Ring Resonator-based Synaptic Weighting in Generic InP Photonic Technology

L. Puts[1], R. R. Ghosh[1] and W. Yao[1]

[1] Photonic Integration Group, Department of Electrical Engineering, Eindhoven University of Technology

As an alternative to von-Neumann-based computing systems, neuromorphic computing aims to develop novel hardware inspired by the operating principles of the brain. In particular, the excitable and spiking dynamics observed in biological neurons form the foundation for the Spiking Neural Network (SNN) [1]. Such a network consists of excitable spiking nodes and tunable synaptic weights and can be used as a vector-matrix multiplier. Over the last decade, different approaches to mimic the spiking dynamics and synaptic weighting using integrated photonic devices have been investigated. Integrated photonics benefits from high switching speed, high bandwidth, inherent parallelism, and very low latencies [3], and has proven to be an excellent platform to fabricate photonic spiking neurons [2]. The synaptic weighing function can be implemented using various photonic devices such as a modulator, optical attenuator, or ring resonator. The latter is compact and well established, but has limited control over the tunability by nature. Normally, such a device comprises a photonic waveguide in the form of a ring, with electrodes placed on top. A negative voltage on the electrode controls the amount of transmitted light. In our approach, we embed an optical amplifier (SOA) in the ring, which essentially adds one control parameter (i.e., the intra-ring amplification) to the device. A similar structure was used to show neuron-like nonlinearities [4], which demonstrate the versatility of the device. The device is schematically shown in Fig. 1 (top left).

To quantify the voltage-dependent transmission, we have measured the output of the integrated ring-resonator depicted in Fig. 1, bottom left, as a function of the applied voltage and ring amplification currents. Light was injected into the input by an on-chip laser.

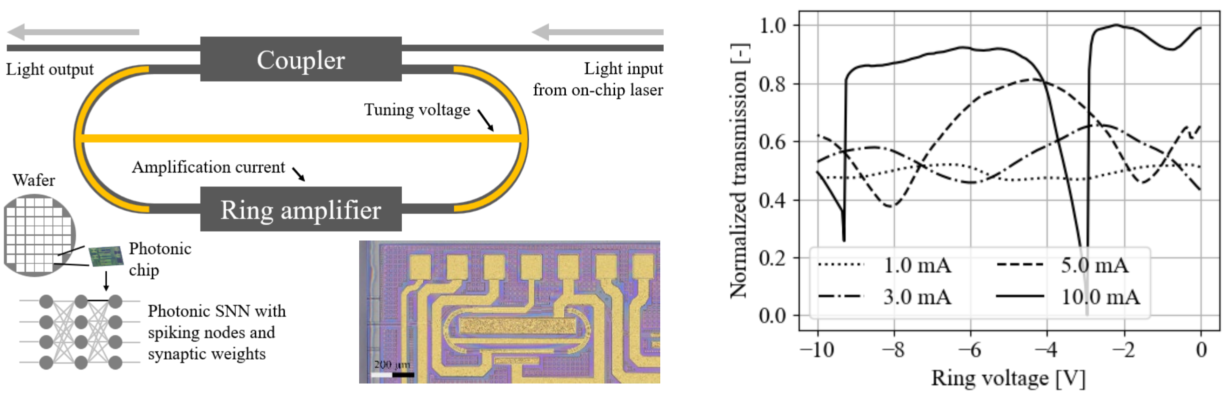

Figure 1: From wafer to photonic chip with a photonic SNN (bottom left), schematic depiction of the ring (top left), micrograph of the fabricated device (bottom), normalized optical transmission as a function of applied ring voltage and amplifier current (right).

Fig. 1 (right) shows that the transmission of light through the ring depends both on the applied voltage and the amplification current. At an amplification current of 10 mA, the extinction ratio is maximum, for voltages of -2.95 and -2.20 V. In short, by changing the voltage, the transmission of an optical input signal can be controlled. Hence, this ring resonator may act as a synaptic weight in a photonic SNN when combined with the optical spiking neuron, which paves the way toward an all-optical spiking neural network.

[1] W. Maass, Neural Netw., vol. 10, no. 9, pp. 1659–1671, Dec. 1997.
[2] L. Puts, et al., Opt. Express, vol. 33, no. 13, pp. 27400–27413, Jun. 2025.
[3] B. J. Shastri et al., Nat. Photonics, vol. 15, no. 2, pp. 102–114, Feb. 2021.
[4] R. Ghosh, et al., PIERS 2025 Chiba, Japan, pp 1-7, Feb. 2026.