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Parallel 2-Qubit Operations on a Programmable Ion Trap Quantum Computer[1] CAROLINE FIGGATT, AARON OSTRANDER, NORBERT LINKE, University of Maryland , KEVIN LANDSMAN, Joint Quantum Institute and University of Maryland Department of Physics, College Park, Maryland 20742, DAIWEI ZHU, University of Maryland, DMITRI MASLOV, National Science Foundation, CHRISTOPHER MONROE, University of Maryland — Performing parallel operations will be a powerful capability as deeper circuits on larger, more complex quantum computers present new challenges. We present experimental results for a pair of 2-qubit gates performed simultaneously in a single chain of trapped ions. The system used is a programmable quantum computer consisting of a linear chain of five trapped $^{171}Yb^{+}$ atomic clock ions with long coherence times. We employ a pulse shaping scheme that modulates the phase and amplitude of the Raman transitions to drive programmable high-fidelity 2-qubit XX gates in parallel by coupling to the collective modes of motion of the ion chain. Ensuring the interaction produced yields only spin-spin interactions between the desired pairs with neither residual spin-motion entanglement nor crosstalk spin-spin entanglement is a nonlinear constraint problem, and pulse solutions are found using optimization techniques. As an application, we demonstrate the quantum full adder [1] using a depth-4 circuit requiring the use of parallel 2-qubit operations [2] as well as modular 1- and 2-qubit operations previously demonstrated on this system [3]. [1] Opt. News, 11, 1120 (1985), [2] IEEE Trans. Comput.-Aided Design Integr. Circuits Syst., 27(3):436-444 (2008), [3] Nature 536, 63 (2016).

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Caroline Figgatt
University of Maryland

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