Room temperature exciton-polariton neural network with perovskite crystal

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Polaritons possess a unique combination of electronic and photonic properties, making them ideal for information processing with low energy consumption. However, all previous realizations of polariton neural networks have been constrained by the need to operate at cryogenic temperatures, limiting their practical applications [1].

To overcome this limitation, we employ non-equilibrium Bose-Einstein condensation in monocrystalline lead halide perovskite waveguides [2], creating the first room-temperature exciton polariton neural network [3]. This achievement marks a major step in developing energy-efficient, low-cost, easy-to-fabricate, compact room-temperature optical computing systems based on light-matter interactions. Our polariton neural network, illustrated in Fig. 1, was validated through machine learning tasks, including object detection and binary classification. The results demonstrated 96% accuracy in shape recognition, achieving higher performance than traditional linear classifiers while maintaining ultra-low energy consumption per operation at only 17.5 fJ [3].

Additionally, compared to the best state-of-the-art electronic neural networks employing a perovskite, our approach relies on an optoelectronic implementation, with the potential for fully optical information processing. This physical implementation of a hardware neural network presents a promising technological solution to address the current limitations of modern electronics. Furthermore, compared to recent work demonstrating room-temperature optical information processing with polariton-based linear logic gates [4], our implementation combines two functionalities in one device: a simple logic gate and, importantly, a nonlinear neuron activation element.

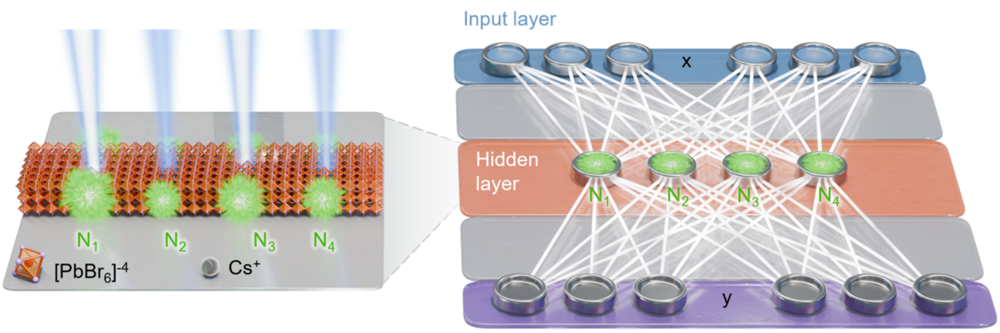

Figure 1: Scheme of feed-forward neural network based on a perovskite waveguide, containing four polariton neurons in the hidden layer [3].

Acknowledgments

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References

[1] N. A. Kavokin, T. C. H. Liew, C. Schneider, et al., *Nat. Rev. Phys* **4**, 435 (2022).

[2] M. Kędziora, A. Opala, R. Mastria, et al., *Nat. Mat.* **52**, 124 (2024).

[3] A. Opala, K. Tyszka, M. Kędziora, et al., *arXiv* 2412.10865, (2024).

[4] H. Li, F. Chen, H. Jia, et al., *Nat. Photon.* **18**, 864 (2024).