

Multi-photon Quantum Simulation of Generalized Dense Hopfield Models

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We introduce a formal connection between multiphoton quantum interference, a core element of emerging photonic quantum technologies, and Hopfield-like Hamiltonians of classical neural networks. Specifically, we show that combining a system composed of N indistinguishable photons in superposition over M field modes, a controlled array of M binary phase shifters, and a linear-optical interferometer, yields output photon statistics described by means of a p -body Hopfield Hamiltonian of M Ising-like neurons ± 1 , with $p = 2N$. We investigate the generalized dense Hopfield model obtained through this procedure, undergoing a transition from a memory retrieval to a memory black-out regime, i.e., a spin-glass phase, as the amount of stored memory increases. The mapping enables novel routes to the realization and investigation of disordered and complex classical systems via photonic quantum simulators and describes aspects of structured photonic systems in terms of “memories” in classical spin Hamiltonians.