DAMOP05-2005-020003

Abstract for an Invited Paper
for the DAMOP05 Meeting of
the American Physical Society

Quantum Information Processing with Trapped Ions*

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Trapped strings of cold ions provide an ideal system for quantum information processing. The quantum information can be stored in individual ions and these qubits can be individually prepared, the corresponding quantum states can be manipulated and measured with nearly 100% detection efficiency. With a small ion-trap quantum computer based on two and three trapped Ca^{+}ions as qubits we have generated in a pre-programmed way genuine quantum states. In particular, entangled states of two particles, i.e. Bell states [1], and of three particles, i.e. GHZ and W states [2], were generated using an algorithmic procedure and their decoherence was investigated. These states are of particular interest for the implementation of a three-ion quantum register: we have demonstrated selective read-out of single qubits (while protecting the other qubits) and manipulation of single qubits of the register conditioned on the read-out results. The generated states have been measured experimentally using a technique known as state tomography allowing the population and phase of the quantum system to be mapped. Moreover, quantum teleportation with trapped ions was implemented [3] and can be used as resource for the transfer of quantum information as well as for quantum information processing.

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