Measuring and Simulating T_1 and T_2 for Qubits

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Introduction

Quantum computers perform computations exploiting quantum mechanics to a possible advantage, allowing us to prepare and manipulate states that do not have a classical equivalent. In particular, phenomena like superposition and entanglement may enable quantum computers to outperform their classical counterparts in certain applications. Implementing these useful quantum algorithms is contingent upon building accurate quantum hardware that is not affected by noise. Environmental noise decreases coherence time of qubits, meaning that qubits do not stay in a desired state long enough to carry out a complex computation. To that end, harnessing the full power of quantum computers necessitate characterization of noise sources and how they impact a given quantum system. Often times, $T_1$and T_2 are used to quantify noise. In this project, we provide an approach as to how T_1 and T_2 values are calculated and simulated for quantum systems. In addition, we compare simulated values of T_1 and T_2 with those of real quantum computer's measurements. IBMQ Experience, an open source software allowing users to simulate and use real quantum hardware, is used. QuTip, a Python-based toolbox offering quantum simulation tools for open quantum systems, is also used.

Measuring T_1 and T_2 is a basic step in characterizing qubits. Therefore, we measured and simulated the values of T_1 and T_2 according to the following steps.

T_1 refers to the thermal relaxation time, which is the time taken by a qubit to spontaneously decay from the first excited state to the ground state. T_1 is measured as follows:

1) Prepare the qubit in the excited state by sending a π-pulse to the qubit.

2) Wait some time t.

3) Measure the state of the qubit.

T_2 is defined as the elapsed time before a qubit's resonance frequency becomes unrecognizable. The value of T_2 is measured as follows:

1) Prepare the qubit in a superposition state of the ground and first energy levels by sending a $\frac{\pi}{2}$ pulse to the qubit.

2) Wait some time t.

3) Apply another $\frac{\pi}{2}$ pulse to bring back the qubit to ground state.

4) Measure the state of the qubit.

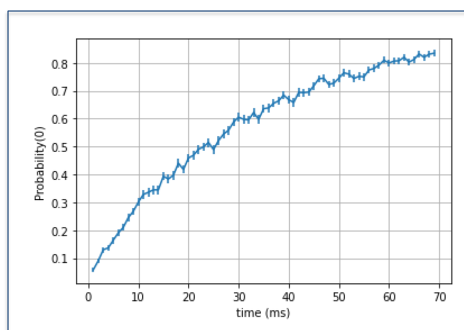

FIG. 1: Measurement of T_1 in μs for qubit 0 of ibmqx2. The probability of the qubit being in the ground state increases as time progresses. After about 70μs, the probably of measuring the systemin the ground state is very close to 1.

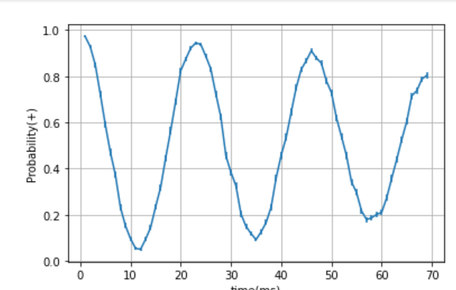

FIG. 2: Measurement of T_2 in μs for qubit 0 of ibmqx2. The envelope of the curve exponentially decays as time progresses. The probability of measuring the qubit in the |+〉 state increases as time goes.

<u>In QuTip</u>, the function Mesolve is used to evolve a given system in time according to the Master Equation. The arguments of the Mesolve function are the system Hamiltonian, initial state, collapse operators, and expectation operators.

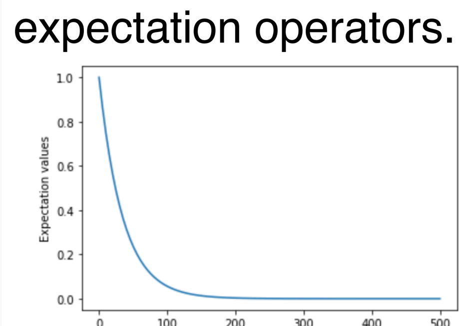

FIG. 3: Simulation of T_1 for a qubit using the Mesolve function. The probability of the qubit being in the first excited state decreases as time progresses. The probability of measuring the qubit in |1〉 decreases effectively to zero as time goes by..

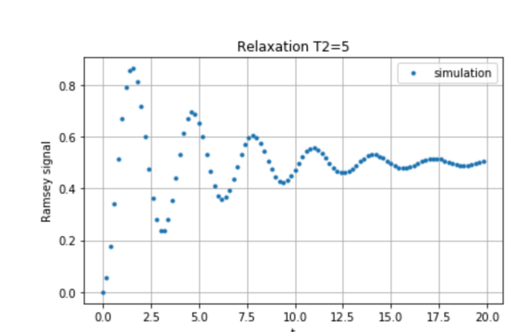

FIG. 4: Simulation of T_2 for a qubit using the Mesolve function. The blue curve represents T_2 (the dephasing) of the first excited state. The envelope of the curve can be reliably simulated as a decaying exponential.

Methods

The following tools are used in this project:

1) **<u>Qiskit:</u>** an open-source software development kit to prepare, run, and measure quantum states on IBM's quantum computers.
2) **<u>QuTip:</u>** an open-source software that is used in simulating the dynamics of open quantum systems.

Results

<u>Using Qiskit:</u> According to IBM, on average, the qubit'$sT_1 \approx 52$μs, while the value of $T_2 \approx 77$μs. Though our experiments did not yield these exact numbers, it still provides insights into the order of magnitude for both values, which isμs. Both of Figures 1 and 2 were produced by measuring the first qubit of the ibmqx2 device, a 5-qubit device that is based in Yorktown, NY.

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