Application Specific Interface to Control and Calibrate Programmable Photonic Integrated Circuits

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***Abstract*—A custom in-house designed interface to provide accurate driving voltage for a 4 × 4 Mach-Zehnder interferometer based photonic processor is presented providing the required tool to assess and calibrate both electrical and optical crosstalk.**

Keywords— driving electronics, optical processors, photonic integrated circuits, neuromorphic computing, crosstalk

I. INTRODUCTION

Photonic processors have shown prominent performance in terms of both computation speed and power efficiency [1]. They demand a specific interface to provide accurate driving electronics to set and hold the target phase settings. In contrast with driving requirements of other photonic integrated circuits (PICs), photonic processors can be susceptible to relatively small errors in applied bias and are prone to accumulating errors endangering the overall device performance [2]. This work presents the architecture of an in-house developed interface to drive a photonic processor based on a coherent Mach-Zehnder interferometer mesh as the target chip.

II. ARCHITECTURE

Fig. 1 (a) represents a simplified measurement set-up. A computer (PC) is responsible for programming the chip through the voltage control interface unit (VCIU) as well as providing communication and storage interface with laser and power-meter. The VCIU not only provides a voltage resolution better than 1 mV to bias the thermo-optic phase-shifters (PS) of the target chip [3] but also it is equipped with multiplexed voltage and current sampling circuitry. Calibration and programming procedures are developed and executed in the PC software module (Fig. 1 (b)).

As shown in Fig. 2 (a), dense metal routing complexity obliges using a common ground path leading to electrical crosstalk (x-talk) due to non-zero resistance of the common ground tree connections ($r_n \neq 0$). This error could be negligible in some digital applications (*e.g.*, optical switch); nonetheless, it is usually above the error budget for photonic processors. The method to calibrate the common ground induced electrical x-talk

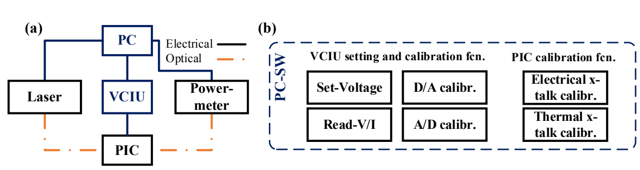

Fig. 1. (a) Simplified measurement set-up; (b) Functional block diagram of the software (SW) executed on a personal computer (PC).

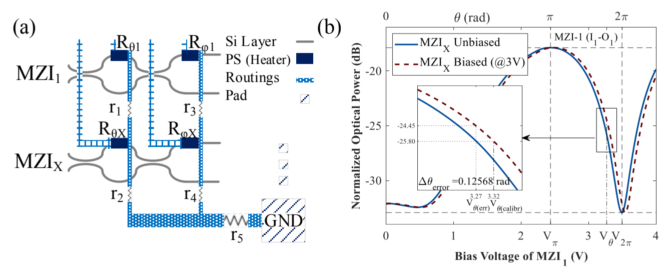

Fig. 2. (a) Partial layout representation of an MZI-based photonic processor; (b) MZI characterization with and without electrical x-talk.

is to either calculate the ground route resistance or measure it using the VCIU. The latter involves voltage measurement of all off channels while a single PS is biased. The voltage data in conjunction with the active PS measured current will lead to known r_n values [4].

Reference [5] proposed measuring the electric resistance of adjacent heaters (as temperature sensors) to evaluate the thermal x-talk. This can also be achieved with the proposed VCIU.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The detrimental impact of the electrical x-talk in a photonic processor is demonstrated by characterizing MZI_1 without and with biasing MZI_X (Fig. 2). Without calibration, a given application initially requires MZI_1 to be biased at 3.27 V for a normalize output power of -25.8 dB ($V_{\theta(err)}$ in Fig. 2(b)). While MZI_X is biased at an arbitrary phase shift, the x-talk leads to a phase error of 0.12568 rad equivalent to a 17 % reduction in accuracy in a 64 × 64 Reck-based optical neural network [2]. The discussed calibration methodology corrects this error ($V_{\theta(calibr)}$) and spares additional optical measurements.

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