Abstract Submitted
for the DAMOP18 Meeting of
The American Physical Society

Non-classical motional states of a trapped ion for quantum-enhanced sensing[1] K.C. MCCORMICK, NIST, University of Colorado Boulder, D. LEIBFRIED, A.C. WILSON, NIST, Boulder CO, S.C. BURD, NIST, University of Colorado Boulder, J. KELLER, D.J. WINELAND, NIST, Boulder CO — Quantum simulations with trapped ions have mostly used internal states of the ions to encode the simulated system. Alternatively, one can employ external quantum degrees of freedom, namely the quantized motion of the ions in the trap. Such simulations could be carried out in compact surface electrode traps with multiple potential wells, which offer individual control of the motional modes of single ions and selective motional coupling between ions. However, the decreased ion-electrode distance in these traps makes the ions more susceptible to motional heating and dephasing due to technical and electrode surface electric-field noise. We present the results of an experiment that demonstrates a high level of motional control of a single trapped ion and investigates the nature of motional dephasing mechanisms in the trap. By generating non-classical superpositions between the ground motional state and a harmonic oscillator number state of up to $n = 18$, we can measure fluctuations of the ion motional frequency, with a quantum advantage over coherent-state-based interferometers that increases with n. We investigate several methods based on such superpositions to characterize motional frequency fluctuations over timescales from hundreds of microseconds to hours.

[1]This work is supported by the NIST Quantum Information Program. K.C.M. acknowledges support from a Quantum Computing Graduate Research fellowship from ARO.

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Date submitted: 26 Jan 2018 Electronic form version 1.4