Building Quantum Processors and Quantum Networks Atom-By-Atom

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Tweezer arrays have emerged as a powerful platform with which to study quantum science. In this architecture, qubits can be encoded into long-lived ground states, and coupling to strongly interacting Rydberg levels enables high-fidelity entangling operations. Moreover, the ability to generate hundreds of trapping sites with dynamically programmable geometries allows the implementation of complex Hamiltonians.

Here, I will introduce a dual-species Rydberg array of rubidium and cesium atoms that builds on these capabilities [1]. This architecture offers several novel features and opportunities, including species-selective trapping, imaging, and control, as well as auxiliary qubit enabled protocols [1]. I will first discuss recent work in which we demonstrated a spectator qubit protocol using this platform, where the combination of mid-circuit measurements with real-time feed-forward enabled the mitigation of correlated errors in a 2D array of up to 120 atomic qubits [2].

Then, I will present our ongoing efforts realizing dual-species Rydberg excitation, characterizing inter-species Rydberg interactions, and implementing two-qubit gates. Moreover, I will discuss near-term opportunities for this platform, such as native multi-qubit gates and non-destructive stabilizer measurements, powerful tools for error correction and quantum state preparation.

An alternative, hybrid approach for engineering interactions and scaling these quantum systems is the coupling of atoms to nanophotonic structures in which photons mediate interactions between atoms. Such a system can function as the building block of a large-scale quantum network. In this context, I will present quantum network node architectures that are capable of long-distance entanglement distribution at telecom wavelengths [3].

References

[1] K Singh, S Anand, A Pocklington, J T Kemp and H Bernien, Phys. Rev. X **12**, 011040 (2022)

[2] K Singh, C E Bradley, S Anand, V Ramesh, R White and H Bernien, Science **380**, 1265 (2023)

[3] S G Menon, K Singh, J Borregaard and H Bernien, New J. Phys. **22**, 073033 (2020)