MULTIPHYSICS MODELING OF PLASMONIC ORGANIC HYBRID E/O MODULATORS

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The abstract describes a coupled electrical-optical multiphysics simulation approach for Plasmonic Organic Hybrid Electro/Optic modulators. The simulated modulator figures of merit (I/O and frequency response) are discussed and compared with experimental results from the literature.

Keywords: Plasmonics, Multiphysics modelling

Plasmonic Organic Hybrid (POH) electro-optic (E/O) Mach-Zehnder (MZ) modulators for 1.3 µm and 1.55 µm systems have been extensively studied during the last few years as an advanced solution for optical modulation within the framework of a Silicon Photonic Integrated platform [1]. Due to the non-diffraction limited characteristics of the plasmonic waveguide exploited in the phase modulation MZ section, nanometer scale cross-section and micron scale total length can be achieved, with spectacular performances in terms of ON-OFF voltage and modulation bandwidth [2].

The layout of a typical MZ interferometer (see [1], [2]) is sketched in Fig. 1. The input signal comes from the left dielectric waveguide. A splitter consisting of two (dielectric and metal) tapers couples the input field into the two MIM plasmonic waveguide phase modulators (6 µm long) and, depending on the modulation voltage, the device can switch from the OFF (top plot, no output power) to the ON state (bottom plot, higher output power). Typical width and height of the plasmonic slots are of the order of 100 nm.

POH modulators exploit polymer-based E/O materials consisting of chromophore molecules dispersed in a host medium, which are previously oriented according to a static poling electric field; modulation of the material refractive index is enabled by imposing an RF electric field to the poled material. This material fills the phase shifters, which are designed to support plasmonic modes; thanks to the nanometer slot widths, very large RF electric fields can be obtained with low applied voltages, thus enhancing the E/O effect. In this view, it is clear how a comprehensive model should predict the electro-optic modulation from RF electrical simulations, whose results are used to obtain a complex, position-dependent and anisotropic refractive index profile as the input of the optical model.

A simplified model based on this principle could exploit 2D modal simulations to achieve the modulator static/dynamic response [5]. Yet, such an approach cannot predict some effects, such as undesired power losses related to surface plasmons pertinent to the top/bottom waveguide walls. Describing these details would require a 3D full-wave model of the entire geometry, which is very challenging because of the extremely severe memory and computational requirements.

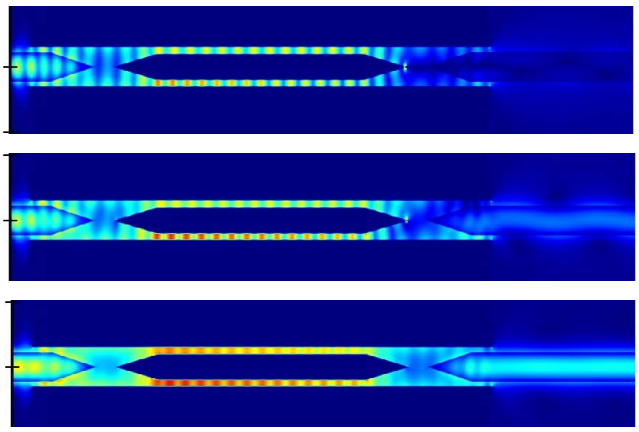

Fig. 1 Top view of the middle section of the modulator in the OFF (top), half-power (center), and ON states (bottom): magnitude of the horizontal electric field component.

The aim of this work is to present a critical appraisal of the available simulation tools for POH MZ modulators ranging from in-house multiphysics 2D FEM codes [3,4,5] to commercial 3D FDTD-based frameworks [6,7]. The shortcomings of each of these instruments are identified through a comparison with experimental results [1,2]. The possibility to establish a hierarchy of hybrid 2D-3D models is investigated, aiming at overcoming the limitations of the single approaches.

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