OPINION

on Dissertation

for obtaining the scientific degree "Doctor of Sciences"

in professional field 4.1 Physical sciences,

on defense procedure at the Faculty of Physics (FzF)

of Sofia University "St. Kliment Ohridski "(Sofia University)

The review was prepared by: Prof. Asen Enev Pashov, Sofia University "St. Kliment Ohridski ", Faculty of Physics, as a member of the scientific jury according to Order №РД20-127 / 22/01/2021. of the Rector of Sofia University.

Topic of the dissertation: "Quantum-optical analogies"

Author of the dissertation: Assoc. Prof. Dr. Andon Rangelov

Candidate details

Dr. Andon Rangelov is a graduate of the Faculty of Physics at Sofia University. Kliment Ohridski. He completed his studies as a student in 2002, and received his educational and scientific degree after defending a thesis at the Higher Attestation Commission in 2008. The topic of the dissertation is "Coherent quantum control of quantum systems with pulsed fields" and was written under the supervision of Prof. Nikolay Vitanov from the Faculty of Physics at the University. Since 2009 he started working at the Faculty of Physics at Sofia University "St. Kliment Ohridski "in the Department of Theoretical Physics as an assistant. Since 2010 he has been a senior assistant, since 2011 - a senior assistant at the same department, and since 2015 - an associate professor.

Initially, Dr. Rangelov's research interests were in the field of quantum optics. He studied the interaction of small quantum systems with laser pulses in order to bring the system to an arbitrarily quantum state. This task is relevant and finds a number of applications in precision laser spectroscopy, metrology (atomic and molecular clocks), quantum information, quantum cryptography, etc. Here the candidate presents himself as a formed and erudite scientist, whose expertise is recognized not only by Bulgarian but also by foreign colleagues with whom he works. Suffice it to mention the names of K. Bergmann, B. Shore, E. Arimondo. Assoc. Prof. Rangelov's scientific career includes numerous visits and exchanges of experience at the universities of Kaiserslautern, Sussex, Pisa, Toulouse, Kassel, Darmstadt, Mainz, Australian National University, Ben-Gurion University, Singapore University of Technology and Design and others. Undoubtedly, the experience gained from these contacts has played an important role in shaping the diverse interests of the candidate.

Dr. Rangelov has been awarded several national scientific prizes: the Evrika Foundation Award for Best Young Scientist in Bulgaria in 2008, the Best Young Scientist Award at Sofia University in 2011 and an award Pythagoras for the Best young scientist in Bulgaria for 2013.

General characteristics of the candidate's scientific achievements

The presented dissertation summarizes the candidate's work in a new scientific field for him - classical optics. He takes advantage of the analogy between the formalism used to describe atom-field interactions in quantum optics and the propagation of an electromagnetic wave in media, and applies the accumulated experience to solve a number of practical problems. These are the control of the polarization of light when passing through birefringent media, the optimization of phase synchronism when mixing frequencies in nonlinear crystals and the efficiency of light dividers in optical waveguides.

The common denominator in the solution of the tasks is the search for solutions that are valid with the greatest possible variation of the input parameters. For example, when constructing wave plates, the candidate has set himself the goal of reducing the influence of the wavelength of the wave. This is an extremely important property of these plates and their price strongly depends on the range of wavelengths for which they provide the necessary phase difference, most often l / 2 or l / 4. For reference, wave plates operating on one wavelength cost about BGN 500 (Thorlabs, Multi-Order Quarter-Wave Plate), better options - about BGN 900 (Thorlabs, Zero-Order Quarter-Wave Plate)), and the achromatic variants, operating in the range of several hundred nm, cost over 1500 BGN (Thorlabs, Achromatic Quarter-Wave Plate). In the dissertation Assoc. Prof. Rangelov proposes schemes with arrangement of several wave plates (multi-order, typically from 3 to 9 pieces), rotated at appropriate angles to each other, which significantly expands the operating spectral range from a few nm to several tens of nm. The solutions for mixing frequencies and realizing light dividers in optical waveguides are similar.

It should be emphasized that the work of Assoc. Prof. Rangelov is theoretical. He finds new approaches and numerical techniques in solving problems. This he declares in his contributions to the dissertation. In parallel, most tasks are accompanied by experimental data that check the quality of the solutions found. They basically confirm the theory, but they are not part of the candidate's work, so I will not evaluate them.

