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Controlling trapped-ion motional modes for precision measurement*

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Motional modes of trapped ions have been shown to be a useful tool for quantum sensing, making use of time reversal protocols. This application requires the ability to prepare well-defined motional states with high fidelity. Many of these states can be generated from motional ground states without the use of laser fields. We report our results in generating one-mode and two-mode squeezed states using parametric excitation. These operations help to create motional state interferometers and can be used to achieve sensitivities approaching the Cramér-Rao bound. We present an implementation of an SU(1,1) interferometer using one and two motional modes of a 40Ca+ ion in a Paul trap, and compare the performance to the more traditional SU(2) Mach-Zender interferometer. To characterize the input and output motional states of the interferometers, the ions' motion is coupled to internal 'spin' states, which are distinguishable through spin-dependent fluorescence. The calculation of the Fisher information from experimental data can be used to quantify the phase sensitivity that we can achieve in our setup.
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