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OPINION

regarding the dissertation submitted for the award of the educational and scientific degree of "Doctor" in professional field 4.1 – Physical Sciences, scientific specialty "Electrical, Magnetic, and Optical Properties of Condensed Matter."

Title of the dissertation: "Sensors Based on Spectral Polarimetric Detection"
Doctoral candidate: Petar Kolev, Institute of Optical Materials and Technologies "Acad. Yordan Malinovsky," Bulgarian Academy of Sciences
Prepared by: Prof. DSc. Elena Stoykova, Institute of Optical Materials and Technologies "Acad. Yordan Malinovsky," Bulgarian Academy of Sciences, in accordance with Order RD-15-959 dated 16.12.2025

The dissertation consists of an introduction, three chapters (one of which is a review-theoretical chapter), a conclusion and main contributions, a list of figures, symbols, abbreviations, and units of measurement, a list of publications related to the dissertation and recorded citations, as well as a list of 135 cited references. The dissertation includes 64 figures and 11 tables.

The dissertation is dedicated to the method of channeled polarimetry (MCP) as an approach for precise determination of the state of polarization over a wide spectral range by creating amplitude–phase modulation in the spectral domain. The spectrum is recorded in a single shot and, through Fourier processing (or an equivalent numerical algorithm), the Stokes parameters are extracted. The dissertation emphasizes that although MCP has been known for more than 25 years, it is still not widely used in optical sensing due to unresolved issues such as accuracy, choice of algorithms, design features, and sources of error. A key aspect of the research presented in the dissertation is the application of MCP in two classes of sensors: sensors based on surface plasmon resonance (SPR) for gas detection and biological studies; magneto-optical sensors (MOS) based on the Faraday effect. It is emphasized that in SPR sensors based on diffraction gratings, conventional amplitude detection exhibits instability and lower sensitivity, whereas phase detection using MCP has the potential to overcome these limitations by measuring the phase difference between p- and s-polarizations at resonance.

Chapter 1, entitled "Literature Review," presents a detailed theoretical analysis of surface plasmon resonance (SPR), examining the physics of the plasmon wave at the metal–dielectric interface. The excitation of SPR using a prism at the external boundary of the metal through attenuated total internal reflection and the spectral or angular observation of a resonance minimum are analyzed, as well as a second excitation method based on a diffraction grating. The dissertation derives the condition for SPR excitation using a grating and analyzes the role of the diffraction order and the grating period. An important part of the theoretical discussion is the definition of the parameters describing SPR sensors, such as sensitivity (angular or spectral), resolution, signal-to-noise ratio, and others. The doctoral candidate, Petar Kolev, compares the use of a prism and a grating and formulates important conclusions, including the main conclusion of the dissertation: that phase detection via MCP can compensate for weaker amplitude detection in grating-based SPR sensors and lead to significantly improved sensitivity and stability.

Chapter 2, "Design of a Channeled Polarimeter," presents the main engineering contribution of the dissertation: the design and implementation of a channeled spectral polarimeter (CSP). The following tasks were accomplished: calculation of the thicknesses of the phase plates; construction of the experimental setup; alignment of the optical elements (both polarimetric and spectral); determination of the fast axes of the phase retarders; experimental verification of the alignment and of the Fourier algorithm and comparison of two phase-plate configurations in the context of phase measurement of SPR. This chapter establishes the fundamental practical basis for the conducted research.

Chapter 3, "Sensors Based on Spectral Polarimetric Detection," demonstrates the application of the developed method and instrumentation in three practical areas. An SPR biosensor for the detection of the bacterium *Helicobacter pylori* is investigated, where the key challenge is the reliable registration of small changes in the refractive index during biomolecular interactions. In this case, a high signal-to-noise ratio and stability are sought, and MCP is used as a tool for phase detection. The second application is an SPR gas sensor for hydrogen detection, where amplitude variations may be small and strongly affected by noise. This type of application is particularly critical in terms of precision, since grating-based SPR sensors exhibit low sensitivity when using amplitude detection, whereas phase detection via MCP can improve the detection limit. The third class of applications is a magneto-optical sensor based on the Faraday effect. The main issue emphasized in the dissertation is the temperature instability of such a sensor, and MCP has the potential to minimize it because, under certain operating conditions, it directly measures a phase difference that is independent of temperature. The chapter analyzes the determination of the state of polarization, the direct measurement of the Faraday phase difference, magnetic field measurement, temperature stability, and accuracy. It should be noted that such investigations have been conducted for the first time.

