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Warm Dense Matter Studies for Improvement of Coupling Efficiency for Fast Ignition

高速点火核融合のための Warm Dense Matter 物性の検討

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Properties of warm dense matter affect fast electrons generation and transport to the fast ignition scheme of the inertial confinement fusion. To measure the electrical conductivity for DLC, we proposed shock heating driven by the exploding wire. Electrical conductivity for gold is drastically changed as a function of density. The electrical conductivity for DLC is possible to evaluate by DLC coated wire explosion. To understand the efficient B-field generation with the coil-capacitor target, we evaluate the electrical conductivity for several matters. It indicates that the skin effect in the coil is small and the electrical conductivity behavior of coil/plasma is important.

1. Introduction

Critical to fast ignition [1] is the transport of the laser-generated fast electrons and their associated heating of compressed DT fuel. Improving coupling efficiency, we should consider the behaviors of unstoppable, un-ejected, and diverging fast electrons.

From the numerical results, the low-Z cone is expected to be the improvement of coupling efficiency [2]. On the other hand, the transport of fast electrons in the cone depends on the electrical conductivity in warm dense matter (WDM) state [3]. The diamond-like-carbon (DLC) [4] cone is promised to increase the coupling efficiency due to the redaction of stopping power in cone compared to the high-Z cone. We should clarify the properties of WDM DLC.

To guide the fast electrons, strong B-field generated by a laser capacitor target has been proposed [5]. Nickel coil for the laser capacitor target can be generate the strong B-field compared to the other materials. Generation rate of fast electrons, skin effect as an electrical conductivity for ablated plasma at the generation of the magnetic field are important. Thus, we evaluate the electrical conductivity to confirm the skin effect.

From above reasons, we confirm the properties of WDM for improvement of coupling efficiency in fast ignition.

2. Proposal of Electrical Conductivity Measurement for WDM DLC

To evaluate the electrical conductivity for DLC WDM, the shock compression driven by an exploding wire discharge with confined by a rigid capillary is considered [6]. The exploding wire has a huge ablation pressure approximately a few GPa. Thus, the pressure of exploding wire drives the shock heating for the insulator as the DLC membrane which is coated on the wire. The heated DLC membrane state is observed by the ruby fluorescence for the pressure and the emission spectrum for the temperature.

Figure 1 shows a one-dimensional hydrodynamic simulation of the shock compression driven by an exploding wire discharge with confined by the rigid capillary. Initially, we assume 5 μm DLC coated on gold wire, which radius is 100 μm. The results indicate that the radius of WDM DLC is almost 100 μm after a few μm from beginning of discharge. From the comparison of both resistance [3,6], the resistance of WDM DLC is smaller than that of WDM gold. It means that the method is possible to generate WDM DLC and to measure the electrical conductivity of WDM DLC.

3. Skin Effect for Laser Capacitor Target

To guide the fast electrons, strong B-field generated by a laser capacitor target depends on the coil materials. Nickel coil for the laser capacitor target can be generate the strong B-field compared to the other materials at the same laser energy. Generated B-field depends on the coil current, that is, the effective resistance for coil is important.

Figure 2 shows an electrical conductivity in WDM nickel generated by the isochoric heating. Electrical conductivities of WDM Al and Cu are estimated to be around 10^4 S/m and that of WDM Au is less than 10^4 S/m [7]. The results indicate that the electrical conductivity of nickel is relatively higher than that of the other materials. It also indicates that the skin effect in the coil is small.

4. Conclusions

To measure the electrical conductivity for DLC, we proposed shock heating driven by the exploding wire. Electrical conductivity for gold is drastically changed as a function of density. The electrical conductivity for DLC is possible to evaluate by DLC coated wire explosion. To understand the efficient B-field generation with the coil-capacitor target, we evaluate the electrical conductivity for several matters. It indicates that the skin effect in the coil is small.

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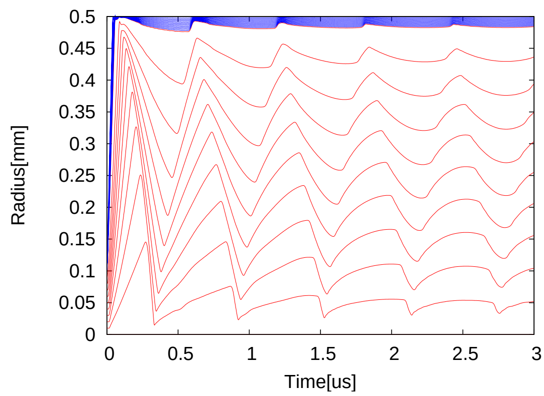

Fig. 1 Hydrodynamic behavior of the shock compression driven by an exploding wire discharge with confined by the rigid capillary. Red lines indicates the gold plasma, and Blue lines shows the DLC plasma.

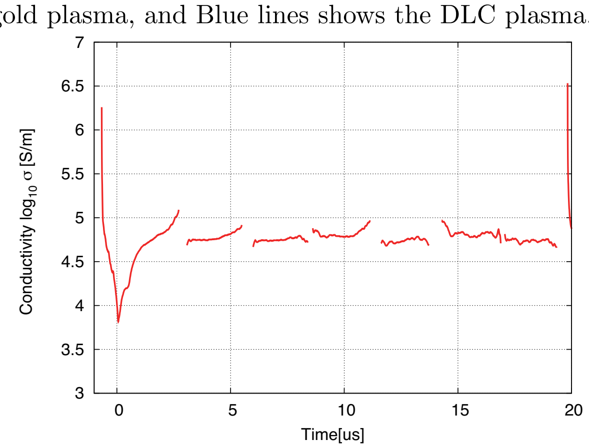

Fig. 2 Time evolution of electrical conductivity of nickel generated by the isochoric heating.