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Numerical simulation of Laser Plasma under the Strong Magnetic Field
強磁場下のレーザープラズマ流体の数値解析

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A compression of external magnetic field is studied using two dimensional radiation hydrodynamic simulation. The simulation results show that (i) it is possible to compress the magnetic field to be 10kT (10^8 Gauss), and (ii) the strong magnetic field should affect the implosion dynamics because of the suppression of the electron heat flux which across strong magnetic field lines. This result suggest that a target and initial conditions for fast ignition with external magnetic field must be designed carefully not only for the control of the hot electron transport but also for the formation of high dense plasma.

1. Introduction

For the fast ignition of inertial confinement fusion, reduction of the divergence angle of heating electron beam is urgent issue. In the recent researches suggest that the magnetic field plays an important role in the problem, especially for the controlling and guiding of the high energy electron transport toward the compressed core plasma. In our previous work, self-generated magnetic field in an asymmetry implosion was studied using radiation hydrodynamic simulation [1]. Also self-magnetic field generation in hot electron transport due to the resistive gradient was estimated using relativistic Fokker-Plank simulation [2]. But these self-generated magnetic field is difficult to control to be preferable distribution for the hot electron guiding. In recent experiments at ILE, Osaka University, generation of a strong external magnetic field of 1kT is demonstrated successfully using a laser-driven capacitor-coil target [3]. In this simulation study, we consider the external magnetic field for the initial condition, which is compressed by the direct laser driven implosion. Not only for the confirmation of compression in implosion, but also side-effects of strong magnetic field to hydrodynamics must be investigated for fast ignition.

2. Simulations

Our 2-D radiation hydrodynamics simulation code (PINOCO:[4]) is extended to take account of the transport of external magnetic field. The electron thermal conductivity appearing in the heat fluxes parallel and perpendicular to a magnetic field is corrected as the reference [5]. Lorentz force is not taken account in this simulation. The Simulation conditions are based on the current direct drive implosion laser GXII performance. The total energy and the wavelength of the laser are assumed as 1.8 kJ and 0.53 μm respectively. The shell is attached with gold cone of which full open angle is 30 degree. The initial radius and thickness of the deuterated polystyrene (CD) shell target are 250 μm and 8 μm respectively (Fig. 1). For a preliminary study, an initial magnetic field is assumed as uniform field of 300T along the axis direction. This condition can be realistic for sophisticated experiment designs in near future.

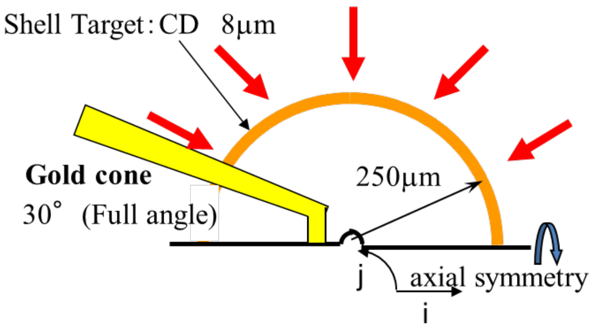

Fig.1. Initial conditions of the simulation. (a) CD shell target with inserted gold cone target and (b) uniform initial magnetic field of which intensity is 300T

The profiles at an acceleration phase are shown in Fig.2. The magnetic field is fairly compressed (Fig.2(a)). In the result, at the maximum compression time of the magnetic field, it reaches about 10 kT, which is high enough to guide hot electrons toward an imploded core. The magnetic field lines forms rather complicated configuration around the core. However, once electron beams are collimated at the guiding cone area, the electron beam may generates a self-magnetic field, which guides itself toward the imploded core (Fig.2(b)). We also observe another important phenomena in the imploding shell target. At an initial phase before the shell acceleration, a structure of ablation surface is affected by the magnetic field at some part of

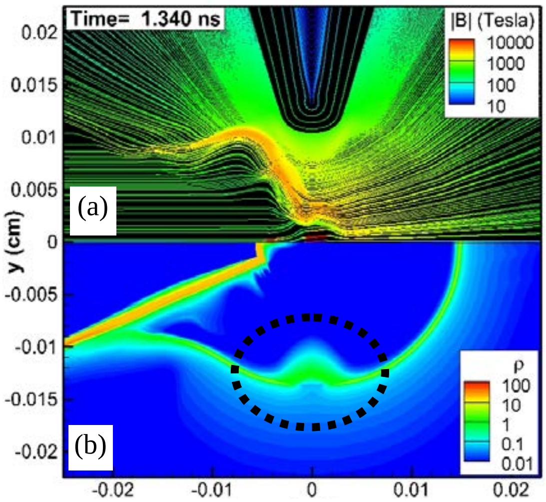

Fig.2. Snapshots of (a) magnetic field lines (colors in Tesla), and (b) mass density (g/cm^3) at an acceleration phase (1.34 ns). The magnetic field is compressed along with the mass compression. In the dotted circle, a mass perturbation is seeded at early phase due to the electron heat flux limitation for the strong magnetic field.

the shell where magnetic field lines are parallel to the ablation surface due to the electron flux limitation for strong magnetic field. After the ablation surface is formed, because of the advection, the magnetic field lines become parallel to the ablation direction, and influence of the magnetic field to electron heat flux along ablation direction weakens. But the disturbance remains as the shell density perturbation, which grows as Rayleigh-Taylor instability. In this simulation, R-T instability seeded by the magnetic field is caused under the extreme and ideal condition. However, it must be considered carefully when we design an experiment configuration.

3. Conclusion

We have studied the compression of external magnetic field by laser driven implosion using two dimensional radiation hydrodynamic simulation. The simulation results show that (i) it is possible to compress the magnetic field to be 10kT, and (ii) the strong magnetic field can affect the implosion dynamics because of the suppression of the electron heat flux which across strong magnetic field lines. This result suggest that a target and initial conditions for fast ignition with external magnetic field must be designed carefully not only for the control of the hot electron transport but also for the formation of high dense plasma.

Acknowledgments

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