A Semi-analytical Simulation model for Capacitor Based E-O Modulators

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Abstract: We introduce a semi-analytical model of capacitor-based electro-optical modulators. By applying this model, the performance dependence on the primary device parameters can be analyzed and a set of design rules has been developed.

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1. Introduction

Because of insufficient understanding of the important parameters of electronic-optical (EO) modulators, a closed-form analytic model of the operation of a modulator is necessary to provide better insight of the device physics, and to develop design rules to optimize system performance. Because of the complex nature of such EO devices, it is very difficult to obtain a pure analytical model describing the operation of EO modulators. In this paper, we introduce a semi-analytical model for the simulation of EO modulator, which involves both analytical derivations and numerical fittings. Our result shows an average error of 23% for waveguide widths ranging from 300 nm to 3 μm.

2. Modeling

EO modulator changes its optical output based on different applied electrical driving signal: first, the external electronic signal is used to trigger the change of optical propagation coefficients, such as the refractive index or absorption coefficient; thereafter, the change of the optical propagation coefficients results in the modulation of the intensity of the output optical signal. A MOS capacitor based EO modulator is the most promising candidate for ultrafast light modulation in silicon in that this structure utilizes majority carriers and therefore does not depend on the minority carrier recombination or drifting, which is relatively slower.

The modeling of MOS capacitor based EO modulator is decomposed into two parts: the electronic modeling and optical modeling. The first part deals with the electronic effects that strongly affect optical modulations, such as carrier concentration and recombination/depletion, and the related optical properties such as optical absorption and changes in refractive index under two operation modes: accumulation and depletion; and the second part is made to describe the distribution of optical field inside such devices, which is based effective index method. Numerical fitting is used to generate a function to describe the relationship between the geometry and the optical properties of the device.

In the validation of the this model, two commercial software packages, ATLAS™ (by Silvaco) and Fullwave™ (by RSOFT Design Group) are applied to test the electronic and optical part respectively. Finally a set of design rules is obtained based on this model.

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