

## **OPINION**

concerning

dissertation for obtaining the scientific degree "Doctor of Sciences"

in a professional direction 4.1. Physical sciences

under the procedure for defense at the Faculty of Physics of Sofia University "St. Kliment Ohridski "

The review was prepared by: **Prof. DSc Asen Enev Pashov**, Sofia University St. Kliment Ohridski, Faculty of Physics, as a member of the scientific jury according to Order № RD-38-148 / 15.03.2021 of the Rector of Sofia University.

Topic of the dissertation: "**Energy transport in optically-created densely populated organic triplet ensembles**"

Author of the dissertation: **Assoc. Prof. Dr. Stanislav Balushev Balushev**

### **I. General description of the submitted materials**

#### **1. Data on the submitted documents**

The candidate has presented a dissertation, abstract, as well as the mandatory tables for the Faculty of Physics from the Regulations on the terms and conditions for obtaining scientific degrees and holding academic positions at Sofia University "St. Kliment Ohridski ". Curricula vitae, master's and doctoral diplomas, articles, patents and supporting tables are also presented.

The documents submitted by the applicant comply with the requirements of the Law on the Protection of the Rights of Persons with Disabilities and the Regulations on the Terms and Conditions for Acquisition of Scientific Degrees and Occupation of Academic Positions at Sofia University St. Kliment Ohridski.

#### **2. Details of the candidate**

Dr. Balushev graduated from the Faculty of Physics at Sofia University St. Kliment Ohridski in 1990. In 1998 he obtained the educational and scientific degree of Doctor after defending a dissertation on "Phase modulation of light beams. Dark Spatial Solitons" in front of the High Attestation Commission. From 1989 to 1999, Dr. Balushev was an assistant / senior assistant at the Technical University of Sofia, and also worked as a DAAD Fellow at Lambda Physik GmbH, Göttingen and the Institute of Quantum Optics, University of Hannover, after this in the Institute of Experimental Physics, Technical University of Graz, Institute of Applied Physics, University of Karlsruhe.

After defending his doctoral dissertation until his habilitation in 2009, Dr. Balushev worked successively in the Department of Complex Systems, Weizmann Institute of Science (Feinberg Fellowship), Physikalisch-Technisch Bundesanstalt (PTB) (Maria-Curie Fellowship), Max-Planck-Institute for Polymer Research (Leader of the Photophysical Chemistry Group).

In 2009 he won a competition for associate professor at the Department of Optics and Spectroscopy at the Faculty of Physics at Sofia University St. Kliment Ohridski. At the same time, he retained his position at the Max-Planck-Institute for Polymer Research as head of the Photophysical Chemistry group. In 2014-2015, Dr. Balushev again won a Marie Curie Fellowship, but this time as a Senior Fellow.

### **3. General characteristics of the candidate's scientific achievements**

Dr. Balushev's scientific interests are in an extremely broad field of science. They cover quantum electronics (creation of lasers and optimization of their parameters, mixing of frequencies, solitons - nonlinear optics), modern atomic physics (cooling of atoms, coherent population trapping, Bose-Einstein condensate, atomic clocks). Without belittling what has been achieved in these areas, it would not be an exaggeration to say that the candidate's contribution to the field of photophysics and photochemistry is the most significant. The research described in Dr. Balushev's dissertation is in that area. Judging by his autobiography and publications, he started working here in 2001 when he joined the Photophysics group at the Max-Planck Institute in Mainz. Cooperation with the Sony branch in Germany was also important. Financially supported by 12 major research projects (Sony, 7th Framework Program, NSF-Bulgaria, Horizon 2020, etc.), the activity on this topic has led to 58 scientific publications since 2003 (out of a total of 70 in Scopus), cited over 2200 times. (out of a total of 2300 independent citations in Scopus and over 2400 independent citations according to Web of Science). Dr. Balushev's activity is characterized by a strong applied nature, which is evidenced not only by projects funded by industry (Sony), but also 9 international patents.

The scientific publications included in the dissertation work meet the minimum national requirements (under Art. 2b, para. 2 and 3 of ZRASRB) and the additional requirements of Sofia University "St. Kliment Ohridski" for obtaining the scientific degree "Doctor of Sciences". The scientific publications included in the dissertation do not repeat those from previous procedures for acquiring a scientific title and academic position. There is no legally proven plagiarism in the submitted dissertation and abstract.

