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Entangled States of Trapped Ions[1]

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Entangled states of the internal degrees of freedom are an important resource in Quantum Information Processing (QIP) and Quantum Simulation (QS) with trapped ions. Most basic requirements for QIP and QS have been demonstrated for trapped ions, with two big challenges remaining: Improving operation fidelity and scaling up to larger numbers of qubits. In the last few years, steady progress has been achieved with laser-based entanglement schemes with demonstrated fidelities of deterministically produced Bell states of 99.3% and up to 14 ion-qubits entangled in generalized GHZ-states. Scalable architectures have been proposed; one scheme, where ion-qubits are moved through a multi-zone trap array, is studied in several laboratories. Sympathetic cooling with a second ion species, which initializes the motional states for multi-qubit operations, has been demonstrated in an experiment where arbitrary operations on two qubits were implemented. Micro-fabrication approaches to ion-trap-arrays have yielded structures that should be capable of holding and manipulating large numbers of ions. Recently, with the use of microwaves, single-qubit rotations with fidelities of 99.998% per gate operation were demonstrated and two ion-qubit gates have been implemented. Microwave control could potentially be easier to scale by directly integrating microwave-lines on micro-fabricated trap devices. It also eliminates several sources of decoherence that are present in laser-based schemes by exclusively coupling to long lived hyperfine ground states.

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