Isolated atomic systems are the cleanest platform for scalable quantum information processing. The inherent stability and replicability enjoyed by atomic clock qubits cannot be matched in any solid-state systems, from semiconductor spins and quantum dot qubits to superconducting circuitry. Moreover, atomic qubits are not hard-wired but connected with externally applied fields (optical or microwave) that allow the quantum connectivity to be gated and reconfigured. This key attribute allows atomic qubits to be readily and efficiently adapted to any future quantum computation or simulation task.

Atomic qubit control systems have not yet been engineered to the same degree as solid-state systems, but this represents an enormous opportunity for the future fabrication of an atomic-based quantum computing or simulator. Here, the challenges do not lie in the fundamental quantum nature of the qubit, but the engineering of the optical/microwave control system. Solid-state qubits, on the other hand, have significant physics hurdles stemming from imperfections in the materials that host the qubit, and how such qubit imperfections and noise scale with qubit number and circuit depth.

This session will extensively cover the state-of-the-art in the use of atomic ions and neutral Rydberg atoms in the development of a scalable quantum computer/simulator. In particular, atomic ions have pushed the furthest in qubit number, coherence time, and gate fidelity, and many small algorithms and simulations have been demonstrated with trapped ion qubits, with full control of up to about 20 qubits and global simulations with up to hundreds of qubits. I will summarize the development and performance of room temperature ion trap systems at both university and industrial settings, including a high-level software layer that allows autonomy and remote use via a cloud service. I will also speculate on how this system can realistically be scaled to thousands of qubits and beyond.