Towards scalable quantum information processing with trapped ions

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We discuss experiments towards scalable quantum information processing and quantum simulation in the Ion Storage Group at NIST Boulder. Our architecture is based on quantum information stored in internal (hyperfine) states of the ions. We investigate the use of laser beams and microwave fields to induce both single-qubit rotations and multi-qubit gates mediated by the Coulomb interaction between ions. Moving ions through a multi-zone trap architecture allows for keeping the number of ions per zone small, while sympathetic cooling with a second ion species can remove energy and entropy from the system. We will provide an update on experiments towards benchmarking operation fidelities and improved ion transport.

Work is under way to leverage miniaturized surface-electrode trap arrays towards a higher level of integration. We have implemented a universal gate set based on microwave near-field control directly integrated on the trap chip on a magnetic field insensitive qubit [1] and are working on improving the operation fidelities in this approach. The close proximity of the ions to the trap electrodes also warrants a better understanding of "anomalous" heating observed by many groups. Some evidence ties this heating to surface effects, so besides cooling the trap to cryogenic temperatures, cleaning of the electrode surfaces can be beneficial. We will report on the status of our efforts to prepare trap surfaces in situ and towards better understanding of anomalous heating.

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[1] C. Ospelkaus, U.Warring, Y. Colombe, K. R. Brown, J. M. Amini, D. Leibfried & D. J.Wineland, "Microwave quantum logic gates for trapped ions", Nature **476**, 181 (2011).