

Photonic Neuromorphic Computing with Vertical Cavity Surface Emitting Lasers

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Abstract. Photonic approaches emulating the powerful computational capabilities of the brain are receiving increasing research interest for radically new paradigms in ultrafast information processing and Artificial Intelligence (AI). In this talk, I will review our research on neuromorphic photonic systems built with artificial optical neurons based upon Vertical-Cavity Surface Emitting Lasers (VCSELs). These are ubiquitous light-emitting optical devices found in mobile phones, supermarket barcode scanners, automotive sensors, optical transceivers in data centres, etc. Hence, there is great potential in adding intelligence and novel processing capabilities in key-enabling VCSELs for a wide range of novel technological developments.

Our research has shown that a rich variety of neuronal computational features (e.g. spiking activation/inhibition) can be reproduced optically in VCSELs at ultrafast sub-nanosecond speeds (up to 9 orders of magnitude faster than the millisecond timescales in cortical neurons) [1-3]. During the talk I will describe how we capitalise on the ultrafast neural-like behaviours elicited in VCSELs to develop novel photonic spike-based processing systems for use in strategic applications (e.g. pattern recognition, image processing) and neuronal circuit emulation at ultrafast speeds [1-3].

This talk will also introduce our recent work on laser-based, Recurrent and Spiking Neural Networks (RNNs and SNNs) for novel VCSEL-based photonic Reservoir Computing (RC) systems, yielding excellent performance across complex computing tasks at ultrafast rates [4].

Finally, this talk will review our recent work on neuromorphic systems merging in the same platform VCSELs with key-enabling Resonant Tunnelling Diodes (RTDs), for novel ultrafast, low power spiking optoelectronic artificial neuronal models, towards future chip-scale SNN implementations of light-enabled brain-inspired computing and AI hardware [5].

Keywords: Neuromorphic Photonics, Vertical-Cavity Surface Emitting Lasers (VCSELs), Resonant Tunnelling Diodes (RTDs), Photonic Neurons, Photonic Reservoir Computing.

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