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LATERAL TRANSPORT OF FAST ELECTRONS IN HIGH-INTENSITY LASER-PLASMA INTERACTIONS

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Abstract Lateral fast electron transport in intense laser-plasma interactions has been studied. The lateral electron transport is identified by multipeak distributions of the fast electrons emitted along the front and rear target surfaces. PIC simulations shown that this is induced by the spontaneous electrostatic and magnetic fields. The fields at the target surface can be used to confine and guide fast electron propagation with shaped targets.

Transport of fast electrons in the interaction of ultrashort high-intensity laser pulses with targets have attracted great interests due to their potential applications in fast ignition scheme for inertial confined fusion[1]. Besides the longitudinal transport into the high density plasma regions, lateral transport of hot electrons along target surfaces has also identified by observation of x-ray[2,3] and ion emissions [4]. Such surface transport has been used to explain why a re-entry cone target can increase the neutron yield by three orders than that from a plane target [5,6,7]. In our previous experiments we have observed a distinct fast electron beam emitted along the target surface for large laser incidence angles [8]. In this paper, we have demonstrated that the fast electron beams can also be emitted along the target surface due to the lateral transport for moderate incidence angles. This transport and the spontaneous electrostatic and magnetic fields can be used to guide fast electron propagation with shaped targeted.

The experiments were carried out using the Xtreme Light II (XL-II) laser system at the Institute of Physics, Chinese Academy of Sciences. The laser system can produce a linearly polarized pulse with energy up to 500 mJ in a duration of 30 fs at a wavelength of 800 nm. The amplified spontaneous emission (ASE) was measured to be ~10^{-5} of the peak intensity of

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the laser pulse. The laser pulses were focused by an f/3 off-axis parabolic mirror on targets, with a focal spot size of 10 μm in diameter. Planar, cylindrical, and wedged copper targets were used, respectively. Spatial distributions of the fast electrons were measured by an array of imaging plate (IP) stacks.

Figure 1 (a) shows a typical angular distribution of the fast electrons. The laser incidence angle was 45°, and the intensity on target was 1.0×10^{18} W/cm^2. One can see that besides the strong emissions in the normal direction (numbered as 5), four collimated fast electron beams along the front and rear target surfaces are presented (numbered as 1-4).The numbers of fast electrons in the front surface are obviously larger than those in the rear side. Group 5 dominates over other emissions, which occupies more than 80% of total counts. Group 1 and Group 4 take about 4% of total, while Group 2 and Group3 about 1%.

We find that even for the incidence angle as small as 22.5°, similar phenomenon of simultaneous four groups of fast electron beams along the target surfaces was also observed. The only difference is that the fractions of each group of fast electrons changes.

