Performance of quantum algorithms on the IBM quantum computers

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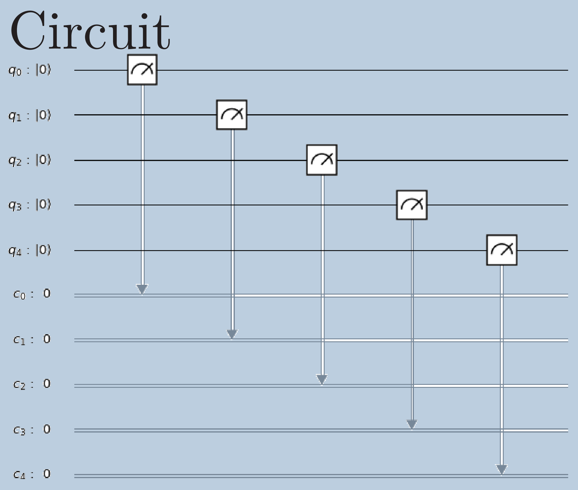
Abstract

Quantum computation is an emerging technology with the prospect to outperform classical computation in many classes of problem. Among the standard algorithms, Shors and Grovers are prominent examples that promise significant improvements over their classical counterparts. In 2016, IBM released the Quantum Experience, an online cloud service for public users to execute quantum algorithms. In this work, we execute Shor's and Grover's on the IBM Q quantum computers to test its ability and to determine the current progress of quantum computing.

