

**REVIEW**  
**Of dissertation work**  
**for obtaining the scientific degree "Doctor of Physical Sciences"**  
**in professional field 4.1 physical sciences, Physics of atoms and molecules**  
**on defense procedure at the Faculty of Physics (FzF)**  
**of Sofia University "St. Kliment Ohridski "(Sofia University)**

The review was prepared by **professor Tsonko Mitev Kolev Doctor of Chemical Sciences**, Institute of Molecular Biology "Roumen Tsanev", Bulgarian Academy of Sciences ., as a member of the scientific jury

According to Order № .ПД, 38-148 / 15.03.2021r. 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 presented materials**

**1. Data on the submitted documents**

*The candidate Assoc. Prof. Dr. Stanislav Balushev presented a dissertation and abstract, as well as the mandatory tables for Physics from the [Regulations on the terms and conditions for obtaining scientific degrees and holding academic positions at Sofia University "St. Kliment Ohridski "](#). There are also a number of other documents (in the form of official notes and certificates from the employer, project manager, funding organization or project assignor, references and feedback, awards and other relevant evidence) supporting the applicant's achievements.*

*Notes and comment on the documents.*

The documents submitted for the defense by the candidate comply with the requirements of the Law on the Protection of Scientific and Technological Research, the [Rules of Procedure](#) and the [Regulations on the Terms and Conditions for Acquisition of Scientific Degrees and Academic Positions at Sofia University "St. Kliment Ohridski "](#) (PURPNSZADSU) .

## 2. Candidate details

*Professional and biographical data about the candidate.*

*Stanislav Balushev Balushev is born on 05.04.1965, Sofia, Bulgaria.*

*He speaks the following languages: Bulgarian (mother tongue), German (fluent), English (fluent), Russian (fluent)*

*Assoc. Prof. Dr. Stanislav Balushev is a member of the Department of Optics and Spectroscopy Faculty of Physics, Sofia University "St. Kliment Ohridski" James Boucher blvd. 5, 1164 Sofia E-mail: [balouche@phys.uni-sofia.bg](mailto:balouche@phys.uni-sofia.bg)*

*<http://optics.phys.uni-sofia.bg/staff/stanislav/Group.html>.*

*Brief biographical data*

*Education:*

*July, 1990 M .Sci. Thesis "Nitrogen laser system generator-amplifier",*

*Faculty of Physics, Sofia University "St. Kliment Ohridski", Sofia, Bulgaria:*

*In October, 1998*

*PhD Dissertation "Phase modulation of light beams. Darkspatial solitons", Faculty of Physics, Sofia University "St. Kliment Ohridski", Sofia, Bulgaria*

*June, 2009 Habilitation*

*Faculty of Physics, Sofia University "St. Kliment Ohridski", Sofia, Bulgaria*

*Positions held in Bulgaria*

*Assistant/Senior Assistant*

*Faculty of German Engineering Training and Industry*

*Management (FaGIOPM) at the Technical University-Sofia, 1000 Sofia, Bulgaria.*

***Positions held abroad***

*July, 1989 - October, 1989 DAAD-Fellowship R&D Division, Lambda Physik GmbH,*

*Hans Bökler str.12, 3400 Göttingen, Germany*

***DAAD-Fellowship*** *July, 1997 - October, 1997*

*Group of Prof. Dr. B. Welleghausen, Project: "Vierwellenmischung in Doppel- $\lambda$ -Konfiguration" Institute of Quantum Optics, University of Hannover, Welfengarten 1 A, 5100 Hannover, Germany*

*January, 1998 - April, 1998*

***Visiting Scientist*** / *Group of Prof. Dr. L. Windholz*

*Project: "Phase dependent coherent population trapping" Institute of Experimental Physics, Technical University of Graz, Petergasse 16, A 8010 Graz, Austria.*

*November, 1998 ÷ January, 1999*

***Visiting Scientist*** / *Group of Prof. Dr. W. Ruppel*

*Institute of Applied Physics, University of Karlsruhe (TH) Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany, April 1999 - March, 2000*

***Feinberg Fellowship***

***Visiting Scientist*** / *Group of Prof. Dr. N. Davidson*

*Project: Feinberg Fellowship*

***Visiting Scientist*** / *Group of Prof. Dr. N. Davidson*

*Project: "Ultrastable master oscillator for Bose-Einstein condensate in Rb"*

Department of Complex Systems, Weizmann Institute of Science  
76100 Rehovot, Israel.

