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Parametric interactions in multimode cavities

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Multimode cavities are a promising resource for quantum information and simulation, due to their large accessible Hilbert space, restricted set of decay and decoherence channels, large single-photon lifetimes, and ease of control using superconducting qubits. In this talk, we describe parametric control of a multimode circuit QED system with a superconducting transmon qubit. We show that single transmon charge control, and flux-driven sideband interactions with the cavity modes are sufficient for universal quantum control of the entire multimode manifold. We demonstrate universal gate operations between arbitrary modes, and efficient schemes for generating highly entangled multi-photon states. The realization of fast, tunable parametric interactions in a multimode cavity with tens of highly coherent quantum bits, shows promise for achieving quantum supremacy in the near term.