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Unitary Transformations in a Large Hilbert Space BRIAN ANDERSON, HECTOR SOSA MARTINEZ, AARON SMITH, University of Arizona, CARLOS RIOFRIO, CHARLIE BALDWIN, IVAN DEUTSCH, University of New Mexico, POUL JESSEN, University of Arizona — Quantum systems with Hilbert space dimension greater than two (qudits) provide an alternative to qubits as carriers of quantum information, and may prove advantageous for quantum information tasks if good laboratory tools for qudit manipulation and readout can be developed. We have implemented a protocol for arbitrary unitary transformations in the 16 dimensional hyperfine ground manifold of Cesium 133 atoms, using phase modulated rf and microwave magnetic fields to drive the atomic evolution. Our phase modulation waveforms are designed numerically using a variant of the highly efficient GRAPE algorithm. The fidelity of the resulting transformations is verified experimentally through randomized benchmarking, which indicates an average fidelity better than 97% across a sample of random unitaries. Our toolbox for quantum control is in principle applicable for a broad class of physical systems, such as large spins or anharmonic oscillators.

Hector Sosa Martinez
University of Arizona

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