§64. Ion Assisted Fast Ignition using Ponderomotive Force Ion Acceleration

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In the fast ignition scheme, first long-pulse implosion lasers implode a fuel target, and then a short-pulse ultrahigh-intense laser heats compressed core. The FIREX project has started at ILE, Osaka University to demonstrate that the fuel core can be heated up to 5 keV with the fast ignition scheme using Au cone-guided targets. Results of both fundamental experiment campaigns and 2D PIC simulations indicate that the coupling efficiency from fast electrons to the core is quite low. Even the energy conversion efficiency from the heating laser to fast electrons is generally high, the divergence angle of fast electrons is too large and their slope temperature is too high to efficiently heat the core.[1)] To mitigate this critical issue, a low-density CH foam is installed in front of the cone tip surface as the ion beam generator and proton (H^+) and carbon (C^{6+}) are accelerated by the Ponderomotive force at the front foam surface[2)], expecting additional core heating by ions.[3)] This simple target design can reduce core-arrival time lags due to different ion energies or between electrons and ions because the distance between the ion generation point and the compressed core is short enough, and not only fast electrons but also energetic ions with wide energy range can be used to heat the core. Additionally, this target design makes it easy to introduce the ion beam generator into FIREX experiments combining with currently used Au cone-guided targets. 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)]

We introduce the low-density CH foam as the ion beam generator in front of the cone tip surface as shown in Fig. 1. As the scaling of ion velocity by the Ponderomotive force is given in $v_i \propto (I_L/n_e)^{1/2}\ (Z/A)^{1/2}$,[2)] lower density gives higher energy, but it should be larger than relativistic critical density, namely $n_e \sim \gamma n_{cr} \propto I_L^{1/2}$ where I_L, Z and A are laser intensity, ionization degree and ion mass number, respectively, γ is the Lorentz factor of quivering electrons under the laser field and n_{cr} is the critical density. Thus the maximum ion energy is scaled with $E_i \propto Av_i^2 \propto I_L^{1/2} Z$. To verify this ion energy scaling for the Ponderomotive force ion acceleration, we chose the electron density of the CH foam to γn_{cr} (6.12, 8.60 and 19.13n_{cr} for I_L=5x10^{19}, 1x10^{20} and 5x10^{20} W/cm^2, respectively), and another parameters of the heating laser are as follows: λ_L=1.06 μm, $\tau_{rise}=\tau_{fall}$=50 fs, τ_{flat}=400 fs and ϕ_{FWHM}=10 μm super-Gaussian with α=5. Time integrated ion energy spectra are show in Fig. 2 for H^+ and C^{6+} with three different laser intensities. Estimated scaling of the maximum ion energy on the laser intensity and ion species roughly agrees with simulation results. Time evolutions of averaged core electron temperatures are obtained by integrated simulations and shown in Fig. 3. As electrons play a dominant role in core heating before the inflection point because ions do not reach the core yet due to slow speed. After that, ions finally reach and dominantly heat the core instead of electrons. Total temperature increments of the core electron are not proportional to the laser energy or laser intensity, and some optimizations of the target structure would be needed to efficiently heat the core.

This work is partially supported by JSPS KAKENHI Grant-in-Aid for Scientific Research (C)(25400539) and (S)(15H05751).

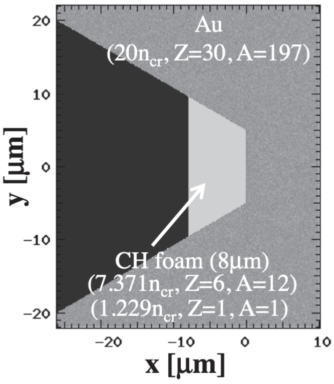

Fig. 1. Targets for Ponderomotive force ion acceleration.

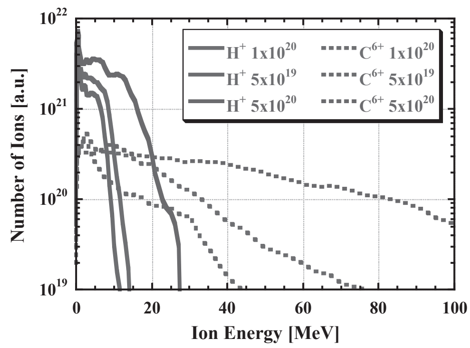

Fig. 2. Time integrated ion energy spectra.

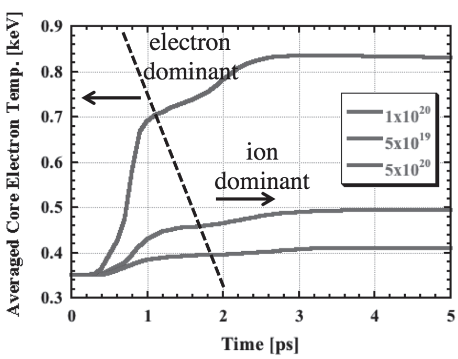

Fig. 3. Time evolutions of averaged core electron temperatures.

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