§50. Design for Fast Ignition Targets with Fast Ion Heating

Sakagami, H.,
Johzaki, T. (Hiroshima Univ.),
Sunahara, A. (Institute for Laser Technology),
Nagatomo, H. (Inst. of Laser Engineering, Osaka Univ.)

FIREX experiments have started at ILE, Osaka University to demonstrate the fast ignition scheme using Au cone-guided targets. Efficient core heating mechanisms have not been, however, clarified yet, and we have been promoting the Fast Ignition Integrated Interconnecting code (FI^3) project to boldly explore fast ignition frontiers.[1)] 2D PIC simulations and basic experiments indicate that the coupling efficiency from fast electrons to the core is quite low even that from the heating laser to fast electrons is generally high because the divergence angle of fast electrons is large and their slope temperature is too high to deposit the energy into the core.[2)] To mitigate this critical issue, a plastic (CH) thin film, which can accelerate not only protons (H^+) but also carbons (C^{6+}) by the sheath field at the rear surface,[3)] is introduced into the cone-guided target, expecting additional core heating by ions. Electron and ion beam characteristics are investigated by 2D PIC simulations and core heating properties are evaluated by integrated simulations by 1D RFP-Hydro code.[4)]

As the heating laser, LFEX, in FIREX project is designed to have 10 ps pulse length and the cone tip is placed 50 μm away from the implosion center, we assume that ion beams should propagate 60 μm long within 5 ps time lag. So ions with the speed faster than 0.04 of the light speed, namely H^+ with the energy higher than 0.7 MeV or C^{6+} higher than 9 MeV, can be used to additionally heat the core. To adapt the sheath field acceleration, we introduce the CH thin film ion generator inside the cone as shown in Fig. 1 (a). The Au cone plasma (Z=30, A=197, $20n_{cr}$, 60 degree open angle, 10 μm tip width) is introduced and the CH thin film (Z=6, A=12, $17.14n_{cr}$ and Z=1, A=1, $2.86n_{cr}$, 4.5 μm thickness) is placed 5 μm away from the cone tip surface. When the sheath field is induced, dense background electrons in the Au plasma are pulled and injected into the CH thin film and it results in reducing the sheath field. Therefore 0.5 μm gaps between the Au and the CH thin film are introduced to prevent the electron flow as shown in Fig. 1 (b). Ion acceleration by the sheath field is incompatible with electron acceleration, so maintained sheath field by the gap prevents fast electrons from propagating forward, and it leads to reduction of core heating by fast electrons. If the ion generator is destroyed after acceleration, the heating laser can interact with the cone tip to generate more fast electrons. Lower density CH thin film leads to earlier destruction, but it cannot maintain the sheath field. Thus we introduce slits as shown in Fig. 1 (c), which are narrow enough that the laser cannot propagate, so that the CH thin film can be destroyed earlier.

The heating laser is set to λ_L=1.06 μm, $I_L=10^{20}$ W/cm^2, $\tau_{rise}=\tau_{fall}$=50 fs, τ_{flat}=400 fs and ϕ_{FWHM}=10 μm super-Gaussian with α=5. Fast electrons and energetic ions are observed at 1 μm behind of the cone tip surface with 30 (±15) μm width. To ignore a circulation of fast electrons, we introduce an artificial cooling region (1 μm width), in which fast electrons are gradually cooled down to the initial temperature, behind the observation region, top and bottom regions of the Au plasma. Using the time-dependent profiles of fast electrons and ions, which are observed in 0 < y < 3 μm in 2D PIC code, into 1D RFP-Hydro code, we carried out integrated simulations to evaluate the core heating properties, including 7 μm transport in the Au cone tip. Time evolutions of averaged core electron temperatures are shown in Fig. 2 for all 3 cases. As electrons finish to heat the core but ions do not reach the core yet due to slow speed, electrons play a dominant role in core heating before the inflection point. After that, ions finally reach and dominantly heat the core instead of electrons. In the case with the gap, enhancement by ions is larger than that without the gap. On the other hand, the forward propagation of fast electrons is disturbed by the same sheath field, and electron heating is reduced. In the slit with gap case, the ion generator is successfully destroyed after ion acceleration and the heating laser can interact with the cone tip. So fast electrons are enhanced after the destruction, and the number of fast electrons that are suitable to heat the core is recovered.

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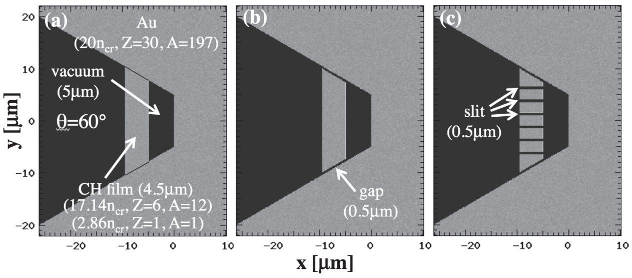

Fig. 1. Targets for sheath field acceleration (a) without gap, (b) with gap and (c) slit with gap.

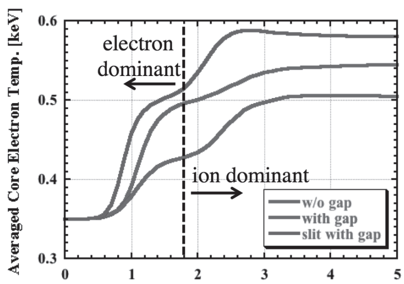

Fig. 2. Time evolutions of averaged core electron temperatures.

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2) Johzaki, T., et al.:Nucl. Fusion **51** (2011) 073022.
3) Snavely, R. A., et al.:Phys. Rev. Lett. **85** (2000) 2945.
4) Sakagami, H., et al.:Nucl. Fusion **49** (2009) 075026.