## Supervisor's review, PhD thesis of Ing. Martin Duda

## „Harmonic frequency generation and nonlinear compression of ultrashort pulses“

The submitted dissertation is a result of the author's three-year doctoral studies at the Department of Physical Electronics, FJFI CTU in Prague, and research carried out at the HiLASE Centre of the Institute of Physics of the CAS in the period of October 2018 - June 2021. The aim of the work was research and development in the field of frequency conversion, shortening, and shaping of ultrashort pulses generated by Yb:YAG thin-disk laser using nonlinear optical phenomena of the $2^{nd}$ order. The thesis is written in English and has a total of 104 pages including all required sections and appendices. It is divided into six chapters.

The thesis has two main objectives. The first one is the development of a nonlinear frequency conversion to $2^{nd}$ harmonic frequency of the Yb:YAG laser Perla B with pulse duration < 2 ps and pulse energy of approximately 6.5mJ. General introduction of frequency conversion issues with focus on a specific case of the Perla B laser is addressed in Chapters 1 and 2. The second objective is to investigate a potential of $2^{nd}$ order nonlinear optical phenomena for further shortening and shaping of picosecond optical pulses with wavelength of 1030 nm into the femtosecond temporal range. In particular, the author's unique contribution to this problem is the use of back-conversion process and controlled tilting of the ultrashort pulse fronts to maximize the spectral bandwidth of the pulse being converted to the $2^{nd}$ harmonic frequency. In this way, spectral bandwidth of 4.5 nm was achieved at a wavelength of 515 nm, corresponding to transform-limited pulses shorter than 100 fs. The author investigated the above mentioned problem in a very comprehensive way. As part of the optimization, he systematically performed a larger number of simulations in the SNLO simulation software (Chapter 3) and experimentally implemented the most promising ones. Chapter 4 summarizes the experiments performed using pulse shaping by back-conversion of the radiation to 1030 nm, while Chapter 5 describes a much more promising shaping using the tilt of the laser pulse fronts by means of a diffraction grating. The original results obtained and a number of interesting design details are valuable for realization of similar schemes on other laser systems or different wavelengths.

The author has demonstrated an excellent knowledge of lasers and nonlinear optics, as well as the ability to perform high quality numerical simulations. The developed procedure with wavefront tilting by a diffraction grating is also unique worldwide. This is evidenced by the successful publication of the problem in the Journal of Optical Society of America B. In addition to the above-mentioned work, several scientific papers were published as a part of the dissertation. Successes of the student in the field of frequency conversion of picosecond optical pulses were also supported by the author's intensive collaboration with other members of the ALD dept. at the HiLASE centre, especially with colleagues in the nonlinear optics and thin-disk laser development teams. The author's work is pioneering in this approach to pulse shaping techniques and has inspired further development of thin-disk lasers and their harmonic conversion within the HiLASE centre.

In addition to his own work on pulse shortening, the author has also actively collaborated in the design and construction of frequency conversion to $2^{nd}$, $3^{rd}$ and $4^{th}$ harmonic frequencies on other thin-disk lasers within the HiLASE Centre. With the active contribution of the author, a number of interesting user experiments have also been carried out on the Perla B laser. Most of them are related to new approaches to laser micromachining and their results have also been published. For example, one of the most important ones is a novel multi-beam machining of material using 784 beams at 515 nm simultaneously.

The author also passed an overseas internship in Japan at the National Institute for Fusion Science near Nagoya, where he collaborated on measurement of the Verdet constant of new types of magneto-optical materials. The experiment was finished by an impacted paper as well. The author also participated on investigation of several tasks supported from the EU funding program Horizon 2020, cohesion funding of the EU and the MŠMT OP VVV, and tasks of contracted research at the HiLASE centre of the Institute of Physics.

During his PhD study period, the author has demonstrated, among others, purposefulness, skill and precision in designing and execution of experiments. He also demonstrated ability to integrate state-of-the-art information technology and automation to experiments. As mentioned above, all reached results were published in impacted journals, presented at international conferences, and were accepted by international scientific community. The dissertation thesis has excellent formating and graphical design, and can very well serve as a textbook for other undergraduate and postgraduate students.

It can be clearly concluded that the results correspond to the set objectives in the form, methodology, content, scientific achievemnets, contribution to potential industrial use, and conditions given by the law 111/1998 §47 for PhD theses. Therefore I strongly recommend to accept this PhD thesis to defence.

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Supervisor