TorchQuantum + cuQuantum Collaboration Plan

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Quantum Computer System Stack

High Level Framework

cuQuantum

Torch Quantum

Qiskit

Paddle Quantum

SILQ

BQSKit

Cirq

幺

Intermediate Representation

Quil

OpenQASM

Blackbird

QMASM

Classical Simulation

Real Hardware Deployment

Runtime / Control Signal Generation

cuDNN

OpenMP

Amazon Braket

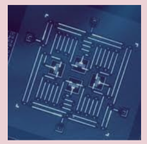
IBM Q

IONQ

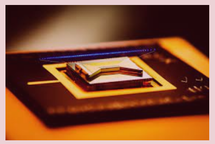
Device

GPU

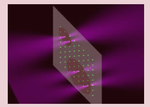
CPU



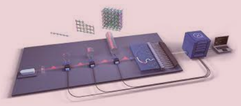
Superconducting



Trapped Ion



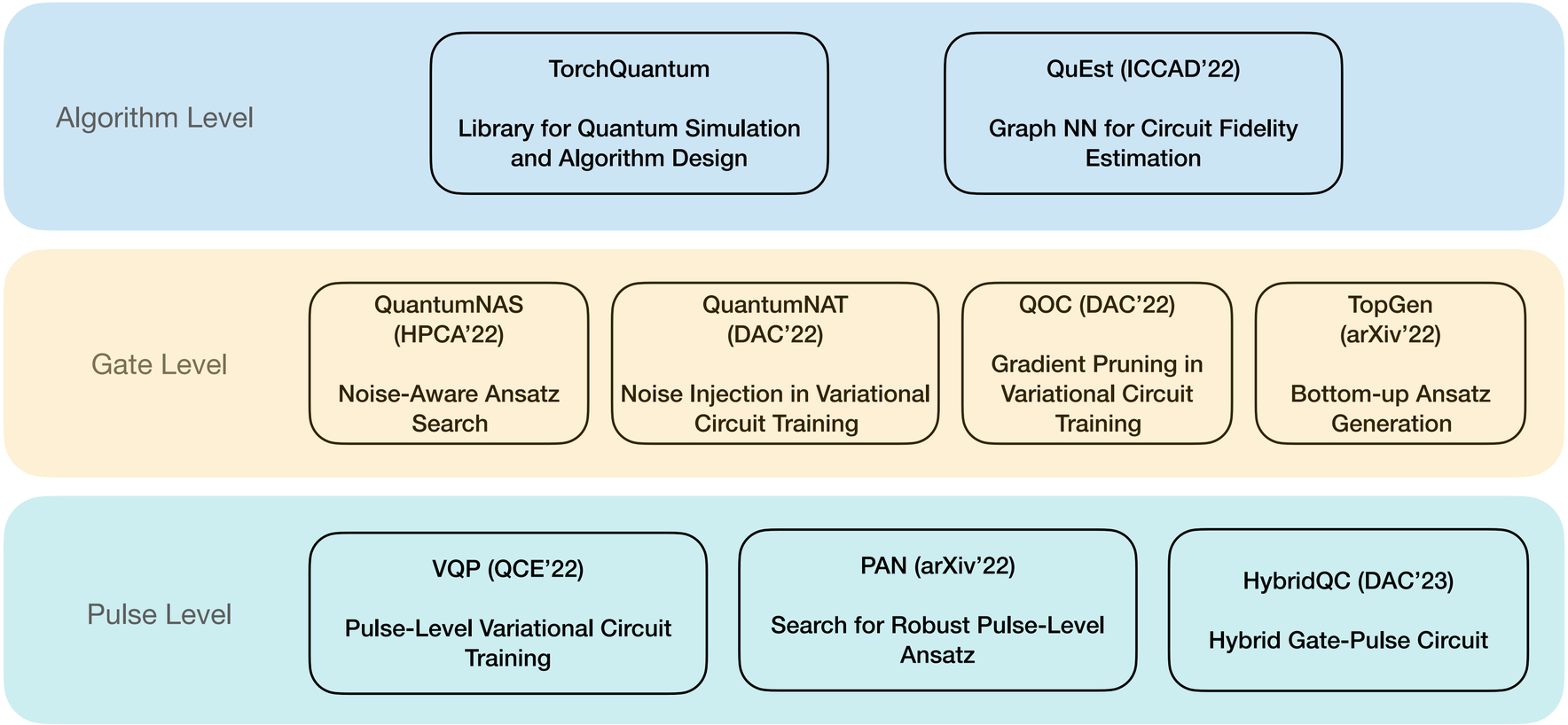
Neutral Atom



Photonics

Quantum Architecture Research at HAN Lab

- At HAN Lab, we focus on AI-assisted cross-layer codesign for efficient and practical quantum computer system

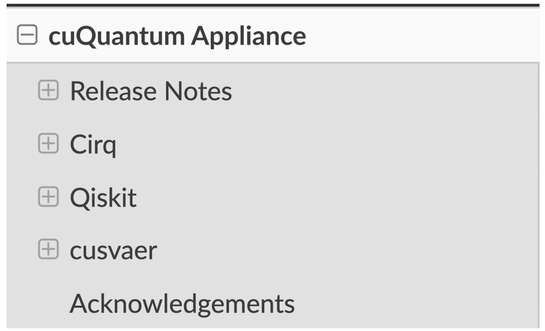


TorchQuantum with cuQuantum backend

- TorchQuantum implements a statevector simulator using matrix multiplications with the cuDNN/ cuBLAS library as backend.
- Potential advantages of using cuQuantum as an alternative backend (cuTensorNet and cuStatevec)
  - cuQuantum supports tensor network contraction which brings higher scalability
    - Explore the sparsity nature of the state vector. Not all values in the statevector are equally important.
    - Statevector of N qubits can be thought as a rank-N tensor, that could be broken down into low-rank tensors.
    - cuTensorNet provides an automatic way to do the contraction
  - The cuStatevec has **multi-GPU** simulation support which also improves scalability

Integration of cuQuantum as backend of TorchQuantum

- Feasibility
  - cuQuantum has Python interfaces which can be wrapped into TorchQuantum. The circuit construction uses torchQuantum interface (PyTorch style). Then calling cuQuantum functions to perform state vector simulation or tensor network contraction.
- Format
  - cuQuantum can have one TorchQuantum Appliance



	When Building	When Running
Python	3.8+	3.8+
pip	22.3.1+	N/A
setuptools	>=61.0.0	N/A
wheel	>=0.34.0	N/A
Cython	>=0.29.22,<3	N/A
cuStateVec	1.2.0	~=1.1
cuTensorNet	2.0.0	~=2.0
NumPy	N/A	v1.19+
CuPy (see CuPy installation guide)	N/A	v9.5.0+
PyTorch (optional, see PyTorch installation guide)	N/A	v1.10+
Qiskit (optional, see Qiskit installation guide)	N/A	v0.24.0+
Cirq (optional, see Cirq installation guide)	N/A	v0.6.0+
mpi4py (optional, see mpi4py installation guide)	N/A	v3.1.0+