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Classical training of a quantum extreme learning machine

Quantum extreme learning machines (QELMs) are unconventional computing architectures that have shown strong potential for classical and quantum machine-learning tasks. However, the probabilistic nature of quantum measurements typically requires extensive experimental repetitions to accurately estimate expectation values, leading to severe trade-offs among acquisition time, experimental resources, and signal-to-noise ratio, particularly for large datasets. Here we experimentally demonstrate that a QELM trained exclusively on strong classical signals can accurately predict quantum properties of previously unseen quantum states. This approach reduces acquisition times by two orders of magnitude while simultaneously improving precision. Our photonic implementation generates a broad family of frequency-bin–encoded two-photon states, analyzed using a QELM trained via stimulated emission tomography. We achieve (93 ± 4)% accuracy in entanglement witnessing, certify high-dimensional entanglement, and obtain (96 ± 4)% fidelity in nonlinear Hamiltonian learning. These results represent a paradigm shift toward faster and more resource-efficient QELM training for quantum information processing.

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