Introduction to Quantum Software and TKET

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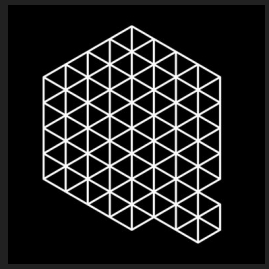
QUANTINUUM

Why do Quantum Computing?

- Shor’s Algorithm - near exponential advantage for factoring
- Grover’s Algorithm - Unstructured search
- Quantum Chemistry/Materials - Simulating quantum systems
- Others - Machine learning, industrial optimisation, differential equations…

Note: Many of the most interesting applications of quantum computing require quantum error correction. Errors correction codes typically require many additional physical qubits to implement logical operations.

Quantum Software?



System software

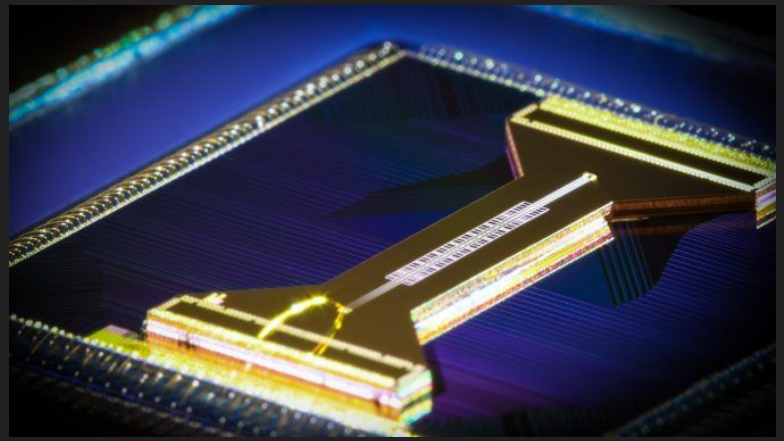
- **Compiler - TKET,** qiskit
- Online services - AWS Braket, Azure quantum
- Quantum Error Correction/Mitigation - Qermit, others
- Quantum Programming languages - Q#, Silq, quipper

Applications Software

- Quantum chemistry/materials science - InQuanto
- Machine learning - Pennylane, others
- Industrial optimisation

Quantum Hardware?

- Trapped ions - **Quantinuum,** IONQ, AQT
- Superconductors - IBM, Google, Rigetti, IQM
- Photonics - PsiQuantum, Quandela…
- Neutral atoms - Pasqal, Infleqtion…
- Others - Semiconductors, topological qubits…



