Approaching Unit Visibility for Control of a Superconducting Qubit with Dispersive Readout

Authors: Wallraf, D.I. Schuster, A. Blais, L. Frunzio, J. Majer, S.M. Girvin, and R.J. Schoelkopf

Recommended and a commentary by J.R. Kirtley, IBM Research, Yorktown Heights

A fundamental measure of the quality of the control and readout of a qubit is the visibility, defined as the maximum qubit population difference observed, for example, in a Rabi oscillation experiment [1]. Visibilities approaching unity are important for viable approaches to quantum computation [2]. Experimental visibilities, as reported by several experimental groups, while initially low, have recently been improving rapidly. The current paper reports values for the visibility of 95±6%, approaching unity for the first time. This work uses a Cooper pair box architecture, with small superconducting Josephson junctions in which the charging energy is larger than the Josephson coupling energy. A novel feature of these experiments is the use of a dispersive microwave readout scheme in a circuit quantum electrodynamics (QED) architecture. In this scheme the qubit is strongly coupled to a transmission line resonator. When the qubit is operated off-resonance, there is a dispersive shift in the resonator frequency which depends on the qubit state. This shift in the resonance frequency can be used to read the state of the qubit without exciting the qubit out of its ground state (quantum non-demolition). In addition to the high visibilities, remarkably long coherence times of 500ns and a quality factor of 6500 are reported. These results represent a significant advance in the development of superconducting qubits. However, there are still opportunities for further work: as the authors point out, in these experiments each Rabi oscillation data point was acquired by averaging over 5×10^4 individual measurements, the signal to noise ratio for a single shot was 0.1, and the single-shot read-out fidelity integrated over the relaxation time of ~7μs was approximately 30%.

[1] M.H. Devoret, A. Wallraff, and J.M. Martinez, *Superconducting qubits: A short review* (2004), [cond-mat/0411174].
[2] D.P. DiVincenzo, *The Physical Implementation of Quantum Computation* (2000), [quant-ph/002077].