CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Electrical Engineering
Department of Physics
Technicka 2, 166 27 Prague 6

Reviewer's Report on PhD thesis

Thesis title:	Novel Schemes in Ion Acceleration Driven by High-Intensity Lasers	
Author:	Ing. Martin Matys	(Czech Technical University in Prague)
Supervisor:	doc. Ing. Jan Pšikal, Ph.D.	(CTU; ELI ERIC)
Supervisor specialist:	prof. Sergei V. Bulanov, Ph.D.	(ELI ERIC)

Martin Matys' PhD thesis deals with the acceleration of ions by the interaction of high-intensity lasers with matter. The subject of the thesis is highly topical due to widespread use of high-energy ion beams in fundamental research (plasma and nuclear physics, materials science) and many promising applications (hadron therapy, nuclear medicine, cargo inspection). Martin Matys contribution to this field lies mainly in particle-in-cell simulations of laser-driven ion acceleration through new acceleration regimes and with advanced solid targets. He complemented his computational results with subsequent analysis, theoretical explanations, and visualisation of large amounts of data. The PhD thesis was carried out within the research activities of two research groups, namely the Computational Physics Group at the Czech Technical University in Prague (prof. Limpouch, doc. Klimo, and doc. Pšikal) and the team at the Extreme Light Infrastructure ERIC (prof. Bulanov). As a result, Martin Matys' activities focused mainly on simulations of the laser interaction at high intensities, which are anticipated to be achieved at ELI Beamlines and other high-power laser facilities that will be available in the near future.

The thesis was submitted as a collection of 5 author's papers, appropriately accompanied by an integrating text: Chapter 1 describes state of the art and the author's contribution to the collaborative research and selected papers. Chapter 2 presents a basic theoretical background that is well related to the topic of the thesis and to the content of the selected articles. Chapter 3 gives a brief overview of the methods used. In particular, it describes the particle-in-cell method and numerical schemes for the calculation of charged-particle motion and electromagnetic-field quantities. Chapter 4 represents the central part of the thesis providing a logical synthesis of the selected papers and highlighting the main results obtained by the author. Chapter 5 finally summarises the results and outlines the author's prospects for the research in the near and distant future.

Overall, the thesis is well organised and meets all the requirements expected of a PhD thesis submitted as a collection of articles. The page size of the integrating text is adequate. Nevertheless, I would have expected a more detailed description of the methods used and a more elaborate outlook for the future. However, it is essential that the author's most important original findings are clearly presented in a scientifically sound and logical manner. Although the selected articles were written under different circumstances and have different topics, the author has managed to combine and integrate them well into the thesis. The common feature of three research topics (the study of various acceleration mechanisms, the use of advanced targets, shaping of the laser pulse profile in time and space) was the optimisation of ion beams accelerated by high-intensity lasers.

The thesis is readable and easy to understand. The accompanying figures are of good quality and show the author's experience with data visualisation. Therefore, it is unfortunate that the overall impression of the thesis is marred by the presence of typing errors, some errors in formulas, and deficiencies in the use of the English language (Czechisms, etc.). These deficiencies do not affect the main results and conclusions presented in the thesis.

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For the defence of the thesis, I have the following questions:

1. The thesis is mostly computational. I understand that simulations were performed for higher laser intensities that will be available in future laser experiments. But have at least some of the numerical simulations been directly compared with experiments? And what was the result?
2. Most of the numerical simulations were done in the EPOCH code. Were there any parts of the code that the PhD student had to modify or improve for his simulations? How computationally intensive in terms of CPU hours were the most demanding numerical simulations?
3. Which ion acceleration mechanism seems to be the most promising for ELI Beamlines? What acceleration mechanisms can be expected for next-generation laser facilities with a laser intensity approaching 10^{25} W/cm^2 ?
4. There are quite a lot of original results in the papers. Which result does the PhD student value the most?

The thesis contains many original results and meets well the requirements set for PhD theses. The research methods were correctly chosen and applied. The main objective of the thesis, i.e., to make a contribution to the field of laser-driven ion acceleration, has been achieved. The author has sufficiently demonstrated, especially in his peer-reviewed articles, his ability to carry out research at a high scientific level and to achieve results that contribute to the field of high-intensity laser interaction with matter. **I highly recommend the thesis for defense with the aim of obtaining a Ph.D. degree.**

Date: 14th April 2023

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