§6. Large-scale Simulation of High-energy Electron Generation via Ultrahigh-intense Laser

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Fast Ignition Realization Experiment project phase-I (FIREX-I) is being performed at Institute of Laser Engineering, Osaka University. In this project, the four-beam bundled high-energy petawatt laser (LFEX) is being operated. LFEX laser provides great multi-beam irradiation flexibility, with the possibility to arrange the pulses in temporal sequence, spatially separate them in distinct spots, and focus them in a single spot. Features of the LFEX, which are high power, long pulse (1 kJ / 1–5 ps), and large spot diameter (30–60 μm), are considered to cause interesting results that differ from many usual researches, where the laser is ultrahigh intensity, but femtosecond and small spot size close to the diffraction limit. Kemp *et al.* [1] reported that a high power long pulse laser such as the LFEX creates a large underdense plasma during first 1 picosecond, after that the laser interacts with the self-generated large underdense plasma, and the effective temperature becomes high even in the case of initially no pre-plasma. Therefore, large-scale simulations using realistic laser and target parameters are strongly desired. In this paper, we study the two-beam interference effect on high-intensity LPI by two-dimensional relativistic Particle-In-Cell simulations.

Interactions between high-intense picosecond laser beam and planar target are simulated with 2-D Particle-In-Cell code. The target is simulated as a simple 20 μm Au plasma with uniform electron density of $40n_{cr}$ and an exponentially decreasing, 1 μm scale-length pre-plasma extending from 0.1 to $40n_{cr}$, where n_{cr} is the critical electron density of 1 μm laser wavelength. From the left boundary, temporally and spatially Gaussian laser beam irradiates the target surface. The spot diameter and pulse duration are 60 μm and 1.5 ps at full width of half maximum respectively. The laser beam is linearly polarized and the laser electric field oscillates in 2-D simulation plane. The peak intensities of the laser beam are set to be 1.36×10^{19} $\mathrm{Wcm^{-2}}$ for one-beam irradiation and 6.8×10^{18} $\mathrm{Wcm^{-2}}$ for two-beam irradiation, keeping the same total laser energy. The laser is focused at the center of the target surface. Laser incidence angle is normal for one-beam irradiation and tilted by ± 2.86 degrees for two-beam irradiation.

Figure 1 shows two-dimensional spatial profile of (a) square of the electric field and (b) electron density for (1) one- and (2) two-beam irradiation at 2228 fs , close to the time of peak laser irradiation on the plasma surface. In fig. 1(a-2), apparent interference pattern can be observed with interval of about 10 μm. Considering interference of two plane waves, the interference pattern interval is expressed by $l_{\mathrm{interference}} = \lambda_L/(2\sin\theta)$, where λ_L is the wavelength and θ is the half of angle between two waves, and it is calculated to be 10.0 μm using simulated parameters of λ_L = 1 μm and θ = 2.86 degrees, in agreement with the observed interval. Laser interference generates a periodic intensity pattern at specific points with hole boring occurring at high-intensity irradiation areas, correspondingly generating a periodic surface structure as shown in fig. 1(b-2). As a result, in the case of two-beam irradiation, number of generated fast electrons increases because of high laser absorption due to the surface structure made by the interference and the locally higher intensity causes higher effective temperature as shown in fig. 2.

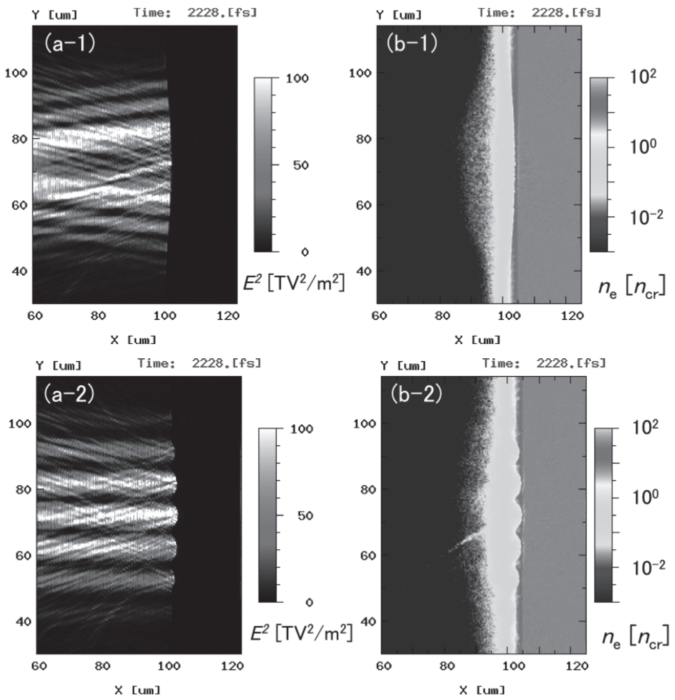

Fig. 1. 2-D spatial profile of (a) square of electric field and (b) electron density in the cases of (1) one-beam and (2) two-beam irradiation at 2228 fs, namely around the time of laser peak intensity.

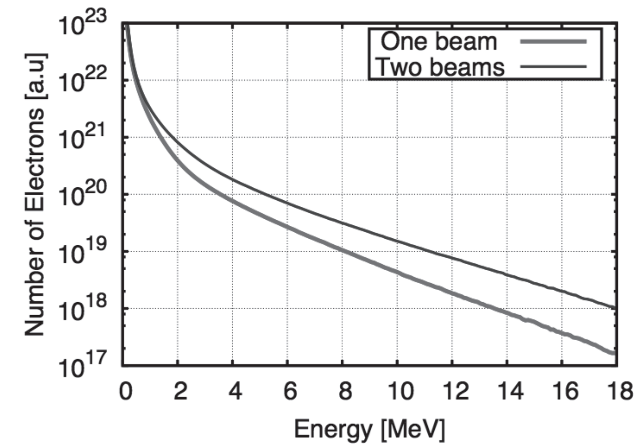

Fig. 2. Time-integrated energy spectra of generated fast electrons

1) Kemp, A. J. and Divol, L. : Phys. Rev.Lett. **109** (2012) 195005.