Encoding a logical qubit in a trapped-ion oscillator.

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Quantum error correction requires storing qubits in systems with enlarged Hilbert spaces, on which measurements can be made without disturbing the stored information. While much focus is placed on implementing this in qubit arrays, such a space is also available in single harmonic oscillators. An oscillator codes which is optimal for many of the most prominent errors involves basis states which are a periodic array of squeezed states[1,2]. I will describe experiments in which we create, measure and manipulate logical information stored in such a code using the oscillatory motion of a single trapped atomic ion. These elements are implemented using a laser which couples the motion to an ancilliary pseudo-spin qubit stored in the internal electronic ion, which can be read out in a single shot with high fidelity. The sequence of spin-motion coupling and state readout allows us to measure modular variables of the position and momentum of the oscillator state, which is used for both the logical and stabilizer operator measurements of the code [3]. We demonstrate preparation of the cardinal states on the encoded Bloch sphere with a fidelity of 85%, and perform process tomography to characterize operations on the encoded qubit. The states and techniques developed in this work may be applied to sensing as well as for early stage studies of quantum error-correcting codes.

[1] Gottesman et al. PRA 64, 012310 (2001)
[2] Noh et al. arXiv:1801.07271 (2018)
[3] Flühmann et al. PRX 8, 021001 (2018)