***Maria-Curie Fellowship***

**Visiting Scientist** / Group of Prof. Dr. F. Riehle

*Project: CAUAC - "Cold Atoms and Ultrastabile Atomic Clocks"*

Physikalisch-Technisch Bundesanstalt (PTB) Bundesallee 100  
38116 Braunschweig, Germany

***Leader of the Photophysical Chemistry Group***

AK Prof. G. Wegner / AK Prof. K. Landfester

Max-Planck-Institute for Polymer Research

Ackermannweg 10, 55128 Mainz, Germany.

***Projects, funded of international institutions***

***Maria-Curie Fellowship***

February, 2003-May, 2009

**PI of Grant No. 356:** *"Hybrid Excitons"*, Max-Planck-Society, Germany

February, 2003 - July, 2004

***Grant # 13N8165 :***

***OLAS -Project "Thin Layer Laser Diodes"***, Federal Ministry for Science and Research,  
Germany

***Maria-Curie Fellowship***

***Senior Fellow*** FCFP FRIAS COFUND Fellowship Programme (FP7-MCA #609305)

Freiburg Institute for Advanced Studies (FRIAS),

Albert-Ludwigs-Universität Freiburg,

Albertstraße 19, 79104 Freiburg im Breisgau, Germany.

January, 2001 -March, 2005

***PI of Grant No 3851:***

*"All Optical System for Temperature Sensing"*, SONY International (Europe) GmbH, Germany

***PI of Grant No 356:*** *"Hybrid Excitons"*,

Max-Planck-Society, Germany

***PI of Grant No 0479***

*"Temperature measurements in macroscopic objects"*

SONY International (Europe) GmbH, Germany.

***PI of Grant No 0267***

*"Photon Up-conversion in organic systems"*

SONY International (Europe) GmbH, Germany *"Photon Up-conversion in organic systems"* SONY International (Europe) GmbH, Germany.

May, 2008 -April, 2013

***PI of Grant No. 0483***

*"Temperature measurements and Photon Up-conversion, continuation"*

SONY International (Europe) GmbH, Germany

***PI of 7th FP: Grant No 227127: EphoCell – Project***

*"Smart light collecting system for the efficiency enhancement of solar Cells"*

***PI of Grant RG 02/2-2010***

*"Annihilation Assisted Upconversion in Multicomponent Systems: All-*

*Organic, Flexible and Transparent Multicolour Display”*

Фонд Научни Изследвания, България. Fund Scientific Research, Bulgaria. January 2014- November 2017.

**Grant DFNI E02 / 11: Grant DFNI E02/11: SunStore -Project**

*Molecular solar thermal systems, enhanced by annihilation upconversion* Fund Scientific Research, Bulgaria. November 2016-October 2019.

*PI of Horizon 2020 Grant # 732794: HypoSens-Project Nano-confined photonic system for detection of breast cancer spread to the lymph nodes*

*H2020-ICT-2016-1 /ICT-29-2016; Photonics KET 2016*

April, 2018- March, 2021

*PI of Grant # 3075 (SONY) -NIS, Sofia University*

*“Chromophores, dyes and their combinations for photonic sensing. Applications for cell analysis and imaging”*SONY Europe Ltd., Zweigniederlassung Deutschland November, 2019 -October , 2022

*PI of Grant KII-06-H37/15-06.12.19: SunUp – Project Organic solar energy storage systems optimized by annihilation Upconversion* Fund Scientific Research, Bulgaria. November 2019- October 2022.

