Silicon Photonic Weight Bank Control of Integrated Analog Network Dynamics

Ellen Zhou, Alexander N. Tait, Allie X. Wu, Thomas Ferreira de Lima,
Mitchell A. Nahmias, Bhavin J. Shastri, and Paul R. Prucnal
Princeton University, Princeton, NJ, 08544 USA
ellenz@princeton.edu

***Abstract*—Analog interconnection networks are configured setting connection weights. Microring weight banks are a key device for making such networks in silicon photonic circuits. We demonstrate a small analog network in silicon using a single node with simple dynamics, showing dynamics parameterized by microring weight banks.**

I. Introduction

Recent times have seen massive amounts of progress in systems using photonics integrated technology, specifically in silicon photonics, where the aim is to bring more efficient interconnects to the chip level. At the same time, recent research in unconventional electronics decentralizes signal processing, creating an even larger demand for efficient interconnect performance. The potential for optics to play a role in an unconventional processing has re-ignited investigation of laser devices that exhibit similar dynamics to biological neurons [1]. Utilization of analog physical dynamics represents a key step towards attaining the efficiency and functionality exhibited by biophysical information processors [2]; however, research on neural-inspired dynamics in photonics has focused largely on single lasers. Networks that can be implemented in silicon are a crucial aspect of neuron-inspired photonics.

We experimentally demonstrate optoelectronic dynamics controlled by a thermally-tuned silicon photonic microring (MRR) weight bank. MRR weight banks enable continuous and complementary (+/–) weighting of wavelength-division multiplexed (WDM) signals. By adjusting the weights of a MRR bank, we are able to control the shape of the non-linearities that the system is outputting, demonstrating control of complex dynamics in a small analog network in silicon with a single node. While time-delayed electro-optic oscilators as demonstrated possess an extremely rich repertoire of behaviors, they have relatively little ability to be configured to network-based models [3]. Ultimately, larger networks of MRR weight banks could support a highly configurable and high-bandwidth photonic processing network, called broadcast-and-weight [4] (Fig. 1).

Broadcast-and-weight leverages recent advances in photonic integrated circuit technology to address interconnect challenges faced by distributed processing. In a neural network, each node receives multiple signals through a tunable function of weighted additon, and performs a nonlinear function. The single output signal is then sent to multiple receiver neurons. In this schema, a single waveguide can carry multiple signals, allowing for great efficiency. The broadcast loops allows each is calibrated using a method shown in [6] in order to obtain an accurate estimate of the weight values.

WDM signals are directly inputted into the MRR weight bank. Mach-Zehnder modulators are used to introduce nonlinear effects into the system. The signals are added together in the balanced photodetector, and this output signal is multiplexed with an input signal, creating a feedback loop in the system. MRR weights are calibrated for optimal results. Thermal tuning is applied to the weight banks to vary the degree of nonlinearity produced by the system.