IOMT INSTITUTE OF OPTICAL MATERIALS AND TECHNOLOGIES "ACAD. J. MALINOWSKI"
BULGARIAN ACADEMY OF SCIENCES
ИНСТИТУТ ПО ОПТИЧЕСКИ МАТЕРИАЛИ И ТЕХНОЛОГИИ "АКАД. Й. МАЛИНОВСКИ"
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OPINION

on the PhD dissertation for awarding the educational and scientific degree "Doctor of Philosophy" in higher education area 4. Natural Sciences, Mathematics and Computing, professional field 4.1 Physical sciences, doctoral program "Physics of wave processes"

PhD candidate: Mikhail Andreevich Levchenko, Institute of Optical Materials and Technologies "Acad. J Malinowski", Bulgarian Academy of Sciences

Scientific supervisors: Prof. Elena Stoykova, DSc; Assoc. Prof. Violeta Madjarova, PhD

Dissertation title: **"Analysis and compression of dynamic speckle"**

Member of the scientific jury, appointed by order № RD-15901/20.12.2024 of the Director of IOMT-BAS. Assoc. Prof. Silvia Emilova Angelova, PhD; Institute of Optical Materials and Technologies "Acad. J Malinowski", Bulgarian Academy of Sciences

I. Biographical information

Mikhail Levchenko graduated with a Bachelor's and Master's degree from the Moscow Power Engineering Institute, Moscow, Russian Federation, in 2015 and 2019, respectively He is enrolled as a PhD student at IOMT in 2021 within the framework of PLENOPTIMA project, the study being joint with the Technical University of Berlin (TUB), Germany

II. General description of the dissertation

The dissertation entitled "Analysis and compression of dynamic speckle" submitted for peer review has a total length of 143 pages and is structured as follows: it consists of a list of abbreviations, an introduction, a literature review (Chapter 1), results and discussion (Chapters 2-4), main contributions, bibliography, list of publications, list of presentations, and list of citations. The thesis is illustrated with 134 figures and 1 table. The bibliography includes 110 references. The literature used is focused on the research problem. The presentation in the dissertation is well structured and logical, supported by extremely rich illustrative material. The dissertation is accompanied by an abstract of 46 pages, which follows its structure and reproduces its content except for the literature review

The literature review introduces the reader to the optical phenomenon "speckle", detailing the theoretical basis of the phenomenon, as well as the dynamic speckle imaging (DSI) technique and various computational algorithms for estimating the activity in the sample. The aim of this dissertation is to contribute to the solution of critical problems of DSI related to the sensitivity of the method and the need to apply efficient algorithms to process large volumes of data. To achieve

this goal, the PhD student formulated a series of research tasks, mainly focused on the analysis of normalization algorithms in DSI to reduce the non-uniform laser illumination of the test object, the analysis of the possibilities to improve the resolution in the spatial and/or time domain, the development of different ways to compress the speckle images, and the testing of the capabilities of a custom-built portable DSA (Dynamic speckle analysis) system for application in the field of non-destructive testing, the use of DSA to detect hidden defects and to characterize high strain rate events.

To solve these precisely formulated problems, theoretical simulations of speckle imaging with symmetric/asymmetric intensity distributions and introduced time variations, as well as experiments (drying of paint and polymers and nondestructive testing of specimens subjected to low and high tensile stress) were conducted using different experimental setups and different test objects. It can be concluded that modern research techniques and approaches have been successfully applied to the research. These methodological approaches quite accurately meet the research objectives and make the achievement of the dissertation goal possible.

III. Main scientific results

The thesis describes a systematic study using DSI, a technique that allows the detection of microscopic motions and structural changes by imaging and analyzing speckle fields formed on the sample surface under illumination with coherent light. Known computational algorithms are used to process the raw data, and modifications of these algorithms are proposed to improve resolution in the spatial and/or temporal domains. Different ways to compress the speckle images in DSA have been investigated. JPEG/JPEG2000, SVD and PCA compression. It is concluded that the compression works well for symmetric/asymmetric speckle intensity distributions and is also suitable for non-uniform illumination with normalized processing. From the results obtained from the processing of synthetic and experimental speckle data, it was found that both JPEG formats (JPEG/JPEG2000) provide high quality activity visualization at relatively high compression ratios. Given the significant saving of computer memory in JPEG/JPEG2000 compression, the distortion of time dependencies was judged to be of secondary importance. On this basis it was recommended to record the input data in JPEG formats when performing dynamic event measurements with DSA in non-laboratory (outdoor) conditions. A new PCA-based temporal compression algorithm has been developed that outperforms JPEG compression results in terms of preserving the quality of the activity map. Portable and low-cost equipment for conducting DSA in non-laboratory conditions has been developed and tested, with raw data collected in compressed format. The feasibility of using DSI (laser speckle photometry, LSP) to detect hidden defects and to characterize high strain rate events has been tested.

IV. Contributions and significance of research

The research described in this dissertation is in the area of wave physics and more specifically in coherent optical metrology As a result of the systematic theoretical and experimental investigation, new solutions for advanced data processing and storage have been proposed and new applications of DSI methods have been developed. The dissertation contains scientific results that are fundamental in nature and contribute to the understanding of the properties of matter and specific phenomena. At the same time, the results have practical significance - there is a possibility of using them to improve methods and technologies used in

practice, as well as to develop new ones. What distinguishes the dissertation is the delicate balance achieved between theory and experiment and the depth of knowledge demonstrated by the PhD student.

The main contributions formulated in the dissertation accurately reflect the scientific results.

V. Assessment of publications and personal contribution of the candidate

The research on the topic of the dissertation has been published in full or in part in 10 scientific papers in full text. There are 4 citations of 3 of the publications related to the dissertation. Of the publications included in the dissertation, 1 is in a Q1 journal, 2 in a Q2 journal. Mikhail Levchenko is first author in 4 of the 10 publications, second author in other 3, which is a clear indicator of his contribution to the research.

VI. Critical remarks and recommendations

The PhD student demonstrates an excellent knowledge of the material in the area of the thesis, including its theoretical foundations. I have no comments and recommendations.

VII. Conclusion

Mikhail Levchenko's dissertation is a focused, well-planned (and qualitatively executed) study in the field of dynamic specle imaging. A large body of material is synthesized into a cogent, well-organized, and effectively argued dissertation. The results achieved represent a significant scientific contribution, which justifies me to give the dissertation a high grade. In accordance with the requirements of TUB under this procedure, I give the dissertation a grade of "very good"

The dissertation fully meets the requirements for the award of the PhD degree. On the basis of the scientific contributions and the significance of the dissertation, I express my positive opinion and propose to the members of the esteemed scientific jury to award the educational and scientific degree "Doctor of Philosophy" in the professional field 4.1 Physical Sciences to Mikhail Andreevich Levchenko.

Sofia
22.02.2025 г.

/Assoc. Prof. Silvia Angelova, PhD/