Multi-qubit Operations Using Scalable Techniques

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Quantum information processing (QIP) promises significant gains for some important computational tasks as well as the potential to simulate interesting physical systems. Storing quantum bits (qubits) in the internal states of trapped atomic ions has been a fruitful approach to QIP because of long coherence times and precise interaction with light fields for coherent control and entanglement generation.

Here, we present a complete methods set for scalable ion-trap QIP, including robust qubit storage, single- and two-qubit logic gates, state initialization and readout, and quantum information transport. This combination of techniques enables sustained processing, in which repeated multiple-qubit operations show no loss of performance despite qubit transport over macroscopic distances[1].

We present the first realization of a programmable two-qubit quantum processor[2] and discuss progress towards applying these techniques to three or more qubits.

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[1]J. P. Home, D. Hanneke, J. D. Jost, J. M. Amini, D. Leibfried, and D. J. Wineland, "Complete methods set for scalable ion trap quantum information processing," Science **325** 1227–1230 (2009)

[2]D. Hanneke, J. P. Home, J. D. Jost, J. M. Amini, D. Leibfried, and D. J. Wineland, "Realization of a programmable two-qubit quantum processor," Nature Phys. **6** 13–16 (2010)