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Scalable Trapped-Ion Quantum Computers from Trap Fabrication to User Interface

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Trapped-ion quantum technology is one of the most promising candidates for the realization of scalable quantum processors. To address individual ions and perform high-fidelity two-qubit entangling gates in a linear segmented Paul trap, we dynamically employ register reconfiguration operations to place specific qubits in a laser interaction zone in combination with addressing of sub registers. Efficient operation of scalable systems requires not only microfabricated ion traps and custom control electronics, but also a software stack including a convenient user interface such as Qiskit.
After a short introduction to shuttling- and addressing-based trapped-ion quantum computer architectures, we present a new trap fabrication facility recently setup in Mainz, required for fast prototyping of complex trapping devices. This clean room facility is specialized in the production of complex 3D microfabricated ion traps and fits to the demands of iterative and generative ion trap developments within weeks instead of months. Additionally, details about our latest quantum computing hardware and software stack are going to be presented. Building on the experience of manually compiled shuttling and operation sequences, such as in the realization of an error correction building block [3], a software framework was implemented to fully automize this compilation process. This allows external users to execute quantum algorithms including hybrid computation, parametrized gates, in-sequence measurements and feedback, without detailed knowledge of the hardware backend.

References
[3] J. Hilder et al., Phys. Rev. X 12, 011032 (2022)

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