Multi-Qubit Coherent Operations (MQCO)

Investigating the Challenges to Large-Scale Systems

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Quantum computers will likely consist of millions of qubits

- Before MQCO most research concentrated on improving fidelity in single, isolated qubits
- Little was known about the challenges that would arise when multiple qubits had to coexist and be controlled in close proximity to each other

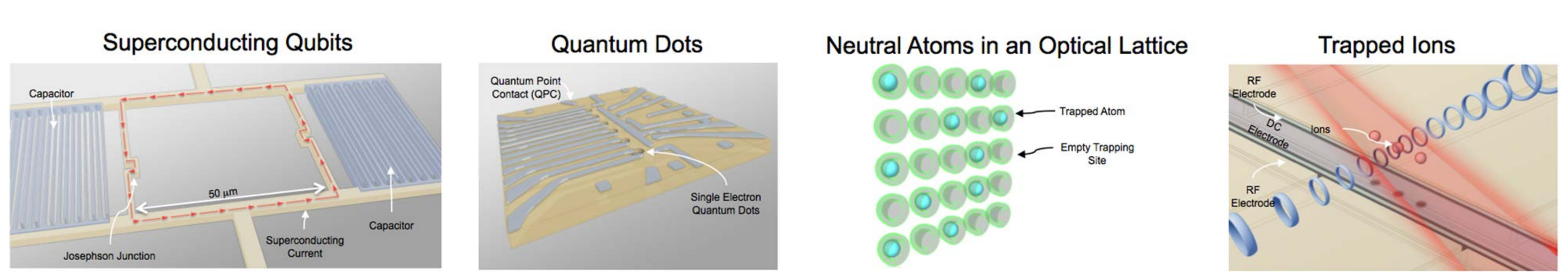
The program bootstraps its way up from qubits to systems to algorithms

- Six performing teams and two supporting government labs
- Four different qubit technologies: Ion traps, superconducting qubits, neutral atoms, and quantum dots

Phase 1 (2010-2012): assemble a multi-qubit system, validate its basic functionality

Phase 2 (2012-2013): quantify the performance of multi-qubit system, and develop a test plan for phase 3 goals

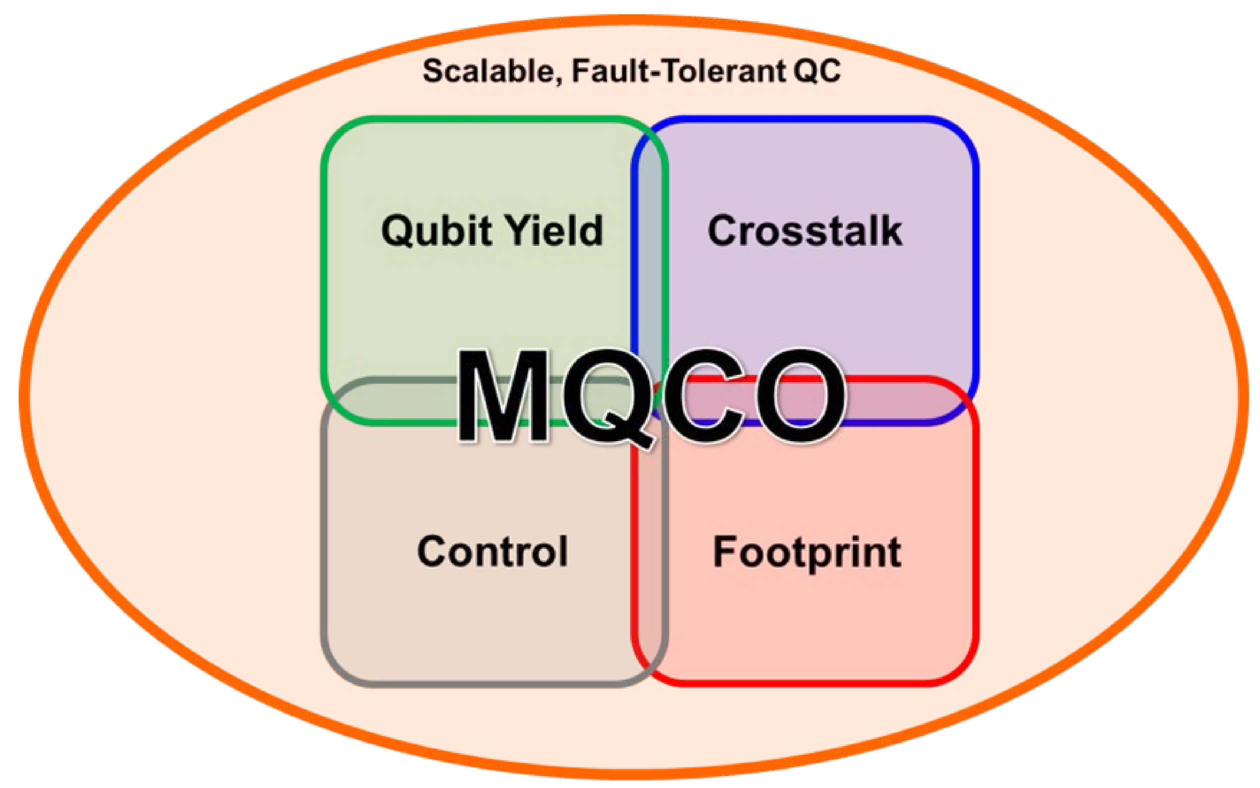
Phase 3 (2013-2015): demonstrate a quantitatively improved multi-qubit system that implements a multi-qubit quantum algorithm



