FAKULTA JADERNÁ A FYZIKÁLNĚ INŽENÝRSKÁ
ČVUT V PRAZE
Katedra inženýrství pevných látek

Supervisor's Report on Doctoral Thesis

Author:	Ing. **Juraj Sládek**
Title:	**Modification of bandgap materials by ultra-short laser pulses**
Supervisor:	prof. Ing. Zdeněk Bryknar, CSc. Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Solid State engineering
Supervisor specialist:	Dr. Yoann Levy Czech academy of sciences, Institute of physics, HiLASE Centre

Ing. Juraj Sládek started his doctoral studies in the program of Application of Natural Sciences, branch of Physical Engineering, specialization Solid State Engineering at the Department of Solid State Engineering, Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, on March 1, 2018. He successfully completed the study block, which concluded with the Dissertation Discussion (Study on the topic "Modification of bandgap materials") and successfully passed the State Doctoral Examination on June 26, 2020.

During his PhD studies Juraj Sládek dealt with surface and volume modifications of materials with band gap using ultrashort laser pulses, mainly on silicon and glass.

The doctoral thesis reports on the state of the art, methods and main results obtained during the doctoral studies. In addition to the presentation of the characterization techniques used during the PhD, the chapter "Experimental methods" together with some appendices informs about the significant efforts Juraj made during his PhD studies. In particular, regarding the experimental setup combining both the creation of the optical path layout (some of them with in-situ visualization), the integration of the motorized stages, the preparation of the electronics for synchronization and fixation of the motion stage drivers, and the programming both for scripting the irradiation tests

with different parameters and for some data analysis and interpretation.

The first part of the results chapter is mainly concerned with laser-induced damage thresholds (LIDT) of materials, which are essential in laser processing of materials. Instead of a trivial report on damage thresholds, the study reveals surprising features, such as the importance of the angular direction of polarization with respect to the crystalline orientation of Si samples, which is often neglected.

In the second part of the results chapter, the report focuses on silicon and glass surface texturing with emphasis on attempts to obtain regular laser-induced periodic surface structures (LIPSS). The successful generation of regular LIPSS is presented with unexpected but interesting phenomena. For example, not one but several substantially different laser fluence and pulse overlapping modes are identified for which good regularity can be achieved; the generation of low spatial frequency LIPSS bands on silicon forming perpendicular to the scanning direction and on the periphery of individual (spatially Gaussian) laser pulses during scanning; the possibility of obtaining a control LSFL pattern in the imprint of each individual pulse using a cylindrical lens, etc. Juraj Sládek also managed to explain some of the observed effects convincingly by further investigation.

The last part of the results chapter presents experimental investigations concerning the bulk modification of crystalline silicon. The results presented are interesting, although further studies at higher energies and with better laser energy and pointing stability would be needed to obtain comparisons with several band gap materials. This shortcoming is explained by the decision with hierarchy to shift the priorities of Juraj Sladek's PhD studies towards surface texturing, since the laser used for volumetric modification was still under development, which led to many difficulties.

In spite of this, the objectives, revised after variations in the initial topic planed for his PhD, were achieved. Juraj was able to integrate very well into the environment and easily used the various equipment available in the department to work. The significant supportive work of his original supervisor-specialist Dr. Inam Mirza, in the first half of his PhD studies should also be acknowledged, as it allowed Juraj's experimental skills with

ultrashort laser pulse processing to be consolidated and gave rise to several published papers. The ease of Juraj's seamless continuation after a change in topic and leadership circumstances is again a evidence to his perseverance and adaptability. His curiosity and pragmatism are great additional skills for pursuing research and engineering with the advantage of being able to deal with unexpected phenomena that he can observe experimentally. This is probably why his help is very often requested in the Science and Laser Applications Department at the HiLASE Centre and why he has been able to participate in several other studies not directly mentioned in his PhD thesis. He has also shown considerable independence in problem solving and perfect communication. Considering that Juraj Sládek has published 3 papers as first author, 6 as co-author, authored/co-authored 22 conf. contributions, has been a member of the research project research team 5 times and his H-index = 4, he clearly demonstrates the ability to produce high quality, qualified and independent work in the field of physical engineering.

Since all the conditions required by the study regulations are also fulfilled, **I recommend the submitted dissertation of Ing. Juraj Sládek's thesis be accepted for defence.**

Prague on 2.6.2023

prof. Ing. Zdeněk Bryknar, CSc.

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