面向卷积脉冲神经网络的光子集成神经突触芯片

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脑科学与类脑智能是世界各国争相抢占的前沿尖端科技制高点。近年来，光神经网络朝着大规模、可重构、高速率、低功耗等方向发展，目前仍处于发展的起步阶段，尤其是亟需突破光域非线性计算难题。

针对上述难题，在郝跃院士的悉心指导下，项水英教授团队自主研制 DFB-SA 光子集成神经突触芯片，成功模拟了生物神经元的内在可塑性。在固定外部突触权重的条件下，仅通过调谐 DFB-SA 的增益电流，即可实现可控的类神经元非线性响应 (包括时域积分、阈值激发及不应期)，单通道非线性脉冲激活速率达到 2 GHz (比生物脉冲神经元响应速率快 7 个数量级)，单脉冲能耗 19.99 pJ。通过将权重映射到 DFB-SA 的增益电流，基于单个 DFB-SA 芯片即可同时实现非线性脉冲激活，以及对激活脉冲的线性加权，提供了一种全功能神经形态计算光芯片。

在此基础上，成功研制 4 通道 DFB-SA 阵列芯片，提出光电异构脉冲卷积神经网络软硬协同计算架构，在光域实现基于脉冲机制的 2×2 矩阵卷积，完成卷积脉冲神经网络硬件与算法协同，实现了 MNIST 分类，准确率 87%，为单片集成大规模光脉冲神经网络的硬件实现奠定了重要基础。

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Photonic integrated neuro-synaptic core for convolutional spiking neural network

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Brain science and brain-like intelligence are the cutting-edge science and technology that countries all over the world compete to seize. In recent years, photonic neural networks have developed toward large-scale, reconfigurable, high speed and low power consumption, and are still in the initial stage of development. Especially, it is urgent to break through the nonlinear computing problems in the optical domain.

To solve the problem, photonic integrated synaptic chip based on DFB-SA laser was developed. The intrinsic plasticity of biological neurons was successfully simulated. Under the condition of fixed external synaptic weights, the controllable neuron-like nonlinear response (including temporal integration, excitable threshold and refractory period) can be achieved only by tuning the gain current of DFB-SA laser. The single-channel nonlinear spike activation rate reaches 2 GHz (7 orders of magnitude faster than the response rate of biological neurons), and the energy consumption of a single spike is 19.99 pJ. By mapping the weight to the gain current of DFB-SA laser, the nonlinear spike activation and linear weighting of the activated spike can be realized simultaneously based on a single DFB-SA laser chip, providing a fully functional neuromorphic computing photonic chip. On this basis, the 4-channel DFB-SA array chip was successfully developed.

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