Performance Benchmarks of Prototype Quantum Processors

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The lab class offers a unique opportunity for students to explore quantum computing using the IBM Quantum Cloud and Qiskit toolkit. In this intensive course, participants will benchmark quantum processors, assessing crucial performance metrics such as state preparation and measurement errors, coherence times, and gate fidelities. Students will gain more insight into advanced quantum hardware, the principles of quantum information processing, and current technical limitations.

Keywords: quantum bit, superposition, entanglement, Bell states, dephasing and decoherence effects, single and two-qubit gate operations

Training skills: Programming, error analysis, data visualization, experimental documentation, critical thinking

Welcome to our Master Lab, where we explore the captivating realm of quantum computing, emphasizing the IBM Quantum Cloud and the Qiskit toolkit. In our program, students will seize the opportunity to learn about and engage with state-of-the-art quantum technology while systematically evaluating the performance of quantum processors. During this one-week intensive lab, students will gain hands-on experience with an advanced cloud-based platform that provides access to real quantum computers and powerful simulators. By leveraging the power of cloud computing, this platform has made prototype quantum processors accessible to researchers, students, and enthusiasts worldwide, allowing them to experiment without the need for owning or maintaining expensive quantum hardware. The physical platform behind this cloud-based quantum computing service is based on superconducting qubits, electronic circuits made from superconducting materials that can carry electric current without resistance. These qubits have the ability to exist in multiple quantum states concurrently, such as coherent superposition and entangled states, which facilitate the parallel processing capabilities that lie at the core of quantum computing. The quantum computers provided through this platform employ state-of-the-art technology, including advanced cryogenic systems to maintain ultra-low temperatures, microwave pulse control, and cutting-edge error mitigation techniques to minimize the effects of noise and other sources of error on the qubits.

In this lab, students will undertake a comprehensive benchmarking process for state-of-the-art quantum information processing systems. The evaluation will involve measuring the performance of quantum systems using metrics such as state preparation and measurement (SPAM) errors, gate fidelity, and coherence times (T1 and T2*). Thorough and methodical benchmarking is crucial for identifying the advantages and limitations of quantum systems, which in turn fosters the development of more efficient and reliable quantum algorithms and hardware enhancements. Throughout the lab, students, typically collaborating in pairs, will be expected to meticulously record their observations and results in lab notes, fostering a deeper comprehension of experimental procedures and the underlying principles of quantum computing. Ideally, this effort will culminate in a thoroughly documented Jupyter Lab notebook, supplemented by relevant Python modules. This class requires a strong commitment to self-learning and a high level of self-motivation from the participants. To conclude the lab experience, each team will deliver a 40-minute oral presentation summarizing their discoveries and insights, followed by a 20-minute discussion session to further engage with critical thinkers.

The objective of our lab class is to provide students with the essential knowledge and skills to thrive in the fast-paced domain of quantum computing while promoting teamwork and innovation in the pursuit of advanced quantum technologies. Our class forms part of the elective specialization in quantum science and technology and is closely connected to the quantum hardware lecture offered at our institute. Contact us via email to obtain more information and arrange your lab session.

REFERENCES FOR PREPARATION

1. Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge University Press. `https://doi.org/10.1017/CBO9780511976667`

2. Open-Source Quantum Development – qiskit 0.42.1. `https://qiskit.org`

3. Access to IBM Quantum Cloud – create a free account `https://quantum-computing.ibm.com/`

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