Scalable electro-optical spiking neural network

Ria Talukder* , Xavier Porte and Daniel Brunner

FEMTO-ST/Optics Dept., UMR CNRS 6174, Univ. Bourgogne Franche-Comte, 15B avenue des Mountboucons, 25030, Besancon Cedex,France

**ria.talukder@femto-st.fr*

Abstract :

Photonic neural networks are currently one of the most sought after areas of research. Comprehensive studies and experiments have laid a strong foundation for future high-performance complex computing. In artificial neural networks, neurons are simple, nonlinear maps. On the contrary, information transmission and computation in biological neurons occur through spikes, where spike time and/or rate presumably play a significant role. We developed the first large-scale spiking photonic neural network, which serves as an excellent proof of concept experiment for novel bio-inspired learning concepts.

Photonic hardware integration of neural networks can benefit from the inherent properties of parallelism, high-speed data processing and potentially low energy consumption. Considering this, we designed a photonic reservoir computer (RC) [1] based on photonic recurrent spiking neural networks (SNN) [2], i.e. a photonic liquid state machine (see Fig 1a). A Spatial light modulator encodes our neural network's state by being operated in the amplitude modulation configuration. Recording of these neurons by a camera closes the recurrent loop, as the recorded image drives the SLM by electronic feedback. In the read-out section of our experiment, neurons are imaged on a digital micromirror device (DMD) that implements Boolean weights and the such weighted network's state is recorded by a detector (see Fig1b). We go beyond and create excitability of our electro-optical neurons by including a high-pass filter in the electronic feedback loop and experimentally demonstrate the neuron's all-or-nothing spiking response to input stimuli (see Fig 1 c). When the injection stimuli crosses the threshold, the neurons response to the injected stimuli with a spike, whose amplitude is independent of that of the input stimuli. Furthermore, our neurons exhibit spike-time latency that is a function of the input stimuli's strength. This is an important feature for implementing bio-inspired learning concepts.

We have successfully implemented a scalable electro-optical spiking neural network, comprising of more than 30,000 neurons [3-4]. This system presents an excellent testbed for demonstrating next generation bio-inspired learning in photonic systems.

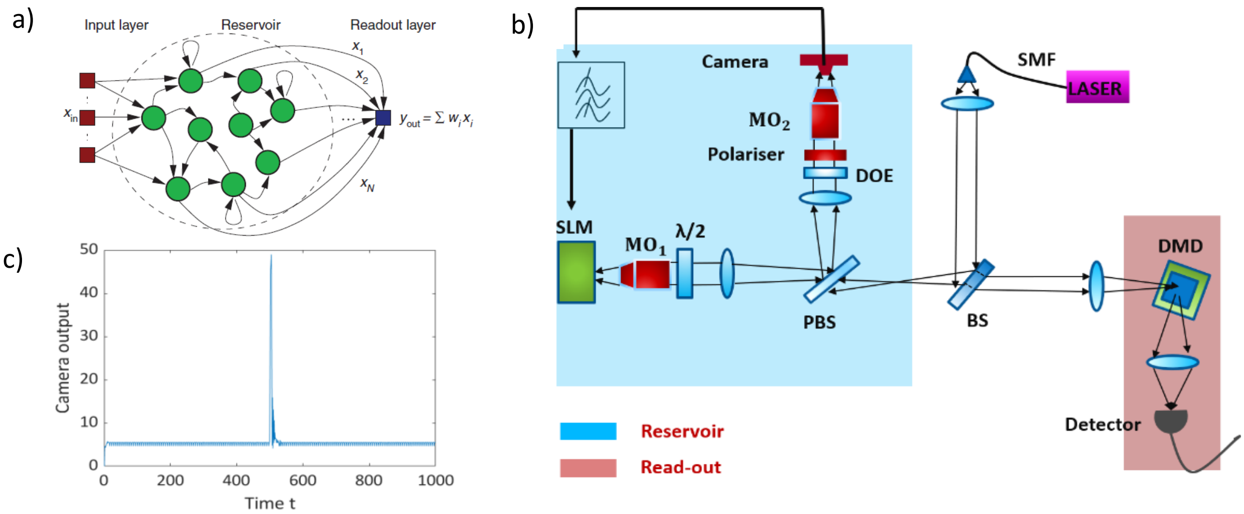

Figure : a) Layout of a simple reservoir computer, consisting of the input layer (in red), the reservoir with connections between them (in green) and a simplified one-dimensional read out (in blue), figure reproduced from [5]. b) Schematic diagram of the setup. c) Response of the neurons to a particular injection strength at different time.

References:

[1] J. Bueno et. al. , Optica, **5**, page 756 (2018).

[2] V. A. Pammi et. al. , IEEE JSTQE, , **26** (1), 1-7(2020).

[3] M. Rafayelyan et. al., Phys. Rev., X **10**, 041037 (2020).

[4] S. Maktoobi et. al., IEEE JSTQE, 26, 1-8 (2020).

[5] G.V. der Sande, page 563 (2017).