Principles and Metrics of Photonic Learning Machines

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Photonic systems have emerged as promising alternatives to electronic computing. Deep physical neural networks trained with physics-aware backpropagation show that nonlinear optical systems can function as neural networks, leveraging inherent parallelism, energy efficiency, and speed. Unconventional platforms such as optical fibers and semiconductor lasers demonstrate significant computing capabilities.

We characterize two such systems, a highly nonlinear fiber (HNLF) and a vertical-cavity surface-emitting laser (VCSEL), using several metrics including dimensionality, which measures the effective degrees of freedom, and consistency, which assesses the reproducibility of the response. The HNLF reaches up to 100 principal components and achieves 87% accuracy on the MNIST dataset, while VCSELs exhibit similar parameter-dependent computational scaling.