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Ultrafast neuromorphic computing driven by polariton nonlinearities

GA, UNITED STATES, June 6, 2025 /EINPresswire.com/ -- Neuromorphic computing, inspired by the human brain, offers a path to faster and more efficient AI. In a pioneering breakthrough, Chinese scientists demonstrate the first use of perovskite microcavity exciton-polariton as a platform for neuromorphic computing, achieving 92% accuracy in digit recognition with single-step training. Operating at room temperature and driven by strong optical nonlinearity, the system enables ultrafast and power-efficient computation—paving the way for next-generation light-based intelligent hardware.

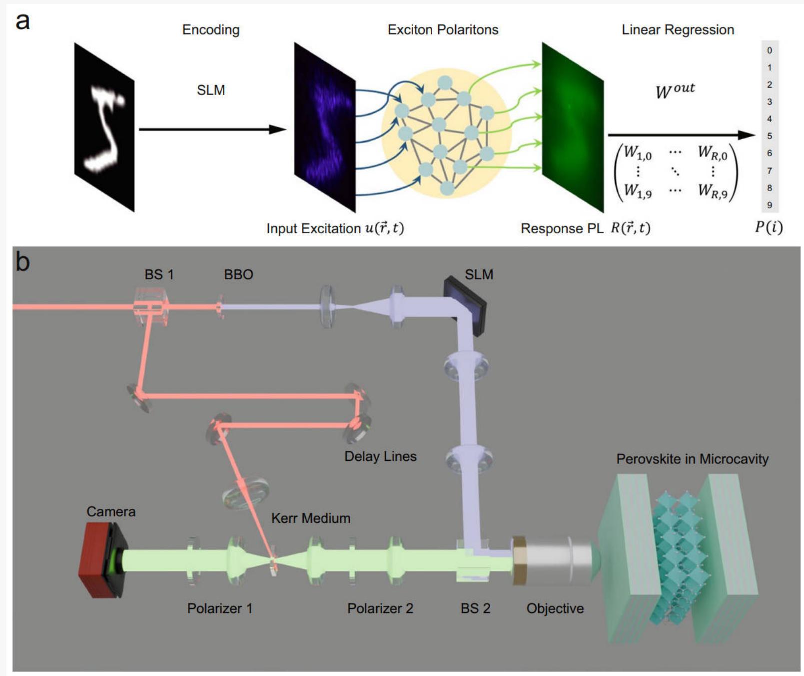

Figure | Working principle of polaritonic neuromorphic computing.

Neuromorphic computing, inspired by the human brain, is considered as the next-generation paradigm for artificial intelligence (AI), offering dramatically increased speed and lower energy consumption. While software-based artificial neural networks (ANNs) have made remarkable strides, unlocking their full potential calls for physical platforms that combine ultrafast operation, high computational density, energy efficiency, and scalability. Among various physical systems, microcavity exciton polaritons have attracted attention for neuromorphic computing due to their ultrafast dynamics, strong nonlinearities, and light-based architecture, which naturally align with the requirements of brain-inspired computation. However, their practical use has been hampered by the need for cryogenic operation and intricate fabrication processes.

In a new paper published in eLight, a team of scientists led by Professor Qihua Xiong from Tsinghua University and Beijing Academy of Quantum Information Sciences report a demonstration of neuromorphic computing utilizing perovskite microcavity exciton polaritons operating at room temperature. Their novel system achieves high-speed digit recognition with 92% accuracy using only single-step training and opens new opportunities for scalable, light-driven neural hardware.

The core of their system is a planar FAPbBr3 perovskite microcavity which supports exciton-polariton condensation under non-resonant optical pumping. Input images from the MNIST dataset are optically encoded by a spatial light modulator (SLM) and projected onto the microcavity as spatially structured excitation beams. The resulting polariton emission patterns serve as the output of the ANN, which is then linearly processed using ridge regression. Remarkably, this scheme requires no predefined network structure—only the physical response of the polariton system—and achieves competitive accuracy using a lightweight training set of 900 images.

“Unlike conventional approaches that rely on prefabricated structures or predefined network nodes, our method employs a fully connected spatial mapping, utilizing the entire perovskite sample area without additional structural constraints,” the corresponding author Qihua Xiong replied. This not only improves the system's scalability but also simplifies experimental realization.

What makes this system stand out is the intrinsic nonlinear and dynamical response of the polaritons. The researchers show that below the condensation threshold, the system behaves nearly linearly, while near and above threshold, nonlinearities emerge sharply, enhancing pattern discrimination. Moreover, by applying ultrafast Kerr-gated time-resolved photoluminescence, the team probes the temporal evolution of polariton responses. They find that polariton dynamics unfold on the picosecond scale and exhibit time-dependent nonlinear mappings, which significantly broaden the system’s capacity for processing complex and temporally varying inputs.

The researchers conclude that “perovskite microcavity exciton polaritons offer ultrafast processing speeds on the picosecond timescale and exhibit exceptionally strong nonlinear interactions, significantly surpassing those in traditional photonic systems.” These attributes make them powerful candidates for future physical neural networks capable of real-time, energy-efficient AI.

This work highlights the growing role of halide perovskites in next-generation photonic computing and marks an important step toward developing all-optical neuromorphic hardware—free from the energy and speed limitations of traditional electronics.

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