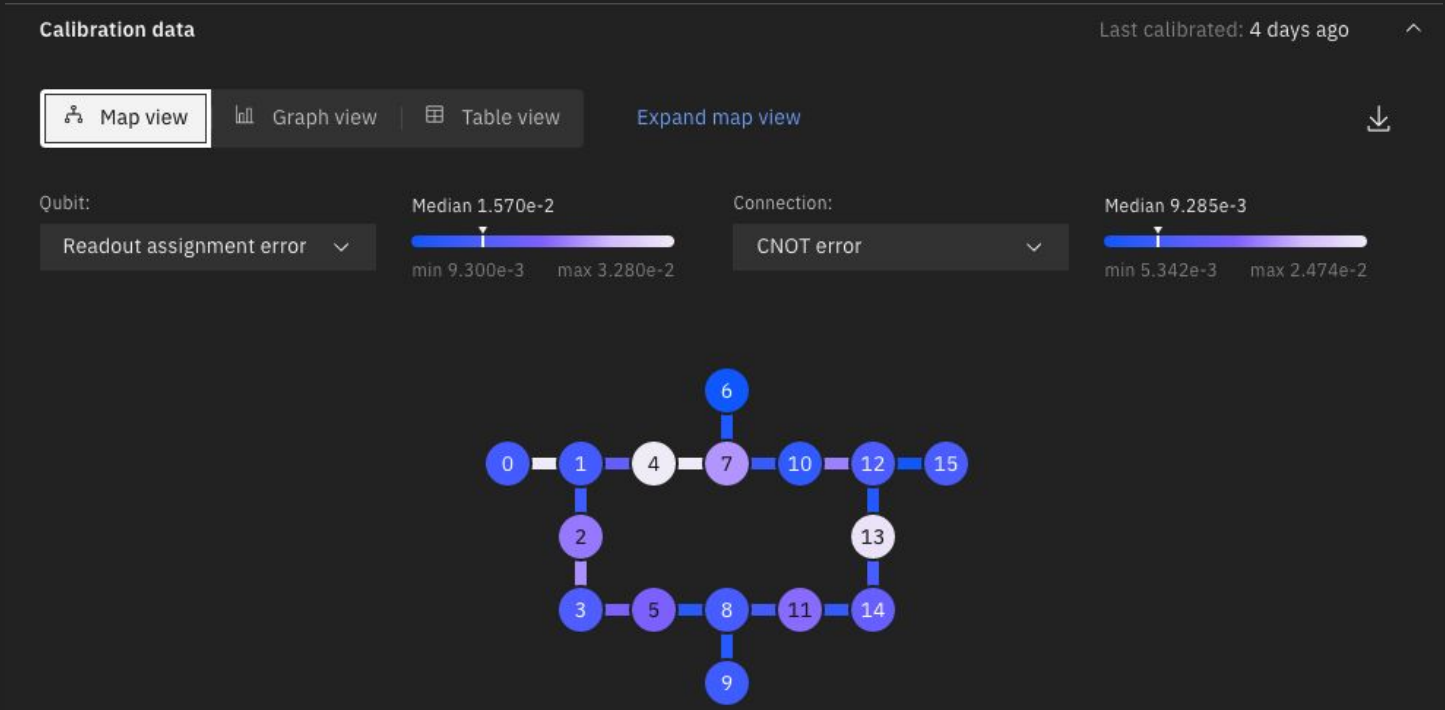
H-series Ion traps

Superconducting circuits - IBM

Some Challenges with Quantum computing

- Not enough qubits for many of the exciting applications
- The qubits we do have are subject to noise
- Complicated error channels which are hard to model
- Quantum error correction at an early stage
- **Low-level details greatly influence performance -** gate count, connectivity

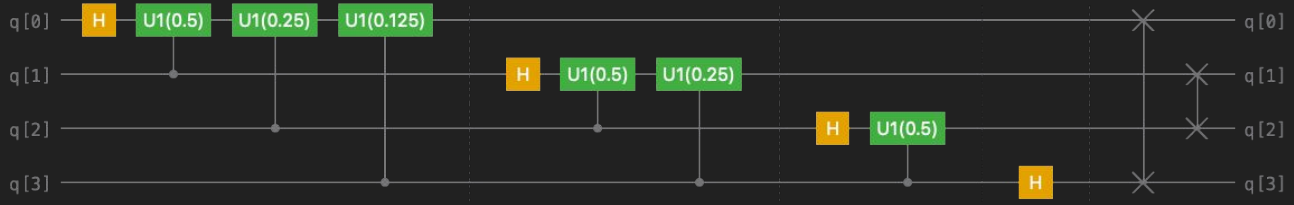
A Real Quantum device



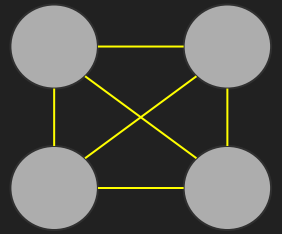
Source: IBM Quantum

Quantum compilation

Example: Quantum Fourier Transform Circuit

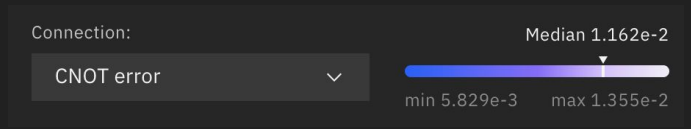


Complete connectivity graph

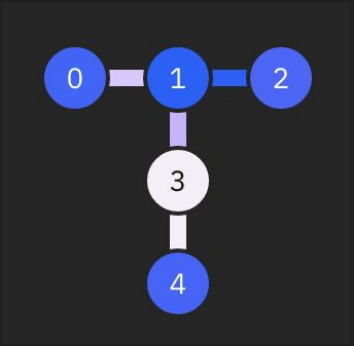


Target device: IBMQ Belem

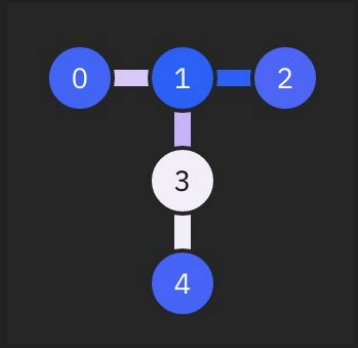
- Nearest neighbour interaction only
- Limited gateset {X, SX, Rz, CX}
- CNOT error