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

*The scientific results of the candidate, reflected in the dissertation, are in the field of triplet-triplet annihilation up-conversion. The international cooperation in which Assoc. Prof. Dr. Balushev participates is impressive. The above research stays in leading European and Israeli institutes and universities have contributed to Mr.Balushev scientific growth of him but the main reason is his talent and hard work.*

**ORCID ID** <https://orcid.org/0000-0002-0742-0687>

**H – index** (without self-citations): **25**

**Times Cited** (without self-citations ): **2463**

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

### **4. Characteristics and assessment of the teaching activity of the candidate (if**

**there is a requirement in PURPNSZADSU for this)**

Received national and /or international awards, inclusive and nomination for such

- 1.2014 - 2015 /*Maria-Curie Fellowship, Senior Fellow* /Freiburg Institute for Advanced Studies (FRIAS), Albert-Ludwigs – Universität Freiburg, Germany
- 2.2000-2001/*Maria-Curie Fellowship*/Physikalisch-Technisch Bundesanstalt (PTB) Germany
- 3.1999-2000/*Feinberg Fellowship*/ Department of Complex Systems, Weizmann Institute of Science/Israel
- 4.1997 - 1998 /*OeAD-Fellowship*/Institute of Experimental Physics, Technical University of Graz/Austria
- 5.1995 - 1996 /*DAAD-Fellowship* Institute of Quantum Optics, University of Hannover/Germany
- 6.1989 /*DAAD-Fellowship*, /R&D Division, Lambda Physik GmbH/Germany

The number of successfully defended doctoral students - 4.

Management and / or participation in national and international scientific networks, projects and programs.

1. 01.11.2016 - 31.10.2019 / ICT-29-2016, RIA, Horizon 2020, EU / “*Nano-confined photonic system for detection of breast cancer spread to the lymph nodes*” # 732794 (*HypoSens*) and #3210 - NIS, Sofia University /project manager
2. 01.04.2018 - 04.12.2019 / SONY Europe Ltd. Zweigniederlassung Deutschland / “*Chromophores, dyes and their combinations for photonic sensing. Applications for cell analysis and imaging*” # 3075 (SONY) -NIS, Sofia University /project manager
3. *Grant DFNI E02 / 11 Molecular solar thermal systems, enhanced by annihilation upconversion* National Science Fund, Bulgaria /head of work packages.
4. February, 2010 - February, 2013 Grant RG 02 / 2-2010, “*Annihilation Assisted Up conversion in Multicomponent Systems: All-Organic, Flexible and Transparent Multicolor Display*” National Science Fund, Bulgaria /project manager
5. February, 2009 - January, 2013 # 227127 “*Smart light collecting system for the efficiency enhancement of solar cells*”, 7th FP: *EphoCell- Project*, European Community.project manager from the German side. The project is based on publication No.14 of the attached list
6. May, 2008 - April, 2013 #0483 “*Temperature measurements and Photon Up-conversion, continuation*” SONY International (Europe) GmbH, Germany

**Series of lectures for doctoral students (3** 1. Stanislav Balouchev, “*Energy Transport in Dense Populated Organic Triplet Ensembles:*

*Non-coherently Excited Annihilation Upconversion*”, *Colloquium FRIAS Research Focus Quantum Transport*, **2015**, Freiburg Institute for Advanced Studies (FRIAS), Albert-

Ludwigs- Universität, Freiburg, **Germany**.

2. Stanislav Balushev, “*Energy Transport in Dense Populated Organic Triplet Ensembles: Towards Non-invasive Temperature Sensing*”, *Materials and Energy lecture series, Johannes Gutenberg Universität Mainz & Technische Universität Kaiserslautern*, **2015**, Mainz, **Germany**.

3. S. Balushev, *Chalmers Soft Matter Grad School 2013: Unconventional Solar Energy Technologies*, June 24-29, **2013**, Rönning, **Sweden**:

1) “*Photon Energy Conversion Techniques: Overview*”.

