual researchers, including three from researchers abroad, have been performed. Those collaborations were on electron-driven fast ignition (4 collaborations), ion-driven fast ignition (5), alternative scheme of laser-driven inertial fusion (3), diagnostics of high-temperature and high-density plasmas (4), and reactor technology (5). Twelve collaborations were continued from the previous year(s) and nine were newly accepted in FY2016.

(H. Azechi)

Fig. 2 Amplifier chain of the LFEX laser beams.