

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Alexandra Tambova

PhD Program: Computational and Data Science and Engineering

Title of Thesis: The numerical modeling of nanophotonics by means of well-conditioned volume integral equation methods

Supervisor: Prof. Maxim Fedorov

Co-advisor: Prof. Athanasios Polimeridis

Chair of PhD defense Jury: Prof. Ivan Oseledets

Email: I.Oseledets@skoltech.ru

Date of Thesis Defense: 28 November 2019

Name of the Reviewer: Vladimir Okhmatovski

<p>I confirm the absence of any conflict of interest</p> <p>(Alternatively, Reviewer can formulate a possible conflict)</p>	<p>Signature:</p>  <p>Date: 28-10-2019</p>
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The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

The Ph.D. thesis of Aleksandra Tambova focuses on construction of computational methods for efficient electromagnetic analysis of nanophotonic structures. The Method of Moments (MoM) discretization of the Volume Integral Equation (VIE) is chosen for the solution of the targeted applied problems. Novel approaches to evaluation of the MoM integrals, pre-conditioning of resultant matrix equations, and truncation of the waveguiding structures are developed and validated. The proposed advances are made to the state-of-the-art methods currently used in the Computational Electromagnetics (CEM) community. The novelty of the contributions is in compliance with the international standards, which is testified by candidate's publications in the top-tier journals in the areas of CEM and optics. Proposed novel method for evaluation of singular 4D integrals on quadrilateral elements has applications in MoM solutions of both volume and surface integral equations of electromagnetics. As such it is applicable to the problems of CEM going far beyond the scope of applications targeted in the thesis.

The main contributions of the thesis are in:

- 1) Generalization of the DIRECTFN method to singular integrals on general quadrilateral patches. Previously DIRECTFN formulation was only available for triangular elements.
- 2) Use of adiabatic absorbers in FFT-accelerated VIE formulation for nano-photonic devices, which do not impose complications into computational framework, while enabling imitation of infinite extent of dielectric waveguides.

Contribution (1) was published in IEEE Transactions on Antennas and Propagation, which is a top tier journal in computational and applied electromagnetics. Contribution (2) was published in the Journal of Lightwave Technology.

The candidate also made her contribution to the work on circulant preconditioners for the VIE solvers accelerated with FFT and co-authored a paper on this work with Dr. Groth and her co-advisors in the Journal of the Optical Society of America.

The strengths of the thesis are in:

- a) Introduction of a new approach to computation of 4D integrals on arbitrary quadrilaterals, it's comprehensive description in the thesis, and public release of pertinent software, which can greatly ease the adoption of the method by the community;
- b) Introduction of the adiabatic absorbers into fast VIE formulations combined with potentially well-scalable parallel algorithms for the proposed FFT-based formulation, and robust preconditioning which make complete and powerful framework for analysis of nanophotonic devices;
- c) Careful numerical study of the proposed methods demonstrating their capabilities and limitations;
- d) Endorsement of the methods through publication of peer reviewed articles in high impact journals;
- e) Well written thesis document which is easy to read for experts in the field.

The weaknesses of the thesis are in:

a) Lack of discussion on pros and cons of the proposed VIE formulation and alternative hybrid surface IE + VIE alternatives. Considered nanophotonics structures are homogeneous except for relatively small regions of adiabatic absorbers. As a result, surface integral equation formulations could be utilized for analysis of the bulk of the structures, while VIE could be used only for the absorber regions. Such formulation could be significantly more efficient.

b) Lack of breadth in the literature review. References on use of MLFMA accelerated surface integral equation formulations for solution on nanophotonics problems should be added (e.g works of O. Ergul) as well as overview of new integral equations formulations such as, for example, de-coupled potential integral equations (works by L. Greengard and W.C. Chew).

The merits of the thesis by far outweigh the above-mentioned weaknesses, as it provides a comprehensive treatment of the subject matter and makes distinct novel contributions to the field. As such I recommend the thesis for admission to public defense.

Provisional Recommendation

I recommend that the candidate should defend the thesis by means of a formal thesis defense

I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report

The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense