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Ultrafast Spin-Motion Control In Trapped-Ion System By Resonant Laser Pulses

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Ultrafast spin-phonon entanglement based on SDKs provides an approach to realize fast entangling gates with intrinsic robustness and scalability for trapped ion quantum computing. Such SDKs so far have been implemented on a nanosecond timescale by off-resonant Raman transitions where each laser pulse is split into a sequence of perturbation pulses with carefully designed temporal patterns.

Here we demonstrate the spin-phonon entanglement with SDKs on a hyperfine qubit using resonant laser pulses. In our scheme, complicated pulse shaping and splitting are avoided. Compared with the earlier proposal for resonant pulses on optical qubits, our scheme uses hyperfine qubits and thus has advantages on qubit coherence time. Then by applying two pulses from opposite directions, each with half the pulse area, we obtain the desired SDK in 80 ps, which is faster than the previous results by more than an order of magnitude. It removes the need to engineer the pattern of a sequence of perturbation pulses and is less vulnerable to noise, simplifying the approach to large-scale trapped-ion quantum computing based on fast quantum gates with SDKs. Finally, we present a two-qubit gate scheme based on the new SDKs' scheme which can achieve a high fidelity in theory thus can be a building block for the large-scale trapped ion quantum computing in future.

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