of linear neurons, these approaches do not scale well to higher numbers of neuron inputs due to the substantial increase in circuit complexity with each added wavelength, which severely limits their suitability for practically relevant applications. Additionally, many WDM schemes merely apply unsigned weights in the optical domain, and rely on optoelectronic conversion to enable addition or subtraction of the weighted signals in the electrical domain (e.g., using a pair of balanced photodetectors to sum over positive and negative weights), which impedes the subsequent employment of all-optical non-linear activation functions. An alternative previously proposed approach implements the linear algebraic summation by coherent electric-field addition — exploiting the phase of the optical carrier electric field for sign-encoding purposes — in a complex spatial layout that includes multiple cascaded Mach-Zehnder interferometers (MZIs), e.g., as described in U.S. Patent Application Publication No. 2018/0260703. While this coherent approach can yield single-wavelength and single-laser optical linear neurons, signal errors accumulate along the cascade of MZIs, which has so far precluded precision high enough, or bit error rates (BER) low enough, for large-scale practical applications.

SUMMARY OF THE INVENTION

[0004a] According to a first aspect of the present invention, there is provided a system comprising a photonic circuit that includes: an optical splitter configured to split carrier light into a plurality of optical carrier signals; a plurality of input cells comprising first optical amplitude modulators configured to impart a plurality of computational inputs onto the plurality of optical carrier signals to thereby output first modulated optical signals; a plurality of sets of weighting cells, the weighting cells in each set being coupled at their inputs to outputs of the plurality of input cells and comprising a plurality of second optical amplitude modulators configured to impart a plurality of computational weights onto the first modulated optical signals received from the input cells to thereby output second modulated optical signals associated with the set; and a plurality of optical combiners each associated with one of the sets of weighting cells and configured to coherently combine the second modulated optical signals associated with the set into an optical output signal.

[0004b] According to a second aspect of the present invention, there is provided a photonic circuit comprising: an optical splitter configured to split multiplexed light into a plurality of multiplexed optical carrier signals associated with a plurality of inputs; a plurality of

interferometric optical paths configured to receive the plurality of multiplexed optical carrier signals and generate multiplexed weighted optical input signals; and an optical combiner configured to combine the multiplexed weighted optical input signals into a multiplexed optical output signal, wherein each interferometric optical path of the plurality of interferometric optical paths comprises: a first electro-optical switch, a second electro-optical switch, and a third electro-optical switch, the first and second electro-optical switches configurable to switch the plurality of multiplexed optical carrier signals between first and second input optical paths and the second and third electro-optical switches configurable to switch multiplexed optical input signals between first and second weighting optical paths; between the first and second electro-optical switches, an input cell comprising a set of first optical amplitude modulators associated with multiple wavelengths of the plurality of multiplexed optical carrier signals and preceded by a demultiplexer and followed by a multiplexer along the first input optical path, and a separate first optical amplitude modulator along the second input optical path, the input cell configured to generate the multiplexed optical input signals; and between the second and third electro-optical switches, a weighting cell comprising a set of second optical amplitude modulators and phase shifters associated with multiple wavelengths of the plurality of multiplexed optical carrier signals and preceded by a demultiplexer and followed by a multiplexer along the first weighting optical path, and a separate second optical amplitude modulator and phase shifter along the second weighting optical path, the weighting cell configured to generate the multiplexed weighted optical input signals.

[0004c] According to a third aspect of the present invention, there is provided a photonic computing method comprising: splitting light into a plurality of optical carrier signals associated with a plurality of computational inputs; modulating amplitudes of the plurality of optical carrier signals to impart the computational inputs onto the optical carrier signals, thereby outputting a plurality of first modulated optical signals; splitting each of the optical input signals between a plurality of optical paths associated with a plurality of computational outputs; modulating amplitudes and/or phases of the first modulated optical signals in each of the plurality of optical paths to impart computational weights, each associated with one of the plurality of computational inputs and one of the plurality of computational outputs, onto the first modulated optical signals, thereby generating second modulated optical signals; and coherently combining, for each of the

computational outputs, the second modulated optical signals in optical paths associated with the computational output into an optical output signal encoding the computational output.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Disclosed herein are systems and photonic circuit architectures that optically implement linear algebraic computations, e.g., as used in artificial neural networks. Various example embodiments of the inventive subject matter are described with respect to the accompanying drawings, in which:

[0006] FIG. 1 is a diagram conceptually illustrating an example artificial neuron.

[0007] FIG. 2 is a schematic diagram of an example photonic circuit implementing an individual artificial neuron, in accordance with various embodiments.

[0008] FIG. 3 is a schematic diagram of an example photonic crossbar suitable for implementing a neural network layer, in accordance with various embodiments.

[0009] FIG. 4 is a schematic diagram of an example WDM photonic circuit configuration suitable for implementing multiple independent artificial neurons, in accordance with one embodiment.

[0010] FIG. 5 is a schematic diagram of an example WDM photonic circuit configuration suitable for implementing a convolutional neural network layer, in accordance with one embodiment.