Observation of the non-local electron transport effect by using phase zone plate

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Abstract. Non-local electron transport effect plays a significant role in inertial confinement fusion because it potentially preheats the fusion fuel and lowers the target density. Non-local electron transport effect is more pronounced for longer laser wave-length and higher intensity. We measured the density of the plastic target irradiated with 0.53 µm laser by using a phase zone plate (PZP) that has spatial resolution of about 2 µm. The target density predicted by the ILESTA-1D simulation with Spitzer-Härm thermal conduction is 1.5 times as large as that predicted with Fokker-Planck thermal conduction. The measured density profile is close to the density profile predicted by the simulation with Fokker-Planck thermal conduction.

1. Introduction

Non-local electron transport effect plays a significant role in inertial confinement fusion because it potentially preheats the fusion fuel and lowers the target density. The direct observation of this effect is very difficult. Because it musts observed the non-Maxwell components of electron energy distribution inside the laser produced plasma.

Non-local electron transport effect lowers the target density and lengthens the density scale length. So that effect can be observed by measuring the density. In the case of 0.35-µm laser irradiation [1, 2] and the case of 0.53-µm 1×10¹⁵ W/cm² intense laser irradiation [3], the non-local electron effect was not observed. Non-local electron effect increases by the target irradiated with longer wave-length and higher intensity laser because of the lower density and higher temperature. Therefore we measured the density of the plastic target irradiated with 0.53-µm wave length and 4×10¹⁴ W/cm² intense laser.

To measure the density profile, we need the high temporal and spatial resolution because the width of the compressed target is about 10 µm and the velocity of the accelerated target is about...
1.0×10⁷ cm/s. We use a phase zone plate (PZP) for x ray imager, because that has high spatial resolution of about 2 µm [4]. And we use a x ray streak camera (XSC) for x ray detector, because we need to the temporal resolution of faster than 100 ps.

2. Experimental setup and procedure

We performed the experiment at the Gekko-XII HIPER facility. To measure the target density, we used the x ray backlighting with a PZP that has a special resolution about 2 µm. Figure 1 shows a schematic view of the experimental setup. We used Ti He-α x ray (4.7 - 4.8 keV) for the backlighter because the transmittance is about 0.6 when the target is compressed and the refraction in the target is small. Temporal resolution is 100 ps, because the accelerated target velocity is 1.0×10⁷ cm/s. A 20-µm thick Be filter was placed between the Ti backlight target and the plastic target driven by the HIPER laser to cut off the soft x ray. A 100-µm Be blast shield placed in front of a PZP to prevent a PZP from breaking by debris. A 5-µm Ti filter placed in front of XSC to eliminate a self emission of the plastic target. We used the polystyrene target with thickness of 22 µm. The intensity of the main drive laser was 4×10¹⁴ W/cm² and the pulse width was 2.5 ns, because the target density predicted by the ILESTA-1D simulation [5, 6] with Spitzer-Härm thermal conduction is 1.5 times as large as that predicted with Fokker-Planck thermal conduction.

Figure 1 Experimental setup for density measurement

"Observed" density profile included the motion blur. So we blur the result of ILESTA-1D simulation. First, we calculated the density profile of simulation to the transmittance profile. Next, we multiplied the profile by weight that is from backlight time profile. And we summated that multiplied profiles for 100 ps. Then we calculated the summated transmittance profile to the density profile. The blurred density profile is lower and wider than the “actual” density profile. So we use this result to compare with the experiment.
3. Experimental result

Figure 2 shows the experimental density profile and that of simulations. Dot is the experimental data, solid line is the result of Fokker-Planck (F-P) code, and dashed line is the result of Spitzer-Härm (S-H) code. Both two simulations included the radiation transport. The value of flux limiter of the Spitzer-Härm code is 0.1. Position shows a distance from the initial target front surface. We adjust the peak position of simulations for that of experiment density profile because the precision of the position is about 10 µm. From figure 2 (a), the experimental data is in good agreement with the both two simulations in early time. From figure 2 (b), the experimental data is in closer agreement with the result of Fokker-Planck simulation than that of Spitzer-Härm simulation in later time.

4. Summary

We measured the density profile to observe the non-local electron transport effect. So we used a phase zone plate that has high spatial resolution of about 2 µm and x ray streak camera that is the high temporal resolution of about 100 ps.

In early time, the non-local electron transport effect was not prominent. Therefore the observed density profile was good agreement with both two simulations.

In later time, the non-local electron transport effect was prominent. So the observed density profile was closer agreement with the result of the Fokker-Planck simulation than that of the Spitzer- Härm simulation.
5. References

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