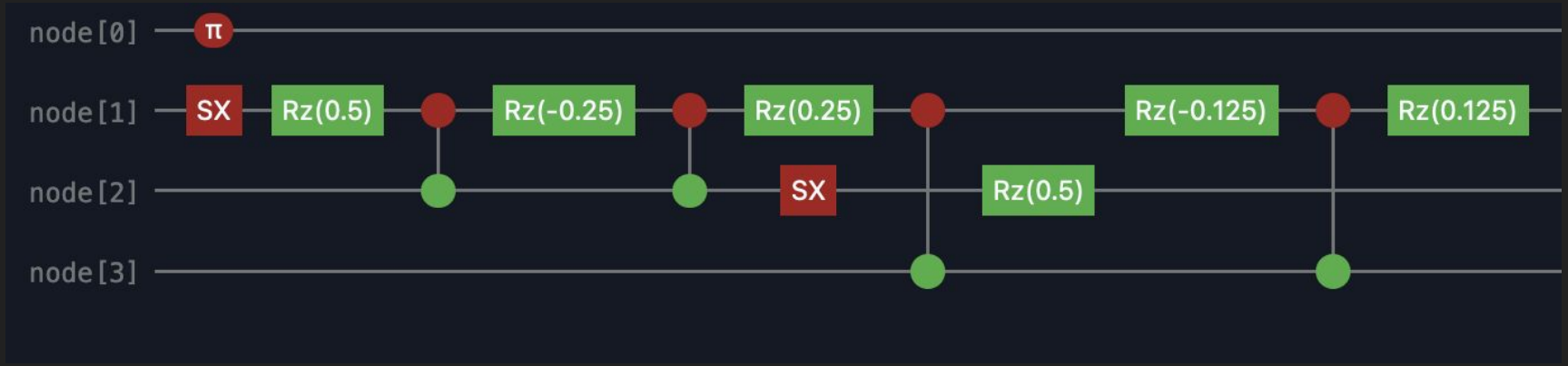
Belem qubit topology



Quantum compilation II



Compiled QFT Circuit (incomplete) - meets device constraints



What is TKET?

A quantum software library developed by Quantinuum

- A high performance quantum compiler
- Open source! https://github.com/CQCL/tket
- “Hardware agnostic” - Targets a range of devices and simulators
- Compatible with popular libraries - Qiskit, Cirq, Braket, pennylane + more

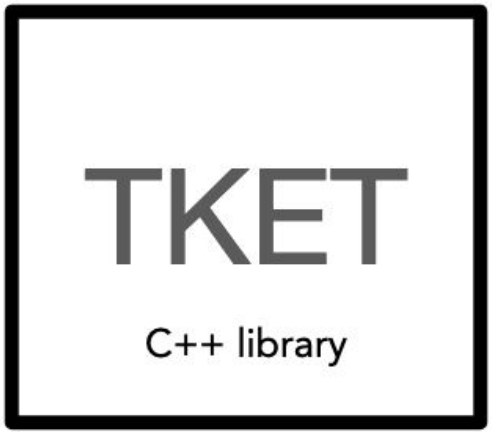
```
pip install pytket
```

Note: Cloud access through Azure and AWS Braket is also available

Front ends
High level interface

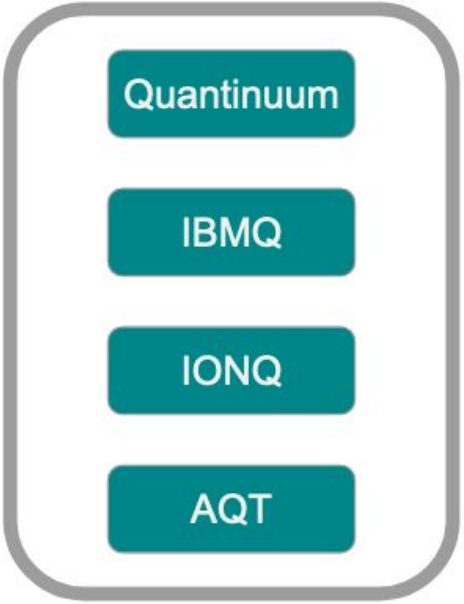
Build Circuits

pytket
python



Rewrite Circuits
Solve for device constraints
Perform optimisations

Backends
Quantum devices/simulators



Execute Circuits