# Photonic implementation of an elementary unit of artificial intelligence based on solitonic waveguides

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*This paper shows the implementation of photonic neuromorphic hardware based on solitonic waveguides able to perform reinforcement learning. Learning is based on recognizing an input state or a specific output that is highlighted by an external supervisor. For this reason, learning can be of two types: supervised or unsupervised. Both have been implemented in the proposed photonic circuit.*
**Keywords**: Neuromorphic photonics, reinforcement learning, photorefractive spatial solitons, soliton waveguiding, artificial intelligence

## 1. Introduction

In recent years, the problem of managing and processing large quantities of data has pushed towards new methods that could guarantee high speed of computation, parallel processing and efficiency. In particular, it has started to implement software models capable of replicating the typical learning functions of the brain. But differently from real neural tissues, traditional computing structures separate the core computing functions of memory and processing. The most immediate consequences of this separation are found in a difficulty in achieving high computational speeds, efficiency and low energy conditions. In response to these needs, research has been directed towards a neuromorphic approach, that intends to replicate at hardware level the fundamental blocks typical of brain biology, so as to allow the analysis and processing of data directly on small units. The electronic hardware implementations present limitations because they are not easily adaptable to different learning situations and require high power supply. Optical and photonic hardwares seem to play a significant role for parallel processing, speed and low power losses.

## 2. Solitonic X junction

To get closer to nonlinear neuronal dynamics using photonic technology, we propose a neuromorphic model based on solitonic-waveguide X-junctions [1], as shown in fig.1.

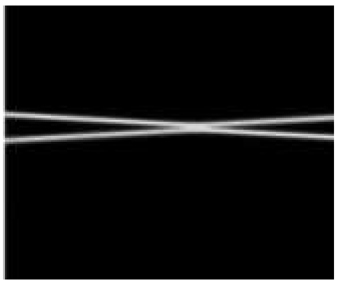

Fig. 2 Solitonic X junction

Such junction is obtained by two self-confined beams (writing beams) inside which signal beams propagate (represented in colours in fig.2). Such scheme reproduces the fundamental parts of a neuron: the input arms describe the input dendrites; the signals are elaborated at the junction (neuron soma) and transmitted toward the outputs (axon and postsynaptic terminals).

## 3. Supervised and Unsupervised Reinforcement Learning

The learning process is implemented by applying an optical feedback to the channels [2]. The supervised learning implies that the instructor would inject a writing signal from the output inside the channel to be highlighted. This is a supervised because the instructor decides which channel should be highlighted by his/her own. As a consequence of the feedback the junction switches from a balanced configuration to an unbalanced one, as shown in fig.2.

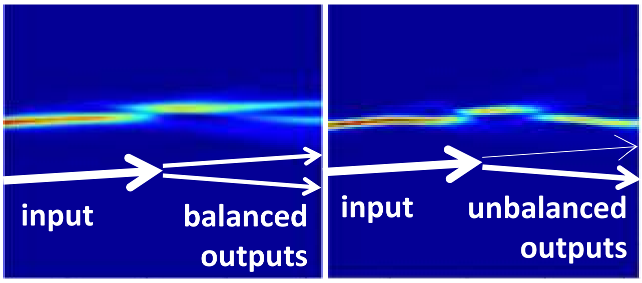


Fig. 2 Junction learning scheme of the signal beams

The unsupervised learning implies that each channel gets a feedback from its own output. Thus, the junction will recognise the output states and evolves towards and unbalanced situation. In this second case the nonlinearity of the host material must be sensitive to the signal state as well and must transfer information from the signal to the writing beams [3].

## References

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