REFERENCE

of **Volodymyr V. Yachin** as official opponent of the dissertation of Dariia O. Herasymova entitled, **" Diffraction radiation from dielectric, silver and graphene circular nanowire configurations excited by modulated electron beam,"** submitted for the defense of the degree of Doctor of Philosophy in specialty 104 - Physics and Astronomy (10 - Natural Sciences).

Timeliness of the dissertation topic. Microwave-range DR is already used as a convenient method for non-invasive diagnostics of beams in accelerators, which are commonly referred to as beam position monitors (BPM). Today, the development of BPM can be extended to the optical range, because the emergence and rapid development of nanotechnology opens the way to create ensembles of nanosized optical scatterers with controlled shape and location. Nanoscale components introduce very little perturbation to the beam, its velocity and trajectory, and therefore its field can be considered fixed. Therefore, the analysis of the DR effect of a beam of charged particles moving near nanoscale obstacles is necessary and insufficiently covered in the available scientific works. Hence, the subject of research of the D.O. Herasymova's dissertation is the resonance and spectral characteristics of the EM field scattering and absorption by finite configurations of circular nanowires and nanotubes, excited by the modulated beams of charged particles, as well as the eigenmodes of such nanowire configurations.

The **relevance** of the topic of Herasymova's D.O. dissertation is linked with fundamental research in the field of nanophotonics and optics, and the additional practical interest of application in the field of radio physics (accelerator physics). Namely, the study of phenomena of the scattering and absorption of the modulated electron beam field by dimer configurations of dielectric, silver, and coated with graphene as beam position monitors and finite gratins of such wires as dielectric laser accelerators is relevant.

The goal of this work is to analyze the DR effect for various structures of circular nanowires and nanotubes made of dielectric, metal, and graphene for choosing the configurations which are the most sensitive to variations in the trajectory of the beam and to the changes in its velocity. To achieve these goals, the following tasks are solved: building adequate 2-D mathematical models of investigated configurations; developing corresponding numerical algorithms for computation of the scattering and absorption characteristics, as well as the fields in the near and far zones of the studied structures; the influence of different types of resonances on the DR of a modulated electron beam was investigated; Optical Theorem was modified (relationship between the DR scattering and absorption characteristics) for modulated electron beam case; the theoretical results was confirmed by the use of the commercial numerical codes; recommendations for an optimal design of the optical BPM were made.

Structure of the dissertation of Herasymova D.O. consists of an abstract, an introduction, five chapters, general conclusions, list of used sources and appendix. The dissertation work based on 6 journal papers, that was published in the international scientific editions and 19 conference papers in proceedings of international conferences.

The **first chapter** deals with the basic methods of analysis of wave scattering by circular configurations of dielectric wires, the representation of the incident field as a harmonically modulated field of a beam of charged particles, the complex permittivity of silver as a function of frequency, the description of graphene conductivity using the Kubo formalism, scattering and absorption the characteristics representation, and the description of Optical theorem adapted to the beam field, and the formulation of the eigenvalue laser problem.

In the **second** chapter, the scattering problem is formulated for a finite number of circular nanowires excited by the modulate electron beam. Also, the chapter is devoted to the numerical study of the scattering and absorption characteristics in the visible range for a single dielectric nanowire and a dimer of two such nanowires.

The **third** chapter contains an analysis of the scattering and absorption characteristics for a single circular silver nanowire and a dimer configuration of silver nanowires and nanotubes in the visible range. In addition, this section provides a comparison of the absorption characteristics of the silver tubes dimer with results of a commercial solver (by the FDTD method).

The **fourth** chapter numerically investigates the scattering and absorption characteristics in the terahertz range for a single graphene-coated circular dielectric nanowire, a dimer configuration of such graphene-coated nanowires, and a finite array of graphene-coated circular dielectric nanowires.

The **fifth** chapter presents the implementation of the to the laser eigenvalues problem approach for study of the electromagnetic field in the presence of one circular quantum wire, which is made of a gain material and wrapped in graphene and a dimer of two identical such wires, at the threshold of stationary radiation.

At the end of each chapter of the dissertation, the author gives relevant conclusions, overall results are given at the end of the work. Therefore, the personal contribution of the PhD student is decisive.

Validity and reliability of scientific conclusions. In opponent's opinion, the presented research results are correct and reliable. This is confirmed by the use of well-known and reliable research, publications in rating professional international journals, which are included in international multidisciplinary databases. The results presented in the work have been successfully tested at international scientific conferences in Ukraine and abroad. Therefore, there is no doubt about the validity of the scientific statements, conclusions and recommendations formulated by the acquirer.

Scientific novelty. Among the number of new results obtained, the significant ones are the following:

- the effect of resonant response in the DR of modulated beam of electrons of high refractive-index dielectric wires, thin noble-metal nanotubes, and graphene-covered wires at the high enough values of graphene's chemical potential was revealed;
- the results of numerical analysis of the DR-caused scattering and absorption characteristics versus the frequency and other parameters, the far and near field patterns of the wave emission from charged particle beam moving near various nanowire scatterers and gratings of them were obtained. They have fundamental significance and a wide range of applications including the BPM and DLA designs. The analysis of thresholds conditions for the plasmon modes of the considered in the thesis nanolasers can help in the creation of new, more efficient sources of waves;
- the Optical Theorem has been adapted to the DR effect of modulated electron beam.

Critical comments on the thesis. Among the questions and comments on the content of the work, which are worth discussing, it is necessary to note the following imperfections:

- In my opinion, it was worth analyzing in more detail the effectiveness of monitoring the position of the beam with round bars made of different materials and configurations. Additionally, provide a graphical comparison;
- There are few comparisons with simulation results in commercial applications. It would be necessary to provide a comparison of theoretical data with experiment;
- The author should not have used the term near field to the distribution of the field inside the cylindrical object - this is the internal field of the object;
- The work does not analyze the influence of the angular displacement of the trajectory of the modulated beam of charged particles on the diffraction radiation;
- In the last chapter for the study of grating made of dielectric nanowires covered with graphene, the absorption characteristics are not presented;
- The shortcomings should also include the presence of stylistic and typographical errors in the text.

Worth noticing that the above-mentioned shortcomings are not of a fundamental nature and do not affect the overall positive assessment of the work.

General conclusion. I believe that the dissertation work of Dariia O. Herasymova is a completed, self-prepared qualifying scientific study in which new scientifically based and practically valuable results were obtained. The main advantages of this dissertation work include the fact that all the results obtained by the author were published and approbated in highly-rated international journals and conferences.

I am convinced that according to the relevance, novelty, scientific level and scope of the conducted research the dissertation of D.O. Herasymova entitled «Diffraction radiation from dielectric, silver and graphene circular nanowire configurations excited by modulated electron beam» meets the requirements of the Ministry of Education and Science of Ukraine, which are submitted to the works submitted for obtaining the scientific degree of Doctor of Philosophy, in particular clauses 9, 10, 11, 12 of the "Temporary procedure for awarding the degree of Doctor of Philosophy", approved by the Decree of the Cabinet of Ministers of Ukraine dated March 6, 2019 No. 167 with changes according to the Decree of the Cabinet of Ministers No. 608 dated 09.06. 2021, and its author Dariia O. Herasymova, deserves to be awarded the degree of Doctor of Philosophy in specialty 104 - physics and astronomy, 10 - natural sciences.

Opponent
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Signature of Doctor of Ph.-M. Sc. Volodymyr YACHIN certifies:
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February 5, 2024