RESEARCH VISION

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Both power and speed set a new photonic roadmap for next generation quantum communication, cognitive computing, and intelligent sensing system to impact everyday life in the looming 4^{th} industrial revolution of digitalization. In this context Nanophotonics plays a key role as it combines both down scalability at the device level with high data-rates enabled by optical parallelism and minuscule capacitance. Here atto-joule per bit energy consumption is critical to address a multitude of constrains set by optics, electronics, and thermal budgets. Since the power consumption of lasers and modulators scales with volume, we demonstrate the first semiconductor plasmon laser, and recently the first sub-1V Graphene plasmon electro-optic modulator on-chip consuming just 100's of aJ/bit - a 100x improvement over state-of-the-art Silicon photonics while being 1000 times more compact. Beyond communication, optics naturally allows for mathematical functions and convolutions, which can be utilized in revolutionary analogue photonic compute engines. Our approach is to not mimic electronics, but to synergistically 'map' computational algorithms onto photonics hardware. As an example I will show our first optical on-chip FFT capable of handling 100 Tbps data rates at a fraction of the energy of GPUs. Here the delay (~1/data-rate) only depends on the photon's time-of-flight through the waveguide system, which enables a continuous 'pipelining-like' mode of operation – a fundamental advantage over electronics. Further, I discuss recent advances in optical brain-inspired neuromorphic computing. Our contribution to this exciting topic is a nanophotonic perceptron using aJ/bit efficient modulators to perform the neuron's nonlinearity coupled to a common WDM waveguide ring to enable N^2 synaptic connectivity. Our expected system performance of 10^9 GMAC/J is an orders of magnitude improvement over the CMOS digital efficiency wall (~10 GMAC/J). Such brain-inspired analogue compute engines are able to not only speed up applications in deep learning, but also enable non-linear optimization such as quantum simulations in real-time. Lastly, using the coincidence detection property of a leaky-integrate-and-fire neuromorphic network, I will share our latest results in revealing the symmetry of an image – a property key for human 3D vision and even argued to be a signature for intelligence.