Photonic ELM by free space optical Propagation

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Abstract

This gives us a high level understanding of what this research paper is about

Photonic brain-inspired platforms are fast and energy efficient for ML operation but they require tailored optical elements which are challenging to train. In this paper we present the photonic extreme learning machine, which can be implemented simply by using an optical encoder and coherent wave propagation in free space.

Our findings point out an optical machine learning device that is easy to train, energetically efficient, scalable, and fabrication-constraint free

The scheme can be generalised to a plethora of photonic systems, opening the route to real-time neuromorphic processing of optical data.

Introduction

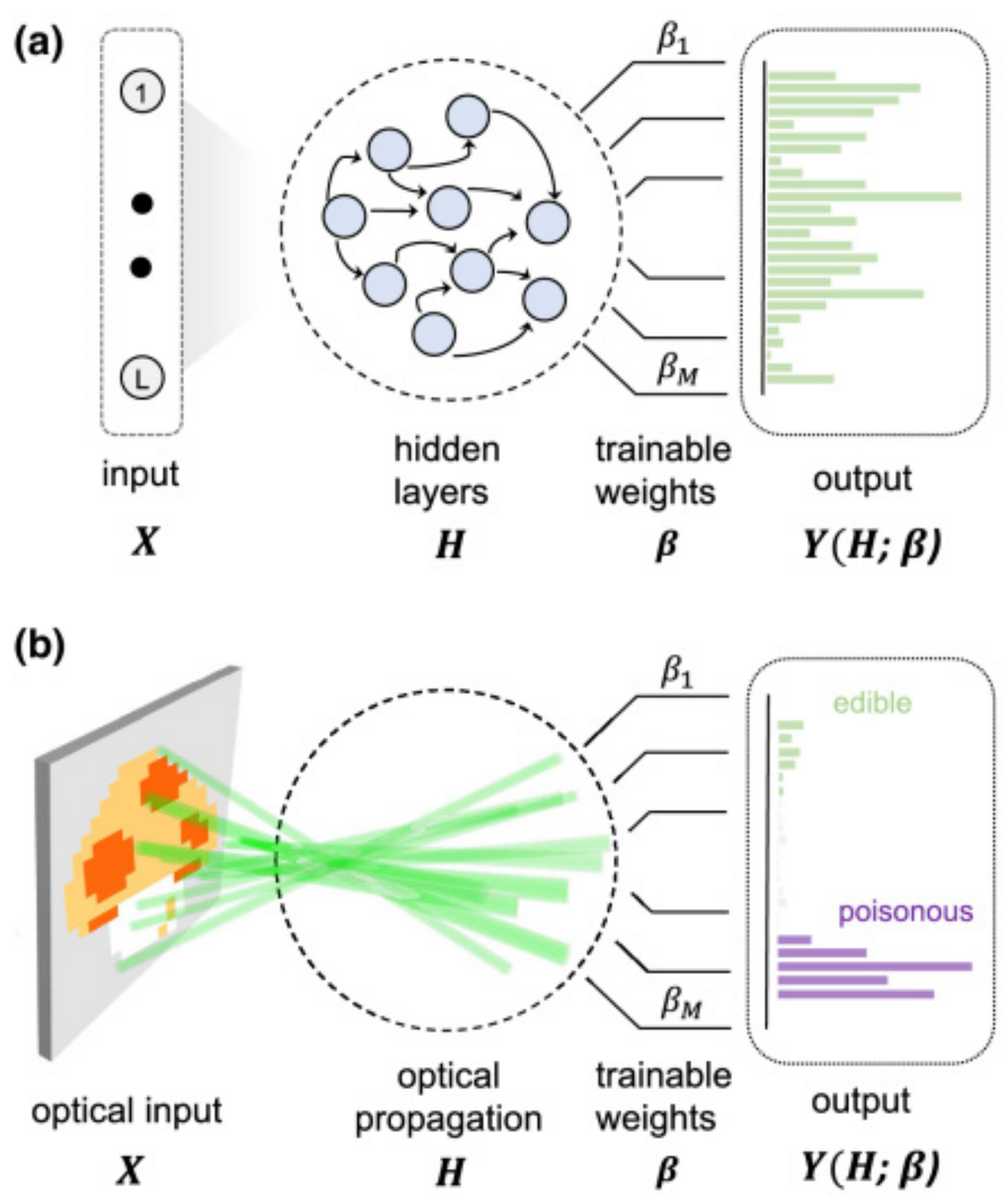
About field of research , what we already know and purpose of research

