Memory-Dependent Quantum Transformations with a Photonic Quantum Memristor

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We present a theoretical proposal for a quantum memristor operating at the single-photon level, implementing memristive behavior, including characteristic hysteresis loops, in a quantum optical system through measurement-based controlled feedback on photonic polarization states [1]. Analogous to classical memristors, where resistance depends on the system's past electrical history, our quantum device transforms input photon states according to $|\psi out(t)\rangle = U(\theta(t)) |\psi in(t)\rangle$, where the unitary operator $U(\theta)$ evolves based on measurement outcomes of previous photons, exhibiting path-dependent memory effects [2]. Unlike classical memristors that rely on material properties, our theoretical device achieves memory effects through quantum measurements and high-speed feedback, with dynamics characterized by $d\theta/dt = \eta N(t)+\gamma(\theta_0-\theta)$, where η is the feedback strength, $N(t)$ represents detection events, and γ is the relaxation rate. The theoretical model predicts high state fidelity while operating under timing constraints where feedback processes must be completed within the photon coherence time ($\sim\mu$s). Our proposal provides insights into implementing quantum memristive systems differently from those in [3] and with applications in photonic quantum computing, adaptive quantum sensing, and neuromorphic quantum architectures.

References

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