DAMOP12-2012-000106
Abstract for an Invited Paper
for the DAMOP12 Meeting of
the American Physical Society

# Quantum Control and Tomography in the 16-Dimensional Ground Manifold of Atomic Cesium

POUL JESSEN, Center for Quantum Information and Control, College of Optical Sciences, University of Arizona

The standard paradigm for Quantum Information Science involves a collection of qubits, whereas the physical building blocks of a quantum processor or simulator often have more than two accessible levels. Taking advantage of these higher dimensional Hilbert spaces (qudits) requires the development of good laboratory tools for qudit manipulation and readout. We have successfully implemented a protocol for quantum state-to-state mapping in the 16-dimensional hyperfine ground manifold of individual Cesium atoms, using only DC, rf and microwave magnetic fields to drive the atomic evolution. Our control waveforms (rf and $\mu$w phases versus time) are found by numerical optimization, and designed to compensate for errors in the driving and background magnetic fields. Experimentally we achieve a state-to-state mapping fidelity of better than 99%, averaged over a sample of randomly chosen initial and target states. Preliminary results suggest that unitary transformations can be designed and implemented in a similar manner. To perform quantum state tomography, we drive an ensemble of identically prepared atoms with phase modulated rf and $\mu$w fields while performing a continuous weak measurement of an atomic observable via polarization spectroscopy. The resulting measurement record is numerically inverted to obtain an estimate of the unknown quantum state. We have reconstructed the density matrices for a set of randomly chosen pure test states using algorithms based either on least squares fitting or compressed sensing. The latter is slightly more tolerant of experimental errors and achieves an average fidelity above 90%.