IBM Reports Significant Progress in Superconducting Qubit Coherence Time and Demonstrates Complete Universal Quantum Gate Set Approaching Fault-tolerant Thresholds

March 26, 2012 (HP45). Near the end of February 2012, researchers at IBM T.J. Watson Research Center (Yorktown Heights, NY, USA) reported significant progress towards quantum computing using superconducting qubits. The following two short papers/letters were posted in *arXiv* and submitted for publication:

- "Superconducting qubit in waveguide cavity with coherence time approaching 0.1 ms" by Chad Rigetti *et al*. (*arXiv*:1202.5533v1 [quant-ph], February 24, 2012) and
- "Complete universal quantum gate set approaching fault-tolerant thresholds" by Jerry M. Chow et al. (*arXiv*:1202.5344v1 [quant-ph], February 23, 2012).

The first letter describes a qubit with an observed quantum coherence time of T_2^* = 95 μs and energy relaxation time T_1 = 70 μs. The system consists of a single Josephson junction transmon qubit embedded in an empty three-dimensional (3D) copper waveguide cavity whose lowest eigenmode is dispersively coupled to the qubit transition. The authors attribute the factor of four increase in the coherence quality factors Q_2, Q_1 ($Q_2 \approx 2.5\text{x}10^6$ and $Q_1 \approx 1.8\text{x}10^6$) relative to previous reports to device modifications aimed at reducing qubit dephasing from residual cavity photons. These modifications represent the gist of the letter. The attained level of T_2^* and T_1 places the device well within the range of performance required for large-scale tests of error correction fault-tolerant quantum computing. The reported work confirms the basic reproducibility of the breakthrough work by Paik *et al*. [1] (see HP44), who first reported enhanced coherence times when embedding a transmon qubit in a superconducting 3D waveguide catity.

The second short paper describes the use of quantum process tomography (QPT) to characterize a full universal set of all-microwave gates on two single-frequency transmon qubits. The Ramsey fringe coherence times for the two qubits were $T_2^{(1)}$ = 7.1 and $T_2^{(2)}$ = 10.3 μs. Gate fidelities for Clifford group generators, single-qubit π-4 and π-8 rotations,and a two-qubit controlled-NOT were determined. All extracted gate fidelities exceeded 95% without accounting for state preparation and measurement errors and 98% when accounting for these. The error sources were analyzed in detail. The QPT results reinforced the importance of introducing other methods for gate characterization such as randomized benchmarking. While such improvements are necessary, the authors believe that their demonstration paves the road towards scalable >10 qubit architectures for error correction schemes.

[1] H.Paik *et al*., *Phys. Rev.Lett*. **107** 240501(2011).