Quantum Information Processing, BME 2019 Spring
Lecture 4, Feb 20, 2019
Exercises

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I. EXERCISES

1. Find the average frequency f_L and the average relaxation time T_1 for the qubits of the QX machines Melbourne, Tenerife, Yorktown. (QX website / Technology / Devices and Simulators)

2. Use the Lindblad equation to describe the dynamics of a qubit that is initialized in the excited state and is the subject of relaxation. The Larmor frequency is $f_L = 5$ GHz, the relaxation time is $T_1 = 10\,\mu$s, and the temperature is zero.

   (a) Plot the excited-state occupation probability as a function of time, in the time window between 0 and 50 μs.

   (b) Repeat (a) for finite temperature, $T = 100$ mK.

   (c) (homework) Solve the zero-temperature Lindblad equation for an initial state $|x\rangle = (1,1)/\sqrt{2}$. Calculate the time dependencies of all three elements of the density matrix. Calculate the time dependence of the polarization vector components. Plot the time dependence of these quantities in the time window between 0 and 50 μs.

   (d) (homework) Transform the Lindblad equation to the so-called *rotating frame*, a.k.a. the *Heisenberg picture*, which is defined via the time-dependent unitary transformation

$$\tilde{\rho}(t) = e^{iHt/\hbar}\rho(t)e^{-iHt/\hbar}. \tag{1}$$

   Repeat (c) for the rotating-frame density matrix $\tilde{\rho}(t)$.

   (e) (homework) Repeat the calculations and plots of (c) and (d) for 100 mK temperature.

3. Using the previously measured data set (fizipedia / `Q0_test.csv`), determine the relaxation time T_1. The data set is a csv file that contains the excited state probability $\rho_{11}(t)$ (first column) for different waiting times t (third column). Determine the relaxation time T_1 by fitting the exponential decay curve

$$\rho_{11}(t) = Ae^{-t/T_1} + B \tag{2}$$

   on the data. Look up the qubit Larmor frequency f_L, and determine the temperature of the qubit from the fit parameters.

4. Write a code that takes the data for determining the relaxation time T_1 of a selected qubit of a selected machine of QX. Use an X gate to prepare the qubit in the excited state. Define different circuits with different waiting times between the X gate and the qubit measurement: add idle gates in between to control the waiting time. Run each circuit with 1024 shots. Save the results in a csv file, e.g., time points in the first column and the corresponding excited-state probability in the second column.
   (See also the nice jupyter notebook on relaxation and decoherence through `qiskit.org` / Try it out / 1.5 Qiskit Ignis / Relaxation and decoherence)