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Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Gür, U. M., Gregersen, N., Arslanagic, S., & Mattes, M. (2020). *Analysis of Open Elliptical Nanophotonic Structures with the Modal Method*. Paper presented at Workshop on Theoretical and Numerical Tools for Nanophotonics, Berlin, Berlin, Germany.

Analysis of Open Elliptical Nanophotonic Structures with the Modal Method

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In this contribution, open boundary elliptical nanophotonic structures are modeled and simulated via a full-wave vectorial modal method. Analytical basis modes based on the splitting of transverse magnetic and transverse electric fields are constructed. The special basis modes used in the implementation lead to analytical coupling integrals, and therefore fast and efficient simulations.

Introduction

Transforming foundational knowledge into real applications requires high-efficiency devices. This is not different for quantum and laser photonics [1]. To design efficient photonic structures, one needs to have a powerful, efficient simulation tools at hand. The modal method provides not only rigorous solutions to electromagnetic problems but also provides an understanding of the phenomenon via direct access to physical quantities such as propagation constants, eigenmodes, and modal reflection coefficients. That access eases the calculation of spontaneous emission rates and of β factors of lasers and single-photon sources significantly.

Elliptical structures are known to allow polarization control and true-monomode operation capabilities [2]. Their simulation with traditional full-wave solvers such as the Finite Element Method or the Finite Difference Time Domain Method are computationally expensive. Those methods employ absorbing boundary layers which have to be tuned to model the open boundary environment. However, with the modal method exploiting the symmetry of the structure and modeling intrinsically the correct boundary conditions, it is possible to implement an efficient solver without such artificial layers.

Method

We expand transverse fields in terms of known basis modes and unknown modal coefficients. We employ a splitting in the basis modes based on transverse magnetic and transverse electric fields, unlike the splitting based on coordinate variables usually applied in the literature [3]. We obtain the basis modes from analytical solutions of the empty geometry. That leads to analytical coupling integrals which can be evaluated easily. The open boundary environment is taken into account by discretizing non-uniformly the infinite k-space domain [4]. That further increases the stability and efficiency of the solver.

This work has been funded by Villum Fonden (VKR Center of Excellence NATEC-II, grant 8692).

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