REVIEW

of the dissertation by Dariia O. Herasymova

"Diffraction radiation from dielectric, silver and graphene circular nanowire configurations excited by modulated electron beam"

submitted for the degree of Doctor of Philosophy in the field of knowledge 10 "Natural Sciences" and the specialization 104 "Physics and Astronomy"

Urgency of the research topic

The dissertation is dedicated to the diffraction radiation generated by structures composed of individual, paired, and periodic arrays of circular dielectric, metallic, and graphene-coated nanowires and nanotubes under electron beam excitation. Theoretical investigations delve into the resonant effects of diffraction radiation and explore the prospects for developing novel devices. This dissertation contributes to globally relevant and urgent topics, such as the use of graphene for creating new devices, contactless monitoring of the position and velocity of electron beams, miniature dielectric laser accelerators, and new sources of THz radiation. Graphene is a novel material with unique properties. While flat graphene structures on dielectric substrates have been extensively studied, graphene-coated circular nanowire remain less-explored, and diffraction radiation from such structures is entirely unexplored. This is precisely the focus of this work. The initial analysis examines the diffraction radiation from individual nanowires, which is crucial for understanding the physics of the phenomena under study. Although this analysis is relatively straightforward, it has not been performed previously. Then, dimers (pairs) of dielectric, silver, and graphene-coated nanowires and nanotubes are considered. These structures exhibit the highest sensitivity to spatial displacements of the electron beam and can be utilized for beam position monitoring. Additionally, periodic structures (gratings) of graphene-coated nanowires are in studied because they form the basis of dielectric laser accelerators and THz radiation sources.

Structure, content, and formatting of the dissertation

The dissertation of Herasymova D. O. is a logically built research, systematically progressing through stages such as literature review, identification of inadequately studied areas, selection of approaches and methods, formulation of mathematical problems, and their solution using numerical methods. Subsequently, the developed algorithms are employed to model the electromagnetic structures under study, and the simulation results are thoroughly analyzed. The dissertation is written in excellent English, making it easy and engaging to read.

The dissertation comprises an abstract (in Ukrainian and English), an introduction, five chapters with conclusions for each, general conclusions, a list of references, and an appendix listing scientific publications and conference presentations based on the dissertation's material. The introduction defines the relevance, purpose, and objectives of the research, briefly describes the methods used, discusses the novelty and value of the obtained results, highlights the author's contribution, publication of results, connection to scientific programs, plans, and themes, as well as grants and awards received. The first chapter contains a literature review on the research topic, defines the research direction, provides a detailed description of the addressed problems, and outlines the methods used. The second chapter focuses on the investigation of diffraction radiation from an electron beam near dielectric nanowires, covers the mathematical formulation of the problem, and the analysis of computer simulation results. The third and fourth chapters are dedicated to silver nanowires and nanotubes (Chapter 3) and graphene-coated nanowires (Chapter 4). They have the same structure as Chapter 2. The fifth chapter explores the conditions for laser radiation of graphene-coated nanowires made of gain material.
The dissertation is formatted according to the current requirements

Connection with scientific programs, plans, and topics

The dissertation work was carried out at O. Ya. Usikov Institute of Radiophysics and Electronics of the National Academy of Sciences of Ukraine (Department of quasi-optics, Laboratory of micro- and nanooptics). The dissertation aligns with the scientific work of the Institute. The research was conducted within the framework of six state-funded and competitive research projects, including collaborations with University of Rennes 1 in France. Additionally, the work was supported by seven(!) grants and awards from IEEE and European Association on Antennas and Propagation.

Scientific results and their novelty

The following new scientific results were obtained during the work on dissertation: (i) The emergence of new resonances when an electron beam deviates from the central position between the two wires of a dimer. This effect is thoroughly analyzed in the dissertation, and the conditions for its manifestation or absence are identified. It is noted that these resonances are associated with dimer’s supermodes, and their intensity is proportional to the beam shift. (ii) Adaptation of the Optical theorem from the theory of scattering of plane waves to the scenario with diffraction radiation. (iii) The dominance of resonances on the plasmon modes of nanowires and lattice modes in the diffraction radiation of finite gratings of graphene-covered nanowires is revealed. (iv) The dependence between the radius of active graphene-covered nanowires and the frequencies and threshold values of amplification of plasmon and dielectric modes is established. (v) The

properties of plasmon supermodes of dimers with graphene-covered nanowires made of gain material are investigated.

Rationale grounds of the obtained results

The reliability of the obtained results stems from the accurate formulation of the problem being solved, the partial inversion of it using a mathematically rigorous approach (the method of analytical regularization), and numerical solution with controlled accuracy. The developed algorithms were thoroughly tested before exploring previously uninvestigated structures.

The dissertation materials are published as six articles in peer-reviewed journals (all Q1 and Q2) and were presented as 19 talks at international conferences. The quality and quantity of publications serve as an additional evidence of the high scientific level of the research.

Practical value of obtained results

The developed algorithms exhibit controlled precision and are computationally efficient, allowing for the reliable and effective investigation of diffraction radiation generated by nanowires and nanotubes made of dielectrics, noble metals, and graphene, even on moderately powered computers. Furthermore, these algorithms can serve as a foundation for optimization programs for optical devices based on nanowires and nanotubes. The dependencies of diffraction radiation characteristics on frequency and other parameters, as well as the behavior in near and far zones, hold both fundamental scientific value and practical importance for the development of, for example, beam position monitors or dielectric laser accelerators. The analysis of threshold conditions for plasmon modes in the nanolasers considered in the dissertation can be valuable in creating new, more efficient THz radiation sources.

Accomplishment of research tasks and mastery of the methodology of scientific work

The set scientific task was successfully accomplished, involving (i) the construction of accurate mathematical models for the interaction of an electron beam with nanowires and nanotubes; (ii) the development of algorithms for the numerical solution of these mathematical problems; (iii) the investigation of the influence of resonances of various natures on the diffraction radiation; (iv) the adaptation of the Optical Theorem for the case of diffraction radiation; (v) the exploration of eigenmodes of dimers as open resonators, determining threshold conditions in the presence of gain materials; (vi) the demonstration of the potential use of dimers for beam position monitoring. The successful resolution of these tasks attests to the high level of accomplishment in the scientific research and the author’s mastery of the methodology of scientific work.

Feedback on the dissertation

There are several comments on this dissertation:

1. At some points, it is not entirely clear where known results end and original contributions begin. For example, during the modification of the Optical Theorem for diffraction radiation.
2. There is almost a complete absence of references when the method of analytical regularization is utilized in sections 2.2 and 3.3.1.
3. It would be interesting to see results for a greater variety of values of h (distance between the x-axis and a beam) in sections 3.2 and 3.3. The structures investigated there (dimers of silver nanowires and nanotubes) are proposed for use as beam characteristic monitors, and it would be useful to see how the properties of diffraction radiation change when an electron beam is shifted at various distances from the symmetry axis.
4. A number of minor errors were noticed, though they are likely corrected in the final version of the text. These include typos, formatting issues, confusion with notation, references, formulas and figures numbers.

All these comments are purely cosmetic and do not diminish the overall positive impression of the dissertation.

Information on the academic integrity compliance

In the dissertation and scientific publications of Herasymova D. O., no violations of academic integrity have been noticed.

Conclusions on the dissertation

The dissertation by Herasymova D. O. “Diffraction radiation from dielectric, silver and graphene circular nanowire configurations excited by modulated electron beam” is a completed scientific work that fully complies with the requirements of the Ministry of Education and Science of Ukraine order No. 40 dated January 12, 2017 "On approval of the requirements for the design of the dissertation" (with subsequent changes) and the Cabinet of Ministers of Ukraine resolution No. 44 dated January 12, 2022 "On approval of the procedure for awarding the degree of Doctor of Philosophy and canceling the decision of a one-time specialized academic council of a higher education institution or a research institution on awarding the degree of Doctor of Philosophy". The author, Dariia O. Herasymova, deserves to be awarded the degree of Doctor of Philosophy in the field of knowledge 10 “Natural Sciences” in the specialty 104 “Physics and Astronomy”.

Reviewer

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senior researcher

O. Ya. Usikov Institute for Radiophysics and Electronics NASU

Kostyantyn Sirenko

The signature of Kostyantyn Sirenko
is attested
Acting scientific secretary
of Institute

УКРАЇНА
ІНСТИТУТ РАДІОФІЗИКИ ТА ЕЛЕКТРОНІКИ ім. О.Я.УСИКОВА НАЦІОНАЛЬНОЇ АКАДЕМІЇ НАУК УКРАЇНИ
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