DAMOP08-2008-000391

Abstract for an Invited Paper
for the DAMOP08 Meeting of
the American Physical Society

Optimal Control of Large Spin Systems

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Laboratory techniques to manipulate and observe ultracold atoms make these an attractive platform for testing new ideas in quantum control and measurement. I will discuss recent experiments in which we use tensor AC Stark shifts and magnetic fields to drive non-trivial quantum dynamics of a large spin-angular momentum associated with an atomic hyperfine ground state. The nonlinear spin Hamiltonian is sufficiently general to achieve universal quantum control over the 2F+1 dimensional state space, and allows us to generate arbitrary spin states and perform a full quantum state reconstruction of the result. We have implemented and verified time optimal controls to generate a broad variety of spin states, as well as an adiabatic scheme to generate spin-squeezed states for metrology. Most recently we have used our control and measurement tools to realize a common paradigm for quantum chaos known as the quantum kicked top. Direct observation of the phase space dynamics of this system has given an unprecedented look at quantum/classical correspondence. In the future we hope to use coherent optical feedback on atomic ensembles to extend our toolbox for control and measurement to collective spins. Applications include quantum metrology, quantum information processing and simulations of quantum manybody physics.