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Quantum non-Gaussianity of multiphonon states of a single atom

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Generation and manipulation of non-classical states of motion has been of interest with motivation in quantum metrology, quantum enhanced sensing [1] and quantum thermodynamics. Fock states of motion with exactly defined discrete value of energy are experimentally achievable realizations of such non-classical states in ion trap. Although the significant progress in the Fock state preparation has been achieved [2], the optimal method to characterize their quantitative properties remains a subject of discussion.

We demonstrate the generation of motional Fock states up to 10 in a single 40Ca+ trapped ion oscillator, and we derive the set of quantum non - Gaussianity (QNG) criteria, to characterize the measured state's non-classicality. We further subject the generated state to the controlled interaction with thermal environment and evaluate the QNG depth and other quantitative parameters of the imperfect state with losses. We also demonstrate the metrological advantage of our states proving the ability for quantum enhanced sensing.

We further experimentally realize the novel method for Fock state generation from thermal motional states with high energies, based on pioneering work of Blatt et al. [3]. By unconditional repetitive accumulation of anti-Jaynes –Cummings interaction with fixed interaction time, we prove that it is possible to generate a chosen mixture of motional Fock states within the finite number of iterations, and for an ion initially prepared in a thermal motional state [4]. The non-classical properties of the states are again proved by several complementary measures, and in addition, we investigate the QNG depth. Finally, we demonstrate our recent work showing the non-classicality of states generated by the process of repetitive absorption of phonons from thermal motional state of a single ion.

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