Forcing the building of small systems of qubits implementing quantum algorithms uncovers obstacles that only emerge in such a context

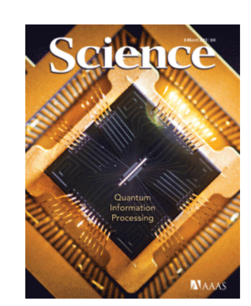
We project four main issues for multi-qubit operations:

- **Control**: fine-grained operation on specific qubits
- **Crosstalk:** interference of qubits with each other
- Fabrication **yield:** keeping the system populated
- Spatial challenges caused by an increased **footprint**



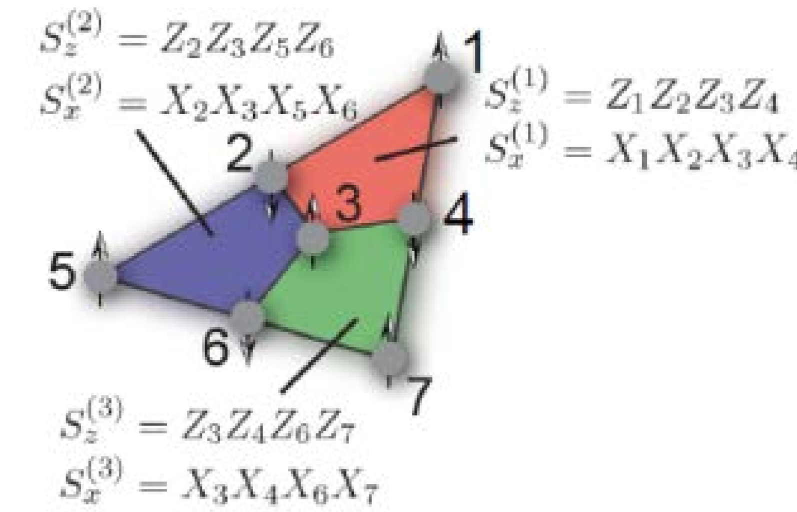
MQCO has demonstrated the largest number of coupled qubits so far for each of the technologies it is pursuing

- Ion traps: 11
- Superconducting qubits: 9
- Neutral atoms: 6
- Quantum dots: 4
- ***Publications: >370; 32 in Nature and Science***



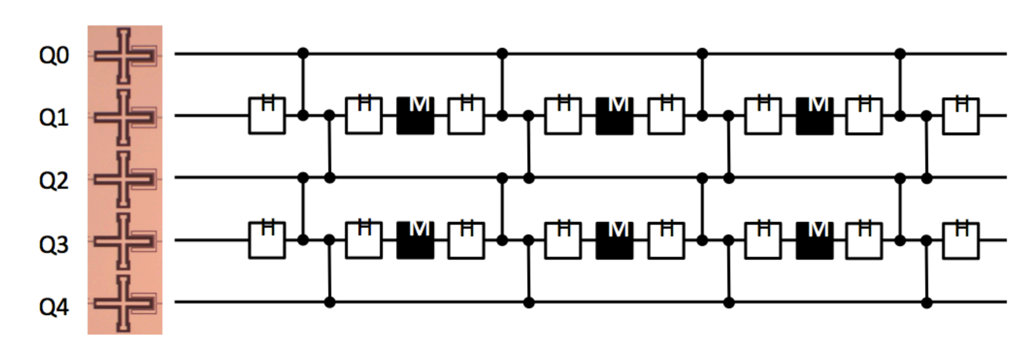
We've realized an encoded "logical" qubit construct with 7 trapped ions that detects and corrects one error

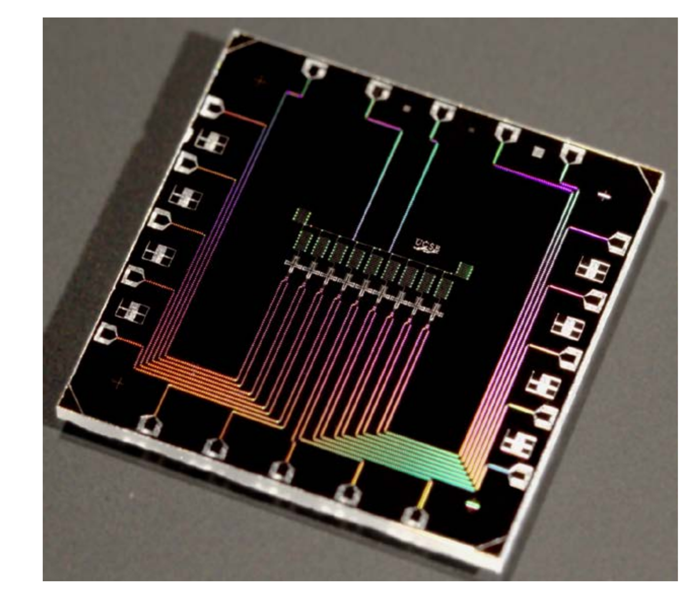
- Demonstrated all ingredients including a universal gate set to implement a topological error correcting code



Demonstrated error detection in a superconducting qubit system

- Performed 5-qubit surface code bit-flip error detection in a 9-qubit chip with high-fidelity gates





These first proofs of concept pave the way for the next phase of quantum computing research

- Building on MQCO it will be possible to begin
  - ➢ exploring the realization of a true logical qubit
  - ➢ exploring modular coupling of multi-qubit systems