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# Multiphysics Simulation of Electro-optic Modulators Based on Plasmonic Waveguides

By


**Mohammadamin Ghomashi**


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**Supervisor(s):**
Prof. Giovanni Ghione, Supervisor
Prof. Francesco Bertazzi Co-supervisor
Dr. Alberto Tibaldi Co-supervisor


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# Abstract

Optical modulation is one the most important elements in optical telecommunication systems. Due to the increasing usage of internet and social media at every place in the world, the demand on modulator performance is dramatically increasing. In other words, to meet the need for the telecommunication systems of the future, modulators with higher speeds and bandwidths must be developed, possibily compliant with low-cost silicon-based plaftorms. Several structures and technologies can be used to create an optical modulator. Among these, plasmonic modulator have great potential to be responsive to the needs of future demands. In this study, the modeling of modulators based on plasmonic waveguides is investigated. The two types of Mach-Zehnder and directional coupler modulators are the main focus of the study. The devices contain nonlinear polymers exhibiting the Pockels effect as an active material. This kind of polymer can be grown on silicon photonics chips. The modulator operating wavelengths considered is 1550 nm, which is typical of data center and long-haul telecommunication systems. Chapter 1 covers the review of the modulation of light and nonlinear optical effects. Also, the models of phase modulators and Mach-Zehnder modulators are recalled and the plasmonic modulators are introduced. In chapter 2, the modeling of the plasmonic modulator is addressed both through analytical techniques and by means of commercailly available simulation codes. The introduced analytical methods are very helpful to have a better insight on the intrinsic physics of plasmonic devices. But such simplified models are not enough to simulate and design actual devices. To this aim, more complex methods such as the finite-difference eigenmode method (FDE), the Finite Element Method (FEM) and the Finite-Difference Time-Domain (FDTD) method should be adopted. The FDE and FEM methods are very fast but they can be used in waveguide-level simulations only. For 3D analysis of a full device, FDTD is required, which is very accurate. However, the FDTD method is very computationally demanding in terms of memory and CPU. On the other hand, accurate numerical optimization is an indispensable tool

for device design, and cannot be practically performed, dut to its huge computational intensity, through FTDT. To overcome this limitation, the modal-FDTD method developed in this study can be used. This technique is much faster than FDTD and exhibits the same degree of accuracy. Chapter 3 is dedicated to the modeling of plasmonic Mach-Zehnder modulator and the modal-FDTD is adopted on the reference structure. In Chapter 4, a novel geometry for directional coupler modulator is introduced, and the required simulation and device design are perfomed. Some conclusions are drawn in Chapter 5.