

Electron Laser Wakefield Acceleration With The CILEX Facility

A PIC simulation based investigation

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The CILEX facility, home of the APOLLO-10P laser

- Currently under construction
- Located a few km away from Paris
- Surrounded by many “satellite laser facilities” (10^2 to 10^3 TW)
- Will be open to the scientific community
(mid 2015 secondary beam, 2017 full facility)
- Large variety of scientific applications

APOLLO-10P

- 10 PW
- UHI up to 10^{24} W/cm²
- 2 beams
- Main beam F1 :
15 fs < pulse < few ps / 150 J
- Secondary beam F2 :
15 fs < pulse < few ps / 15 J



laboratoire thématique appliquée



Brigitte Cros presentation, tomorrow 11h40.

For today's presentation, we restrict ourselves to

Laser Energy

$$U = 15 \text{ J}$$

Pulse Length

$$\tau = 15 \text{ fs}$$

Varying quantities are

- Spot size $r_0 = 8.5$ or $20 \mu\text{m}$
- Corresponding a_0 between 5 and 20
- Densities between 7×10^{17} and 3×10^{19} particles cm^{-3}

A. Lifschitz et. al. *Particle-in-Cell modelling of laser-plasma interaction using Fourier decomposition. JCP, 2009.*

Currently maintained by LOA and CEA. (Big thanks to X. Davoine, A. Lifschitz, R. Lehe)

Numerical parameters

- 4800×512 cells
- $dx = 0.125$, $dy = 1.5 [c/\omega_0]$
- Domain $\simeq 75 \times 95 \mu m$
- $dt = 0.12 [1/\omega_0]$
- 50 particles per cell

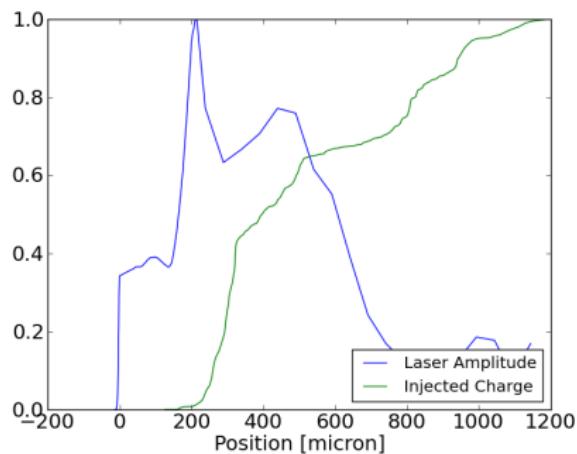
Laser Wakefield Electron Acceleration

Scenario 1 : high intensity, high density, short pulse

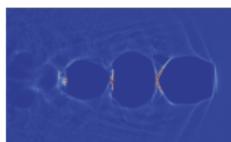
Parameters

$$a_0 = 20, r_0 = 8.5 \mu m, P = 1 PW, n_e = 3.13 \times 10^{19} cm^{-3}$$

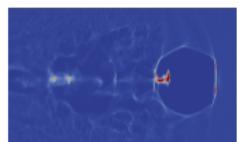
Pulse is matched to bubble size $r_{\text{bubble}} \simeq \frac{2\sqrt{a_0}c}{\omega_p} \simeq r_0$



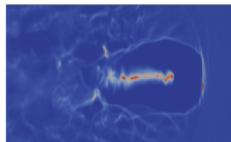
$x = 200 \mu m$



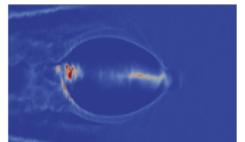
$x = 250 \mu m$



$x = 650 \mu m$



$x = 1050 \mu m$

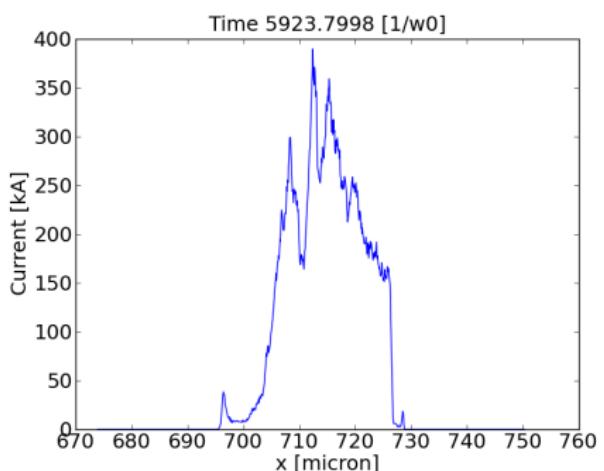


Pulse evolution

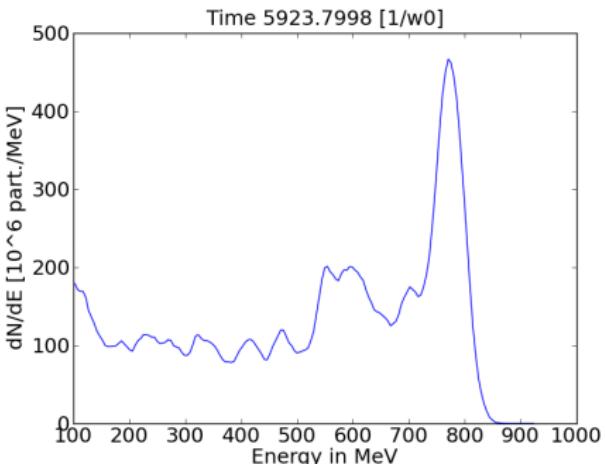
Amplitude of the transverse component of the electric field

Laser is almost fully depleted after 0.8 mm of propagation.

