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Project Title.
Polariton-based optical neural networks toward next-generation energy-efficient artificial intelligence.

Abstract.

Remarkable progress in artificial intelligence over the past decade has transformed research and industry, driving breakthroughs in data mining, natural language processing, healthcare, finance, autonomous systems, cybersecurity, and more. The dominant AI systems rely on artificial neural networks (ANNs) implemented via software simulations that emulate the behavior of biological neural networks, such as the human brain. These simulations are executed on conventional von Neumann architectures, which increasingly face energy efficiency challenges with the exponential growth of data. The energy required for training and maintaining state-of-the-art AI models, especially large language models and deep learning networks, not only poses economic and environmental challenges but also raises concerns about long-term scalability and sustainability. Toward next-generation energy-efficient AI technology, the collaborative team will explore an innovative approach that transitions from conventional software-based neural network simulations to physical systems where the neural architecture is directly implemented in hardware. Central to this project is the development of a nonlinear activation layer, a key component of optical neural networks, using the unique exciton-polariton properties of lead halide perovskite (LHP). Known for its large exciton binding energy and strong light-matter coupling, both heterogeneous and monolithic optical cavities will be developed to achieve room-temperature polariton condensation and nonlinear neuromorphic functionality utilizing this emerging quantum material (*Years 1&2*). Built on these polariton platforms, an optical neural network (ONN) will be trained in a reservoir computing (RC) scheme (*Year 2*). The performance of the proposed ONN will be benchmarked through the classification of handwritten digits, serving as a proof-of-concept for broader machine learning applications. This interdisciplinary project will pave the way toward scalable, ultrafast, and energy-efficient AI systems based on novel quantum photonic materials.