Comparing the Architectures of the First Programmable Quantum Computers

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Last year saw the first quantum computers realized that can be programmed from a high level user interface to run arbitrary quantum algorithms [1,2]. While these devices are still small in scale, only comprising a handful of qubits each, they nevertheless allow the implementation of quantum circuits in a way that is basically blind to the underlying hardware itself. This constitutes a new level of development in quantum computer technology for the two leading approaches, trapped atomic ions [1] and superconducting circuits [3]. It also gives us the opportunity to test quantum computers irrespective of their particular physical implementation for the first time. With multiple companies (IBM, Google, Microsoft, as well as several start-ups) aiming for a larger scale device of commercial viability in the near future, benchmarking quantum computers becomes a crucial pursuit and this work is a step in that direction.

Our device consists of five $^{171}Yb^+$ atomic ions trapped in a Paul trap [1]. Each provides a pristine “atomic clock” qubit in its atomic structure that can be manipulated with laser light and read out via state-dependent fluorescence. Two-qubit gates between any pair are implemented via laser-mediated interaction of qubits through the normal modes of motion in the trap [4] making it a fully connected system.

IBM has made a superconducting chip available for public use as a cloud service via a web interface [2]. It consists of five qubits with a star-shaped connectivity graph. This allows us to run identical algorithms on two machines of identical size and similar capability based on two different technology platforms. This study is a first of its kind and presents both an interesting snapshot of the rapidly advancing field of quantum computers, and informs future progress of the present technologies.

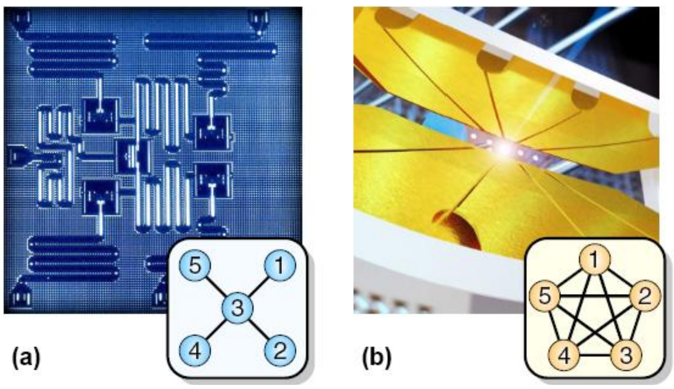

Fig. 1 Graphic representations of the two systems: (a) the superconducting qubits connected by microwave resonators (Credit: IBM Research), and (b) the linear chain of trapped ions connected by laser-mediated interactions. Insets: Qubit connectivity graphs, star-shaped (a) and fully connected (b).

We present results from running a selection of algorithms on the two quantum computers, including the first realization of the Hidden Shift algorithm [5]. The strengths of the superconducting system lie in faster gate speeds and a solid-state platform, while the ion trap system features superior qubits and reconfigurable connections. The performance of these systems is seen to reflect the level of connectivity in the base hardware, indicating that quantum computer applications and hardware should be “co-designed".

References

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