§15. Effective Parallelization of PIC Simulation for the Calculation of Laser Plasma Interaction

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In fast ignition scheme of laser inertial fusion, compressed core plasma whose electron density exceeds 1000 times of solid density is irradiated by ultra intense laser beam to heat the core to ignite the thermonuclear reactions. However, because the ultra intense laser beam can be propagated up to its critical density (=1/100 of solid density), the fast electrons are created at this point through the laser plasma interactions and must be propagated for several 100 µm to the core. These processes involve board range of the non-linear effects such as relativistic laser self-focusing, creation of high-energy electrons, and high current beam propagation in the plasma. In order to understand such comprehensive physics during both the laser and beam propagations, a particle-in-cell (PIC) calculation is widely used. The simulation traces dynamic particle motions via Lorenz force, so that the system size will be proportion in the particle numbers. Because this makes difficult to calculate large size plasma (~mm) as used in the experiment, many parallelization methods has been developed in order to reduce the calculation resources. The most of previous methods divides the calculation region into several sub-regions equally. However, when the difference of particle numbers in each sub-region is large, the parallelization efficiency does not increase with number of calculation nodes.

In order to improve the efficiency, we applied Oh!Help[1)] library to our PIC code. This library enables to have a primary and secondary domain in each node. The secondary domain with light load helps the calculation of other primary domain having heavy load, resulting in balance of the load among the nodes. Using this library, we conducted a calculation for laser plasma interactions by changing the node number as shown in Fig. 1. The total grid size of this simulation is 1200 x 600 (corresponding to the size of 18µm x 9µm). The square density plasma is located around left middle with 6µm x 2µm, in which electron density is 10^{21}cm^{-3} (particle number: 5068800). The ultra intense laser (focal intensity of 10^{20}W/cm^2) is irradiated

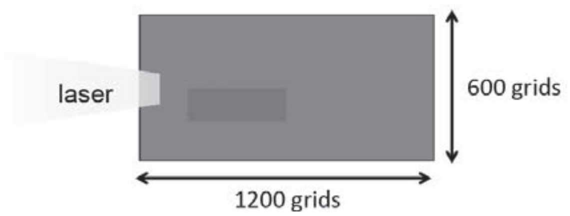

Fig. 1. Test calculation system. Background is vacuum. The plasma with 100 times of critical density is located in the left middle of the system. The intense laser with 10^{20}W/cm^2 is irradiated into the plasma from the left.

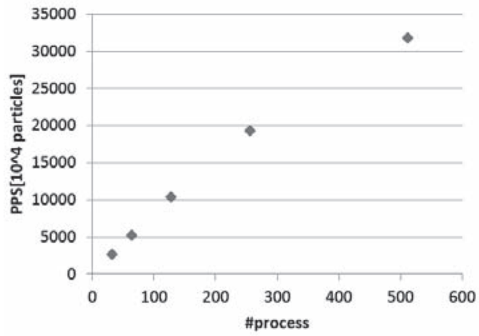

Fig. 2. PSS (Particle-per-second) value as a function of node number.

from the left side on the plasma with the spot size of 5µm. The laser wavelength is 1µm and the pulse duration is 200fs. In this calculation, we investigate the total calculation time by changing the node number from 32 to 512. Figure 2 indicate the PPS (Particle per second) value as a function of node number. The PPS means the number of particles per second in which the whole system can be calculated. In the result, the PPS relatively seems to be proportion to the node number. This fact means the communication time or idol time waiting the end of other node's calculation are small in each node, indicating the feasibility of this parallelization method. In the future, we plan to increase the node number more than 1000 and calculate the realistic laser plasma calculation.

1) H.Nakashima *et al.*, ICS'09 (2009) 90-99.