Development of an open-source calibration framework for superconducting qubits

Master degree in Physics

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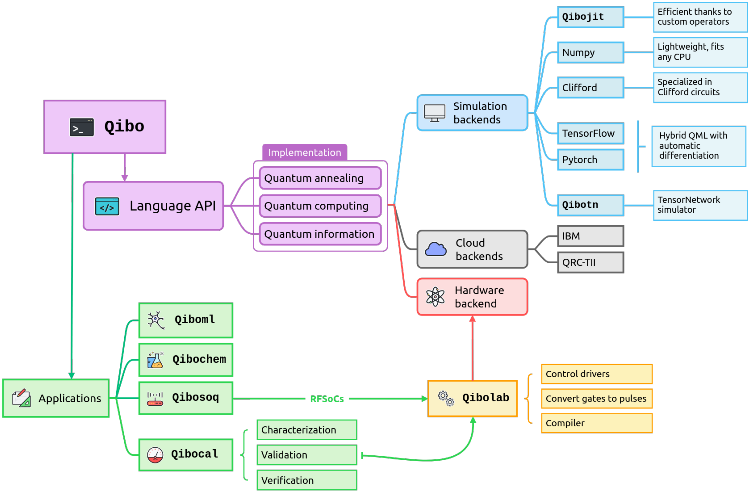
Qibo framework



Superconducting qubits

Artificial atoms

Qubit: two level system

Superconducting qubits: use Josephson Junctions to build anharmonic oscillators

State readout

Qubit - resonator hamiltonian:

$$\hat{H} = \hbar\omega_r \hat{a}\hat{a}^\dagger - \frac{\hbar\omega_{01}}{2}\hat{\sigma}_z + \hbar g(\hat{\sigma}^+\hat{a} + \hat{\sigma}^-\hat{a}^\dagger)$$

Dispersive regime $g \ll \omega_q - \omega_r$

$$\hat{H}_{disp} = \hbar(\omega_r - \chi\hat{\sigma}_z)\hat{a}^\dagger\hat{a} - \frac{\hbar}{2}(\omega_{01} + \chi)\hat{\sigma}_z$$

dispersive shift:

$\chi = \frac{g^2}{\Delta}, \Delta = \omega_q - \omega_r$

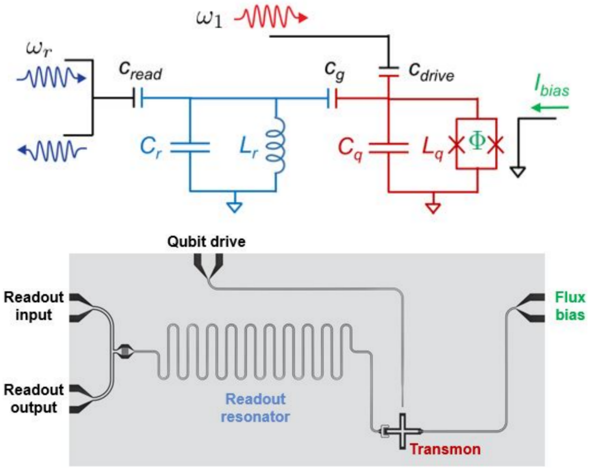


Figure 1: DOI: 10.1109/MAP.2022.3176593

Average Clifford gate fidelity optimization

Randomized Benchmarking

Randomized benchmarking estimates average gate fidelity by applying random sequences of Clifford gates followed by an inverting gate.

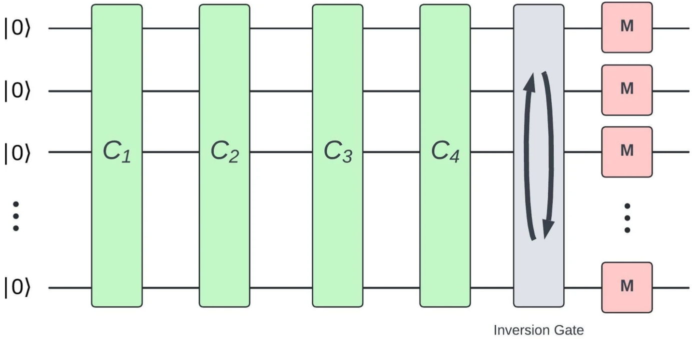
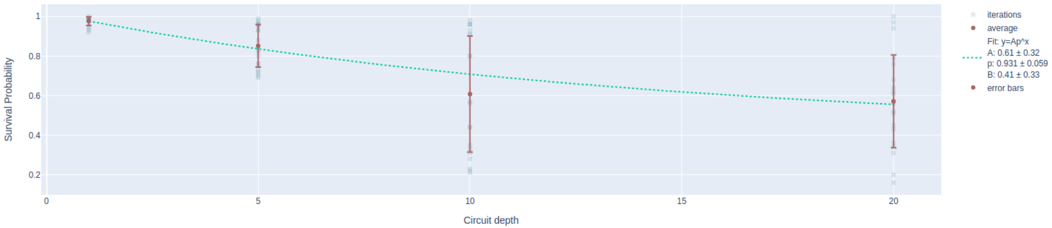


Figure 2: DOI: 10.1007/s10773-024-05811-8

Randomized Benchmarking

Randomized benchmarking estimates average gate fidelity by applying random sequences of Clifford gates followed by an inverting gate.