2) “*Sun Spectrum Engineering: Non-coherently Excited Annihilation Upconversion in Multicomponent Organic Systems*”.

3) “*Sun Spectrum Engineering: Limitations, Photon Management and Applicability*”

4) “*Non - coherent Annihilation Upconversion in Multicomponent Organic Systems:*

## *Asymmetrically Annelated Porphyrin Family”*

Head of MP Optometry

Prepared courses of lectures for students of the Master and Bachelor Programs Optometry

1. Wave Optics (45 hours).
2. Interaction of Organic Matter with Light (45 hours).

Photo adaptation Mechanisms (45 hours). For the students from MP Photonics

1. Organic Optoelectronics (45 hours) Lecture load - over 500 hours each year, corresponds to approximately 2 full loads.

Dissertation research reflects the author in the field of energy transport in densely populated triplet organic ensembles and especially, the process of incoherent annihilation *up* conversion. The results were obtained after 1999 in several international research institutions

- *Institute of Experimental Physics, Technical University Graz, Austria*
- *Department of Complex Systems, Weizmann Institute of Science, Rehovot, Israel*
- *Physical Chemistry of Polymers, Max-Planck-Institute for Polymer Research, Mainz, Germany*
- *Freiburg Institute for Advanced Studies, (FRIAS), Albert-Ludwigs-University, Freiburg, Germany*
- *Optics and Spectroscopy Department, Faculty of Physics, Sofia University “Saint Kliment Ohridski”, Sofia, Bulgaria.*

The dissertation has structured the presented work in 12 chapters as follows: chapter **1**, considered process, leading to photon up-conversion. In ch. **2** describes TTA- UC processes in a matrix of soft matter with high glass transition temperature. This part of the thesis was written on 23 pages in avtoferat while in the thesis is the description of 51 pages. The TTA-UC process caught his attention during experiments, conducted in his laboratory (MPI- Mainz) within the project OLAS13 # 8165 Fundamental researches in the field of organic thin film laser diodes funded by the Federal Ministry of Education and research, Germany). Assoc. Prof. Balushev studies thin polymer films, composed of PF 26 /PtOEP with the primary objective to create **electrically pumped** red emitting organic semiconductor laser. I appreciate this part of his research TTA-UC in soft glass matrix with low glass transition temperature is discussed in Part 3.

A very important part of the study of Assoc. Prof. Balushev is optimization process TTA-UC *through* modification of the molecular structures described in Chapter **4**.

Chapter **5** describes organic, flexible and transparent multicolor displays based on TTA-UC. *The up*-conversion applied to DSSC solar cells is discussed in Chapter 6. Expanding IR-limit oxygen photosynthesis *by* annihilation up-conversion described in Part 7, show that there Dr Balushev insight not only in fundamental research but also practical application of "pure science.". In Chapter **8** is described diffusion controlled energy transport in densely populated organic triplet ensembles. I appreciate this part of the dissertation as very important. Here the physicist Assoc. Prof. Balushev, who possesses in high chemical culture and knowledge, uses them to explain the fundamental experimental limitations imposed on TTA UC by diffusion. The structures of typical TTA-UC couple: sensitizer –meso tetraphenyl-tetrabenz[2,3]porphyrin palladium(II) (PdTBP); emitter - 3- (4-*Tert*-butylphenyl)perylene(BPP) and solvent 1-Phenylhexadecane(PHD) give the author reason to explain the high quantum yield when using sensitizers - metalloporphyrins and emitters of conjugated aromatic hydrocarbons.

Chapter 9 is dedicated to TTA-UC in aquatic environment. The motivation of the study is logical due to the fact that all life processes take place in an aquatic environment. Working in an aquatic environment has the advantage that the samples do not age. This part of the dissertation is related

to the subsequent research of living objects. Model system includes typical TTA-UC couple: sensitizer –meso-tetraphenyl-tetrabenz[2,3] porphyrin palladium (II) (PdTBP); emitter - 3-(4-Tert-butylphenyl)perylene (BPP) and solvent 1-Phenylhexadecane (PHD).

