Fast Electron Beams along Target Surface Irradiated by Intense Laser Pulses

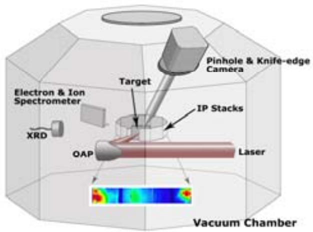
1. Self-organization of fast electron transport

Inside plasmas or solid targets, huge spontaneous electromagnetic fields are induced in the transport of a fast electron beam with a current > Alfven limit:

- Electrostatic fields: self-inhibition of the electron beam (energy loss)
- Static magnetic fields: self-collimation of the electron beam
- Instabilities: self-organized filamentation

At target surfaces:
We have demonstrated that fast electrons can be self-organized into novel jets along the target surface due to the confinement of the surface quasistatic electromagnetic fields induced by the fast electrons themselves.

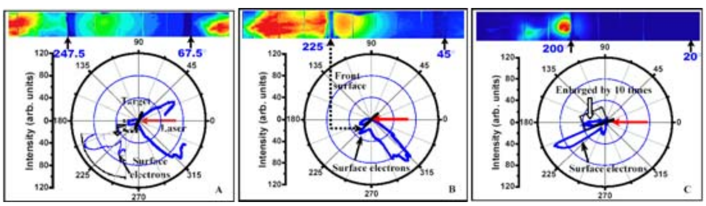
2. Experiment



Xtreme Light-II (XL-II) Laser :
0.6 J, 30 fs,800 nm, 20TW
Focus: 10-15μ (f/3.5)
Diagnostic:
Energy spectra and angular distributions of fast electrons, X-ray images

3. Angular distributions of hot electrons .vs. incident angles

Angular distributions for three incidence angles of 22.5° (A), 45° (B) and 70° (C). Conditions: Electron energies > 300 keV, p-polarized, I~1-2×10^{18} W/cm^2 .



A novel fast electron jet emitted along the front target surface (hereafter referred to as "surface fast electron") is observed. The jet becomes stronger and stronger with the increase of the laser incident angles.

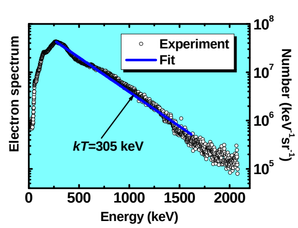
4. Fractions of the surface electrons and transmitted ones

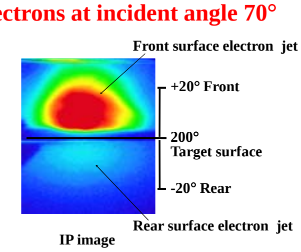
The fractions of the fast electrons along the front surface (f_{se}) and the fractions of the transmitted electrons (f_{te}) to the total electrons of 2π in the incident plane

Incident angle	f_{se}	f_{te}
22.5°	<6%	20%–28%
45°	17%–28%	8%–16%
60°	40%–45%	<6%
70°	50%–65%	<5%

The ratio of the front surface electrons increases with the incidence angle, while the transmitted fraction is on the contrary.

5. Characteristic of the surface electrons at incident angle 70°





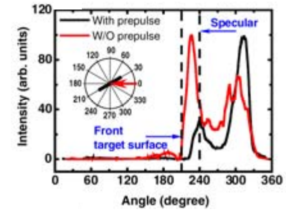
Typical spectra,kT~300 keV

Typical pattern,Cone angle <15° (FWHM).

6. Necessary conditions for the surface electron jets

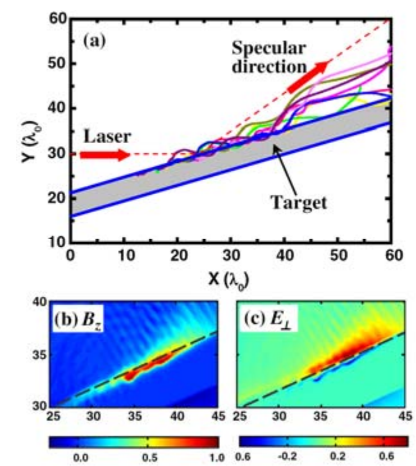
S-polarized and circularly-polarized laser pulses, different target materials (CH and Al targets), were also tried for different laser incident angles in the experiments, respectively. The results were similar. However, no surface electrons were observed when the scale length of the plasma is large.

θ= 60°, without (red), and with (black) a preplasma produced by a 200 ps laser pulse at 0.5ns ahead of the main pulse. →



Steep electron density gradients are necessary to generate the surface electron jets.

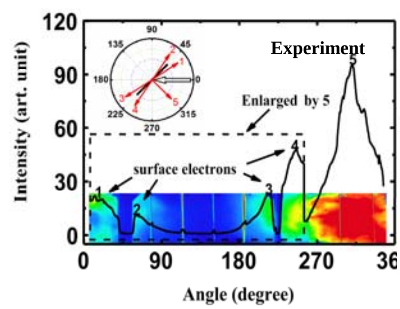
7. Formation of the surface fast electron jet (2D PIC simulations)



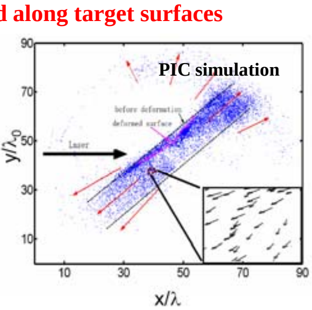
Laser: p-polarized,
2-5x10^{18}W/cm^2, θ=70° ,
focus diameter d=10λ_0;
Plasma slab: 8 n_c, 4λ_0 thick,
sharp boundary

PIC simulations show that the fast electrons move along the target surface in an oscillating form due to the confinement of the surface magnetic fields and electric fields.

8. For moderate laser incidence angles fast electrons are still emitted along target surfaces



θ=45°, E> 900 keV, 30 μm CH target



Four groups of fast electrons along the target surfaces.

Large number of electrons inside the target are transported laterally away from the focus.

The target surface is deformed.

9. Summary

1. We present experimental evidence that fast electrons can be self-organized at the front target surface, forming novel fast electron jets emitted along the target surface (lateral electron transport).
2. Two-dimensional PIC simulations reveal clearly that the fast electron jets are formed due to confinement of the surface quasistatic electromagnetic fields induced by the fast electrons themselves.
3. Our results suggest that the cone target in fast ignition experiments can guide fast electrons to the compressed fuel region, and an easy way to obtain a well collimated, highly directional and stable laser-based fast electron source with ultrashort laser pulses.

References:
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