Ultrafast exciton-polariton neuromorphic computing

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According to many economists, big data is the most important asset of the 21^{st} century. The amount of generated information is exponentially growing. Finding an efficient and fast way of processing the data will have a huge impact on a future world. We propose a system performing neuromorphic computation using exciton-polaritons. These are quasi-particles formed in a semiconductor microcavities as a result of strong coupling between photons and excitons. Polaritons are an excellent platform for information processing due to their small effective mass, high propagation speeds, and strong nonlinearities.

We study CdTe-based semiconductor structure with quantum wells placed between distributed Bragg reflectors. In our work we use nonlinear interactions present in nonequilibrium exciton-polariton Bose-Einstein condensate to create artificial neural network with efficiencies and speed beating top electronic systems in data classification problems. We demonstrate the time-coded interactions with the excitonic reservoir allowing for creation of artificial neurons. We present the time-resolved photoluminescence studies, performed with the use of a streak camera, proving the picosecond scale of the XOR operation.

We demonstrate ultrafast binarized network made of nonlinear XOR logic gates based on exciton-polariton condensate [1]. In our approach the XOR gates nonlinearly transform the input data what allows for linear classification and solving simple classification tasks. We show, that the nonlinearities allow to create a nonlinear XOR logic gate that can perform operations with outstanding efficiency (below 6 pJ per synaptic operation) on the picosecond timescale. We perform classification of handwritten digits from MNIST dataset with 96% accuracy and speech recognition tasks with accuracy exceeding 96% in an opto-electronic realization of a binary network [1,2].

Our work is the first step for building complex all-optical solid-state systems performing classification tasks with much better performance than previously implemented.

[1] R. Mirek et al., Nano Letters **21,** 3715-3720 (2021).
[2] R. Mirek, et al., under review, arXiv:2201.00225 (2022).