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Author
Korotkov, Alexander N.

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Special issue on quantum computing with superconducting qubits

Alexander N. Korotkov

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Ten years ago the first superconducting qubit was demonstrated experimentally [1]. By now quantum computing with superconducting qubits has become a subject of intensive experimental and theoretical research in dozens of groups around the world. The idea of this Special Issue of the journal is to show the status of *experimental* research in this area after the first decade of work. Most of the best experimental groups working with superconducting qubits (with a few regrettable exceptions) are represented in this Special Issue. We hope that it gives a useful snapshot in time, demonstrating the main experimental achievements and directions of research in superconducting quantum computing.

There are many possible physical realizations of qubits [2,3]. Among the candidate systems, the obvious advantages of quantum computing with Josephson junctions are the efficient control of a quantum circuit with voltage/current/microwave pulses and use of a well-developed technology suitable for large scale integration. The fast experimental progress in experiments with superconducting qubits in the last decade confirms the importance of these advantages.

Superconducting qubits come in a variety of types, which are often separated into three categories: charge, flux, and phase qubits (though not all groups use this terminology). Single Cooper pair charge of an island carries the quantum information in the charge qubit (e.g., [1,4–16]), while the superconducting phase is the relevant degree of freedom for flux and phase qubits, which differ by the logic state encoding: two quantum levels in different wells of a potential profile are used in the flux qubit (e.g., [17–32]), and two levels in the same well are used in the phase qubit (e.g., [33–42]).

Guest Editor: Alexander N. Korotkov.

A. N. Korotkov (✉)
Department of Electrical Engineering, University of California, Riverside, CA 92521, USA
e-mail: korotkov@ee.ucr.edu

This separation into three types is rather simplistic, and some realizations do not fit well into these categories.

By a widely accepted experimental definition, the qubit is a two-level system demonstrating Rabi oscillations. While for the first experiments with superconducting qubits even a slight evidence of Rabi oscillations was considered as a significant achievement, nowadays the "really good" Rabi oscillations imply high quality factor (long dephasing time) and a single-shot measurement with visibility approaching or exceeding 90% (e.g., [43,44]). Two-qubit logic operations have been demonstrated by a number of groups (e.g., [45–51]). There have been also experiments involving three and more superconducting qubits (e.g., [52,53]), but the logic operation of such circuits is still a challenge. Another very important problem for quantum computing is the realization of tunable coupling between qubits (e.g., [32,54–57]). A new dimension of research has been opened up with the demonstration of qubits coupled to microwave resonators (e.g., [50,51,58–64]). Besides experiments having a straightforward importance for quantum computing, many interesting experiments from a physical point of view have been realized with superconducting qubits as, for example, demonstration of Berry's phase [65], interference of Landau-Zener transitions (e.g., [13,14,28,29]), partial collapse [66], single-qubit lasing [61], etc. Because of the fast progress, we can hope that in a few years superconducting qubits will be sufficiently mature to be used for demonstration of simple quantum algorithms.

There are several existing reviews on superconducting quantum computing (e.g., [67–72]); however, because of the rapid progress and branching of the research subjects, it is difficult to keep up with the latest achievements. We hope that this Special Issue will be useful for readers to learn first hand about the current experimental status of the field.

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