Towards Fault-Tolerant Quantum Computing using Neutral Atoms

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Over the last years, the field of quantum computing has witnessed a rapid growth towards fault-tolerant quantum computing. Recent breakthroughs have been achieved on various quantum processor architectures, such as ones based on superconducting circuits, ion traps, and neutral atoms [1–3]. At Pasqal, we developed an atom-based logical quantum processor and we report on the progress towards fault-tolerant preparation of logical states. We first characterize our qubits and exhibit a relaxation time $T1 = 5.0(2)\,\mathrm{s}$ and a coherence time under dynamical decoupling $T2 = 1.49(8)\,\mathrm{s}$. We then describe the fidelity of the different unitary operations – namely coherent atom transport, single-qubit gates and two-qubit gates. We demonstrate a single-qubit gate fidelity of 99.956(8)% and a two-qubit gate fidelity of 98.7(2)% via randomized benchmarking [4, 5]. We then detail the architecture of our logical processor, which is based on a zoning approach [6–8], where regions of space are dedicated to specific operations. Next, we demonstrate the ability of our processor to prepare logical qubits in a fault-tolerant fashion. We encode two logical qubits into four physical qubits with the [[4, 2, 2]] quantum error-detecting code [9]. We use a flag qubit to detect and discard faulty runs, then post-select on parity to improve logical state fidelity.

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