

## R E P O R T

of a dissertation for the acquisition of a scientific degree "Doctor of Physical Sciences" in professional direction 4.1 physical sciences, by defense procedure at the Faculty of Physics (FzF) of Sofia University "St. Kliment Ohridski" (SU)

The review was prepared by: Prof. Ph.D. Kiril Borisov Blagoev, in his capacity as a member of the scientific jury according to Order No. 249 / 20.05.2022 of the Rector of Sofia University. Dissertation topic: "Critical phenomena and quantum methodology with strongly correlated quantum-optical systems"

Author of the dissertation: Associate Professor Petar Alexandrov Ivanov, PhD

### I. General description of the presented materials

1. Data on the submitted documents. The candidate, Associate Professor Petar Alexandrov Ivanov, PhD, has submitted a dissertation and an Author's Abstract, as well as the mandatory tables for the Physical Faculty from the Regulations for the Terms and Conditions for Acquiring Scientific Degrees and Holding Academic Positions at SU "St. Kliment Ohridski". 4 other documents are also presented (diploma for the acquisition of a bachelor's degree from the Faculty of Physics of SU "Kl. Ohridski"; diploma for the acquisition of the scientific and educational degree "doctor"; list of citations; declaration of authorship) supporting the achievements of the candidate. The dissertation is written in English. The work is presented on a total of 313 pages. The material is divided into an abstract, 13 chapters; 12 appendices and a bibliography of 313 titles. The dissertation contains 100 figures. Chapters begin with a brief introduction or/and motivation for the research and most of them of the end with conclusions. Detailed abstracts in English and Bulgarian are also presented. The documents submitted by the candidate for the defense correspond to the requirements of the ŽRASRB, PPZRASRB and the Regulations for the terms and conditions for acquiring scientific degrees and occupying academic positions at SU "St. Kliment Ohridski" (PURPNSZADSU).

### II. 2. Applicant data Professional and biographical data for the candidate.

Associate Professor Petar Ivanov graduated from the Bachelor's program at the Faculty of Physics. of SU" Kl. Ohridski" in 2002. In 2008, Assoc. Prof. Ivanov and obtained the educational and scientific

degree "doctor" again in Phys. Fac. From 2012 to 2015 is a senior assistant in Phys. Fac., and since 2015 he is an associate professor in Phys. Fac.

## 2. General characteristics of the candidate's scientific achievements

Assoc. Dr. Petar Ivanov works in the field of atomic physics and in particular in the field of quantum optics-quantum metrology, quantum chaos, quantum informatics, quantum phase transitions. Assoc. Prof. Ivanov maintains scientific contacts with colleagues from the University of Kassel, Mainz, Kaiserslautern - Germany and the University of Madrid. In total, P. Ivanov has published 42 works in high rating scientific journals - all of them with Q1 and Q2, such as Phys. Rev. A; J. Phys. B; Rev. of Modern Physics; Opt. Commun. 9 papers are the basis of the dissertation for obtaining the scientific and educational degree "doctor", and 23 papers are the basis of the present dissertation. All to gather, these works have been cited 452 times by other authors. The Hirsch index is 12. Associate Professor P. Ivanov has published his works in co-authorship with colleagues from SU "Kl. Ohridski" and its foreign partners. Assoc. Prof. Ivanov is a single author of 8 of the publications. This shows that Assoc. Prof. Ivanov is equal to the other authors and has a significant contribution to the coauthor's papers. The scientific publications included in the dissertation meet the minimum national requirements (according to Art. 2b, paras. 2 and 3 of the RSARB) and, accordingly, the additional requirements of the SU "St. Kliment Ohridski" for the acquisition of a scientific degree "Doctor of Physical Sciences" in the relevant scientific field and professional direction, as well as the requirements of Phys. Fac. They have Q1 factors and 6 of them have Q2 factors. In total they have 545 points. The scientific publications included in the dissertation work do not repeat those from previous procedures for acquiring a scientific title and academic positions. The works included in this dissertation were published in the period of 2009 until 2022. I have not found any plagiarism in the submitted dissertation and abstract.

## 4. Characterization and assessment of the candidate's teaching activity.

Assoc. Prof. P. Ivanov has a significant teaching activity. He led lectures and exercises on quantum mechanics for the specialty "medical physics" in Phys. Fac.; lectures and exercises on theoretical mechanics and methods and applications of quantum mechanics for students majoring in theoretical physics; quantum simulations and quantum methodology for the master's program, as well as an selective course on quantum phase transitions. Assoc. Prof. P. Ivanov was the supervisor of successfully defended 5 bachelor's theses and 1 master's thesis.