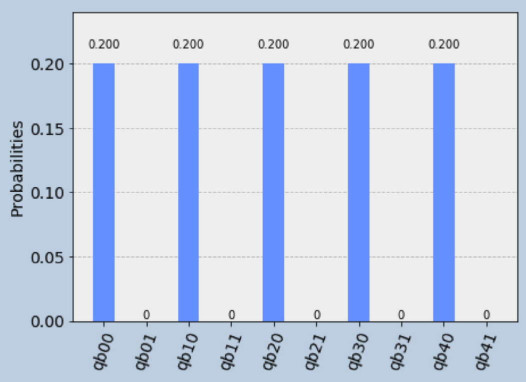
Simple circuit test

$|0\rangle$ preparation on IBMQx2 and IBMQx4

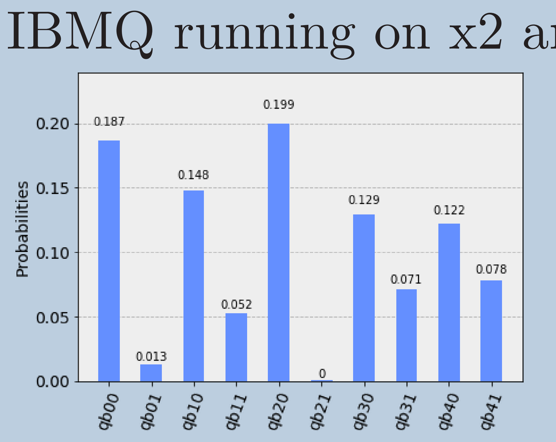
Circuit

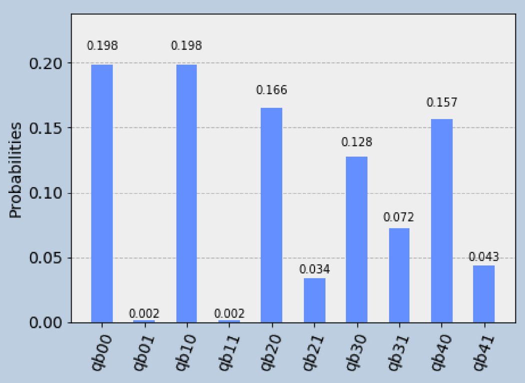


Simulation



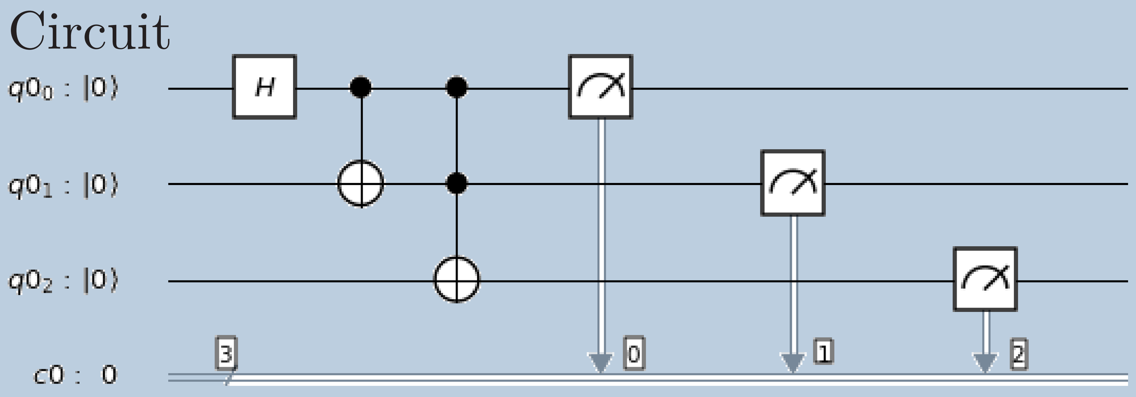
IBMQ running on x2 and x4



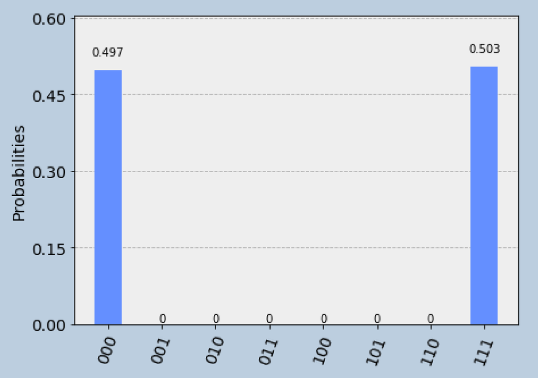


H + CNOT + Toffoli on IBMQ16

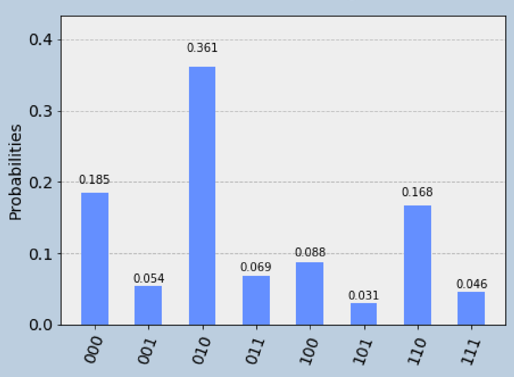
Circuit



Simulation



IBMQ running



The simulated results are the ideal data, are shown next to the real results gathered from running the circuits on the IBMQ computers. The IBMQ computers yield noticable error rate even for simple tasks like $|0\rangle$ preparation or applying basic gates. Major improvements in quantum error correcting are needed.

References

[1] Monz, T. et al. *"Realization Of A Scalable Shor Algorithm"*. Science, vol 351, no. 6277, 2016, pp. 1068-1070. American Association For The Advancement Of Science (AAAS), doi:10.1126/science.aad9480. Accessed 29 July 2019.

