Quantum Legos: Atom-by-Atom Towards Quantum Processors and Quantum Networks

Hannes Bernien – University of Chicago

Reconfigurable arrays of neutral atoms are an exciting new platform to study quantum many-body phenomena and quantum information protocols. Their excellent coherence combined with programmable Rydberg interactions have led to intriguing observations such as quantum phase transitions, the discovery of quantum many-body scars, and novel quantum computing architectures.
Here, I will introduce new methods for controlling and measuring atom arrays that open up new directions in quantum state control, quantum feedback and many-body physics. First, I will introduce a dual-species atomic array in which the second atomic species can be used to measure and control the primary species [1]. We use an array of cesium qubits to correct correlated phase errors on an array of rubidium data qubits [2]. Crucially, by combining in-sequence readouts, data processing, and feed-forward operations, these correlated errors are suppressed within the execution of the quantum circuit. Furthermore, such a dual-species can be used to explore new paradigms for creating large-scale entanglement via mediated interactions and engineered dissipation.

An alternative, hybrid approach for realizing interactions and scaling these quantum systems is the coupling of atoms to nanophotonic structures in which photons lead to interactions between atoms. Such a system can function as the building block of a large-scale quantum network [3]. In this context, I will present quantum network node architectures that are capable of long-distance entanglement distribution at telecom wavelengths [4].

[1] Singh, Anand, Pocklington, Kemp, Bernien PRX 12, 011040 (2022)
[2] Singh, Bradley, Anand, Ramesh, White, Bernien arXiv:2208.11716 (2022) [accepted to Science]
[3] Covey, Weinfurter, Bernien arXiv:2304.02088 (2023)
[4] Menon, Singh, Borregaard, Bernien NJP 22, 073033 (2020)