The ideas and approaches proposed by Assoc. Prof. Rangelov are interesting and original. As far as I know, their application in classical optics is new. I appreciate the expansion and application of experience from one field of knowledge to another - this is not common in modern science. More often, scientists publish papers in a narrow specialized field, communication between them is difficult and often in different fields "the wheel is rediscovered." In fact, the initial developments for optimization in quantum optics (by means of composite pulses), developed by the candidate and colleagues from Prof. Vitanov's group, were also initially applied in another field - nuclear magnetic resonance. Thus, the application of techniques from different fields of physics to observed analogies in the formalism for describing the phenomena in them is not a new. It shows a good knowledge not only of one's scientific field, but also the ability to transfer knowledge and experience from one field to another.

The publication activity of the candidate is impressive and significantly exceeds the requirements not only of ZRAS, but also of the Faculty of Physics of Sofia University St. Kliment Ohridski. The articles with a significant contribution, published in less than 10 years, are 17! Almost all papers are in magazines from Q1. The citations are 151. The variety of co-authors from Bulgaria and abroad is impressive.

The time is yet to show whether the theoretical developments of the candidate will find application in practice. For example, in the case of wave plates, I think that large companies should be interested in investing in the development of serial production of finished products, because the currently implemented prototypes of broadband plates are significantly more expensive than the available options on the market. On the other hand, the proposed optimization solutions are universal and they can be applied in special cases when the main goal is high quality and the price plays a secondary role.

Critical remarks and recommendations

The dissertation is written in English and is formatted on 153 pages. The presentation is concise and is in the spirit of publication in a scientific journal. I have no critical remarks on the methods and approaches used. I just want to ask:

> Is there a more detailed analysis of the poor correspondence between the theory and the experiment presented in Fig.5.8, p.86 (p. 60, Fig. 37 of the Bulgarian Abstract). Imperfection of wave plates and polarizers is assumed. This can be checked by the characteristics of these components in the manufacturer's catalogue, and also

measured, as was done by examining the wave plates in the previous chapters. Has it been tested theoretically whether the estimated imperfections of these components can lead to the difference between the experiment and the theory?

The Bulgarian Abstract reflects the content of the dissertation, but here I have remarks on the translation of some of the terms:

• Half-wave wave plate (as on page 60 of the abstract)

• Fidelity

• Page 27 "If we look at continuous electric fields, then the time derivatives fall ..." - in the original of the dissertation is CW (continuous wave or continuous waveform). It is true that a continuous laser is used in this sense, but for fields, it seems to me that it is more appropriate to say stationary fields.

• Page 31 Figure 16 shows the pumping intensities of the field and the wavelengths at which phase synchronism is achieved. This is GW / cm^2. How can such intensities be achieved in CW fields? If we are talking about short pulses, is the assumption on the zeroing of time derivatives valid (page 27 of the Abstract)?

• Page 32, again it is assumed that the amplitude of the pumping field (A) is constant, and on page 36 one reads "ultrashort pulses" and "fundamental electric field with a duration of 100 fs". This is definitely not a CW laser, can such a field be considered stationary?

• Page 51 Verdet

• Page 59 Faraday rotator

• Page 59 Collimated light beam

• Page 60 .... the two polarizers ... were borrowed from a Lambda-950 spectrometer.

• Page 60 Quarter-wave plates with a hole - ... with a diameter

• Page 60 Fig. 37 Black curves with a dash show

• Page 61 Experimental data on the transmission (or transmission coefficient) in both directions (or in the forward and reverse direction) of a composite optical insulator, together with theoretical predictions ....

• Page 86 Outlet - Town - in the original Autler-Townes?

• Page 86 … by appropriate mutual adjustment (or matching, selection) of the propagation constants

Conclusions. The dissertation, the Bulgarian Abstract and the scientific publications of Dr. Rangelov cover the minimum scientific requirements of ZRAS and the Regulations to it, as well as the requirements of the Faculty of Physics of Sofia University St. Kliment Ohridski. The candidate is a competent and experienced scientist, able to set and solve new tasks on his own, as well as to lead young specialists. He has a broad view on modern science, works in modern areas, he collaborates with leaders in various fields both in Bulgaria and abroad. I support the award of the scientific degree "Doctor of Science".

04/17/2021

Sofia

Asen Pashov

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