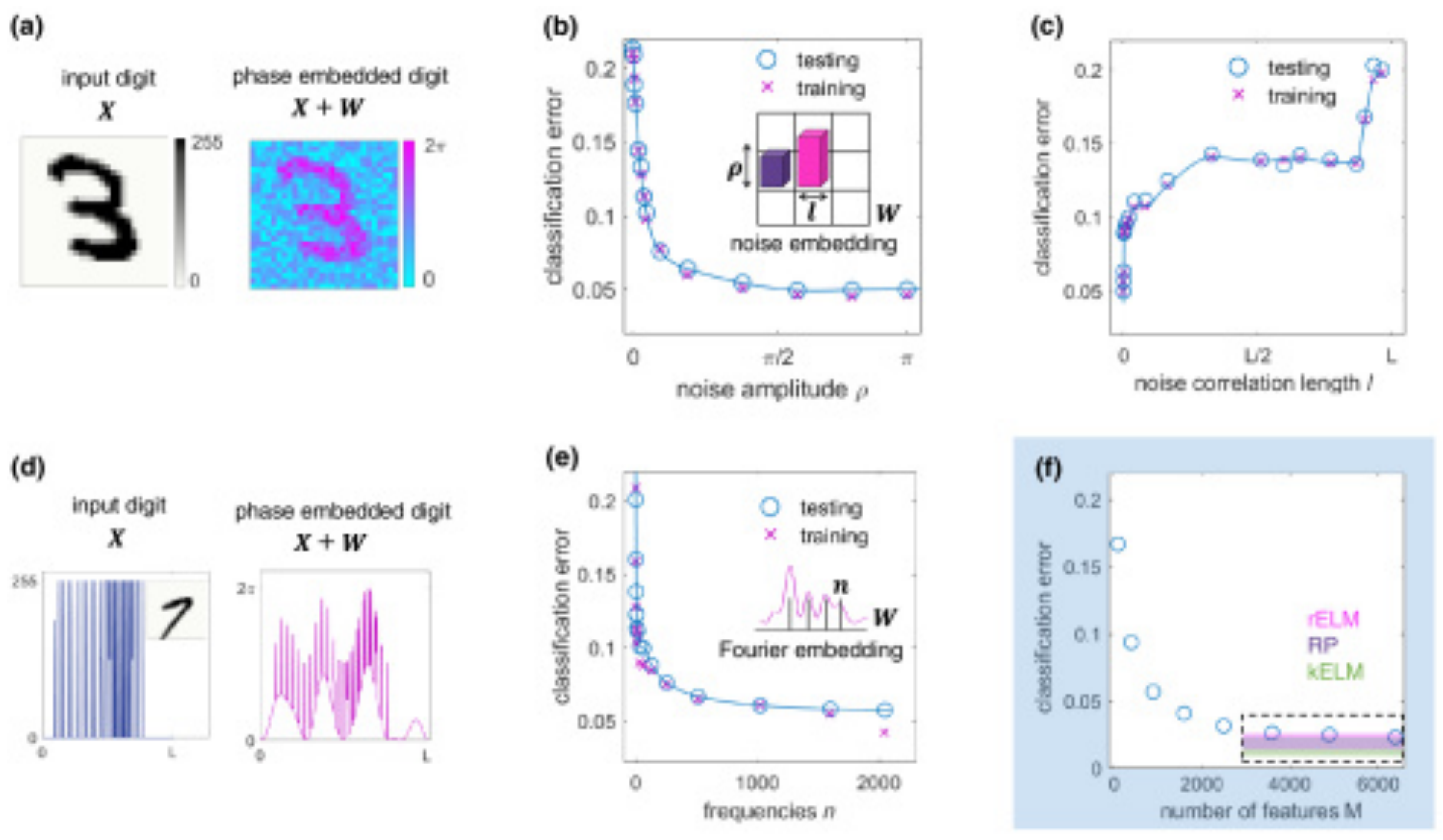
- As data information content increases, simulating these models becomes computationally expensive on conventional computers
- Photonics provides a valuable alternative toward sustainable computing technologies. For this reason, machine learning through photonic components is gaining enormous interest
- A general and promising idea to overcome the issue is to adapt machine-learning paradigms and make them inclined to optical platforms. In this paper, we pursue this approach by constructing an easy-to-train optical architecture that requires only free-space optical propagation.

PELM Architecture

- ELM - An ELM is a feed-forward neural network in which a set of input signals is connected to at least one output node by a large structure of generalised artificial neurons.

- The hidden neurons form the computing reservoir. Unlike for neurons in a deep neural network, they do not require any training, and their individual responses can be unknown to the user.
- To train a classifier we just need to determine optimal output weights (betas) which can be achieved by ridge regression.
- In optical domain, it’s a three layered structure th input vector are embedded into the phase and/or amplitude of the field by an optical modulator.
- The reservoir consists of linear optical propagation and nonlinear detection of the final state.

