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Study of the C-band dynamical response of an injection locked LA-EEL for fully integrated telecommunication data processing

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Abstract. A high-performance photonic reservoir, which utilizes the injection locking effect in a highly multimodal semiconductor laser, has been developed. This innovative design allows for fully parallel and high-bandwidth operation. The output of this system is projected in space and imaged onto a digital micromirror device, which provides a readout and facilitates the hardware integration of programmable output weights. By using a highly multimodal semiconductor laser, the injection locking effect enables a large number of modes to be simultaneously locked to the injected signal, resulting in high dimensionality of the reservoir, reducing the computational time and complexity. The use of a digital micromirror device provides a flexible readout, allowing the output to be programmed to suit a range of applications. The hardware integration of programmable output weights enables the system to be optimized for specific tasks, improving performance and reducing power consumption.

In the pursuit of developing new architectures for neural networks (NNs) in photonics, optical reservoir computing is emerging as a promising option for fully integrated systems. This technology has the potential to significantly reduce energy consumption and data processing operations in telecommunications while eliminating the need for transduction of signals between electronic s and optics.

To create a hardware reservoir for computation, semiconductor lasers (SLs) provide a highly nonlinear environment. However, integrating photonic reservoirs is challenging due to the absence of adjustable hardware output weights. The current study addresses this issue by utilizing a digital micromirror device to spatially select spectral components of the signal, enabling tunable Boolean output weights. A schematic of the experiment can be found in Figure 1.

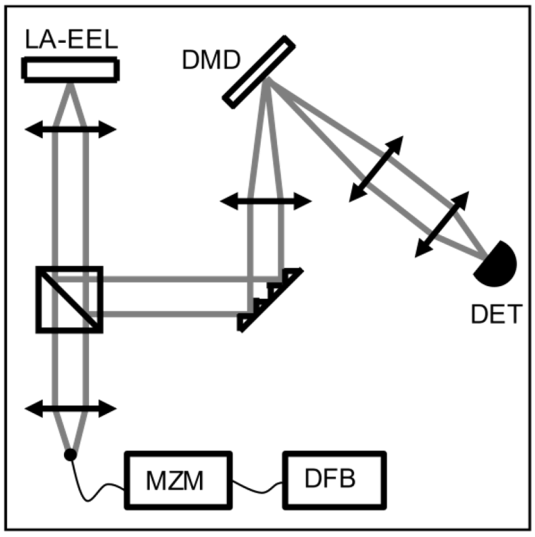

Fig. 1. Schematic of the experimental setup

The Large Area Edge Emitting Laser (LA-EEL) is a commercially available device that operates at C-band wavelength, as illustrated by the spectrum in Figure 2. Under normal conditions, this laser is highly multimode in both its transversal and longitudinal directions. However, our study demonstrates that the LA-EEL can be locked into a single mode state by an external distributed feedback laser, as shown in Figure 2. To inject information into our system, we modulate the DFB signal using a Mach-Zehnder Modulator (MZM).

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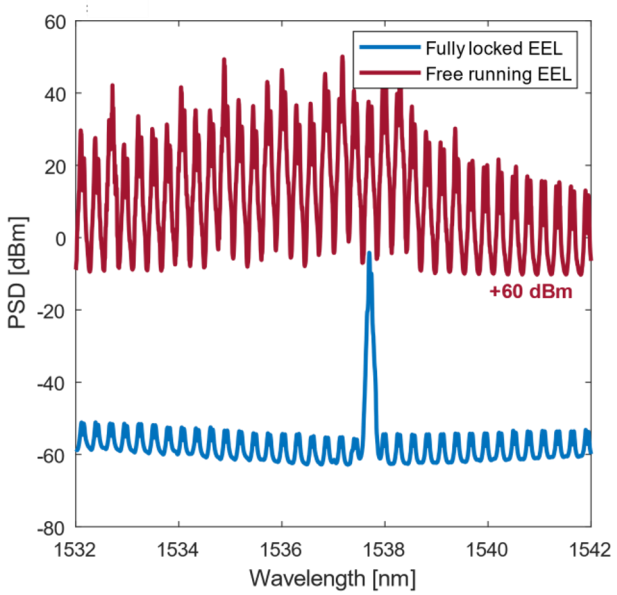

Fig. 2. Spectral response in both fully-locked and free running regimes, for clarity a 60dB offset is added to the free running signal.

Our approach leverages both spectral and spatial degrees of freedom to implement photonic neurons. The transversal modes are accessible through imaging the optical signal, while the longitudinal components are projected from the spectral domain to the spatial domain using a blaze grating. This distribution is then focused on a digital micromirror device (DMD) that acts as the network output weights. The resulting signal is retrieved with a photodiode and analysed.

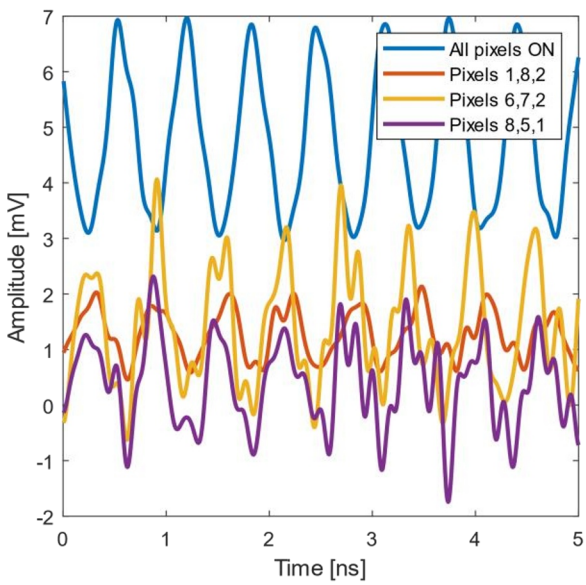

Fig. 3. Spatially selected responses for three particular DMD's mirrors configuration, and the full DMD mirrors on. For all cases the input modulated signal is sinusoidal of frequency 2GHz.

In Figure 3, we obtain specific responses for each selected group of pixels on the DMD's hyperspectral distribution. The signal controlled by each group of mirrors is identified as the specific response for each individual neuron in the reservoir.

Our study reports successful injection locking of the LA-EEL with a modulated input signal. We utilized hyper-spectral imaging of the signal on the DMD to dynamically read our reservoir's specific neural responses. By doing so, we were able to implement programmable weights in our fully parallel high bandwidth photonic reservoir. These results demonstrate the potential of our approach for creating photonic computing systems with efficient data processing capabilities.

References

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