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Direct Measurement of the Entanglement of Two Superconducting Qubits via State Tomography.

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The Josephson phase qubit can be thought of as an electrical “atom” whose resonance frequency can be tuned via an external control bias. Owing to its potential compatibility with conventional integrated circuit fabrication techniques, this system is a promising candidate for a scalable architecture for a quantum computer. Currently, the critical path towards a real device consists of understanding all sources of decoherence that destroy the fragile quantum states. Recently, dielectric loss was identified as the main source of decoherence for phase qubits. By employing techniques to minimize dielectric loss we improved the performance of our quantum bit, which enabled us to show quantum-mechanical entanglement between two phase qubits and identify the generation of a Bell state with a fidelity of up to 0.87, still limited by decoherence effects. We detail the experiment and outline further progress on reducing dielectric loss, leading to an improvement of the measured energy relaxation time by a factor of five. We also identified other insulating materials, which should improve the energy relaxation time by an additional factor of two, resulting in overall coherence times of about one microsecond.