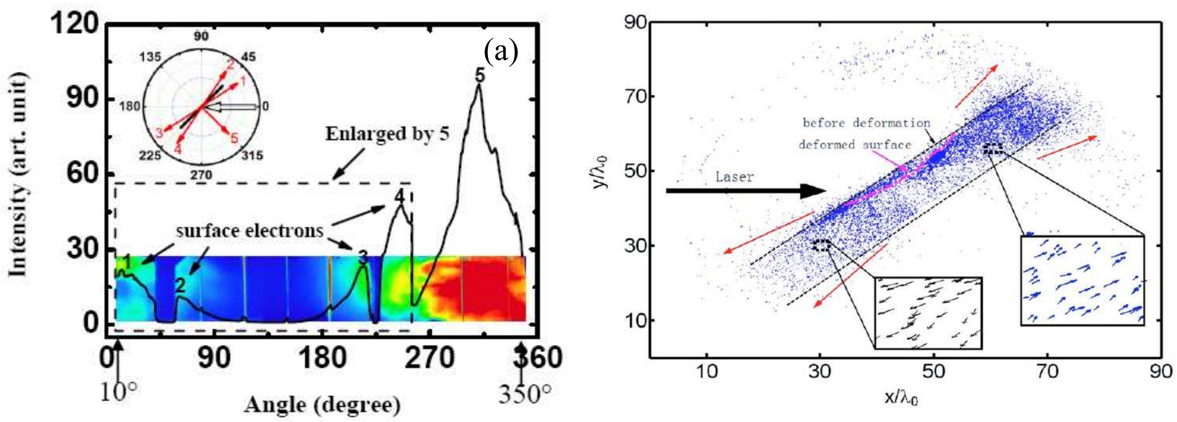

Figure 1. (a) Angular distribution of fast electrons with energies larger than 900 *keV* for a plastic target of 30 *μm* thickness. The inset shows the laser incidence direction and each group of fast electron beams (marked by red numbered arrows). (b) Phase space distribution of fast electrons at the 100 T_0.

To understand the measured multi-peak emissions of fast electrons along target surfaces, two-dimensional (2D) particle-in-cell (PIC) simulations are conducted. The laser conditions are similar with the experimental. The density of the plasma increases exponentially from 0.1 n_c to 2 n_c in 6 λ_0, then keeps to be constant for a length of 5 λ_0, where n_c is the critical density of plasma, λ_0 is the laser wavelength in vacuum. The pulse duration is 30 T_0 and diameter of the laser focal spot is 10 λ_0, where T_0 is the laser oscillation period. The phase-space distributions of the fast electrons at the 100 T_0 are shown in Fig. 1 (b). One can see a large number of fast electrons inside the target are transported laterally away from the focus region. To see the electron movement clearly, a small part of the phase-space enlarged is shown in the inset, where the arrows indicate the movement directions of the fast electrons. Four groups of fast electrons out of the target are observed along the target surfaces, as shown by red arrows, which is consistent with the experimental results. Our simulations show that strong quasistatic electrical and magnetic fields are induced around the target surface. The electrical fields in the front and rear of target surfaces are both unipolar, which is negative in the front and positive in the rear of target, while the magnetic fields are bi-polar structures both in the front and rear of target. This electrical field is formed by charge separation when fast electrons escape from the target and ions with large mass are left unmoved. The quasistatic magnetic field is generated self-consistently by the surface electrons as supposed by Nakamura [6]. It is the fields that lead to the fast electron lateral transport.

Strong electrostatic or magnetic fields induced at the target surfaces can be applied to guide fast electron propagation. Figure 2 shows the angular distributions of the E>300 keV fast electrons for the shaped targets. For the 65 μm thick copper planar target, the fast electron emission peaks between the laser propagation and target normal direction. However, for the 25°wedged and the cylindrical target in a diameter of 100 μm, a large number of electrons are emitted in the tip and the cylinder axis direction. More details can be found in references 9 and 10.

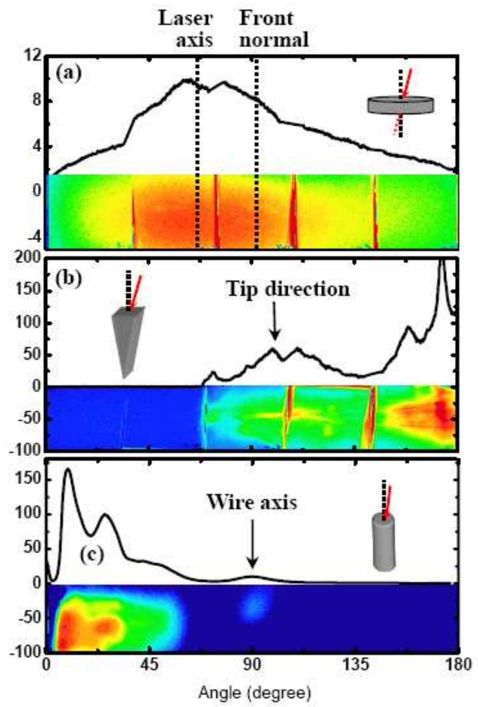

Figure 2. Angular distributions of the E>300 keV fast electrons for a planar (a), 25° wedged (b), cylindrical (c) targets, respectively. The insets illustrate the target shape and orientation.

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