Modelling open nanophotonic structures using the Fourier modal method in infinite domains

Andreas D. Osterkryger*[1], Teppo Häyrynen[1], Jakob R. de Lasson[1], and Niels Gregersen[1]

1. Technical University of Denmark Institute of Photonics, Ørsteds Plads, Building 343, DK-2800 Kongens Lyngby
**corresponding author, E-mail: adyh@fotonik.dtu.dk*

The Fourier modal method in Cartesian coordinates uses Fourier series as the expansion basis [1]. This leads to periodic boundary conditions, which is advantageous for periodic structures like photonic crystals. However, for modelling open geometries periodic boundary conditions leads to parasitic reflections from the leaky modes into the computational domain. This can be overcome by using absorbing boundaries, such as perfectly matched layers (PMLs), but convergence of these PML boundaries towards an open geometry limit is generally not obtained. [2]. To avoid the need for PMLs open boundary conditions can be used and recently this was developed for structures having cylindrical symmetry [3], where a non-uniform sampling of the k-space was shown to converge much faster than for the standard equidistant k-space discretization. The open boundaries are introduced by using Fourier integrals instead of Fourier series as the expansion basis for the eigenmodes.

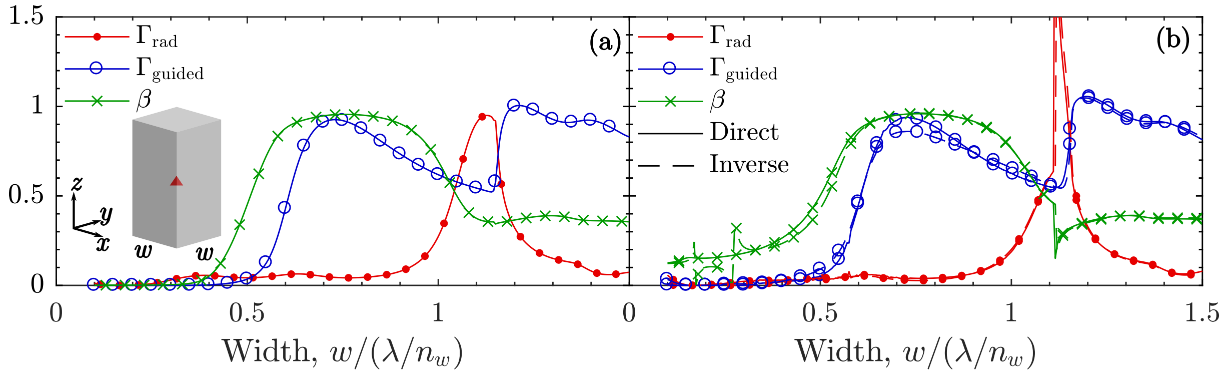

Figure 1: Normalised emission rates for an x-oriented dipole located on axis in an infinte square nanowire. (a) The emission rates computed with a clever sampling of the k-space using 5558 modes and (b) using a standard equidistant sampling with 6400 modes (80 k-points in each direction) employing both the direct rule and Li's inverse factorization rule [4].

In this work we have developed an open-geometry Fourier modal method with open boundary conditions in 3D Cartesian coordinates [5]. Our results show that a non-uniform sampling of the k-space is essential to obtain good convergence especially for the leaky modes. This is seen in Fig. 1, where the emission rates into the guided and radiating modes and the beta factor are computed using (a) a similar non-uniform discretization of the k-space as in [3] and (b) using an equidistant k-grid employing the direct rule and Li's inverse rule for Fourier factorization [4]. The emission rate into the guided modes is well described with both discretization schemes, but the radiation modes are poorly described with the equidistant grid. Additionally, we will discuss which type of geometries benefits from the open-geometry Fourier modal method.

References

[1] A. V. Lavrinenko, J. Lægsgaard, N. Gregersen, F. Schmidt, and T. Søndergaard, *Numerical methods in photonics* (CRC Press, 2014).

[2] J. R. de Lasson, "Modeling and simulations of light emission and propagation in open nanophotonic systems," Ph.D. thesis, Technical University of Denmark (2015).

[3] T. Häyrynen, J. R. de Lasson, and N. Gregersen, "Open-geometry Fourier modal method: modeling nanophotonic structures in infinite domains," J. Opt. Soc. Am. A **33**, 1298–1306 (2016).

[4] L. Li, "Use of fourier series in the analysis of discontinuous periodic structures," J. Opt. Soc. Am. A **13**, 1870–1876 (1996).

[5] T. Häyrynen, A. D. Osterkryger, J. R. de Lasson, and N. Gregersen, "Modeling open nanophotonic systems using the fourier modal method: Generalization to 3d cartesian coordinates," (2017). Submitted.