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REVIEW

on a dissertation for the acquisition of the educational and scientific degree **'doctor'** in the scientific field 4. "Natural Sciences, Mathematics and Informatics", Professional Field 4.1 Physical Sciences, Doctoral Program "Electrical, Magnetic and Optical Properties of Condensed Matter"

Author: Petar Kolev

Topic: ***Sensors based on spectral polarimetric detection.***

Scientific advisor: Prof. Dr. Georgi Dyankov, Institute of Optical Materials and Technologies - Bulgarian Academy of Sciences

Reviewer: Assoc. Prof. Dr. Tihomir Tenev, Institute of Solid State Physics – BAS

1. General description of the materials presented

By order No. RD-15 959/16.12.2025 of the Director of the Institute of Optical Materials and Technologies "Acad. Yordan Malinovski" at the Bulgarian Academy of Sciences, I am appointed as a member of the scientific jury for conducting a procedure for the defense of a dissertation on the topic: **„Sensors based on spectral polarimetric detection"** for the acquisition of the educational and scientific degree "doctor" in the field of higher education: 4. "Natural Sciences, Mathematics and Informatics", Professional Direction 4.1 Physical Sciences, Doctoral Program "Electrical, Magnetic and Optical Properties of Condensed Matter"

The author of the dissertation is Petar Kolev, a full-time doctoral student, enrolled with the right to defend at the Institute of Optical Materials and Technologies (IOMT) at the Bulgarian Academy of Sciences, with scientific supervisor Prof. Dr. Georgi Dyankov.

The set of materials presented by Petar Kolev is in accordance with the Law on the Development of the Academic Staff of the Republic of Bulgaria and the Regulations for its implementation and contains the required number of documents.

The dissertation is 106 pages long, contains 64 figures and 11 tables. The work is well structured and consists of an Introduction, a section on the relevance of the topic and the goals and objectives of the dissertation, and a Literature Review.

The work ends with a Conclusion, a summary of the main contributions, a list of figures, a list of the author's publications included in the dissertation and his participation in scientific forums, and references.

The main results are presented in two chapters: Construction of a channel spectral polarimeter (CSP) and Its application in sensors based on spectral polarimetric detection.

Brief biographical data about the doctoral student

Petar Kolev is an engineer by education, he obtained a master's degree in the field of hydraulics from the Technical University, Sofia. Since January 2022 he has been a doctoral student at the Institute of Mechanical Engineering in the Biosensors group.

2. Relevance of the topic and appropriateness of the set goals and objectives

The relevance of the topic is determined by the capacity of the Channel Polarimetry Method (CPM) - determination of the polarization state, and by the field of application - for the study of phenomena manifested in a change in the polarization state. The stated goals and objectives logically follow from this: experimental development of CPM and study of its applicability and efficiency in various types of sensors, the measurable quantities of which are related to a change in the polarization state. Specifically, CPM is applied to sensors based on:

- Surface Plasmon Resonance (SPR), (since the resonance manifests itself as a step change in the phase difference between S- and P- polarizations);
- Magneto-optical (MO) effect, insofar as it manifests itself as a change in the phase difference between circular polarizations.

The relevance of the topic is also proven by the experimentally demonstrated effectiveness of the MCP: increasing the measurement accuracy of PPR sensors and implementing direct measurement of the Faraday phase difference.

3. Knowledge of the problem

The author has presented a literature review including 135 sources. They are distributed between: (i) a review of MCP - principle and experimental implementation; (ii) a review of PPR sensors, with attention paid to sensors based on diffraction gratings, which justifies their use in the conducted studies: (iii) a review of MO sensors. The analysis of previous studies is purposeful, systematic and shows the author's good knowledge.

4. Research Methodology

The work is experimental and to fulfill the goals and objectives three methods were used: MCP, the SPR method excited in diffraction gratings, as well as the spectral modulation method applied with MO sensors. These three methods are implemented with different, for each of them, equipment, which places high demands on the doctoral student in terms of experimental skills and knowledge. Obviously, the doctoral student has successfully mastered and applied these methods, which speaks of a high experimental culture.

5. Characteristics and evaluation of the dissertation work

Chapter II is dedicated to the construction of the channel spectral polarimeter. Based on a methodology reported in the literature, the doctoral student analyzes the various factors determining the main parameters of the polarimeter. Based on the methodology, the characteristics of the phase plates were determined, and they were manufactured and successfully tested. The achieved parameters prove the correctness of the analysis made.

Chapter III is dedicated to the application of the developed channel spectral polarimeter in detection with PPR sensors (biosensors and gas sensors) and an MO sensor.

The first type of sensor detects the bacterium *H. pylori*. This experiment demonstrates the high signal-to-noise ratio in phase detection with MCP. Since the bacterial suspension is dispersive, amplitude detection has a low signal-to-noise ratio. This lowers the detection limit

by about 35% in phase detection compared to amplitude detection, allowing binding reactions to be recorded at concentrations of about 200 CFU/ml.

The hydrogen detection experiment demonstrates the high sensitivity of the MCP - two orders of magnitude higher than that of the amplitude measurement. This experiment also shows the disadvantage of the MCP - a small dynamic range. In a large dynamic range, the sensitivity is about 25% higher than that of the amplitude measurement.

The third type of sensor is magneto-optical and is based on the Faraday effect - rotation of the plane of polarization of radiation in a longitudinal magnetic field. MCP was first applied to measure a magnetic field (or current) in such a type of sensor. This allows for the first time to directly measure the phase shift caused by the Faraday effect. Moreover, it is not affected by the temperature of the magneto-optical medium. It should be noted that the doctoral student demonstrates a critical attitude toward the obtained results.

Initially, their interpretation was contradictory, which required the use of the spectral modulation method for correct comparison of the results.

6. Contributions and significance of the development for science and practice

The results presented thus document scientific and applied achievements that can be grouped into two groups, namely:

A) Experimental implementation of the channel polarimetry method: a spectral polarimeter was created in two modifications, which were experimentally studied in the context of accuracy and sensitivity;

B) The channel polarimetry method has been tested through the application of the spectral polarimeter to study three types of sensors: a biosensor and a gas sensor based on surface plasmon resonance, as well as a magnetic field sensor.

C) Main results

i) The creation of a spectral channel polarimeter is an achievement in itself - it requires simultaneous and precise control of multiple optical parameters, based on knowledge and experimental skills.
ii) Direct measurement of the Faraday phase shift may open new possibilities for detecting magnetic fields.

7. Assessment of dissertation publications

The dissertation is based on four articles indexed in Web of Science and Scopus, two of which are in the first quartile, one in the second and one with impact rank. The articles have been cited eleven times, with the first publication having nine citations in two years. Participations in nine conferences have been reported.

8. Personal participation of the doctoral student

Based on the presented separation protocols and the fact that in one of the publications P. Kolev is a corresponding author, I believe that his contribution is unambiguous in all the research and decisive in the publications in which he is in first place.

9. Author's abstract

The submitted abstract accurately and essentially presents the quantity and quality of the scientific work performed and the results achieved. The conclusions and main contributions are precisely formulated.

The abstract is prepared in accordance with the requirements.

10. Critical remarks and recommendations

My critical remarks to the author are related to terminological inconsistencies and inaccuracies, inevitable when writing such a work. I will not mention them, since they in no way affect the scientific assessment of the research conducted.

11. Questions

1. On page 55 (as well as elsewhere) the factor "degree of polarization" is mentioned as limiting the accuracy of the QSP. Does this factor depend on the optical radiation (collimated or non-collimated) and on the aberrations of the optical system? In your experiment, were these parameters controlled and how?
2. In the magnetic field detection experiment, the phase difference induced by the magnetic field was measured. Why was Faraday rotation, which seems to be a simpler task, not recorded?

12. Recommendations for future use of the dissertation contributions and results

I believe that the channel polarimetry method has a wide field of application. In this aspect, it is good to construct the CSP as a compact optical module that is portable and easy to integrate with other optical circuits.

CONCLUSION

The presented dissertation work unconditionally **contains scientific and applied scientific results that represent an original contribution to science** and **fully meet** the requirements of the Act on the Development of the Academic Staff in the Republic of Bulgaria (ADSRB), the Regulations for the Implementation of the ADSRB and the relevant Regulations of the Bulgarian Academy of Sciences. The presented materials and dissertation results fully comply with the specific requirements of the Bulgarian Academy of Sciences, adopted in connection with the Regulations for the Implementation of the ADSRB.

The dissertation shows that the doctoral student Petar Kolev **possesses** in-depth theoretical knowledge and experimental skills, **demonstrating** qualities and skills for independent scientific research. In view of the above, I confidently give my **positive assessment** of the research conducted, presented by the above-reviewed dissertation, abstract, achieved results and contributions, and **I propose to the esteemed scientific jury to award the educational and scientific degree of 'doctor'** to Petar Kolev in the field of higher education: 4. "Natural Sciences, Mathematics and Informatics", professional field 4. 1. "Physical Sciences", doctoral program "Electrical, Magnetic and Optical Properties of Condensed Matter''.

26.02.2026 г. Reviewer:

Assoc. Prof. Dr. Tihomir Tenev