5. Content analysis of the applicant's scientific and scientific-applied achievements contained in the materials for participation in the competition.

The dissertation work of Associate Professor P. Ivanov has a theoretical character. It is devoted to various properties and phenomena occurring in Pauli trapping. The Pauli trap combines the properties of ions of one-type and/or different-type atoms trapped and cooled by laser fields. The formed structure has the properties of a linear crystal with its degrees of freedom and modes of oscillation and phase transitions. The interaction of the atomic states and the linear crystal as well as the laser fields turn the Pauli trap into a unique tool for studying phenomena from quantum optics. A number of models of the system during a quantum phase transition have been examined. The atomic system acts as an intermediary in the transfer of orbital momentum to the photons in a planar resonator. The spin-phase interactions in the Pauli trap can be used for quantum metrology. The proposed protocol allows to measure the frequency difference of the atomic transition and the applied laser fields. The possibility of measuring forces on the order of  $10^{-24}$ N with the linear Pauli trap with a single ion and a system of ions is explored. The application of the system for multiparameter quantum metrology is discussed. A method is proposed for measuring the vibrational temperature of ions in a Pauli trap, using an external laser field, which connects the oscillations of the linear crystal and the states of the ions.

Although the work is of a theoretical nature, the proposed and solved models of the real system, such as the Pauli trap, are close to experimental verification and application. Measurable quantities characterizing the quantum phase transition have already been experimentally implemented by other authors. The experimental implementation of the phenomena treated in the dissertation requires a high-tech experimental base, but it is always good to have a theoretical base for the conducted experiments. The results of the dissertation can be classified as new theories and hypotheses.

As noted, the dissertation is based on 23 papers published in reputable journals such as *Phys. Rev. A* (IF – 2.97) (10 pcs.); *Rev. of Mod. Phys.* (IF – 54.49) (1); *Scient. Reports* (IF 4.99)(2); *Phys. Rev. Lett.* (IF 9.16)(1); *J. Phys. B*(IF 1.65); *Phys. Scripta*(IF 2.48); *Opt. Comm.* (IF 2.33); *Entropy*(IF 2.74); *New J. of Phys.* (IF 3.73); *J. Low Temp. Phys.* (IF 1.67); *Phys. Rev. Applied.* (IF 4.19). 18 of the works are with Q1 and 5 are with Q2. Prof. P. Ivanov is the independent author of 7 of the works and is a co-author with one or more co-authors in the others. The review in *Rev. of Mod. Phys.* is a collective work with foreign colleagues. Assoc. Prof. P. Ivanov has a decisive participation in the rest of the collective works. The works included in the dissertation have been cited 220 times by other authors. The list of

cited literature is comprehensive. Each chapter of the dissertation begins with an introduction and motivation for the research conducted and ends with a conclusion where the contributions made in the respective chapter are presented.

#### 6. Critical notes and recommendations

I have no substantive critical notes on the scientific results of dissertation. In the Bulgarian version of the Abstract there are 12 chapters, and the results of chapters 5 and 7 are partly inserted in the other chapters. Contributions are not listed in the English version of the abstract and the dissertation. As noted, however, each chapter ends with contributions, which are collectively the contributions of the dissertation. The results of the work have been tested at the CAMEL conference series.

7. Assoc. Prof. P. Ivanov is a representative of the school in the field of quantum optics, formed in recent years in Phys. Fac. at SU "Kl. Ohridski". I have no personal impressions of the candidate.

#### 8. Conclusion

After having familiarized myself with the presented dissertation work, Abstract and other materials, and based on the analysis of their significance and the scientific content 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 the SU "St. Kliment Ohridski" for obtaining the scientific degree "Doctor of Physical Sciences". Candidate exceeds the minimum national requirements in the professional direction. No plagiarism has been found in the dissertation, abstract and scientific works submitted for the competition. I give my positive assessment of the dissertation work.

### III. GENERAL CONCLUSION

Based on the above and the scientific data of the publications included in the dissertation work, as well as their reflection in the literature, as well as the high quality of the publications, I recommend the scientific jury to award the scientific degree "Doctor of Physical Sciences" in professional direction 4.1 physical sciences to Associate Professor Petar Alexandrov Ivanov, PhD.

22. 08. 2022.

Prepared the review: Prof. Dr. Kiril. Blagoev  
(academic position, scientific degree, name, surname)