### **4. Content analysis of the scientific and scientific-applied achievements of the candidate contained in the materials for participation in the competition**

At the heart of most of Dr. Balushev's publications included in the dissertation is the phenomenon of up-conversion, which can be translated descriptively as a process that increases the energy (frequency) of photons. The mechanisms for carrying out this process are numerous (described at the beginning of the dissertation), but essential in the dissertation are those that do not require nonlinear processes, respectively large peak radiation powers, and coherent fields. The ability to increase the energy of photons has long found a number of applications, and if this can be done at low intensities of incoherent light (such as most sources that surround us), the many applications will certainly become innumerable. One of these applications is to change the spectral composition of sunlight and adjust it to the sensitivity of organic photovoltaic systems in order to increase their efficiency.

As already mentioned, Dr. Balushev's research has a strongly applied character. Therefore, their goal is not the principled demonstration of one or another phenomenon (sometimes in idealized conditions), but the study of the phenomena in detail, allowing their application in practice. As an example I will mention the study of the inconsistency of the standard accepted models for describing the delayed fluorescence of p-type (Chapters 2.7 and 8, the term TTA-UC is used in the dissertation), the influence of factors such as the mobility of molecules (Chapter 8), temperature (Chapter 2, Chapter 12), oxygen content (Chapter 10, Chapter 11), etc. As a result of these and other studies, Dr. Balushev formulated rules for the selection (Chapter 3) of organic molecules, especially suitable for the conversion of photon energy. They allowed new molecular systems to be found (contribution P4). One of the activities of the group in which Dr. Balushev works is the organic synthesis of optically active molecules (Chapter 3). In this way the circle of activities is closed - from the theoretically substantiated search for media suitable for energy conversion, their synthesis, performance of physicochemical and photophysical tests and, finally, the implementation of specific scientific and applied projects.

The main problem, at least in the beginning, was to increase the efficiency of photovoltaic devices by converting the red and infrared parts of sunlight into a spectral region where the sensitivity of photovoltaic cells is maximum (Chapter 6). The sensitivity of the processes of energy conversion from temperature is used as an effect that allows to determine the local temperature in environments with very high spatial resolution (Chapter 2.10, patents NP43 and 45). This idea was further developed by introducing up conversion molecules into nanoparticles, which can be used to study the temperature distribution in organic matter and living organisms (Chapter 9). Of course, the problem of the presence of oxygen in living matter, which reduces the efficiency of energy conversion, must be solved here, and several original solutions are proposed in Chapters 10 and 11. As a result, not only the determination of the temperature distribution, but also the oxygen content in the tested media is demonstrated by means of molecular up conversion systems embedded in nanoparticles (Chapter 12).

Dr. Balushev's contributions are summarized at the end of the abstract (P1-P8). They can be related to the enrichment of existing knowledge and application of scientific achievements in practice. The topic is undoubtedly relevant. In about 20 years of work, about 60 publications published by Dr. Balushev have received over 2,300 independent citations (Scopus). Evidence of the relevance and potential significance of the results are international patents, participation in numerous scientific forums as invited speaker, published book chapters. In a table attached to the documents for the competition, Dr. Balushev announces his contributions in some of the publications, they are mainly conducting experiments, analyzing the results. To these contributions one should add the building of a comprehensive vision for conducting the research, development of the topic, finding new applications, as well as seeking funding. Dr. Balushev is a lead researcher (PI) in most projects.

## **5. Critical remarks and recommendations**

The dissertation is voluminous and interdisciplinary. It is written in English and the Abstract is in Bulgarian. Personally for me, reading the latter is difficult. To some extent, I attribute this to the fact that I am not an expert in some of the issues under consideration. But I also think that there are places where the expression could be more accurate, to use fewer foreign terms, to use a more traditional word order for the Bulgarian language.

## **6. Personal impressions of the candidate**

I have known Dr. Balushev since 2009 when he became an associate professor in the Department of Optics and Spectroscopy at the Faculty of Physics. He is an active scientist, with a flair for the new, with a strong applied attitude. At the same time, the experience gained from working in nonlinear optics and atomic physics until 2001, with a predominantly fundamental focus, has not been forgotten and gives depth to Dr. Balushev's more recent research. To this experience I attribute to some extent the success in the new field.

## **7. Conclusion**

After getting acquainted with the presented dissertation, abstract and other materials, and based on the analysis of their significance and the scientific and applied scientific contributions contained in them, I confirm that the scientific achievements meet the requirements of ZRASRB and the Regulations for its application and the relevant Regulations of Sofia University "St. Kliment Ohridski" for obtaining the scientific degree Doctor of Sciences. The candidate satisfies the minimum national requirements in the professional field and no plagiarism has been established in the dissertation, abstract and scientific papers submitted at the competition.

I give my positive assessment of the dissertation.

## **II. OVERALL CONCLUSION**

Based on the above, I recommend the scientific jury to award the scientific degree Doctor of Science to Assoc. Prof. Dr. Stanislav Balushev in the professional field 4.1. Physical sciences.

May 26, 2021

Prepared the review: .....

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