Review of the doctoral thesis

"New concepts in laser wakefield acceleration"

Written by Dominika Mašlárová

Reviewer: Dr. Gabriele Maria Grittani

The thesis focuses on extending the existing knowledge on laser wakefield acceleration (LWFA), in the field of electron injection inside the accelerating wave, and by proposing novel radiation production schemes based on LWFA.

The author provides an extensive introduction to the subject, by covering each key aspect of LWFA very concisely and clearly. The bibliography referenced in the thesis is of outstanding quality, it is an excellent collection of the key publications in the field, ranging from the initial theoretical studies, to the latest experimental achievements and newest concepts proposed.

After the introduction, the author presents her contribution to the field with her five publications. Three publications are on the problem of the electron injection in the plasma wave. One publication is on the problem of increasing the efficiency of femtosecond x-ray production by betatron radiation inside the plasma wave. The last publication is on the efficient production of positron by colliding a relativistic electron beam with a high intensity laser pulse.

In the publication "Laser wakefield accelerator driven by the super-Gaussian laser beam in the focus", Mašlárová is the first and corresponding author. The work is about a new injection process based on advanced shaping of the laser beam. This new injection process leads to high charge high peak current electron beams, which is actually one of the most studied areas of development of LWFA. This work is based on theoretical modeling and advanced Particle-in-Cell (PIC) computer simulations.

In the publications "Transient Relativistic Plasma Grating to Tailor High-Power Laser Fields, Wakefield Plasma Waves, and Electron Injection", and "Injection of electron beams into two laser wakefields and generation of electron rings" Mašlárová is the second author and had a key contribution for the simulations.

These experimental works are pioneering the interaction of two plasma waves (and electron beams) at acute angle and explain the effects on the plasma tapering and electron injection.

In the publication "Betatron radiation enhancement by a density up-ramp in the bubble regime of LWFA", Mašlárová is the first and corresponding author. This work is about PIC simulations showing an increased efficiency of x-ray production by betatron radiation due to a tailored plasma density profile.

In the publication "Radiation-dominated injection of positrons generated by nonlinear Breit-Wheeler process into a plasma channel", Mašlárová is the first and corresponding author. This work is about computer simulations showing that the interaction of a high intensity laser pulse with a ultra-relativistic electron beam can efficiently generate a positron beam through direct laser acceleration (DLA) in a plasma channel.

I have the following comments and question for the author to discuss:

1. In page 26 the author writes that laser beams with the amplitude envelope given by a Gaussian function are typically used. In current high power laser development, Super-Gaussian laser near field profiles are sometimes used (i.e. L3-HAPLS laser at ELI-Beamlines). How does the focal spot of a Gaussian and Super-Gaussian (in the near field) laser differ?
2. In page 29 the author writes that LWFA are typically based on Joule-class lasers, with repetition rate 1-10 Hz and that the maximum energy is 8 GeV. Recent works showed electron acceleration with >100 J laser (Wang et al., Nature Communications 2013), leading to electron energy up to 10 GeV (Aniculaesei et al., Matter Radiation Extremes 2023). Also, as written by the author later in her thesis, LWFA has been demonstrated with kHz lasers having mJ energy per pulse.
3. Can the scheme of acute angle collision lead to a density tapering beneficial for betatron radiation?

Summarizing all written above, it is to conclude, that the drawbacks outlined by the reviewer do not diminish the importance of the performed work. The Doctoral thesis *"New concepts in laser wakefield acceleration"* written by Dominika Mašlárová complies with the requirements of the Doctoral thesis and I recommend to the committee to accept this thesis.

Prague 17.5.2024

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