Quantum simulation of open quantum many-body systems with giant atoms

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Open quantum many-body systems [1] are both of fundamental interest and have practical applications. In many cases, numerically solving such systems with classical methods is infeasible [2]; instead, quantum simulation is required. However, conventional analog simulators operate within limited intrinsic interactions available, and conventional digital simulators often require ancilla qubits to simulate environmental effects [3]. To overcome these challenges, we put forward a giant-atom-based quantum simulator for generic open quantum many-body systems, where no ancilla qubits nor parametric couplers are required [4,5]. Unlike conventional point-like small atoms, giant atoms couple to the environment at multiple points, yielding interference effects that grant remarkable tunability in the interactions between the atoms and the environment. We demonstrate that this high tunability enables the operation of two-qubit gates such as iSWAP and CZ, as well as qubit decay, solely by tuning the frequency of the giant atoms. Together with single-qubit gates, this enables the operation of universal quantum gates on giant atoms. Based on this, we propose a scalable giant-atom quantum simulator, which allows for the efficient simulation of open quantum many-body systems, in particular those with complex many-body interactions.

References

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Figures

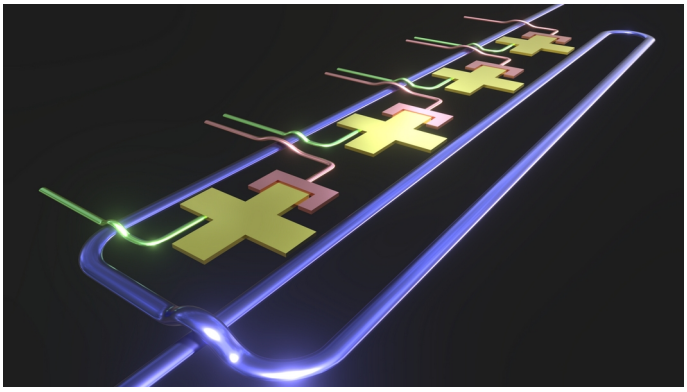

Figure 1: An artistic sketch of a giant-atom-based quantum simulator