Networks of Coupled Phase Oscillators as a Neuromorphic Platform Trained with Equilibrium Propagation

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The growing computational demands of machine learning motivate the study of energy-efficient neuromorphic systems. Such systems exploit physical dynamics for inference and, ideally, also for training. Equilibrium propagation is a technique which enables training gradient estimation through local physical interactions. In this work, we explore networks of coupled phase oscillators (the XY model), like laser arrays or coupled limit cycles, as a potential neuromorphic platform that can be trained in this manner. We address the problems posed by the model's complex, multistable energy landscape [1] and explore the effects of architectures such as lattices and stacked lattices [2]. The results show that networks of sparse connectivity can achieve accuracy comparable to that of dense architectures. Our study identifies coupled phase oscillators as a new general-purpose, experimentally implementable neuromorphic platform.

[1] Qingshan Wang, Clara C Wanjura, and Florian Marquardt. Training coupled phase oscillators as a neuromorphic platform using equilibrium propagation. Neuromorphic Computing and Engineering, 4(3):034014, 2024.

[2] Qingshan Wang, Clara C Wanjura, and Florian Marquardt. Dependence of equilibrium propagation training success on network architecture. arXiv preprint arXiv:2601.21945, 2026.