Training Neural Networks with End-to-End Optical Backpropagation

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The primary algorithm for training a neural network is backpropagation, in which the calculation is performed in the order opposite to the information flow for inference. While straightforward in a digital computer, optical implementation of backpropagation has so far remained elusive, particularly because of the conflicting requirements for the optical element that implements the nonlinear activation function. In this work, we address this challenge for the first time with a surprisingly simple and generic scheme. Saturable absorbers are employed for the role of the activation units, and the required properties are achieved through a pump-probe process, in which the forward propagating signal acts as the pump and backward as the probe. Our approach is adaptable to various analog platforms, materials, and network structures, and it demonstrates the possibility of constructing neural networks entirely reliant on analog optical processes for both training and inference tasks.