Ultra-Short Laser Pulses: A Parameter Study for Laser Wakefield Acceleration

FLANISH D'SOUZA, OLLE LUNDH

Department of Physics, Lund University, P.O. Box 118, SE-22100, Lund, Sweden

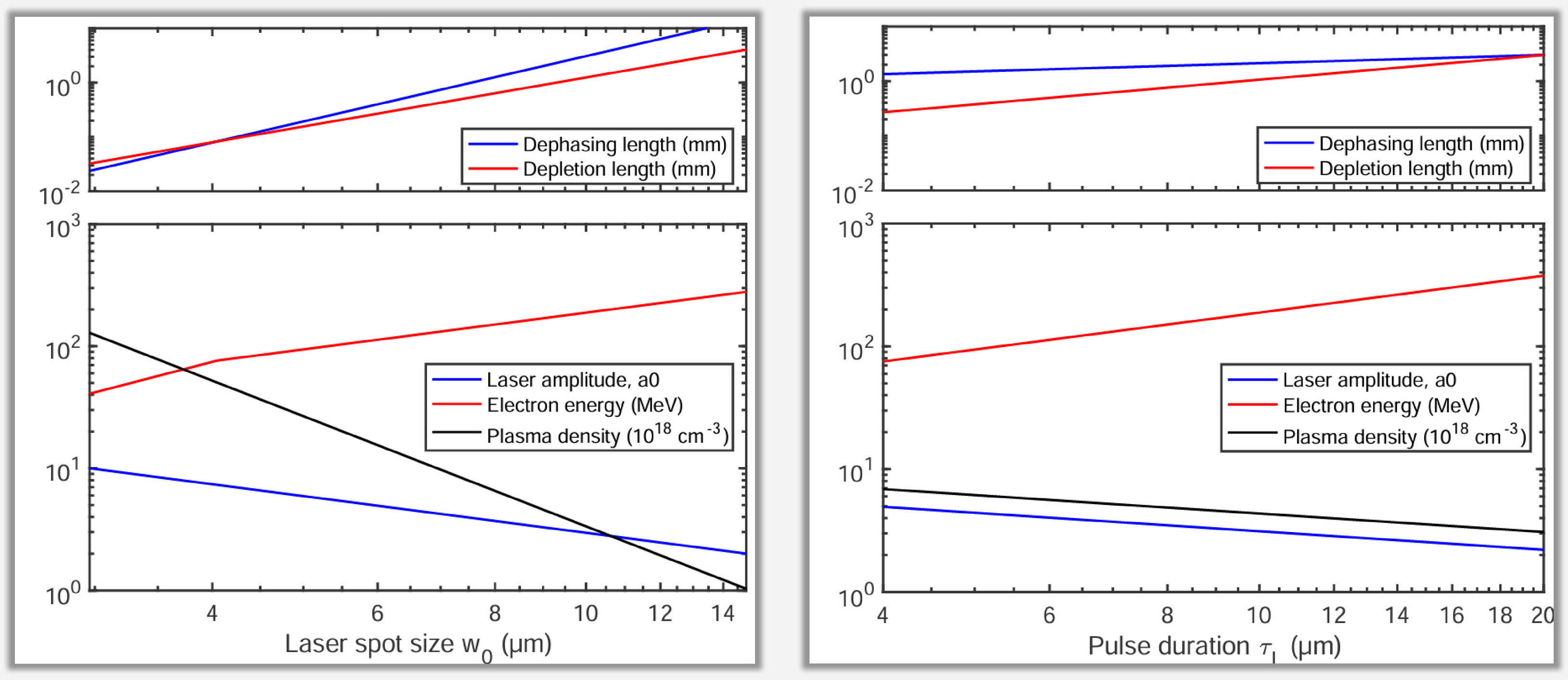
LUND UNIVERSITY

EuPRAXIA Doctoral Network

INTRODUCTION

This work explores the effect of ultrashort laser pulses and tailored plasma density profiles on the injector parameter space, with the aim of optimizing electron injection and acceleration, a step toward meeting EuPRAXIA's requirements. The study focuses on leveraging a new OPCPA based high-energy, short-pulse laser system developed at the Lund Laser Center. The 10 Hz, 250 mJ laser arm, with its ultrashort pulse duration of 9 fs, is particularly suited for exploring laser wakefield acceleration.

