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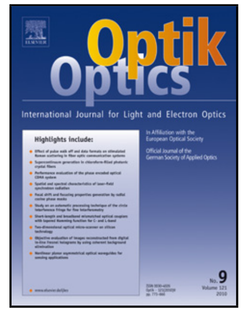

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Adaptive Wavelet Collocation Method for Simulation of a 2D Micro-ring Resonator

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Abstract

In this paper, we use adaptive wavelet collocation method (AWCM) to solve the 2D time domain Maxwell's equations. Our motivation of choosing AWCM is because it effectively adapts numerical grid points along moving signals according to the requirements of resolution levels of them. In the region where moving signals are intensive, there will be assigned more grid points; and in the region where signals are sparse, there will be arranged less grid points. Since signals are moving during time stepping, the grid changes dynamically at each time step. We verified that AWCM is an efficient method especially for problems in which signals are highly concentrated inside and guided through optical waveguides such as micro-ring resonators.

Keywords: adaptive wavelet collocation method (AWCM), Maxwell's equations, perfectly matched layer (PML), total field and scattered field (TF/SF) formulation, micro-ring resonator.

1. Introduction

In this paper we propose and test an adaptive wavelet collocation scheme, which belongs to the finite difference time domain (FDTD) methods, for simulating wave propagation in a micro-ring resonator. As micro-ring resonators are optical devices, their numerical simulation and optimization are essential for future information transmission and processing. For instance, they serve as optical filters, switches and routers, see for example, [10, 21].

Micro-ring resonators are composed of a circular ring cavity and two straight waveguides (Figure 1). We call it a *micro-ring resonator*, since the widths of the ring and the waveguides are in the scale of micrometers. Optical signals which are launched from one of the straight waveguides may resonate into the ring cavity and may switch over to the other straight waveguide if their frequencies match with the so called *resonant frequencies* of the ring.

Numerical simulations of optical waveguides have been done with a variety of numerical methods, such as finite difference time domain (FDTD) method [10, 21], interpolating scaling functions method (ISFM) [7], discontinuous Galerkin time domain (DGTD) method [12, 18]. All these methods use a fixed grid of points for discretization. Hence, the grid may not resolve time-dependent signals with the needed accuracy or it does resolve them, however, using too many points slowing down the computational efficiency and increasing the storage cost. We propose an adaptive grid method which represents moving signals at each time step by a compressed wavelet decomposition and which automatically adapts to the changing shape of the signal. Wavelet decompositions are naturally suited for this purpose as already exploited by Vasilyev [24, 23] who developed the adaptive wavelet collocation method (AWCM) as a general scheme to solve evolution equations and who successfully verified its computational effectiveness in the area of computational fluid dynamics. We rely on his results and present an AWCM implementation for the area of computational electrodynamics, especially, for simulating light propagation through ring resonators.

The paper is organized as follows. In the next section, we provide a brief account on Maxwell's equations and the concept of perfectly matched layers (PML) which allows us to restrict Maxwell's equations to a bounded domain. Then we start section 3 with an introduction to interpolating wavelets and how they can be used to discretize partial differential equations. Also in this section we explain the structure of AWCM in the context of Maxwell's equations. Section 4 contains our numerical experiments of propagating a 2D Gaussian peak in free space and of simulating a micro-ring resonator. Further we compare some AWCM simulation results for the resonator with those obtained by established methods. Finally we close the paper with some concluding remarks.

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