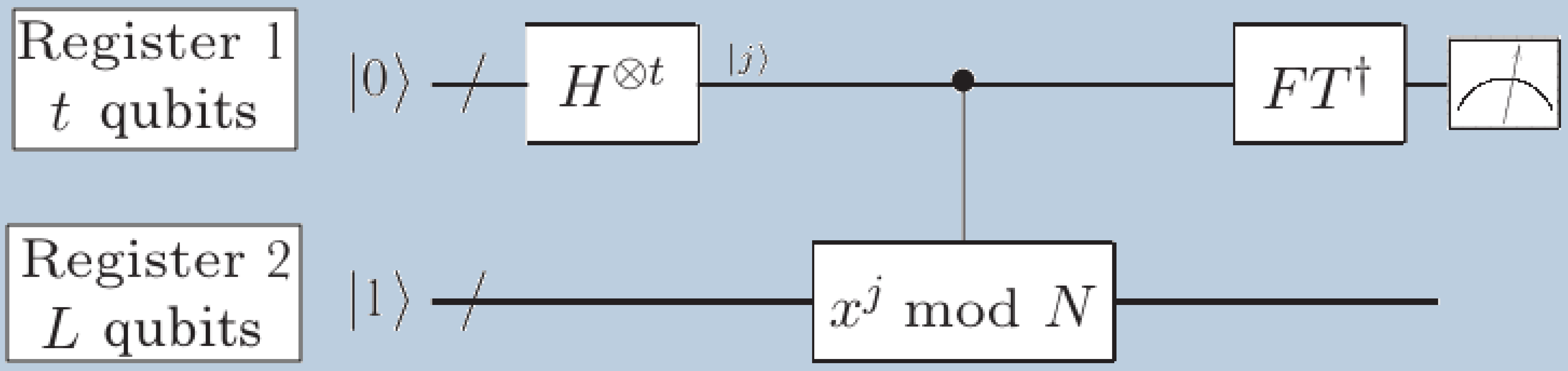
[2] Nielsen, Michael A, and Isaac L Chuang. *Quantum Computation And Quantum Information*. Cambridge University Press, 2019.

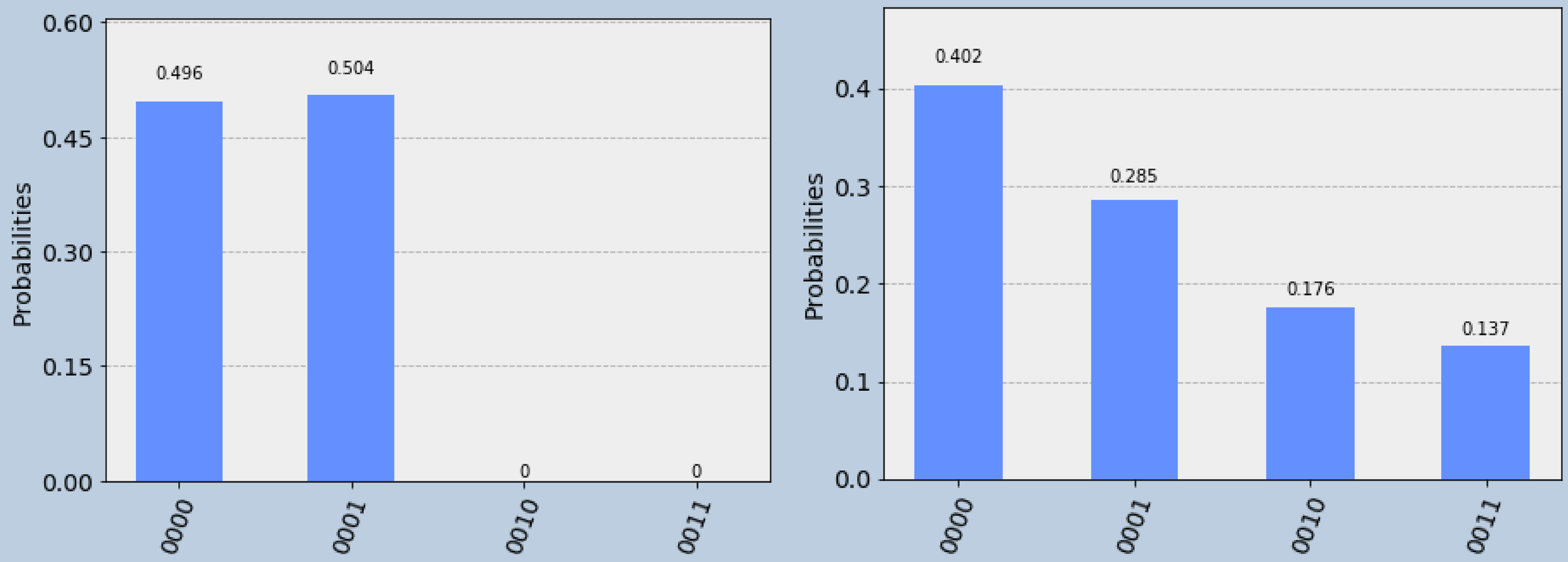
[3] Patrick J. Coles. et al. *Quantum Algorithm Implementations for Beginners*. arXiv:1804.03719 [cs.ET]

