

# Lab X

## Characterizing qubits with $T_1$ , $T_2^*$ , $T_{2e}$ decay times

Jakub Tworzydło

Institute of Theoretical Physics  
[Jakub.Tworzydlo@fuw.edu.pl](mailto:Jakub.Tworzydlo@fuw.edu.pl)

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# Loading necessary functions

We use today: `QuantumCircuit`, `AerSimulator`, `Sampler`, `generate_preset_pass_manager` same as in the introductory exercises with `Qiskit`. We only need to load and setup a fake backend (choose one you like) with a noise model, imports are:

```
from qiskit_aer.noise import NoiseModel
from qiskit_ibm_runtime.fake_provider import .... as Fake
```

Next, create the corresponding simulator:

```
# Create a relaxation noise model for AerSimulator
noise_model = NoiseModel.from_backend(
    Fake(), thermal_relaxation=True, gate_error=True, readout_error=True
)

# Create a fake backend simulator
aer_backend = AerSimulator.from_backend(Fake(), noise_model=noise_model)
```

# Loading necessary functions (continued)

Special options are required for transpiling:

```
# Transpile the circuits for the backend
pm = generate_preset_pass_manager(backend=aer_backend, optimization_level=1,
                                  scheduling_method='asap')
isa_circuit = pm.run(circuits)
```

We will also need tools to fit a function:

```
# Define the exponential decay function
def exp_decay(x, a, tau, b):
    return a * np.exp(-x / tau) + b

# Fit the exponential decay
p0fit, _ = curve_fit(exp_decay, delays, probabilities, p0=[1, 100e-6, 0.1])
```

# Task 1

## Measuring $T_1$ Relaxation Time

Initialize a qubit with an  $X$ -gate, and delay the measurement for some given time `tau`.

Use `qc.barrier` and the command `qc.delay(tau, 0, unit='s')`.

Prepare a list of circuits with varying delay times, and run all the circuits at once. Accumulate the data, plot the probability of measuring '1' versus delay time, fit the exponential decay, and print the fitted  $T_1$  time.

# Task 2

## Measuring $T_2$ Coherence Times

In a similar way, perform experiments for  $T_2^*$  and  $T_{2e}$ . Present the results on plots, including a legend with fitted decay times.

- **2A) Ramsey experiment ( $T_2^*$ ):**

Uses the following sequence of gates:  $R_x(\pi/2)$ , delay by  $\tau$  with an  $R_z(\theta)$  at the end, and a final  $R_x(\pi/2)$ . Here  $\theta = 2\pi f\tau$ , with a detuning frequency  $f = 10\text{kHz}$ .

- **2B) Spin Echo experiment ( $T_{2e}$ ):**

Uses the sequence:  $R_x(\pi/2)$ , delay by  $\tau/2$ , flipping pulse  $R_x(\pi)$ , delay by  $\tau/2$ , and a final  $R_x(\pi/2)$ .

# Presentation - suggestions

Run our characterization on a real backend. Compare with noise model downloaded for that particular backend at the time of computation.

Discuss quantum channel model for the qubit noise (eg. Nielsen & Chuang 8.3).