Spatiotemporal Pattern Recognition with Cascadable Graphene Excitable Lasers

Bhavin J. Shastri, Alexander N. Tait, Mitchein certain problem deniaims. neuromorphic technology with photonics could potentially grant the capacity for complex, ultrafast categoration and decision making [2] The ideas of biophysical computation algorithms the context of harnessing the high speed, high and width, and low crosstalk available tophotonic interconnects [3][] could provide a wide range of computing and signal processing applications (e.g. adaptive control, reatime embedded system analysis, and cognitive RF processing) Neuromorphic signal processing incorpor at essparse coding scheme called spiking. This horid analog and digital processing techniqe takes advartage of both the bandwidth efficiency of analog computation and the noise robustness of digital computation[5] making the spike -based approach attractive for information processing. We recently discovered [3] a close analogy between the dynamics of lasers and those of spiking biological neurons both of which can exhibit excitability[3] blowever, to enable this emerging computation paradigm the following kycriteria must be met: logic-level restoration, inpubutput isolation, and cascadability[9]

He, we demonstrate a photonic spatiotemporal pattern recognition circuit. This simple experiment provides a proof-of-concept for cascadability and inputoutput isolation in excitable lasers for spiking neural network (SNNs) while simultaneously demonstrating polyhrony [10] — an important concept in computational neuroscience, defined as an event relationship that is precisely time ocked to firing patterns but not necessarily spichronized to a global clock reference. Polyhronization presents a minimal spiking network that consists of cortical spiking neurons with axonal delay and spike- timing dependent plasticity (STP) an important learning rule for spike -encoded neurons. As a result of the interplay between the delay and STP, spiking neurons spontaneously self- organize into groups and generate patterns of stereotypical polyhronous activity

The computational primitive in our experiment is a graphene excitable laser. Graphæ2D atomic-scale hexagonal crystal lattice of carbon atoms[1] could be an excellent candidate in excitableaser processing devices [12][3] as a consequence of its nonlinear saturable absorption to Pauli blocking, which includes ultrafast carrier relaxation, low saturable absorption threshold, large modulation deptdi, wavelength independent absorption (lue to linear dispersion near the Ermi energy). We experimentally demonstrated [12][14] an excitable fiber laser incorporating a graphene saturable absorber (SA) for a variety of complex operations including pulse nægetion and reshaping, asynchronous phase locking, interspike time encoding, and coincidence detection.

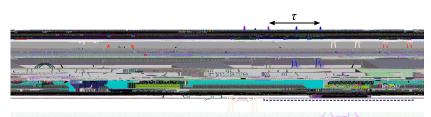


Fig. 1. Spatiotemporal pattern recognition circuit with two cascaded graphene excitable lasers.

In our case the objective is to distinguish (i.e. recognize) a specific input pattern: a pair of pulses separated by time interval t (equal to the delay between the excitable lasers). These analog inputs are directly modulated with an arbitrary waveform generator and are incident on both the lasers. The outputs from the first laser are fed to the second laser via a single-mode fiber (SMF), which acts as a delay element, and a photodetector (PD) to modulate the laser diode (LD) (allowing wavelength conversion from 1560 to 1480 nm). It has recently been shown [15] that such an excitable laser and PD system can emulate both a leaky integrate-and-fire neuron and a synaptic variable, completing a computational paradigm for scalable optical computing. The dynamics introduced by the PD are analogous to synaptic dynamics governing the concentration of neurotransmitters in between signaling biological neurons. The second laser is biased such that it requires stronger perturbations to fire; it will not fire unless two excitatory pulses (original input and output from the first laser) are temporally close together; that is, when t. Synchronous arrival of these two spikes causes enough excitation above the threshold causing the laser to fire a pulse. The system therefore only reacts to a specific spatio-temporal bit pattern. The resulting experimental data—output pulse profile as a function of the normalized time interval between the two input pulses—is shown in Fig. 2.

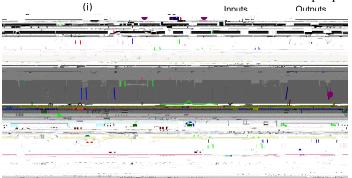


Fig. 1. Measured output pulse peak power, pulse duration, and input and output waveforms as a function of the time interval between the two input pulses. Output pulse energy is the largest when t showing the system only reacts to a specific spatiotemporal input pattern.

In conclusion, we have demonstrated a spe 2()-231(p) a-(e)-2(2()2(sp)-1((a)-20.08(n)-3(c)-2(l)1(ua-3(c)-2(l)2(s)h373(c)-2(l)c)))