TTA-UC in a nano- configured environment of soft matter is discussed in Chapter Ten. Motivation of the study is that the driving force of the process of TTA UC in soft matter is inter-molecular transfer of triplet energy, controlled by the rotational diffusion. In turn, RD depends on the parameters of the environment local temperature, local viscosity and the presence of even very small amounts of oxygen. This chapter demonstrates their application techniques of nano-encapsulation in order to minimize the impact of the attending oxygen.

**Part 11** of the title thesis Protection of densely populated triplet states. In his motivation, the author presents various technological solutions based on the application of singlet oxygen consumers (sacrificial singlet oxygen scavenger, called SSOS). These molecules react (irreversibly) with singlet oxygen, and minimize the free oxygen that can be involved in oxidative processes. He demonstrated that these protecting groups react only with oxygen in the singlet state, and do not react with oxygen in the ground triplet state. This protection becomes active only in the presence of an excited state of the sensitizer or external stimulus. These studies were conducted with the help of DFNI E 02/11 - SunStore- a project supported by the Research Fund (NSF).

Chapter12 describes fully optical, simultaneous and minimally invasive testing of temperature and oxygen content in malignant cells. The chapter is written on 53 pages in the dissertation and the author's motivation is that in all biochemical reactions responsible for cellular functions are exothermic or endothermic, and take place in organelles exposed to different oxygen content and are co-regulated by intracellular temperature distribution. Its aim is to demonstrate for the first time **(i) independent, (ii) intracellular, (iii) minimally invasive and (iv) real-time T- and O<sub>2</sub> testing** by the TTA-UC process in a nanoencapsulated soft matter matrix. This study is supported by Max Planck Institute for Polymer Research, Mainz, Germany and Grant # 732794 Nano confined photonic system for detection of breast cancer spread to the lymph nodes", H2020-ICT-2016-1, Photonics KET HypoSens –Project, EC.

In the dissertation a thorough analysis of the known methods for measuring intracellular temperature and oxygen content is made. As an example of existing unresolved technical problems *will quote Wang and Wolfbeis Chem. Soc.Rev. 2014. 43, 3666-3761. The local temperature change is probably the single biggest source of error in optical sensors for oxygen...*. Even more, that existing methods <http://www.thermofisher.com/order/catalog/product/S36002> *interfere with the metabolism of the cell* arguments, relied on pages 279-282 of the dissertation-cannot be made the conclusion, that more and more *intracellular, independent and minimally invasive determination of local temperature and oxygen concentration* is a significant technological and scientific problem. "*Minimally invasive testing procedure*" means that: **(i)** -O<sub>2</sub> & T testing does not change the pH of the cell; its viscosity; does not cause adverse chemical reactions; does not interfere with cell metabolism. **(ii)** - It is a critical requirement that the measurement is not one-off, but that it is possible to monitor in a dynamic manner the O<sub>2</sub> & T changes, as a consequence of the cellular response to external influences - pathogenic influences, environmental pollution and drugs. Combining technology and nano capsulation process annihilation *up-covertion*: A.Svagan D. Busko, Yu. Avlasevich, G. Glasser, **S. Balushev** and K. Landfester "Photon Energy Upconverting Nanopaper A Bioinspired Oxygen Protection Strategy" *ACS Nano*, **2014**, 8, 8198–8207. **G16**, MA Filatov, E. Heinrich, D. Busko I.Ilieva. K. Landfester and **S. Balushev**, "Reversible oxygen addition on a triplet sensitizer molecule: protection from excited state depopulation " *Phys.Chem.Chem.Phys.*, **2015**, 17, 6501- 6510., let creation that of a nanoscale,

which is able to distinguish the influence of the O<sub>2</sub> concentration the local T and the local diffusion of O<sub>2</sub>. The optimization of the nanosensor core material and the material compositions is described. For all preliminary experiments, the concentration of the sensitizer was constant, 1.10<sup>5</sup> M, while the emitters changed (a) -3,10-Bis (4-*tert*-butylphenyl) perylene, designated Y805; (b) - 3,9 (10) -bis(3,5-dimethoxyphenyl)perylene designated Y833; (c) - 3,4,9,10-tetra(butoxycarbonyl) perylene, designated Y921.

