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Prospects for a prototype quantum processor based on three-dimensional superconducting cavities and qubits

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Superconducting qubits embedded in three-dimensional waveguide resonators (recently pioneered by Paik, et al., arXiv:1105.4652) have shown excellent coherence properties and an ease of implementation that make them an enticing core component for small prototype quantum processors. The relatively large physical dimensions of the microwave modes of these 3D-cQED systems may lead one to discount their prospects for scaling. We argue that the larger characteristic dimensions, among others factors, in fact facilitate scaling for currently practicable prototype systems of ∼10 to 1,000 qubits. This emerges from significantly reduced fabrication complexity and costs, larger tolerances to parameter deviations, a more prevalent role for off-the-shelf components, and greater amenability to full-device electromagnetic simulation. At IBM we are working towards a modular quantum processor prototype based on 3D-cQED. Multi-qubit cavities, each implementing an artificial NMR molecule, are to be connected in an array by non-linear elements which double as tunable couplers between qubits in adjacent cavities and as single-shot readout circuitry. The resulting lattice of physical qubits provides a fabric on which surface code error correction can take place, implying a fault-tolerant threshold error rate for this architecture of ∼1%. We describe recent experiments demonstrating a two-qubit gate with a two qubit/one cavity device and progress toward tunable coupling of qubits in adjacent cavities.