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WHITE PAPERS & APPLICATION NOTES

A Comprehensive Guide to Photonic Design Automation: From Devices to Systems

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ABSTRACT

With the increasing complexity, size, and application variety of Photonic Integrated Circuits (PICs), versatile design automation tools are required. They must be efficient and flexible to support diverse design tasks while providing seamless interfacing between different tools.

This whitepaper presents a versatile and comprehensive photonic design workflow that integrates design and simulation techniques ranging from optical waveguides and fibers to complete optical systems. We show different aspects of the design simulated on three levels of abstraction: device, circuit, and system. Corresponding simulation techniques and examples will be shown for each level, including their interactions. Further, we employ the presented simulation framework for studying the impact of fabrication tolerances of photonic devices on a 16-QAM optical transmission system.

Keywords: Photonic integrated circuits, PICs, Photonic design automation, Optical transmission systems, Telecom, Datacom, QAM, MMI

1. INTRODUCTION

The exponentially growing demand for communication bandwidth and speed requires high-speed transceivers to be constantly developed and optimized, leading to the adoption of integrated photonics [1]. Photonic Integrated Circuits (PICs) are powerful solutions to reduce an optical system's size, weight, power consumption, and cost (SWaP-C). Photonic integration not only makes the devices smaller and cheaper but also gives access to principally new functions. Although telecom and datacom applications remain the main drivers of the integrated photonics industry, PIC technologies have been effectively employed in other application areas, including automotive LiDAR, biosensing & diagnostics, quantum computing/cryptography, and others.

Over time, the size and complexity of PICs increased drastically, and they continue to evolve. Photonic Design Automation (PDA) tools significantly streamline the PIC development process. Using software-aided simulations allows for isolating the effects of devices under study and identifying the parameters' crucial impact on the system performance. Different system parts may be considered with different accuracy and sometimes modeled with fundamentally different methods and techniques. Depending on how detailed the descriptions of the photonic devices are, we could distinguish three levels of abstraction for photonic simulations: device, circuit, and system level.

Device-level simulation involves the physical description of a device, accounting for the actual geometry and material properties. This approach requires significant computational resources and input parameters of the devices, which are frequently unavailable. As a result, circuit-level simulation using behavioral models is advantageous. On this level of abstraction, the individual components are described by their own specific analytical or behavioral models. They are much faster than device-level simulations and usually require fewer parameters for their characterization. Still, circuit-level models can describe physical phenomena. They can contain information specific to the actual implementation of the photonic device and corresponding fabrication technology. Finally, the most abstract description of the building blocks is employed on a system level. It is mainly based on functional properties rather than their physical description. Notably, a broader set of components are available on this level, including optical fibers, electronic equalizers, coders, and monitoring and characterization instruments.

Frequently, the same component could be modeled on all three levels. Depending on the scope of the design task, it is valuable to be able to switch between levels of abstraction and provide more or fewer details to the simulation. To satisfy these needs, software tools for different design tasks must fit into the entire interoperable design workflow. Starting from

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