

Control of trapped-ion motion for quantum simulations and quantum computations

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Due to large accessible Hilbert space, motional states of the trapped ions are attractive for quantum simulations and quantum computing. However, these applications require strong and deterministic nonlinear interactions between the modes of motion. In this talk, I report nonlinear coupling between two and three normal modes of motion in the system of trapped ions that arises due to anharmonicity of the Coulomb interaction between the ions and demonstrate several applications of these interactions, including projective measurement of the phonon number via a cross-Kerr effect and implementation of an absorption refrigerator for studies of quantum effects in thermodynamics. I also describe implementation of a hybrid quantum gate, where populations of two motional modes are swapped conditioned on the spin state of the ion and discuss how such gate can enable universal quantum computations with continuous variables.