The aim of the dissertation, formulated as the experimental development of an MCP system and the investigation of the applicability of this method to various sensors, has been fully achieved by solving specific tasks: designing and constructing a channeled spectral polarimeter, optimizing the structural elements, minimizing errors, evaluating accuracy and resolution, and demonstrating the advantages of MCP through real sensor experiments (biosensor, gas sensor, and magneto-optical sensor).

The results of the dissertation have two main contributions. The first is methodological and instrumental, involving the development of a channeled spectral polarimeter and the experimental implementation of MCP for practical sensing applications. The second contribution is in applied science, demonstrating the effectiveness of MCP in SPR bio- and gas sensors and in magneto-optical sensors, with a focus on improving parameters such as signal-to-noise ratio, sensitivity, and stability. The dissertation shows that MCP, implemented through a specially designed channeled spectral polarimeter, is a practically applicable and promising method for phase polarimetric detection, capable of substantially improving the sensitivity and stability of SPR sensors (especially grating-based ones) and providing more stable measurements in magneto-optical sensors.

A merit of the dissertation is that it is not purely theoretical, but presents a real, functioning polarimetric instrument that enables phase information measurements under conditions relevant to sensing applications. The doctoral candidate demonstrates very good knowledge of the scientific literature on the subject.

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The results of the dissertation have been published in four papers: two of them in Q1 journals (*Sensors*), one in a Q2 journal (*Optics Communications*), and one in a journal with an impact rank. The doctoral candidate, Petar Kolev, is the first author of the paper published in the journal with an impact rank, the second author of one Q1 publication, and the third author of the other publications with an impact factor. According to the contribution statements included in the dissertation documentation, Petar Kolev has made a substantial contribution to the publications in which he is not the first author, through the development of the experimental setup, conducting measurements, processing the results, and performing error analysis. To date, 11 citations of the dissertation-related articles have been recorded. Petar Kolev has presented seven posters at international conferences in Bulgaria and has participated in one poster presented at a conference in Japan. The submitted Synopsis provides an accurate description of the results obtained in the dissertation. After a thorough review of the dissertation, I am left with the impression that it is primarily the work of the doctoral candidate himself.

The dissertation is not written in a monographic style, but rather is structured as a sequence of clearly formulated practical tasks and a description of the methods used to solve them. The presentation is well organized; however, as a shortcoming I would point out the presence of certain terminological inaccuracies, for example the use of "resolution" instead of "resolving power," or "normalized values" as an imprecise translation from English instead of "normed values." The dissertation would undoubtedly benefit from additional stylistic editing, particularly with regard to punctuation.

I would like to receive answers to the following questions below:

What is the purpose of Figure 28?
What does the red curve in Figures 43 and 48 represent?
Figure 54 from reference 131 is left without explanation in the text, and the meaning of the different symbols is unclear.
What does the sentence mean: "The experimental verification of the measurement protocol was carried out by measuring the intrinsic optical activity of BSO. Given the well-known data for this characteristic[131] – Figure 54, we expected to obtain similar results. However, they differed drastically."

The critical remarks do not diminish the high level achieved in the dissertation in the field of precise measurements.

After reviewing the submitted dissertation, synopsis, and other materials, and based on the analysis of their significance and the scientific and applied contributions contained therein, I confirm that the scientific achievements meet the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria (ЗРАСРБ), its implementing regulations, and the corresponding regulations of IOMT-BAS for the award of the educational and scientific degree of "Doctor." In particular, the doctoral candidate meets the minimum national requirements in the professional field, and no plagiarism has been found in the submitted dissertation, abstract, or scientific publications. I give my positive evaluation of the dissertation.

Based on the above, I recommend that the scientific jury award the educational and scientific degree of "Doctor" in professional field 4.1 – Physical Sciences to Petar Todorov Kolev.

26.02.2026 Reviewer: ....

(prof DSc. Elena Stoykova.)