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Deterministic and Cascadable Conditional Phase Gate for Photonic Qubits CHRISTOPHER CHUDZICKI, ISAAC CHUANG, JEFFREY SHAPIRO, MIT — Cross-phase modulation (XPM) at the single-photon level, if strong enough, would enable a simple conditional π-phase gate for photonic qubits. Together with easily realized single-qubit rotations for such qubits, this would provide a universal gate set for quantum computation. However, previous analyses of photonic conditional ϕ-phase gates that treat XPM in a causal, multimode, quantum field setting suggest that a large ($\sim\pi$ rad) nonlinear phase shift is always accompanied by fidelity-degrading noise. We present a conditional phase gate that, for sufficiently small nonzero ϕ, has high fidelity. Moreover, our gate is cascadable, in that it preserves the structure of the principal modes used to encode qubit information, and can therefore be cascaded to realize a high-fidelity conditional π-phase gate. The key components of our gate are: (1) an atomic $\vee$-system to create XPM; (2) a principal-mode restorer that compensates the evolution a principal-mode incurs when the $\vee$-system is driven by a single photon; and (3) a principal-mode projector that exploits the quantum Zeno effect to preclude the accumulation of fidelity-degrading departures from the principal-mode Hilbert space when both control and target photons illuminate the gate.

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