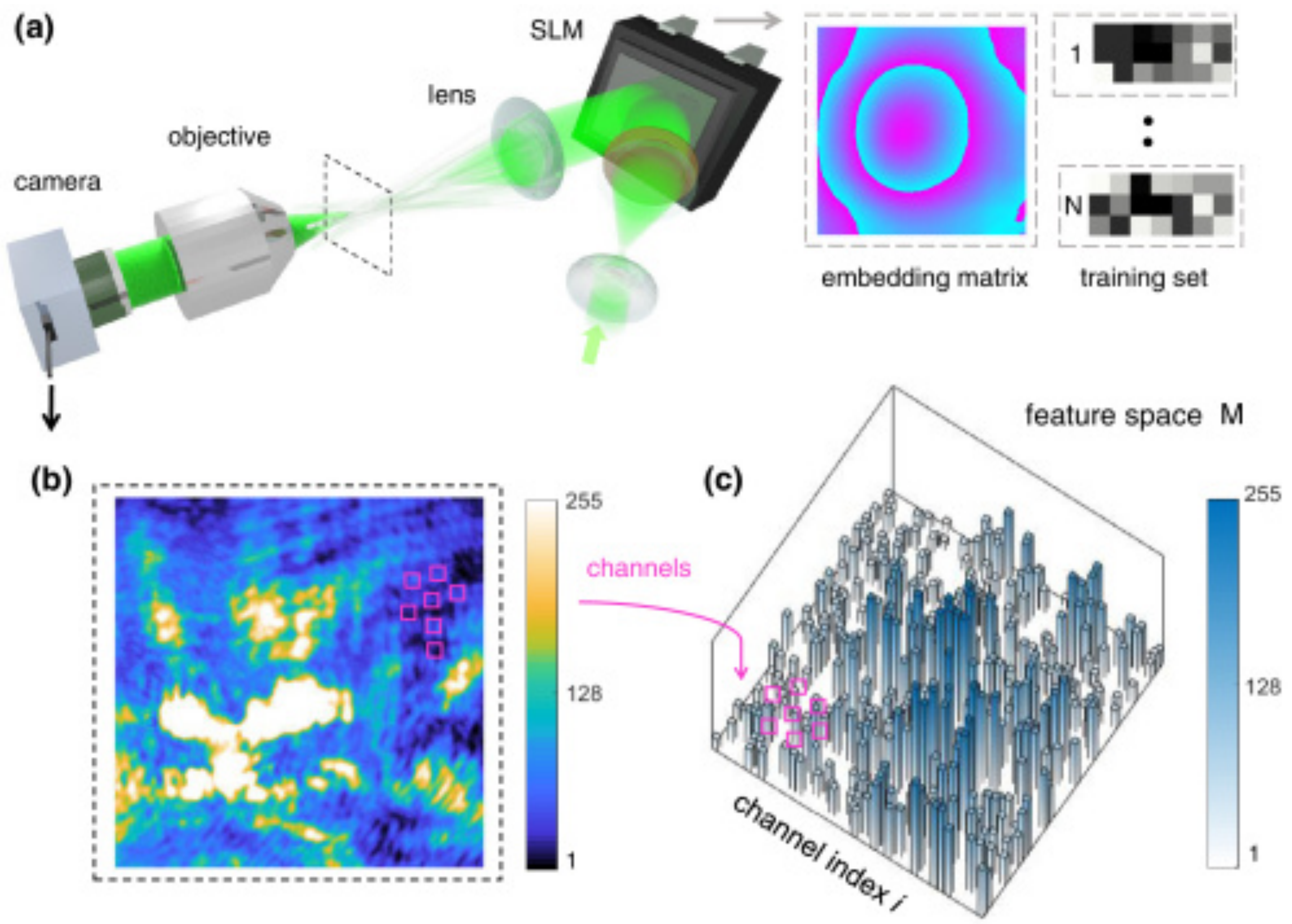




Experimental Device

- A phase-only SLM encodes both the input data set and the embedding matrix on the phase spatial profile of the laser beam.

- In practice, distinct attributes of a data set are arranged in separate blocks, a data sample corresponds to a set of phase values on these blocks, and a preselected phase mask is superimposed
- Phase information self-mixes during light propagation, a linear process that corresponds to the matrix multiplication The far field is detected on a camera that performs the nonlinear activation function , the resulting acquired image is a saturated function of the optical amplitude in the lens focal plane



Discussion

A. Improving the Photonic Hardware

- improved performance is attainable by fine-tuning the optical components
- The limit provided by training errors allows us to identify the various factors toward improving the computational resolution of the optical machine
- Training by use of sparse regression methods may be also useful when dealing with larger data sets.

B. Comparison with Digital Kernel Methods

C. Application Potentials

Conclusion

Key Points and Significance

- Nowadays, artificial intelligence is permeating the field of photonics and vice versa.
- Optical platforms are enabling computing functionalities with unique features, ranging from photonic Ising machines for complex optimization problems to optical devices for cryptography.
- Our results demonstrate that fabricated optical networks, or complex physical processes and materials, are not mandatory ingredients for performing effective machine learning on a optical setup. All the essential factors for learning can be included in optical propagation via encoding and decoding methods