Patras, Greece, 22 March 2023

REFEREE RESPONSE

to the PhD dissertation of Sargsyan Tigran Aram *"Investigation of the properties of vertically coupled cylindrical quantum dots for quantum computations"* for the degree of candidate of physical–mathematical sciences on specialization of 01.04.10 – "Physics of Semiconductors"

The progress in modern semiconductor technologies has made it possible to produce low-dimensional semiconductor structures in which the movement of charge carriers could be limited in the given directions. Structures that are formed in this way are called quantum nanostructures and they appear as key objects for such quantum technologies as quantum information technologies, quantum electronics, quantum photonics, etc. Quantum dots (QDs) are one of the most noteworthy representatives of quantum nanostructures. In these structures, motions of charge carriers are restricted in all three directions and there is very strong dependence of the energy spectrum of charge carriers and, hence, electronic and optical properties of QDs on the geometrical shape and sizes of QD.

The geometrical shapes and sizes of QDs can be predefined during the growth of particular QD. It is possible to obtain QDs of practically any geometrical shape (spherical, cylindrical, cubical, ellipsoidal, conical, lens shaped, etc.). It is also possible to precisely control the size of an individual QD during its growth. Due to these unique properties, QDs find their application in extremely wide-ranging areas including next-generation displays, lasers, LEDs, biomedical imaging and drug-delivery systems, absorbing photovoltaic materials for solar cells, etc.

The immense amount of both theoretical and practical knowledge accumulated in the field of semiconductor manufacturing and nanostructure fabrication, in particular, also makes QDs one of the possible candidates for application in quantum computing. In this context, coupled QDs, which are formed by two QDs placed on each other at a relatively close distance, are quiet interesting and promising structures. Coupled-QD quantum computers have been already proposed, which can be operated by different external perturbations and can operate as different quantum gates. In this PhD work, particularly, the Author proposes the usage of Bessel laser beams to control the electron localization in a coupled QDs system and build quantum states and quantum gates on the latter.

The PhD dissertation is devoted to the theoretical investigation of the properties of vertically coupled cylindrical quantum dots from the point of their application in quantum computing.

The dissertation, which consists of the List of Abbreviations and Notations Used in the Dissertation, Introduction, three Chapters, Conclusion, References, List of Published Works on the Dissertation Topic and Acknowledgments. It comprises 132 pages, contains 57 figures, 3 tables and 159 references.

Introduction states the actuality of the dissertation topic.

Chapter 1 is devoted to the theoretical investigation of linear and nonlinear optical properties of different quantum nanostructures with various confinement potential models. In particular, the investigation of absorption spectra of a hydrogen-like donor impurity in GaAs QW with modified Pöschl-Teller potential and a comparison of obtained results with the ones obtained with parabolic potential has been presented. Further, the investigation of linear and nonlinear optical properties of InAs cylindrical QDs, under the influence of external parallel electric and magnetic fields have been done. Two different types of confinement potential were considered along the axial direction of cylindrical QD: Morse and modified Pöschl-Teller. At the end, comparison of the obtained results with both potential models was conducted.

Chapter 2 is devoted to the modeling process of semiconductor and metallic nanoparticles with different geometrical shapes and sizes. First, the modeling process for Au nanoparticles of different shapes and sizes is described and the optical properties, namely, plasmon resonances, of the modeled nanoparticles are analyzed. The results show good agreement with literature: it is shown that the plasmon resonance peak can be moved closer to the near-infrared region with the change of the geometrical shape and sizes of Au nanoparticles, which can make them extremely useful for biomedical applications, particularly. Further, the report on a experimental study of near-infrared photoluminescence and mid-infrared light absorption spectra in structures with Ge/Si QDs is presented and obtained results are compared with the ones modeled in different environments. The latter results are shifted compared to the experimental ones, which is expected to come from the absence of phonon effect consideration.

In Chapter 3, the properties of vertically coupled cylindrical QDs for quantum computations are investigated with the main focus on the manipulation of the electron localization in a system of vertically coupled cylindrical QDs via intense laser field with Bessel profile. First of all, the electronic states in a cylindrical QD under the influence of Gaussian and Bessel laser beams are investigated and compared. It is shown that under such external influences it is possible to effectively distort the confinement potential and, hence, manipulate the electron localization in the system. Further, the effect of Gaussian and Bessel laser beams on the linear and nonlinear optical properties of vertically coupled cylindrical QDs are investigated. Finally, the application of the considered system in quantum computations are described. A system of vertically coupled cylindrical QDs is considered as a qubit with states $|0\rangle$ and $|1\rangle$ corresponding to the charge carrier localized in the left or right QD, respectively. The localization of the electron is manipulated with the help of Bessel laser beam. Full control of Bloch sphere and possible realization of a few quantum gates are presented.

The results are summarized in Conclusions.

The results obtained in the dissertation are novel, original and interesting both from a fundamental and applied point of view. The PhD candidate has proven to be able to perform theoretical work with great accuracy, given the outstanding theoretical results presented in the dissertation. Considering the amount of references in the dissertation, it is clear that the candidate has a very good knowledge of the physics that rules the semiconducting nanostructures. Also, the dissertation gives a nice overview of previous work and also the latest evolutions in the field. The work was performed on a high theoretical level and results are published in leading physical journals and presented at numerous international conferences. Sargsyan Tigran Aram is also the first author in the six of seven publications.

Notwithstanding the very nice work, there are few remarks, which could give guidelines to improve the dissertation:

- The quality of the figures 1.3, 1.14, 3.14 and 3.15 must be improved.
- More explanations of the formulas used with Comsol.

The minor remarks mentioned above do not affect the high quality of the dissertation. Certainly, the PhD dissertation is an important contribution to the field of solid-state quantum computations.

PhD dissertation satisfies all requirements of the Supreme Certifying Commission of RA, and its author Sargsyan Tigran Aram undoubtedly deserves the scientific degree of candidate of physical–mathematical sciences.

The Synopsis of dissertation correctly corresponds to the contents of dissertation.

Official referee at the Department of Materials Science, University of Patras, Greece

Sotirios Baskoutas, Professor

I certify the signature of Sotirios Baskoutas

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ 1964

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