An all-optical neural network on a single chip

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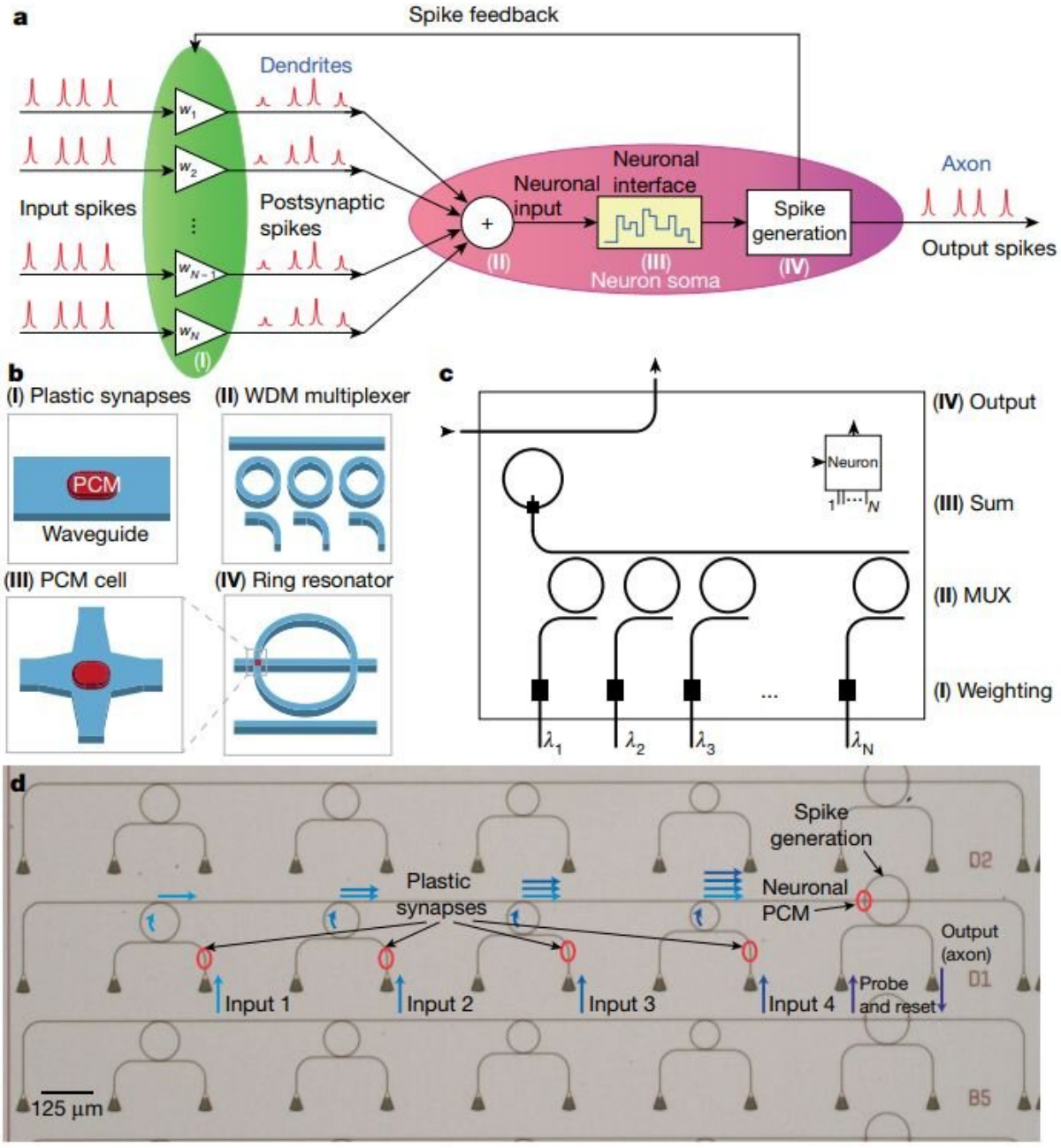

All-optical spiking neuronal circuits. a, b, Schematic of the network realized in this study, consisting of several pre-synaptic input neurons and one post-synaptic output neuron connected via PCM synapses. The input spikes are weighted using PCM cells and summed up using a WDM multiplexer (MUX). If the integrated power of the postsynaptic spikes surpasses a certain threshold, the PCM cell on the ring resonator switches and an output pulse (neuronal spike) is generated. c, Photonic circuit diagram of an integrated optical neuron with symbol block shown in the inset (top right). Several of these blocks can be connected to larger networks using the wavelength inputs and outputs. d, Optical micrograph of three fabricated neurons (B5, D1 and D2), showing four input ports. The four small ring resonators on the left are used to couple light of different wavelengths from the inputs to a single waveguide, which then leads to the PCM cell at the crossing point with the large ring. The triangular structures on the bottom are grating couplers used to couple light onto and off the chip. Credit: *Nature* (2019). DOI: 10.1038/s41586-019-1157-8

A team of researchers from the University of Münster, the University of Oxford and the University of Exeter has built an all-optical neural network on a single chip. In their paper published in the journal *Nature,* the group describes their chip, which has no optical-to-electronic conversions, and how well it worked. Geoffrey Burr with IBM Research – Almaden has published a News and Views piece discussing the work by the team in the same journal issue.

Modern computers run on electricity—it powers devices and serves as a storage and data medium. But for several decades, scientists have wondered if it might be possible to use light as the data medium—crunching photons instead of electrons. Engineers have many hurdles in attempting to create such a device, however, most prominently the bottlenecks that arise when converting between optical and electrical systems. In more recent times, there has been a renewed interest in

building an optically based computer—but now, the focus is energy conservation. Big modern computers used for heavy-duty applications require a lot of electricity. Logic suggests that computers based on light should be less energy intensive, most particularly because they would not generate as much heat, making cooling systems obsolete. In this new effort, the researchers have taken a step toward the creation of optically based computers by building an all-optical neural network on a single chip.

The researchers noted that one type of computer system seemed most amenable to optics—deep neural networks. This is because such networks rely on artificial neurons with synaptic connections that can be weighted based on past learning experiences. They noted also that crystalline phase change materials could also serve such a purpose. They are materials that experience a change in structure when heated—in this case, by a laser. Using such a material, the team built a chip with four neurons connected with 60 synapses using waveguides to control the flow of information represented by light. Testing showed the chip was capable of learning, recognizing patterns and performing computations.

More information: J. Feldmann et al. All-optical spiking neurosynaptic networks with self-learning capabilities, *Nature* (2019). DOI: 10.1038/s41586-019-1157-8

Press release