Hybrid Quantum Information Processing with Rydberg atoms and Superconducting Circuits

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Project Summary:

Over the last 5 years, neutral-atom (or 'Rydberg atom') quantum processors, comprising arrays of atomic qubits confined in reconfigurable optical tweezers, have had a significant impact in quantum computation and quantum simulation [1,2]. In this architecture, strong, controllable few- and many-qubit interactions are realised by excitation of the atoms from their ground state to Rydberg states with high principal quantum numbers. These quantum processors have been exploited, e.g., to realise Ising-type spin models with up to 51 qubits, study topological phases of up to 14 interacting Bosons, simulate 2D antiferromagnets with 200 qubits, and prepare Toric and surface code states by coherent transport of entangled atoms. To extend the capabilities of these systems, it is of interest to implement quantum interfaces to network spatially separated neutral-atom processors, or to connect them to other platforms, e.g., superconducting circuits. This would allow opportunities for enhanced scalability, fast quantum processing within one platform and the implementation of long-coherence-time quantum memories in the another, or optical-to-microwave transduction and optical links between superconducting circuits.

The first coherent interface between Rydberg atoms and superconducting circuits was implemented at UCL in 2020 [1]. This PhD project will build on those pioneering experiments, and more recent advances that have allowed the implementation of more robust and tunable Rydberg-atom quits in this setting. The overarching goal of this project is to demonstrate a first prototype interface between small arrays of Rydberg atoms in a few-qubit neutral-atom quantum processor, and a superconducting microwave circuit. The project will be supervised by Prof Stephen Hogan. It will be well suited to candidates with a strong back ground and interest in experimental quantum optics/cold atom physics.

[1] P. Scholl et al., Nature 595, 233 (2021).

[2] D. Bluvstein et al., Nature 604, 451 (2022).

[3] A. A. Morgan and S. D. Hogan, Phys. Rev. Lett. 124, 193604 (2020)