Energy and current

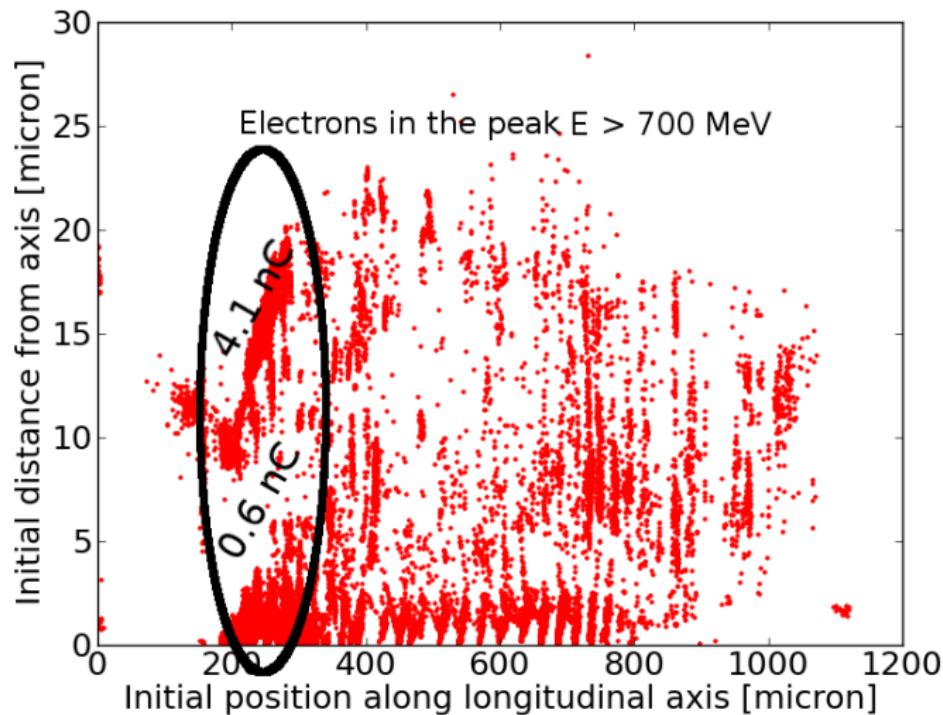


Current profile at $x \simeq 0.75$ mm.
Bunch length is around 30 microns.



Electron distribution function at $x \simeq 0.75$ mm.
Charge in the peak above 700 MeV is
approximately 4.7 nC.
20% efficiency ??

Collection volume



Self-driven regime

Phase space

Self-driven regime

Physical space

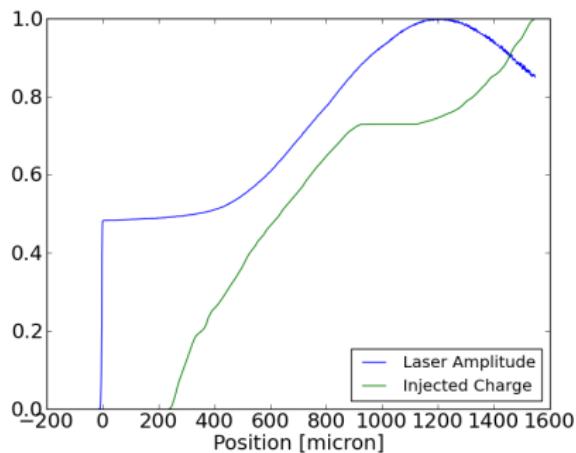
Laser Wakefield Electron Acceleration

Scenario 2 : medium intensity, medium density, short pulse

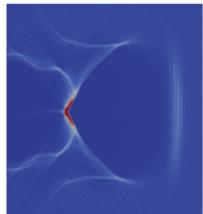
Parameters

$$a_0 = 8.49, r_0 = 20 \mu m, P = 1 PW, n_e = 2.4 \times 10^{18} cm^{-3}$$

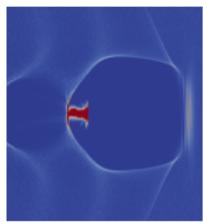
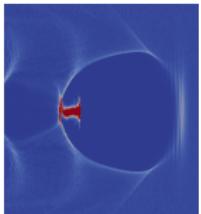
Pulse is matched to bubble size $r_{\text{bubble}} \simeq \frac{2\sqrt{a_0}c}{\omega_p} \simeq r_0$



