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Quantum Control of Harmonic Oscillator Motional States of Ions

Wednesday, 19 February 2020 10:00 (30 minutes)

This talk will give an overview of recent work on quantum control of the har- monic oscillator states of motion realized with trapped ions at NIST. We prepare non-classical states of the motion of a single Be+ or Mg+ ion, such as approxi- mately pure number states of ion motion up to n = 100 [1], coherent superpo- sitions of the ground state with number states up to n = 16 [1] and squeezing to more than 20 dB over a motional ground state [2]. These states are useful to characterize ion motional excitation and frequency noise over a wide range of time-scales, with a quantum advantage over more traditional approaches.

Besides being useful for exploring quantum control of harmonic oscillators, atomic ions are also sensitive to coherent electric fields, such as those that may result from hidden photons or from axions in the presence of a magnetic field. The motional frequencies of ions in the quantum regime typically range from 100 kHz - 10 MHz and can be tuned by changing their confining potential. Harmonic oscillator quality factors of at least 105 have been observed and even better quality factors may be realized by more careful elimination of noise and drifts in the system. Therefore, it could be interesting to use ions as field-sensors for searches of axions and hidden photons in a frequency range where electrical circuits may be limited by thermal noise. Similar experiments can also be done in a Penning trap with hundreds of ions [3]. Penning trap operation requires a strong magnetic field that can potentially serve to convert axion fields into elec- tric fields and the larger number of ions allows for faster averaging of projection noise during readout of the ion state.

[1] K. C. McCormick, J. Keller, S. C. Burd, David J. Wineland, A. C. Wilson, and D. Leibfried, Nature 572, 86 (2019).

[2] S. C. Burd, R. Srinivas, J. J. Bollinger, A. C. Wilson, D. J. Wineland, D. Leibfried, D. H. Slichter, and D. T. C. Allcock, Science 364, 1163 (2019).

[3] K. A. Gilmore, J. G. Bohnet, B. C. Sawyer, J. W. Britton, and J. J. Bollinger, Phys. Rev. Lett. 118, 263602 (2017).

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