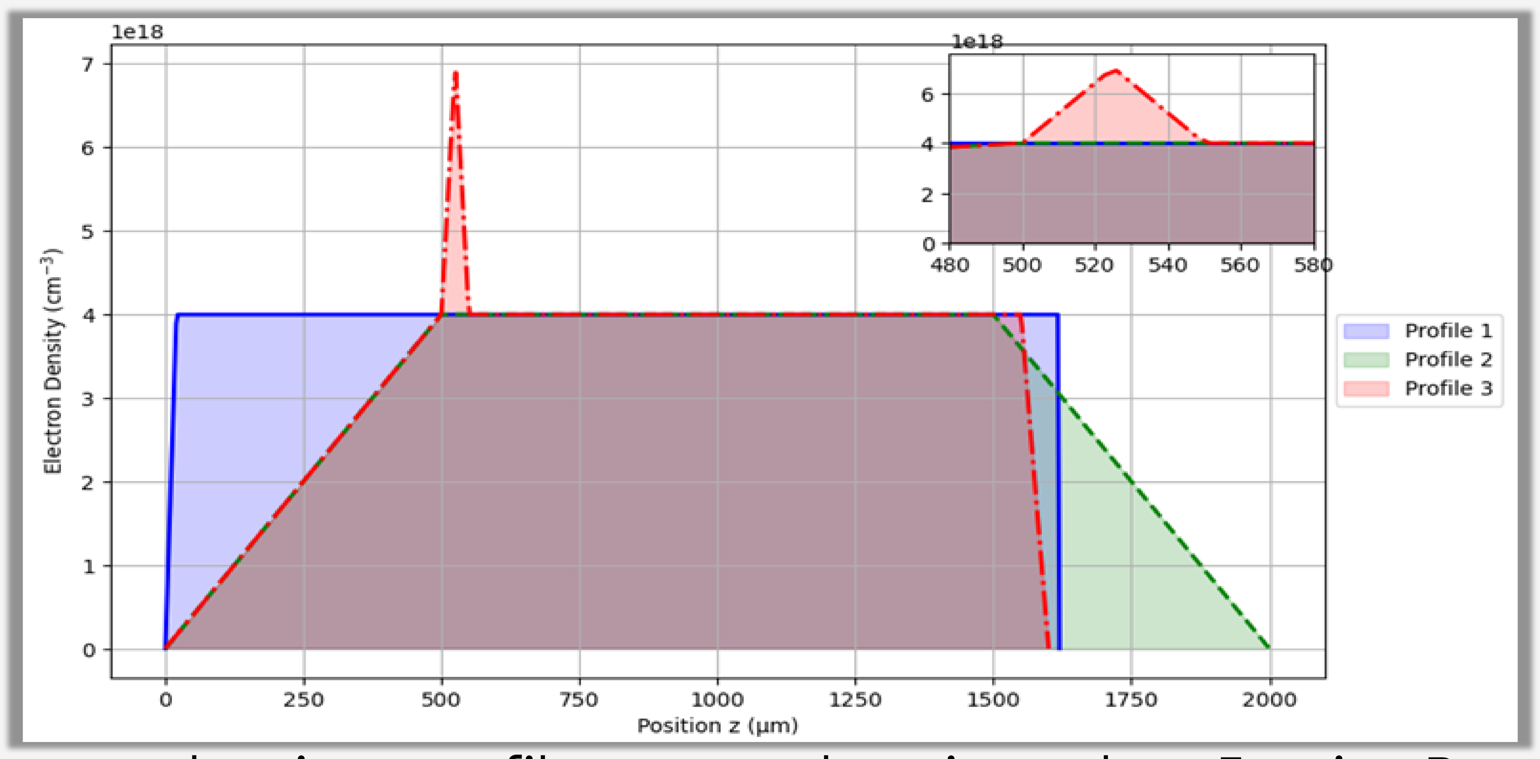
PARAMETERS



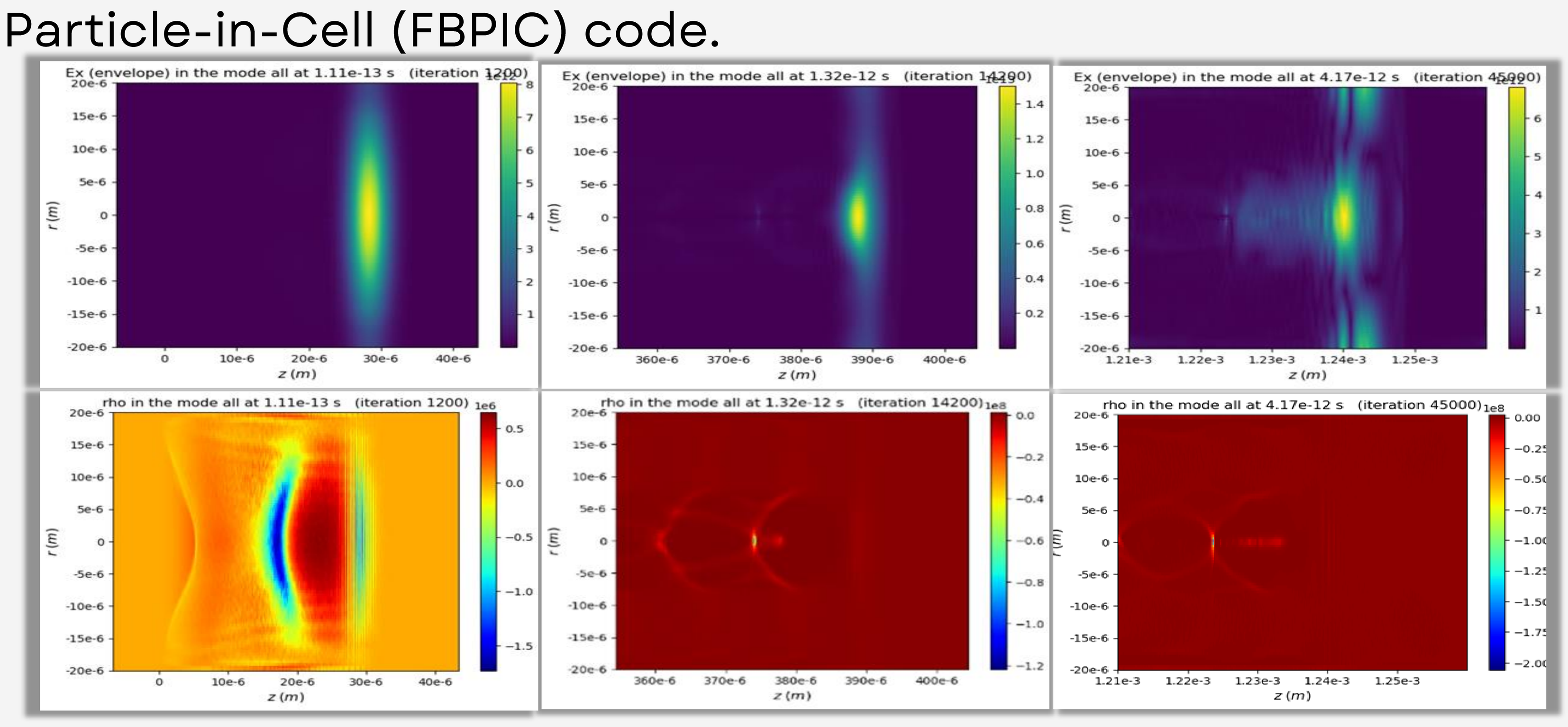
Effect of laser parameters on acceleration length and electron energy at 250 mJ (Lu, Wei, et al 2007) . (a) Shows the effect of varying spot size at fixed pulse duration of 9 fs. (b) Demonstrates the impact of varying pulse duration at a fixed spot size.

a_0	w_0	τ	Target
2	15 μm	9 fs	95%He+5%Ni

DENSITY PROFILES



Plasma density profiles tested using the Fourier-Bessel Particle-in-Cell (FBPIC) code.



Top panels show laser intensity profiles at three time steps, revealing increased pulse concentration along the propagation axis i.e self focusing .

RESULTS AND ANALYSIS

Lower panels display charge density distributions that illustrate the evolving plasma bubble, significantly influencing the accelerating cavity–key for effective electron injection and acceleration.

