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# Synaptic weighting of spiking VCSEL-neurons using integrated photonic microring weight banks

**Matěj Hejda**[1], **Eli A. Doris**[2], **Simon Bilodeau**[2], **Joshua Robertson**[1], **Lei Xu**[2], **Bhavin Shastri**[3], **Paul. R. Prucnal**[2], **Antonio Hurtado**[1]

*1. Institute of Photonics, SUPA Department of Physics, University of Strathclyde, Glasgow, UK*
*2. Department of Electrical Engineering, Princeton University, Princeton, New Jersey, USA*
*3. Department of Physics, Engineering Physics and Astronomy, Queen's University, Kingston, Ontario, Canada*

In this work, we present an optical spike processing architecture based on the combined operation of two types of photonic systems: silicon photonics (SiPh) microring resonator (MRR) weight banks [1] and all-optical spiking artificial neurons based on vertical cavity surface emitting lasers (VCSELs) [2]. These systems have been previously demonstrated as key-enabling building blocks in the rapidly growing field of neuromorphic photonics.

First, a train of excitable spikes was elicited in a 1550 nm injection-locked VCSEL biased far above threshold $I = 5$ mA ($I_{thr} \approx 1.5$ mA). The VCSEL was temperature controlled and stabilized for emission close to the selected MRR resonance frequency. The fiber optics-based experimental setup for operating the VCSEL as an excitable photonic neuron is available from previous works [3]. Excitable spiking was achieved by amplitude modulation of the optical injection, using a sequence of 750 ps wide evenly separated, square-shaped perturbations. Spiking signals from the VCSEL-neuron were amplified using an Erbium Doped Fibre Amplifier (EDFA) and coupled to the SiPh weight bank chip, where the resonant frequency of the weighting microring is adjusted via applying a DC bias to the ring's $n$-doped photoconductive heater. A total of $n_V = 29$ voltage steps were utilized during this weighting procedure, $V_{\mathrm{MRR}} = 1$ V to 3.9 V (with 100 mV increments). Figs. 1(a,b,c) show examples of the real-time, oscilloscope-recorded traces (optical signals) from the THRU port of the microring during the weighting procedure for various DC biases applied to the MRR heating element. As demonstrated in Fig. 1(d), the weight bank element achieves a full range of inhibitory functionality for high-speed (sub-ns) optical spiking signals from the VCSEL-neuron. Furthermore, complementary (excitatory) functionality can be obtained from the DROP port of the MRR. This proof-of-concept experiment represents the first demonstration of practically functional layout combining both spiking photonic neurons based on VCSELs and integrated, microring-based weight banks. This demonstrates the viability of coupled operation of these photonic systems for processing optical spiking signals and paves the way towards more complex, joint information processing architectures.

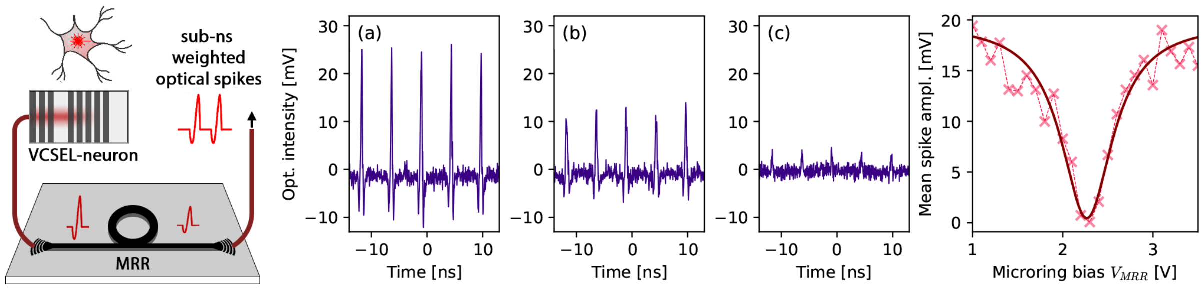


Figure 1: Schematic diagram showing the basic working principle of the experimentally investigated weighting of sub-ns optical spikes produced by a VCSEL-neuron. (a) Timetrace of weighted spikes collected from the THRU port of the microring for $V_{MRR} = 1.0$ V V, (b) for $V_{MRR} = 1.79$ V V, (c) for $V_{MRR} = 2.4$ V. The DC signal component was filtered out at photodetector output. The mean weighted spike amplitudes are shown in (d).

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