OPINION OF THE LEADING ORGANIZATION

TO THE HABILITATION THESIS

Formal reply from the leading organization regarding the habilitation thesis presented by **David Boris Hayrapetyan** entitled "**Investigation of Electrodynamic and Optical Characteristics of Zero-Dimensional Quantum Structures**". This thesis has undergone a comprehensive evaluation based on the established academic norms and requirements for attaining the Doctor of Physical-Mathematical Sciences degree.

Relevance of the topic

Semiconductor quantum dots are at the intersection of material science and quantum mechanics, showcasing unique characteristics that have intrigued experts in various scientific fields. These tiny semiconductor particles, often referred to as synthetic atoms, display specific quantum mechanical attributes that set them apart from their larger bulk material forms. Among their most striking features is their size-dependent optical and electronic behaviors, stemming from the quantum confinement effect. This effect becomes significant when the dimensions of the quantum dot reach a certain threshold, leading to the confinement of electrons and holes in all three dimensions.

The distinctive attributes of quantum dots have led to their broad application in several areas. In optoelectronics, they enhance the functionality and efficiency of devices such as light-emitting diodes and solar panels. Their adjustable emission spectra are perfect for producing vivid displays with improved color fidelity and energy efficiency. In solar energy, quantum dots could greatly boost photovoltaic cell efficiency by capturing a wider range of solar radiation.

In the biomedical field, quantum dots are crucial. Their outstanding optical qualities, like high luminosity and photobleaching resistance, make them excellent for biological imaging and diagnostics. They can be tailored to bind to specific cellular proteins or structures, enabling precise visualization and tracking of cellular activities at a molecular level.

Additionally, quantum dots are vital in the burgeoning area of quantum computing and information processing. Their distinct energy levels and the controllability of electron spin render them suitable for use as quantum bits (qubits), the fundamental units in quantum computers. This has the potential to transform computing by allowing for much faster processing speeds for some calculations than traditional computers.

However, the exploration of the physical and optical properties of semiconductor quantum dots remains a key research focus. Comprehending the principles driving their behavior is crucial for enhancing their efficacy in existing uses and discovering new technological possibilities. Ongoing research is especially needed to overcome challenges in their synthesis and integration, such as controlling size and shape, ensuring stability, and achieving compatibility with various environments and materials. As we deepen our understanding of these nanostructures, quantum dots are poised to become increasingly influential in the technological developments of the 21st century.

Thesis Structure

The thesis, consisting of 267 pages with 83 figures, 15 tables, and 334 references, is organized into an Introduction, six Chapters, a Conclusion, and a References section. It begins with a "List of Abbreviations and Notations Used in the Dissertation," followed by the "Introduction." The introduction highlights the importance of the research, reviews relevant literature, and discusses the current understanding of the problem, culminating in the main findings of the study.

Chapter I focuses on the theoretical analysis of spherical and cylindrical quantum dots. It examines various confinement potential models and their effects in different size quantization regimes. This includes an in-depth look at spherical quantum dots using the modified Pöschl-Teller potential (MPTP), studies on light absorption in cylindrical quantum dots using MPTP, and analysis of the impact of hydrostatic pressure on donor impurity exciton states and interband absorption in cylindrical quantum dots with the Morse confining potential.

Chapter II is devoted to the analysis of ellipsoidal and spheroidal quantum dots. It explores the binding energy and photoionization cross-section of hydrogen-like donor impurities in strongly oblate ellipsoidal quantum dots and provides comparative studies for prolate ellipsoidal and spheroidal quantum dots.

Chapter III investigates excitonic complexes in ellipsoidal and cylindrical quantum dots. It includes calculations of binding energies and photoionization cross-sections, studies the effects of intense laser beams on these complexes, and considers the potential for the Talbot effect in coupled cylindrical quantum dot arrays.

Chapter IV addresses the application of Kohn's theorem in quantum dots with oblate and prolate shapes. This involves analyzing the influence of external magnetic fields and examining Ge/Si quantum dots containing a hole gas.

Chapter V delves into the electronic and optical characteristics of core/shell nanostructures. Topics covered include linear and nonlinear optical absorption, exciton states in core/shell/shell spherical quantum dots, and modeling of quantum dots using the finite element method, with a focus on various confinement potentials and their effects.

Chapter VI evaluates the electronic and optical properties of conical quantum dots. This includes studies on direct interband light absorption, magneto-absorption, and the examination of electronic states in the presence of electric fields.

Conclusion

The works included in the dissertation were published in 47 articles, 10 conference proceedings and 2 books. The results obtained were presented at both local and international conferences.

While the thesis showcases impressive depth and scope, I propose a few minor queries and suggestions that could further polish and elevate its quality.

1. In the Coulomb term's equation, which describes the interaction between an electron and a hole, a constant dielectric permeability is utilized. However, for greater accuracy, employing screening models in place of a constant value would be more effective.
2. In experiments, effective masses, dielectric constants, and other material parameters are typically derived from bulk materials. The relevance of this approach for such calculations raises the question: do these parameters vary depending on the size of the quantum dots?
3. What degree of difference is required between two geometrical parameters of a quantum dot to justify the use of the geometrical adiabatic approximation for quantum dots with either oblate or prolate characteristics?
4. Why is it significant to study quantum dots with impurity centers situated in various positions within the dots?
5. A non-resonant laser, while targeting electronic states, might inadvertently stimulate other quasiparticles during corresponding transitions. How can we prevent these excitations, and what impact might they have on the states being examined?

These minor remarks, as noted earlier, do not diminish the overall exceptional standard of the dissertation. Without a doubt, this Habilitation thesis constitutes a noteworthy addition to the domain of semiconductor nanostructures. The thesis fulfills all the requirements set forth by the Supreme Certifying Commission of the Republic of Armenia, and its author, David Boris Hayrapetyan, is unequivocally worthy of receiving the academic title of Doctor of Physical-Mathematical Sciences. Additionally, the summary of the dissertation (auto-referat) accurately encapsulates the content and core essence of the presented work.

The author presented his dissertation at the Department of Electrical and Photonics Engineering of the Technical University of Denmark on January 12, 2024, at the seminar attended by Senior Researchers and Professors Nika Akopian, Thomas Christensen, Philip

Trøst Kristensen, Martijn Wubs, Elizaveta Semenova, Andrei Laurynenka, and other researchers and Ph.D. students.

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The authenticity of Assoc. Prof. N. Akopian's signature is hereby certified by:

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