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Experimental studies on thermal transport in magnetized high energy density plasma for fast ignition inertial confinement fusion

K. Matsuo[1,2], S.Sakata[2], S.Lee[2], N.Higashi[2], N.Iwata[2], K.F.F.Law[2], H.Morita[2], T. Sano[2], H. Nagatomo[2], H. Sawada[3], T.Johzaki[4], T. Somekawa[2,5], Y.Arikawa[2], H.Azechi[2], R.Kodama[2], Y.Sentoku[2], S. Fujioka[2]

[1] Center for Energy Research, University of California San Diego,
[2] Institute of Laser Engineering, Osaka University, [3] University of Nevada, Reno,
[4] Hiroshima University, [5] Institute for Laser Technology
e-mail (speaker): mattya.azuki1030@gmail.com

The main purpose of this studies is to understand thermal transport in magnetic field for the magnetized fast ignition (MFI) scheme that combines the conventional fast ignition scheme [1,2] with an external strong magnetic field [3]. In MFI scheme, a laser is irradiated on the surface of a target in an external magnetic field, and the target is compressed by the ablation pressure. A part of compressed target is heated instantaneously by using a short pulse and high-intensity laser having several picoseconds of the pulse duration. Effects of thermal transport on the hydrodynamics and heating of high energy density plasma in the external magnetic field was experimentally investigated.

The external magnetic field reduces electron thermal transport across the external magnetic field lines. The suppression of electron thermal transport in a magnetic field increases the temperature and pressure of the ablation plasma, as shown in Fig.1. The velocity of a target driven by intense laser beams in the strong external magnetic field is faster than that in the absence of the external magnetic field [4]. Growth of sinusoidal corrugation imposed initially on the laser-driven target surface is enhanced by the external magnetic field because the plasma pressure distribution becomes non-uniform due to the external magnetic-field structure modulated by the perturbed plasma flow ablated from the corrugated surface. An external magnetic field notably affects hydrodynamics due to the anisotropic thermal transport, even when the magnetic field pressure is much lower than the plasma pressure, namely the high-b condition.

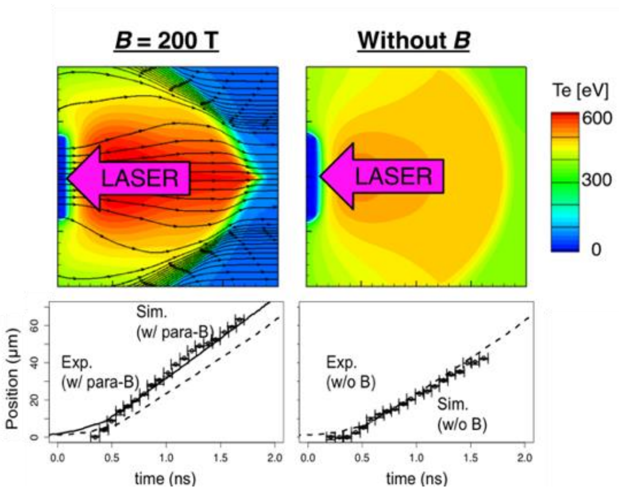

Fig.1 Comparison of temperature distribution of the ablation plasma (top) and trajectory of the target (bottom).

A study of the contribution of thermal transport on the heating with multi-picoseconds intense laser pulse in a strong magnetic field was also studied.

We have achieved experimentally 2.2 petapascal pressure with 4.6 kJ of the total laser energy that is one order of magnitude lower than the energy used in the conventional implosion scheme [5]. Particle-in-cell simulations with the experimental conditions confirm that the diffusive heating mechanism, in which thermal electrons transport their energy diffusively from the laser-heated hot region to the cold dense region, plays an essential role to heat the high-energy-density plasma over keV range, as shown in Fig.2. We showed this scheme could not only provide as an alternative and highly efficient approach to the ignition but also become an experimental platform of high-energy-density plasma physics relevant to the fields of astronomy and solar physics.

References
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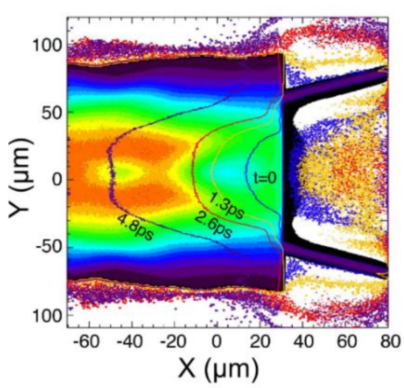

Fig.2 Time evolution of a 1 keV isotherm. The temperature range above 1 keV diffuses from the laser-irradiated side (right side) towards the center of the core.