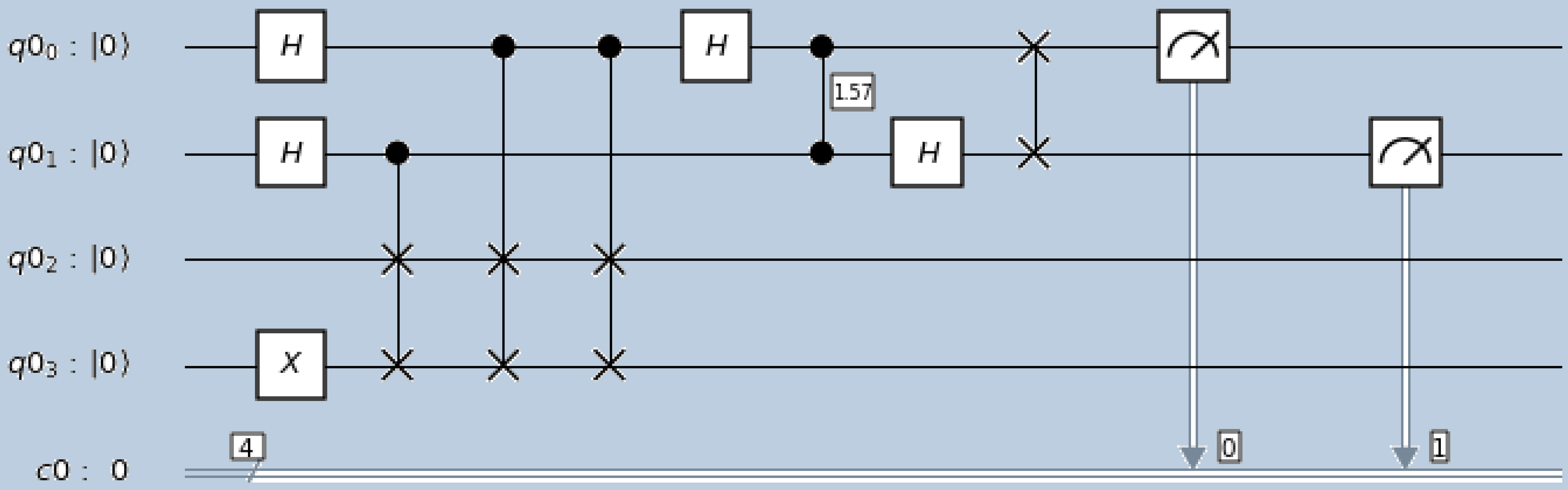
GitHub link

The Jupyter notebooks for the displayed code and various other bigger numbers implementation can be found at:

Shor's algorithm on the IBMQ

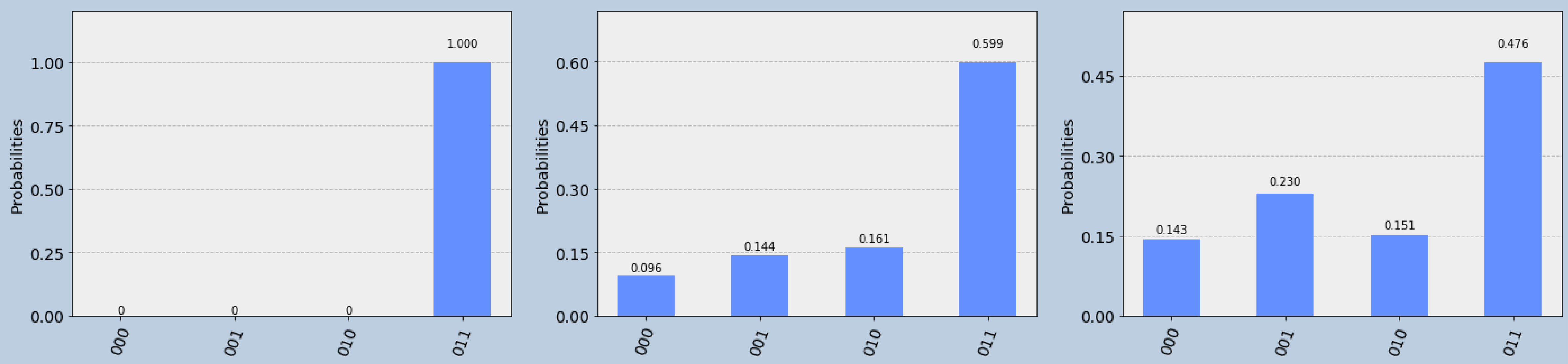


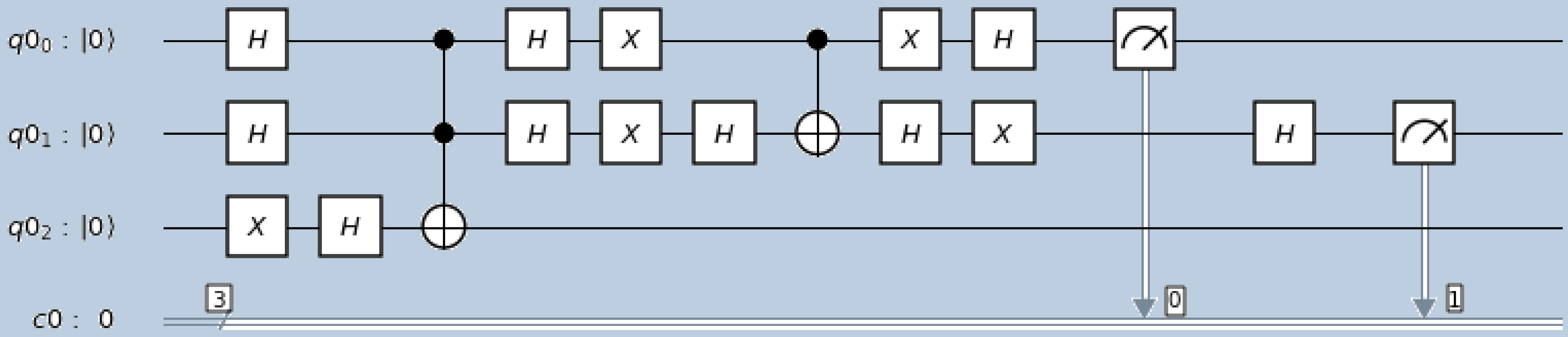




We realize Shor's algorithm using modular multiplication circuits following [1] with Quantum Fourier Transform [2] [3], therefore the circuit is not optimized. Reasonable results were collected only from IBMQx4, with x = 5, N = 6 (hence the period is 2). More complex circuits were also implemented; however due to significant error rate no useful results were gathered.

Grover's algorithm on the IBMQ





The algorithm were ran with the "oracle" circuit simply be a Toffoli gate, therefore the marked input state is $|11\rangle$. Results from the IBMQx2 and IBMQx4 under 1 Grover iteration [2] [3] can be used to correctly interpret the marked input state.

Conclusion

The IBMQx2 was able to run Grover's algorithm, and the IBMQx4 was able to run both Shor's and Grover's. The IBMQ16 did not give acceptable results.

Quantum algorithms like Shor's and Grover's, with proven theoretical advantages over classical techniques, were truly implemented on the IBMQ computers. Albeit faulty and small due to noticable error rate, these circuits are evidences for the progress toward quantum supremacy. Breakthroughs in the field of quantum error correction are needed to realize the power of quantum computing.