**CONTRIBUTIONS: The thesis is written on 4 pages and due to the exhausted limit of pages I will not do well in detail. I want to emphasize that I completely agree with them.**

## **PUBLICATIONS**

Scientific Periodicals - **21 publications** and fully meet the requirements of the *mandatory list of PPZRASRB and the Additional Requirements of the Faculty of Physics at Sofia University "St. Kliment Ohridski"* and have been published in journal such as *Advanced Materials, Appl.Phys.Letters, ChemPhysChem, Physical Review Letters, Angewandte Chemie– International Edition, New Journal of Physics, J. Org.Chem., J.Am.Chem.Soc., Chem. Soc Review et al.* I would like to point out that the first journal published only new materials with proven technological properties and publishing in *Angewandte* by foreigners or mixed teams is extremely difficult. The other journal are also renowned specialized international media. I want to pay attention to the synthesized photosensitizers' substituted porphyrins complexed with palladium salts. From the point of view of organic synthesis, these compounds are difficult to obtain and their synthesis requires a lot of effort. Yields are low and generally require a high chemical synthetic culture. The author and his collaborators have performed the syntheses, but the design of the sensitizers is the work of Assoc. Prof. Balushev. A careful review of the dissertation and the abstract allows me to believe that the candidate is a scientist not only in physics (optics and spectroscopy) but also a scientist working on the interface Physics-Chemistry. I am convinced that his professional knowledge of Chemistry has contributed to the undeniable success in the study and use of triplet-triplet annihilation up-conversion. Triplet-triplet annihilation conversion (TTA-UC) is the only up-conversion method demonstrated experimentally to be performed with incoherent low-intensity light - such as sunlight. The author has proven that poorly concentrated sunlight can generate effective TTA-UC, enabling the creation of a number of unique organic optoelectronic applications in the science of materials, organic solar cells, solar fuels, and in-vitro bio images under critically reduced electromagnetic stress.

World patents - 9. According to the presented materials, the joint work with SONY International (Europe) GmbH, Germany has a key share for the internationally recognized patents - 6 out of 9 patents. The other 3 patents are maintained by Max Planck Gesellschaft zur Forderung der Wissenschaften EV (PLAC-C). Conference reports- 14 of which 3 were invited by the conference organizers. Assoc. Prof. Dr. Balushev has personally reported 10 reports and 4 others are by co-authors.

332 literature sources are cited, which is indicative of the high awareness of the dissertation.

The detailed analysis of the scientific achievements presented in the dissertation shows that the research is fundamental with a strong scientific-applied character.

Contributions: candidate elaboration of new theories, hypotheses. Unscrew existing methods, it is enriched with existing knowledge and application of scientific achievements in practice. Reflection of the candidate's results in the works of other authors. Numerical indicators - citations - **2463** are the observed citations until May 2020 impact factor - **127,1** and the candidate's



contribution to collective publications is crucial, as the candidate is the author of correspondence in 19 of the 21 publications presented.

G1 - 4.2	G6 - 5,009	G11 - 0	G16 - 4,707	G21 - 4,081
G2 - 6.496	G7 - 0	G12 - 4.09	G17 - 4,874	
G3 - 4,591	G8 - 0	G13 - 0	G18 - 39,955	
G4 - 0	G9 - 5.525	G14 - 12,958	G19 - 11,259	
G5 - 3,512	G10 - 0	G15 - 13,646	G20 - 2,204	

**IF<sub>SUMA</sub> = 127,107**

Additional

N34 - 11,076	N37 - 2.287	N40 - 3,595
N34 - 7.328	N38 - 3,994	N41 - 3,595
N36 - 2.287	N39 - 7,412	N42 - 5,723

**IF<sub>SUMA</sub> = 47,297**

**Remark:** The publication of the demonstrated experiment got tremendous response: there was a *chain of press releases*, to mention some of them:

