DAMOP14-2014-000224

Abstract for an Invited Paper
for the DAMOP14 Meeting of
the American Physical Society

Ultrafast Control of Spin and Motion in Trapped Ions

JONATHAN MIZRAHI, Joint Quantum Institute, University of Maryland Department of Physics and National Institute of Standards and Technology, College Park, Maryland 20742

Trapped atomic ions are a promising medium for quantum computing, due to their long coherence times and potential for scalability. Current methods of entangling ions rely on addressing individual modes of motion within the trap and applying qubit state dependent forces with external fields. This approach can limit the speed of entangling gates and make them vulnerable to decoherence due to coupling to unwanted modes or ion heating. This research is directed towards demonstrating novel entanglement schemes which are not limited by the trap frequency, and can be made almost arbitrarily fast. Towards this goal, I will present results from the first experiments using ultrafast laser pulses to control the internal and external states of a single trapped ion. I will begin with experiments in ultrafast spin control, showing how a single laser pulse can be used to completely control both spin degrees of freedom of the ion qubit in tens of picoseconds. Second, I will discuss experiments using pulses to rapidly entangle the spin with the motion, and how careful spectral redistribution allows a single pulse to execute a spin-dependent momentum kick. Finally, I will explain how these spin-dependent momentum kicks can be used in the future to create an ultrafast entangling gate, and will present experimentally realizable pulse sequences. Such a gate would create a maximally entangled state of two ions in a time faster than the period of motion in the trap.