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Creation of entangled coherent states with the motional degrees of freedom of a trapped ion

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The motional degree of freedom of a trapped ion system has been studied as a conveyor of quantum information in the context of continuous variable quantum computing (CVQC) [1,2]. Theoretical and experimental studies concerning quantum information processing with the motional degrees of freedom include phonon sampling [3,4], and encoded qubits [5]. In this work, we experimentally create the entangled coherent state (ECS) of the form $|\alpha\rangle\ |\beta\rangle + |-\alpha\rangle\ |-\beta\rangle$ with a single ion and study its characteristics. The quantum state has previously been realized in other quantum systems such as photons and microwave resonator cavities [6,7], and this work represents its first implementation in a trapped ion system. The ECS is created by simultaneously driving spin-dependent force on the two principal axes of the ion, and then projecting its spin state, which disentangles the spin degree of freedom from the entangled motional states [8,9]. Afterwards, we observe a periodic modulation in the phonon number parity of one of the two entangled modes and confirm that it matches the theoretically predicted pattern where the parity information disappears when the two modes are strongly entangled. We expect the generation of the ECS to facilitate the study of CVQC in trapped ion systems.

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