§20. Simulation on Laser-Plasma Interaction and Fluid Dynamics in Inertial Confinement Fusion

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When the laser photon pressure exceeds the plasma pressure, the ultra intense laser pulse accelerates ions by the photon pressure [1]. To investigate the ion acceleration mechanism, we have done the 1-D PIC simulation which includes three species of particle (electron, deuteron and carbon).

Figure 1 shows simulation results of carbon phase space plot for the intensity $I_L = 6.3 \times 10^{19} W/cm^2$. In the figure, the laser is injected from left side, so that the plasma is pushed to right and compressed. From the carbon phase plot, it is clearly seen that a shock wave is formed and ions are reflected at the shock front ($\omega_o x/c = 30.5$). The reflection of ion is due to the jump of potential at the shock front. The ions in the upstream of the shock mainly flows into the downstream. But, owing to the thermal energy spread, a part of ion can't pass through the potential barrire so that it is reflected.

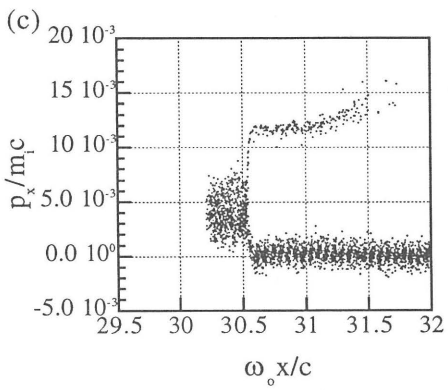

Fig. 1. Simulation result for shock acceleration at $I_L = 6.3 \times 10^{19} W/cm^2$, $\omega_o t = 258$.

Figure 2 shows the results for $I_L = 3.97 \times 10^{21} W/cm^2$. The ion phase plot is completery different from that in Fig. 1. In this case, the ion is reflected at the laser-plasma interface ($\omega_o x/c = 34$).

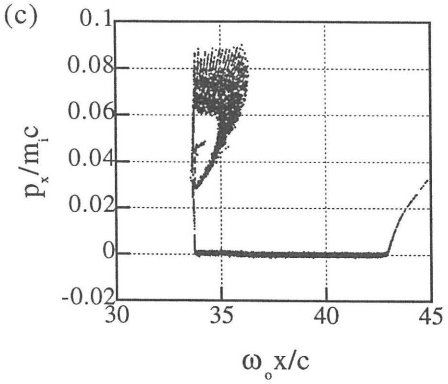

Fig. 2. Simulation result for direct acceleration at $I_L = 3.97 \times 10^{21} W/cm^2$, $\omega_o t = 184$.

The transition of ion acceleration mechanism from the shock acceleration to the direct acceleration is explained by the excess of the shock Mach number over the critical Mach number [2]. The mach number $\mathcal{M}$ must satisfy the condition

$$1 < \mathcal{M} < 1.6 \quad . \tag{1}$$

As increased the laser intensity, plasma pressure increases in proportion to the electron temprature. But the laser radiation pressure increases more rapidly than the plasma pressure, the Mach number increases. Then the Mach number is out of the range of eq. 1 and the acceleration mechanism changes from the shock acceleration to the direct acceleration.

In conclusion, we found that the ion acceleration mechanism changes from the shock acceleration to the direct acceleration. As increases the laser intensity, the ion acceleration mechanism changes at the critical laser intensity $a^2 \approx 100$. In the case of the shock acceleration either ion acceleration energy or conversion efficiency is higher than those in the case of the direct acceleration.

Refarences

1) J. Denavit, Phys. Rev. Lett. 69, 3052 (1992).
2) F. F. Chen, *Introduction to Plasma Physics*, (Plenum Press, 1974).