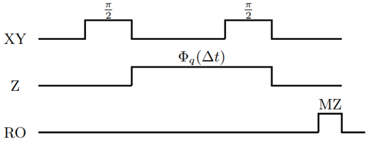
RB optimization

Library additions

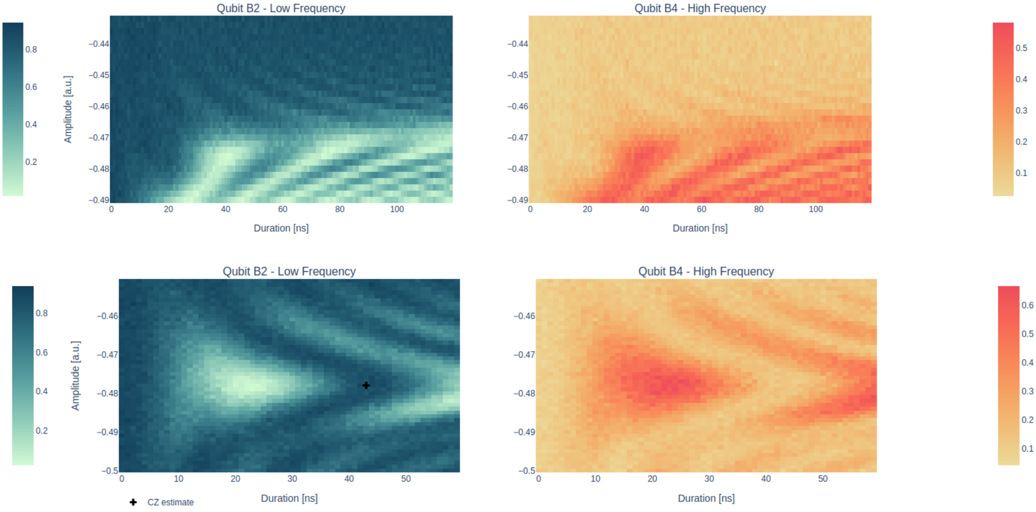
Flux pulse reconstruction

Transmon flux dependence:

$$f_q(\Phi_q) \approx \left(\sqrt{8E_J E_C \left|\cos\left(\pi\frac{\Phi_q}{\Phi_0}\right)\right|}\right)$$



Impact on chevron plots



Conclusions & Outlooks

Questions?

References

What is for?

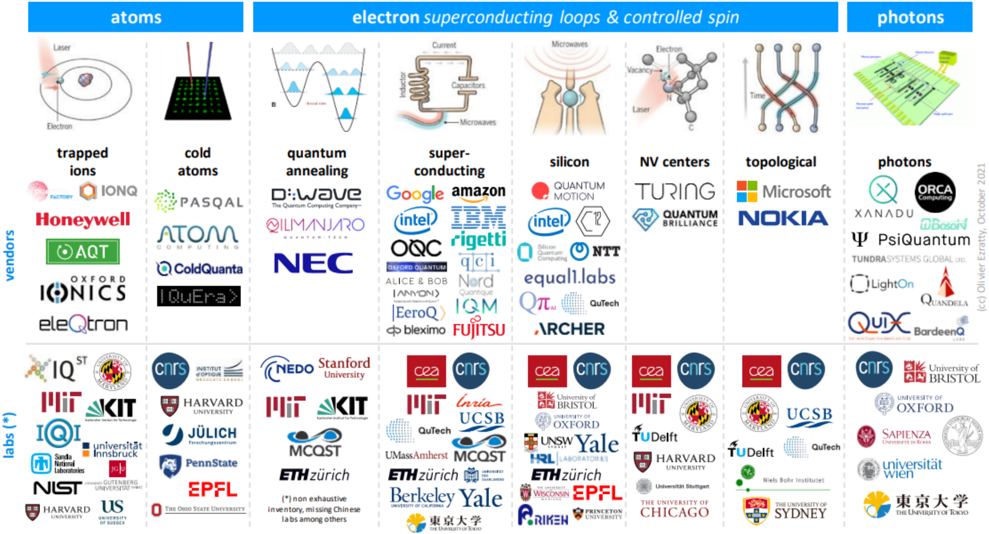
Simulation of quantum system:
"Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy"

Optimization and modeling (finance, traffic, weather...)

Quantum Algorithms

Quantum Machine Learning

Qubit platforms



Standard Randomized Benchmarking protocol

RB protocol

1. Initialize the system in the ground state
2. For each sequence length m, draw a sequence of Clifford group elements
3. Calculate the inverse gate
4. Measure sequence and inverse gate
5. Repeat the process for multiple sequences of the same length while varying the length

RB features

- robust to SPAM errors
- faster than state tomography
- hardware-agnostic

Clifford gates

Special subset of quantum gates that map Pauli operators to Pauli operators under conjugation

Clifford gates group is generated by H, S, $CNOT$ gates

Quantum circuits that consist of only Clifford gates can be efficiently simulated with a classical computer (Gottesman–Knill theorem)