- (1) „Partnervermittlung für Photonen“, *Forschung Aktuell*, 4/2006, Max Planck Forschung.
- (2) Michael Schirber, “Tuning the Sun's Rays”, *Physical Review Focus*, 10 October 2006.
- (3) Thorsten Trupke und Peter Würfel, „Blaues Wunder für grünes Licht: Up-conversion von Photonen für effizientere Solarzellen“, *Physik Journal* 5 (2006) Nr. 12
- (4) Jan Oliver Löffken, “Staffelauf der Moleküle”, *Financial Times* (D), 10 September 2006.
- (5) “Upconversion fluorescence achieved through incoherent excitation with sunlight”, *Laser Focus World*, December 2006, pp 15.
- (6) Stefan Maier, “Frisiertes Sonnenlicht”, *Spektrum der Wissenschaft*, July 2007, pp.18-19

## 5. Critical remarks and recommendations

When reviewing this dissertation I found no significant errors in terms of: staging; analyzes and generalizations; methodological level; accuracy and completeness of the results; literary awareness. I found only inaccuracies in the spelling of some forms in the Abstract, written in Bulgarian, for example on page 14, the abstract uses glove-box, while in Bulgarian it is called dry boxing. Another inaccuracy is the use of the German word doped, while in Bulgarian the English word doted is preferred. On page 19 is written fluorine instead of fluorene oligomer. My question to the candidate is: Are there technical or other difficulties for the widespread use of TTA Up Conversion in practice and what? All these remarks do not change my opinion about the high quality of the dissertation work.

## 6. Personal impressions of the candidate

I learned about the work and achievements of Assoc. Prof. Dr. Stanislav Balushev Balushev a few years ago during a scientific stay in Germany. Colleagues from MPI for polymer research Mainz told me about his success in the Up conversion, but we personally met when receiving the

protection materials. I bring to your attention the following reviews found by me very soon in Chem. Soc. Rev. 2020, 49, 6529--6554 |

Triplet – triplet annihilation based on the near i.r. at the room temperature anti-Stokes delayed fluorescent molecular system was first reported by Balushev’s research group in 2003, as a sensitizer / annihilator couple film of Pd(II)octaethylporphyrin –polyfluorene showing green to blue TTAUC to visible molecular photon up conversion. Since, Balushev's report in 2007, NIR to Vis TTA-UC systems have evolved beyond deoxygenated organic solvents to oxygen stable solid state and aqueous environments to realize practical feasibility for TTA-UC that emerged as a vibrant research field. The first demonstration of room temperature sensitized delayed TTA-UC (Green to blue) was published by Balushev and co-workers, as an approach to increase the efficiency of solar cells. Baluschevs research group realized the potential of TTA–UC in photovoltaics when Pd(II)octaethylporphyrin (PdOEP)/diphenylanthracene (DPA) couple showed green to blue UC emission at low excitation intensity (10 W cm<sup>2</sup>) applying non coherent green sunlight I think it admitted is sufficient for the work and achievements of Assoc. Prof. Dr. Balushev.

### Conclusion

After getting acquainted with the presented dissertation, abstract and other materials, and based on the analysis of their significance and contained in them scientific and scientific-applied contributions, I **confirm** that the scientific achievements meet the requirements of ZRASRB and the Regulations for its application and the respective Regulations of Sofia University “St. Kliment Ohridski ” **for obtaining the scientific degree “Doctor of Physical Sciences ”** In particular, the candidate satisfies the minimum national requirements 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. GENERAL CONCLUSION

Based on the foregoing, convinced **to the recommended** scientific jury to award **the degree of Doctor of Physical Sciences** in a professional field.4.1 Physical Sciences, Physics of Atoms and Molecules of Assoc. Prof. Dr. Stanislav Balushev Balushev.

20.04.2021

reviews prepared:.....  
(Prof. Tsonko Kolev )