Boulder Opal Challenge Summary

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Source code: Github repository

1 Results

We modelled the pulse by using a segment count of 10, 50 ns duration, and shot count of 1000. The values of the pulse were modelled by the following parameters, α, β:

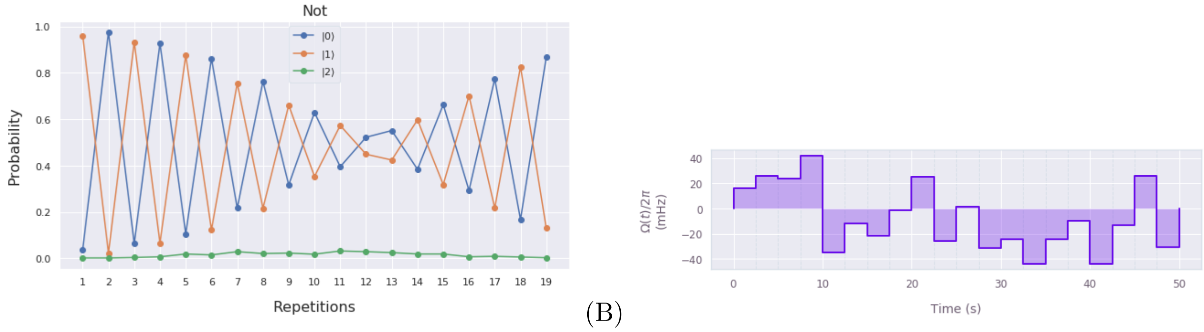
$$\text{values} = \alpha + i\ \beta \tag{1}$$

Our goal is to optimize the infidelity of the NOT gate, this is done by the following cost function:

$$f_{cost}(\alpha, \beta) = 1 - \mathrm{P}(|\psi\rangle = |1\rangle; \alpha, \beta). \tag{2}$$

We chose the Gaussian process, because we have only 20 parameters and this optimizer is expected to work well with a small number of paramaters, for the optimization procedure, the length scale bound was chosen as a box constraint with the values of $l \in [10^{-10}, 10^5]$, the bound was chosen as $[\frac{-5\pi}{\text{duration}}, \frac{-5\pi}{\text{duration}}]$, and finally we set the random number generator (RNG) seed as 0. Our code was written following the steps described in the tutorial: How to automate closed loop hardware optimization.

In order to see that we achieved the NOT gate, we apply that gate in sequence. The expected result is that if we apply an even number of gates, we would have the $|0\rangle$ state, and if we apply an odd number of gates, we would have $|1\rangle$ state. Analyzing the fig. 1 we see that this expected behavior is achieved, however we see that there are coherent errors present in the experiment, because after applying the gate, the probability of getting 0 or 1 gets smaller as we apply the NOT gate in sequence, and also there is no leakage for the $|2\rangle$ state. Another evidence that we are dealing with a coherent error, is that after applying the gate several times, we get the probabilities to go up, which indicates that when we apply the NOT gate on the state $|0\rangle$, we miss the state 1 per a constant factor ϵ. In our test, we achieve a 97.6% fidelity for the NOT gate.



(A) (B)

Figure 1: NOT gate. (A) Probabilities of the states $|0\rangle$ and $|1\rangle$. (B) NOT Control pulse waveform.

Note that our results are in agreement with the theoretical predictions for the probabilities of measurement of the states $|0\rangle$ and $|1\rangle$

$$P(|\psi\rangle = |0\rangle) = \cos^2\left(\frac{\omega t}{2}\right) \tag{3}$$

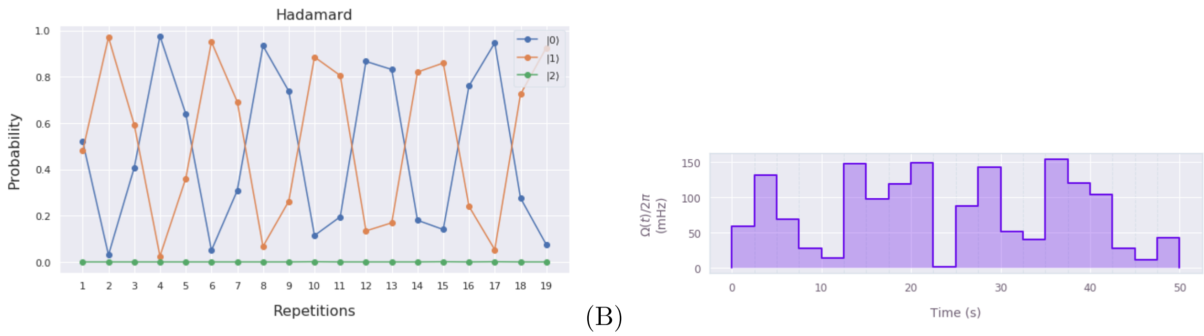
$$P(|\psi\rangle = |1\rangle) = \sin^2\left(\frac{\omega t}{2}\right), \tag{4}$$

where ω is the gate frequency.

In order to get the Hadamard gate, we choose the following cost function

$$f_{cost}(\alpha, \beta) = (0.5 - \mathrm{P}(|\psi\rangle = |1\rangle; \alpha, \beta))^2 + (0.5 - \mathrm{P}(|\psi\rangle = |0\rangle; \alpha, \beta))^2 \tag{5}$$

We can verify that we achieve the Hadamard gate if we apply multiple times the gate and if we apply a multiple of 2 times, we get the superposition $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$ and if we apply a multiple of 4 times, we get $|1\rangle$. The result for the Hadamard gate is in fig. 2.



(A) (B)

Figure 2: Hadamard gate. (A) Probabilities of the states $|0\rangle$ and $|1\rangle$. (B) Hadamard Control pulse waveform.