Coupled Integrated Photonic Quantum Memristors for Neuromorphic Quantum Processing

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Machine learning relies on nonlinear transformations and adaptive, state-dependent responses with memory. Extending these capabilities to quantum systems is challenging, particularly in photonic platforms where single-photon nonlinearities are weak. Photonic quantum memristors (PQMs) provide an alternative route via measurement-induced feedback, enabling effective nonlinearity and memory [1].

While previous implementations have focused on isolated [2] or cascaded PQMs [3], we have experimentally demonstrated two coupled PQMs with crossed feedback (Fig.1(a)), where the state of each element depends on the measurement history of the other [4]. We have implemented them on a silicon nitride photonic integrated circuit and operated at room temperature. Single photons are generated by a silicon-vacancy (SiV^-) color center in a nanodiamond and coupled into the chip. Each PQM is realized by a Mach–Zehnder interferometer whose internal state is dynamically updated based on photon detection events, thereby introducing non-Markovian and history-dependent dynamics. We observe enhanced nonlinear intra-memristors input–output relations and complex hysteresis dynamics, including large-area loops (Fig.1(b)) and self-intersecting curves (Fig.1(c)), which reveal bistability and topologically non-trivial memory effects, respectively. These original features motivate their study as building blocks for photonic quantum neural networks and reservoir computing schemes.

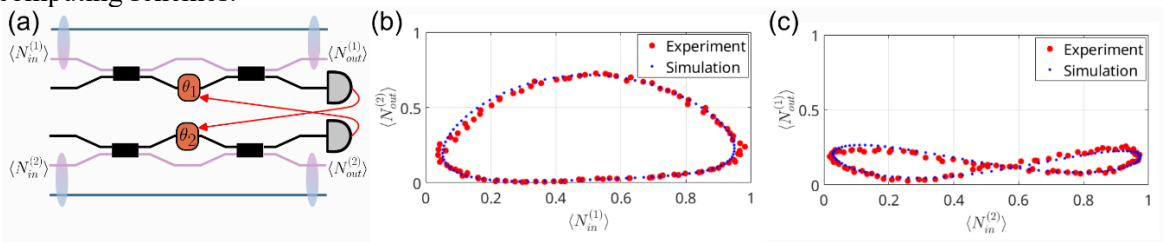

Fig. 1: *(a) Scheme of two coupled photonic quantum memristors with crossed feedback. (b)-(c) Example of peculiar intra-memristor input-output relations.*

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