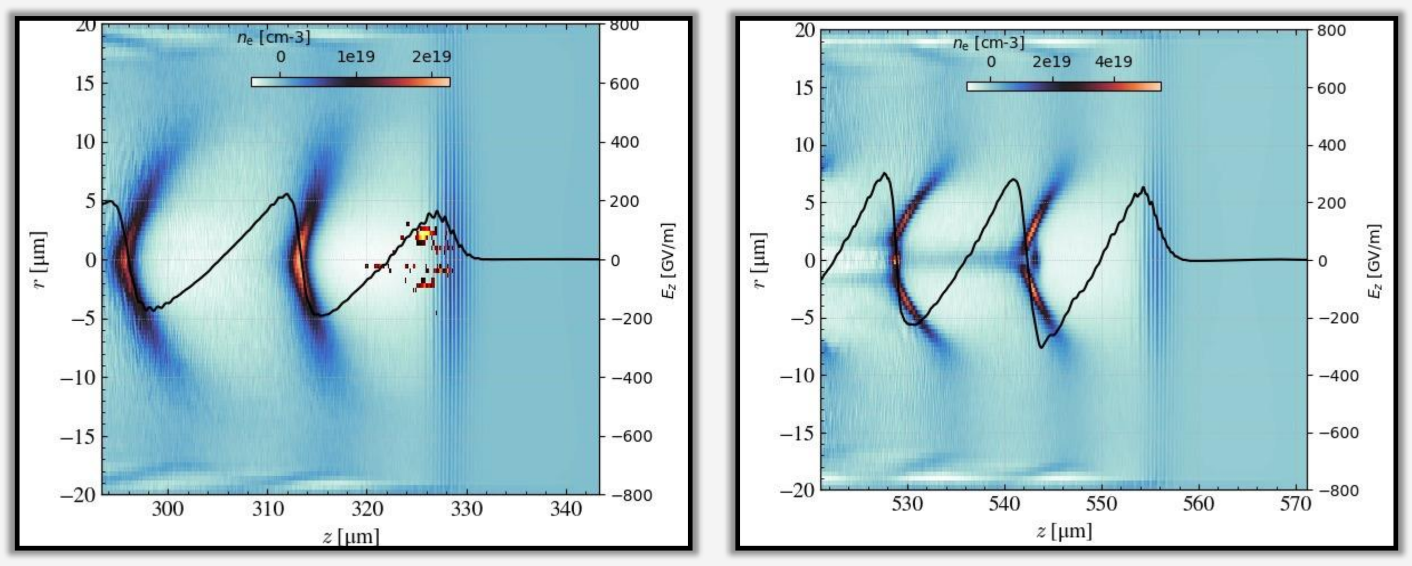
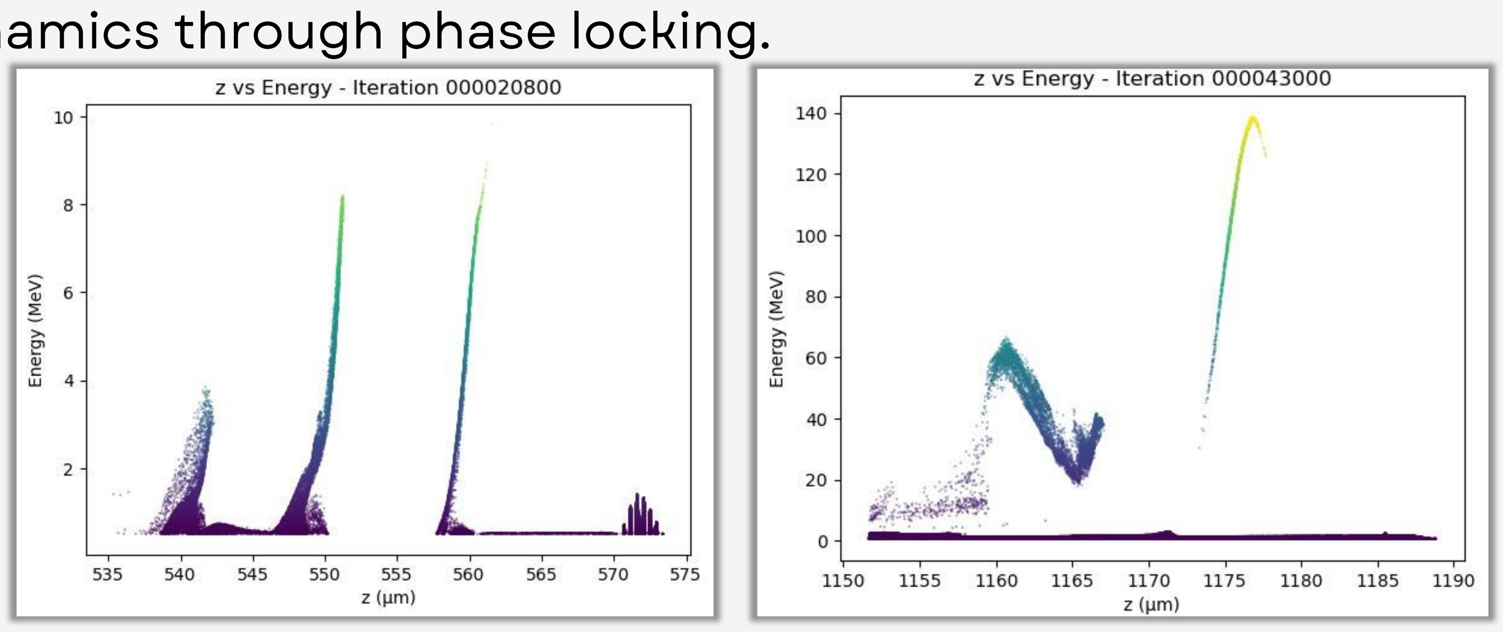
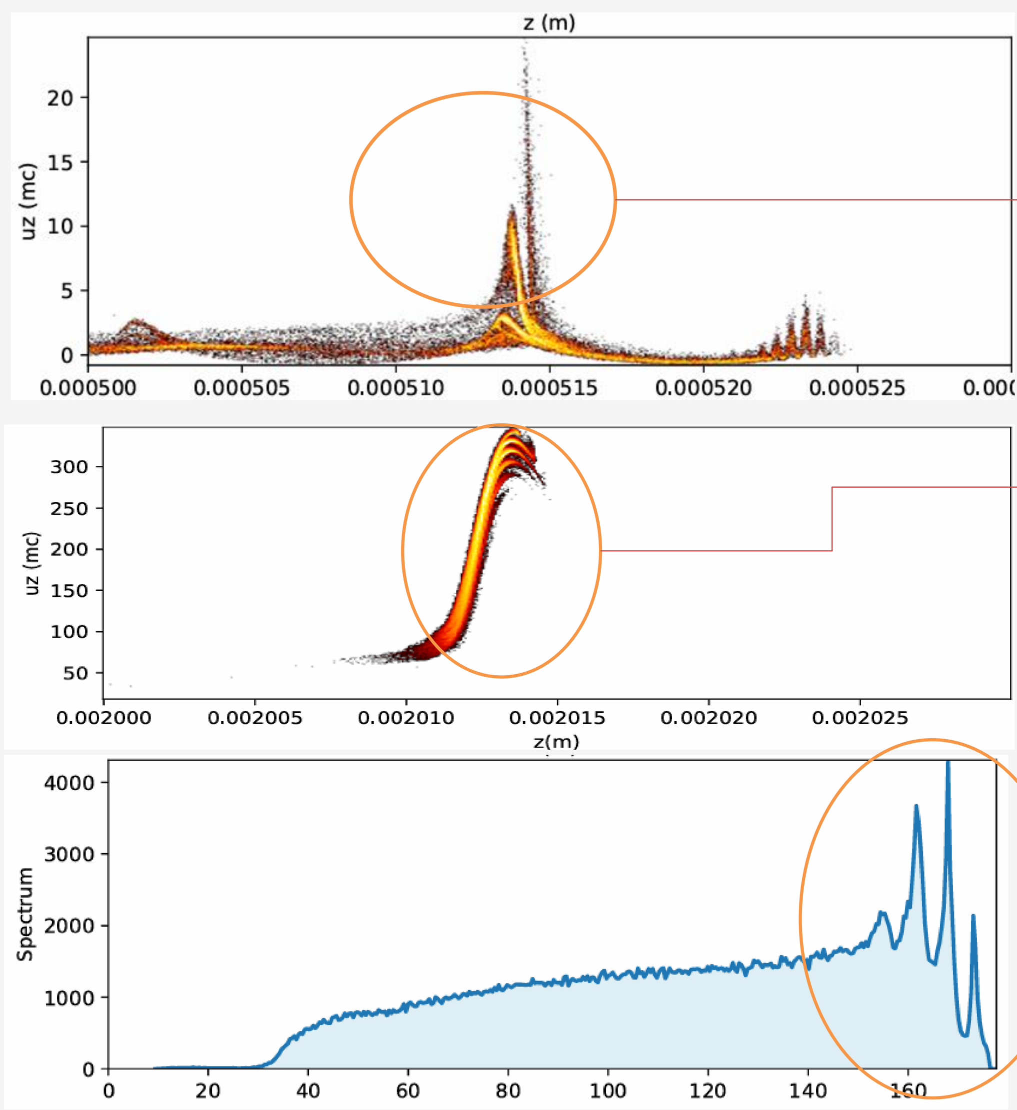


Figure above illustrates the behavior of the plasma bubble as it contracts while propagating through a density up-ramp. This alters the phase velocity and structure of the bubble, significantly impacting electron injection and acceleration dynamics through phase locking.



Figures above show strong perturbations enhanced electron injection via ionization injection and shock-induced mechanisms, leading to multiple injections but also beam loading that reduces the accelerating field effecting energy gain. Despite this, Profile 3 reached up to 150 MeV, demonstrating the potential of density shocks for maximizing energy gain while requiring careful beam quality management.



In addition, another interesting effect that was observed was that of multiple injections by the few cycle laser pulse resulting in an electron spectra with energy modulation!

This was observed experimentally!

EUROPEAN NETWORK FOR NOVEL ACCELERATORS
EuroNNAc4
NPACT supported by EU via I-FAST

This poster presentation has received support from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730 "I.FAST". The study has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101073480 and the UKRI guarantee funds.

iFAST