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Simulative Analysis of InP-based Dual Polarization IQ Mach-Zehnder Modulators

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Abstract: A realistic model of an Indium-Phosphide DP-IQ Mach-Zehnder modulator supported by experimental measurements is introduced within an accurate time-domain simulator. BER vs OSNR results show the effect of model's non-linearities increasing the modulation format complexity at different symbol rates. The intrinsic modulator SNR is estimated. © 2023 The Author(s)

Keywords: Mach-Zehnder modulator; photonic integrated circuits, Indium Phosphide.

1. Introduction

The advent of photonic integrated circuits (PICs) is strongly impacting optical network market focusing on the Indium Phosphide (InP) technology for the realization of integrated electro-optical Mach-Zehnder modulators (MZM), considered a promising semiconductor for PICs evolution related to the exponential increase of photonic chip complexity [1]. Considering the need of an accurate simulation environment to emulate and control realistic physical layer effects in software-defined (SD) optical networks, the goal of this work is to introduce a novel and scalable model of an InP DP-IQ-MZM within an accurate time-domain simulator for quality of transmission (QoT) estimation, integrating measurements performed on a real modulator sample to faithfully reproduce the component non-linear effects. The intrinsic signal-to-noise ratio (SNR) introduced by the modulator is estimated to evaluate the MZM impact on transmission performance.

2. Physical Model & Simulation Results

The InP MZM model which has been considered in the simulation framework presents a voltage-dependent transfer function $T(V)$ and a non-linear phase response $\phi(V)$ which introduce two novel parameters with respect to the legacy modulators, a transmission absorption parameter c and a phase non-linearity parameter b [2], expressed as:

$$T(V) = \left(1 + \exp \left[\frac{V-c}{0.8} \right] \right)^{-1.25} \quad (1) \quad \phi(V) = \left(\frac{2b \cdot V_{CM} \cdot V_{\pi} - \pi}{V_{\pi}} \right) \cdot V - b \cdot V^2 \quad (2)$$

where V is the input bias voltage applied to the electrode, c is the transmission absorption parameter, V_{CM} is the common mode DC bias voltage present on each MZM electrode, V_{π} is the voltage required for inducing a phase variation of π and b is the phase non-linearity parameter. The InP MZM model has been developed to realistically reproduce the component behaviour via simulation. In addition, the custom low pass filter of an InP modulator sample provided by Lumentum Company has been characterized in laboratory, measuring the response of drivers' electrodes, and integrated in the model. This module takes into account the component non-linearities in terms of bandwidth limitation. The simulation framework in use for a single polarization IQ-MZM is represented in Fig. 1: the two red building blocks represent the novel SD InP MZM module, while the blue ones are part of a time-domain simulator used as a QoT estimator [3] for a back-to-back (B2B) simulation of the modulator model.

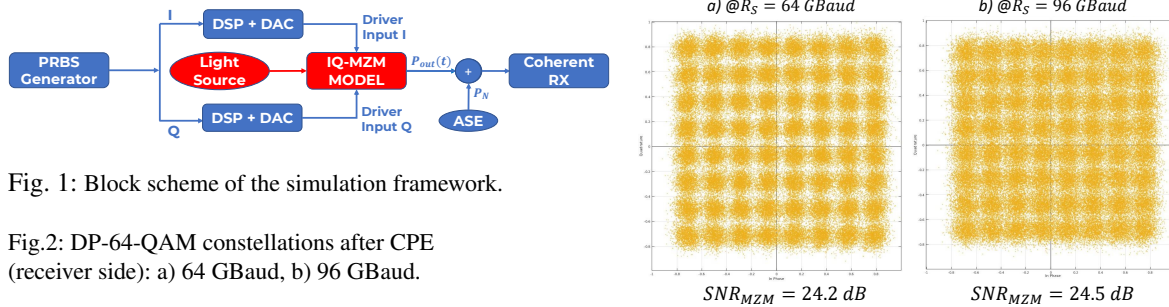


Fig. 1: Block scheme of the simulation framework.

Fig.2: DP-64-QAM constellations after CPE (receiver side): a) 64 GBaud, b) 96 GBaud.

Simulations have been performed for a dual polarization (DP) InP IQ-MZM considering a pseudo-random binary sequence (PRBS) generation (PRBS17, with $2^{17} - 1$ bits) and setting the digital signal processing (DSP) and digital-to-analog converter (DAC) elements with realistic parameters in order to perform a correct pulse shaping to produce a Nyquist shaped spectrum. The custom low pass filter has been modeled thanks to the electrodes' characterization of the modulator sample for the generation of the electric fields sent to the in-phase

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