Investigation of electromagnetic wave propagation and absorption with polarization controlled intense laser pulse

Yoshitaka MORI[1], Takayoshi SANO[2], Natsumi IWATA[2], Yasuhuko SENTOKU[2]

[1]The Graduated School for the Creation of New Photonics Industries,

[2]ILE, Osaka University

INTRODUCTION

Electromagnetic wave propagation and absorption in plasma is one of the fundamental issues on plasma physics since its dawn in relation to wave dispersion relation in discharged materials [1]. Experiments of generation of laser-driven kT class magnetic field [2] have opened theoretical or simulation investigation of laser-plasma interaction with external magnetic field with density close to solid [3, 4]. Extensions of these theoretical or numerical estimations into experiment condition can lead to bulk solid plasma heating by laser pulse in potential.

In the previous ILE research collaboration FY2018, we have evaluated electromagnetic wave propagation and absorption of CO_2 laser pulse (wavelength of 10 μm) in plasma with solid density (0.1 g/cc for hydrogen) region under 10-kT class magnetic field. From this estimation, we found that, as far as the bulk slab density is confirmed, we can investigate external magnetic field from this dispersion relation. This result leads a possibility of probing an external magnetic field in the plasma. This is a promising result to investigate wave propagation experiments using CO_2 laser pulse because understanding of wave plasma interaction under strong magnetic field are enriched.

In this ILE research collaboration FY2019, in order to extend possibility of wave plasma interaction in the magnetized plasma, we have introduced counter illumination scheme that enables momentum conversion into the inertial energy. We have conducted two issues; (i) Theoretical investigation of ultrafast wave-particle energy transfer in the collapse of standing whistler waves [5] and thermonuclear fusion triggered by collapsing standing whistler waves in magnetized overdense plasma [6], (ii) Counter illuminating laser plasma interaction experiments with ultra-intense femto-second laser.

(I) THEORETICAL INVESTIGATION OF THERMONUCLEAR FUSION TRIGGERED BY COLLAPSING STANDING WHISTLER WAVES IN MAGNETIZED OVERDENSE PLASMA [6]

Thermal fusion plasmas initiated by standing whistler waves are investigated numerically by using two or one-dimensional (1D) Particle-in-Cell simulations. When a standing whistler wave collapses due to the wave breaking of ion plasma waves, the energy of the electromagnetic waves can transfer directly to the ion kinetic energy. The energy conversion efficiency to ions becomes as high as 15% of the injected laser energy, which depends significantly on the target thickness and laser pulse duration. The ion temperature could reach a few tens of keV or much higher if appropriate laser-plasma conditions are selected. This result inspires application for fusion reaction. For example, numerical simulations suggest that the neutron generation efficiency exceeds 10^9 n/sr/J for DT plsama, which is beyond the current achievements of the state of- the-art laser experiments. In conclusion, the standing whistler wave heating would expand the experimental possibility for an alternative ignition design of magnetically confined laser fusion, and also for more difficult fusion reactions including the aneutronic proton-boron reaction.

Following this result, we have discussed proposal of ultra-intense CO_2 laser and magnetized plasma interaction experiments in counter illumination with circular polarization.

(II) COUNTER ILLUMINATING LASER PLASMA INTERACTION EXPERIMENTS WITH ULTRA-INTENSE FEMTO-SECOND LASER

The counter illumination with the ultra-intense laser pulses into an imploded pellet has a potential to lead a significant heating with Weibel instability that traps MeV fast electrons and can be mixed into the core thermal energy [6]. According to the previous experiments, a tailored-pulse-assembled core with a diameter of 70 μm is flashed by counterirradiating 110 fs, 7 TW laser pulses. Photon emission (> 40 eV) from the core exceeds the emission from the imploded core by 6 times, even though the heating pulse energies are only one seventh of the implosion energy. The coupling efficiency from the heating laser to the core using counterirradiation is around 10% from the enhancement of photon emission [7]. These experiments reveal that plasma heating by counterirradiating scheme is promising, though, quantitative analysis and scaling toward ignition are open questions.

We are intended to verify physics related to counter illuminating scheme using repetitive Ti-Sapphire laser system Beat 0.2 J/100 fs/10 Hz 2 beam [8]. Figure 1 shows kick-off experiments of counter illumination into Ar gas target. Diagnostics for plasma temperature are under preparing.

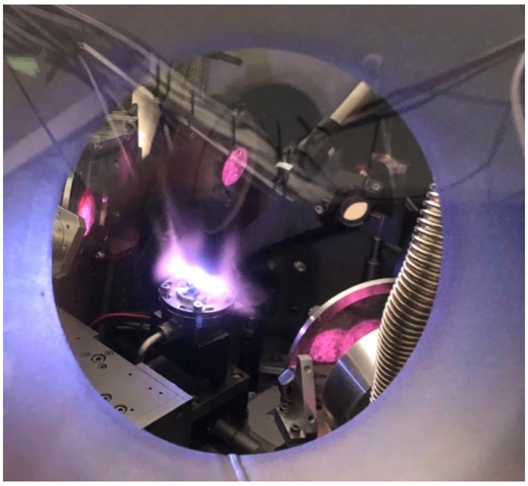

Fig. 1. Counter illuminating experiments Ar gas jet target.

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