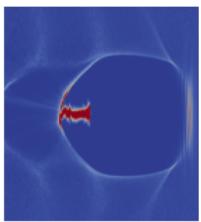
$x = 200 \mu m$



$x = 850 \mu m$

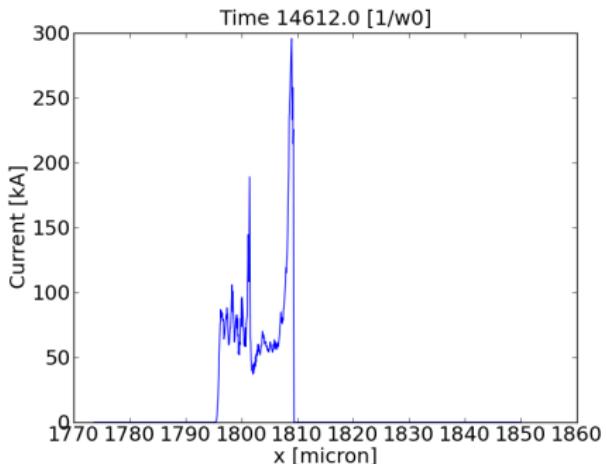


$x = 1150 \mu m$

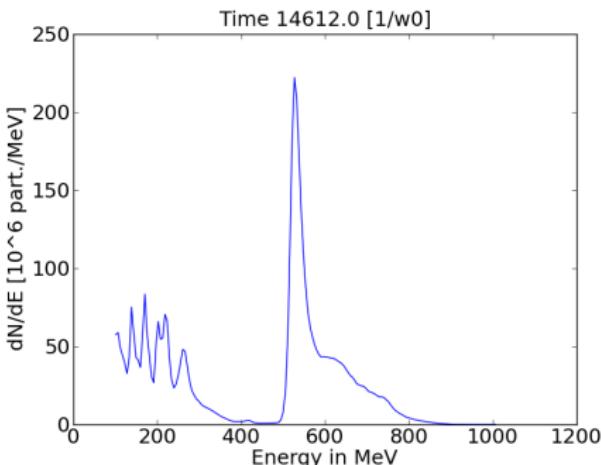


$x = 1500 \mu m$

Energy and current

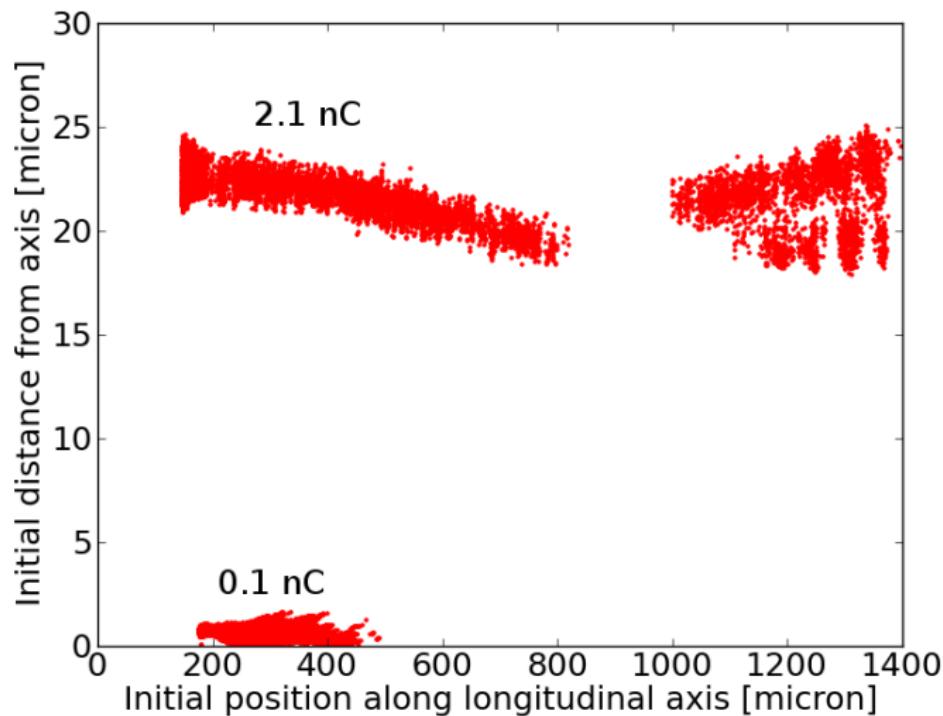


Current profile at $x \simeq 1.8$ mm.
Bunch length is around 12 microns.



Electron distribution function at $x \simeq 1.8$ mm.
Charge in the peak above 450 MeV is
approximately 2.2 nC.
Efficiency so far is around 6 % but the
propagation is not finished.

Collection volume



Conclusions

- There is a correlation between injection and bubble evolution
- Apparently, 2 different injection mechanisms take place
- Injection during laser defocusing looks very chaotic
- Injection during laser focusing at medium density looks clean
- The high intensity, high density does not look promising in terms of beam quality
- Longitudinal injection represents only a small fraction of the total injected charge