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Trapping and ground-state cooling of planar ion crystals in a novel linear Paul trap

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Trapped ions in RF traps are a well-established platform for analog and variational quantum simulation of quantum many-body systems. Up to now, ions in linear Paul traps allow for simulations of the 1D Ising model with up to 50 spins. In our project, we aim for extending this approach to the second dimension which will enable studies of 2D spin models with a larger particle number. Our new ion trap apparatus whose centerpiece is a novel monolithic micro-fabricated linear Paul trap allows for trapping planar crystals of up to 100 ions. For these crystals we observe only a small number of distinct crystal configurations by applying a cluster algorithm to an image series recorded over several hours. We also found stable elongated crystal configurations of up to 91 ions by choosing suitable voltage sets inhibiting any configuration changes. Furthermore, we successfully applied electro-magnetically induced transparency cooling to cool the out-of-plane modes of motion of two-dimensional Coulomb crystals to the ground state. Cooling dynamics were analyzed by sideband-resolved spectroscopy on the vibrational modes of motion. Stable crystal configurations as well as fast and simultaneous ground-state cooling of all out-of-plane modes are laying the foundation for high-fidelity interactions in the near future. Effective spin-spin interactions will be induced by laser fields coupling the ions'electronic levels to excitations of the crystal's out-of-plane modes of motion.

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