CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF NUCLEAR SCIENCES AND PHYSICAL ENGINEERING

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Review of the PhD thesis entitled:

"Laser Ion Acceleration: Theory and Simulation"

by the thesis supervisor **doc. Ing. Jan Pšikal, Ph.D.**

Author:	**Ing. Martina Greplová Žáková**
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PhD thesis and the work of the author

The content of the thesis is a result of doctoral study and research at the Department of Physical Electronics of the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague and at the Department of Ion Acceleration and Applications of High Energy Particles of ELI Beamlines Centre belonging to the Institute of Physics of the Czech Academy of Sciences. Laser-driven ion acceleration is investigated worldwide for more than twenty years from the first demonstration of accelerated protons with energies of a few tens of MeV from a thin foil towards advanced acceleration regimes and targets. These new regimes and advanced targets are being developed with the aim to enhance acceleration efficiency and / or to improve various parameters of the accelerated ions. Since the most intense laser pulses focused on the targets are very short (in tens or hundreds of femtoseconds), numerical simulations are indispensable tool for the explanation of various phenomena related to the laser-target interaction and resulting ion acceleration. That is also proved by the work of the author and her main outputs in the thesis based on the analysis of the performed multidimensional particle-in-cell simulations of femtosecond laser pulse interaction with various target designs.

The main novel results of the author described in more detail in the thesis were also published in the scientific paper in Plasma Physics and Controlled Fusion journal. The author also contributed to several other papers in the frame of her work at ELI Beamlines Centre. A lot of

her work has been devoted to other activities related to the popularization of science or funding of the research. For example, Martina was a guest in TV show "Sama doma" speaking about modern research with high-intensity lasers mostly for women on parental leave or she obtained experimental research project entitled Non-destructive methods of monument testing (about 20 million CZK budget for three and a half year) where she became principal investigator. These activities complicated to finish her theoretical PhD thesis in the planned schedule, so it was submitted about two years later. On the other hand, Martina has gained new interesting experiences, above the level of average PhD student.

Description and evaluation of the thesis

The PhD thesis consists of five chapters. The main aim of the thesis "to suggest an innovative design of the target which would lead to the improved features of the laser accelerated ion beam, primarily to the reduction of angular spread of the ions", is described in the introductory part. The first chapter discussed most important terms and plasma parameters used in the thesis, which is followed by the review of laser-driven ion acceleration mechanisms and absorption and transport of laser pulse energy in targets via electrons. The second chapter deals with various phenomena related to laser-driven ion acceleration. It contains, for example, the section devoted to multipole magnetic field which is important for the most innovative part of the thesis in the forth chapter. Before that, the third chapter briefly describes particle-in-cell method and the code EPOCH used by the author for her numerical calculations in the frame of the thesis. Here, I appreciate very useful discussion about numerical parameters which has to be set in the simulations. The largest part of the thesis about already published results complemented with more details follows. Besides the comparison of various target designs, I would highlight the part showing multipole magnetic fields in flat channel-like target and its effect on the divergence of the accelerated ions from the target. According to my knowledge, this effect was discussed for the first time in this configuration. It can be studied only in the case of computationally demanding three-dimensional particle-in-cell simulations. This part contains much more results, some of them (such as partial transmission of the laser pulse through the target) would deserve more detailed study in the future, but they are out of the main scope of the thesis. The fifth chapter shows selected applications of laser driven ion beams mostly related to other work of the author. Last, but not least, some possibilities of the fabrication of the best target design are discussed, although the target has not been really fabricated yet. Finally, summary of the main achieved results is done, which highlights the main contribution of the author in the field.

In my opinion, theoretical part of PhD thesis (Chapters 1-3) provides a solid basis to better understand the authors' results presented in Chapter 4 and it can serve as a good source of summarized theory relevant for other students and researchers in the field. Plenty of references in the thesis offers an opportunity to go further into details for the reader. Some theoretical parts of the thesis would not be necessary to introduce in such details (for example, about electron heating mechanisms and hot electron temperature scaling) as they are not the main subject of the author's further interest, but they can be useful for some readers. In the main part including author's research outputs, there is shown and discussed plenty of numbers and pictures which could divert the reader's attention from the key results. Relatively extensive discussion is devoted to the sheath field shape in the transverse direction (e.g., section 4.7.1.2), even though it is not clear what is the effect of two ion species assumed in the simulation (compared with single ion species). Nevertheless, the main results achieved by the author hugely prevails these possible imperfections.

Summary

PhD thesis submitted by Martina Greplová Žáková has brought sufficient amount of novel interesting results, especially those related to the existence and the role of multipole magnetic fields generated in advanced target designs during laser-driven ion acceleration. These main results were also published by the author of this thesis in a relatively highly impacted scientific journal in the field. The publication record of the author is otherwise not so impressive at the time of the submission of the thesis. Nevertheless, the author also substantially contributed to another paper currently in the review process in Physical Review Letters. Moreover, she is a co-author of other papers in scientific journals and conference proceedings. Therefore, it can be concluded that the candidate proved her ability for independent and original scientific work of a high level and her work fulfills formal requirements for the doctoral dissertation.

I therefore strongly recommend Martina Greplová Žáková for the award of PhD degree subject to the successful oral defense.

In Prague, September 9, 2021 doc. Ing. Jan Pšikal, Ph.D.