

# Simulation using MEEP library

Elisabetta Ferri

March 14, 2024

## Abstract

The results produced by the simulation of photonics elements are presented. Using the MEEP software, three elements were simulated: a directional coupler, a Bragg refractor and a micro ring resonator.

## 1 Introduction

Meep is a free and open-source software package for the simulation of electromagnetic fields via the finite-difference time-domain (FDTD) method. Its application extend also to the simulation of photonic elements and circuits.

The finite-difference time-domain (FDTD) method is a widely used technique: the space is divided into a discrete grid and the fields are evolved in discrete time steps. The discretization of time is directly determined by the space discretization and as the steps are made finer and finer, the simulation becomes a closer and closer approximation for the true continuous equations.

Considering the 1D case for simplicity, the FDTD algorithm starts from the Ampere's and Faraday's laws.

$$\mu \frac{\partial H_y}{\partial t} = \frac{\partial E_z}{\partial x} \quad \varepsilon \frac{\partial H_z}{\partial t} = \frac{\partial H_y}{\partial x} \quad (1)$$

As the space and time are discretized, the electric and magnetic fields can be written using a discrete notation as  $E_z(x, t) = E_z(m\Delta x, q\Delta t) = E_z^q[m]$  and  $H_y(x, t) = H_y(m\Delta x, q\Delta t) = H_y^q[m]$ . This allows to replace the derivatives in the laws with finite differences

$$\mu \frac{H_y^{q+\frac{1}{2}}[m+\frac{1}{2}] - H_y^{q-\frac{1}{2}}[m+\frac{1}{2}]}{\Delta t} = \frac{E_z^q[m+1] - E_z^q[m]}{\Delta x} \quad (2)$$

$$\varepsilon \frac{E_z^{q+1}[m] - E_z^q[m]}{\Delta t} = \frac{H_y^{q+\frac{1}{2}}[m+\frac{1}{2}] - H_y^{q+\frac{1}{2}}[m-\frac{1}{2}]}{\Delta x} \quad (3)$$

Finally, these difference equations are turned into update equations to determine the "future fields" knowing the "past ones"

$$H_y^{q+\frac{1}{2}}\left[m+\frac{1}{2}\right] = H_y^{q-\frac{1}{2}}\left[m+\frac{1}{2}\right] + \frac{\Delta t}{\mu\Delta x} (E_z^q[m+1] - E_z^q[m]) \quad (4)$$

$$E_z^{q+1}[m] = E_z^q[m] + \frac{\Delta t}{\varepsilon\Delta x} \left( H_y^{q+\frac{1}{2}}\left[m+\frac{1}{2}\right] - H_y^{q+\frac{1}{2}}\left[m-\frac{1}{2}\right] \right) \quad (5)$$

## 2 Directional Coupler

## 3 Bragg reflector

## 4 Micro Ring Resonator