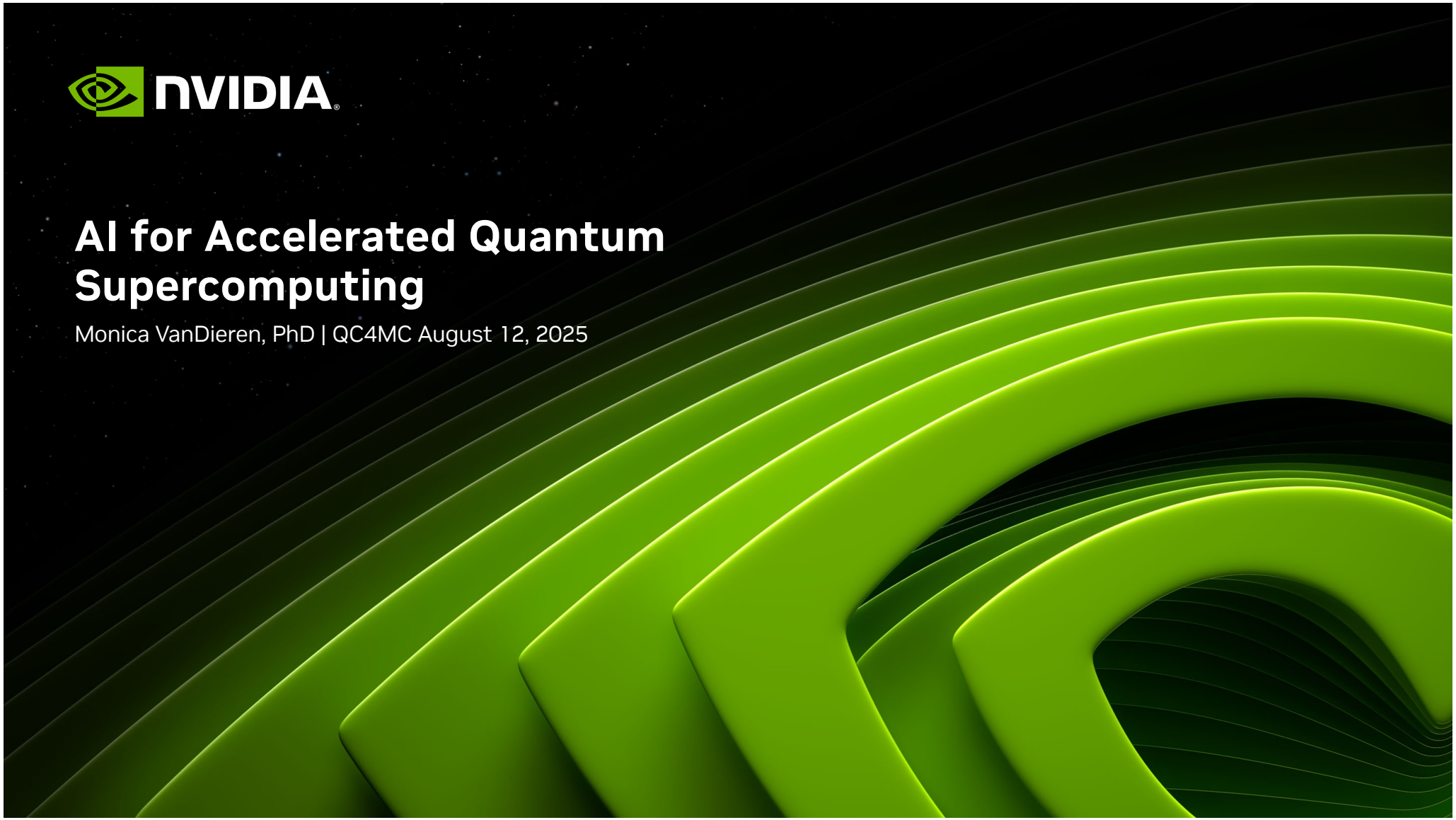

NVIDIA
AI for Accelerated Quantum Supercomputing
Monica VanDieren, PhD | QC4MC August 12, 2025

AI for Accelerated Quantum Computing

menti.com
Code:2569 6565

How familiar are you with …?

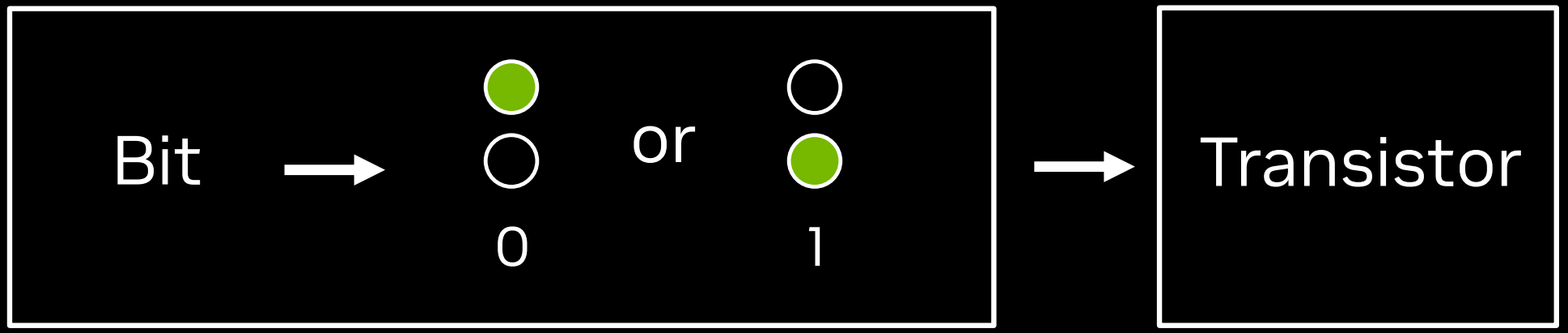
menti.com
Code: 2569 6565

Agenda

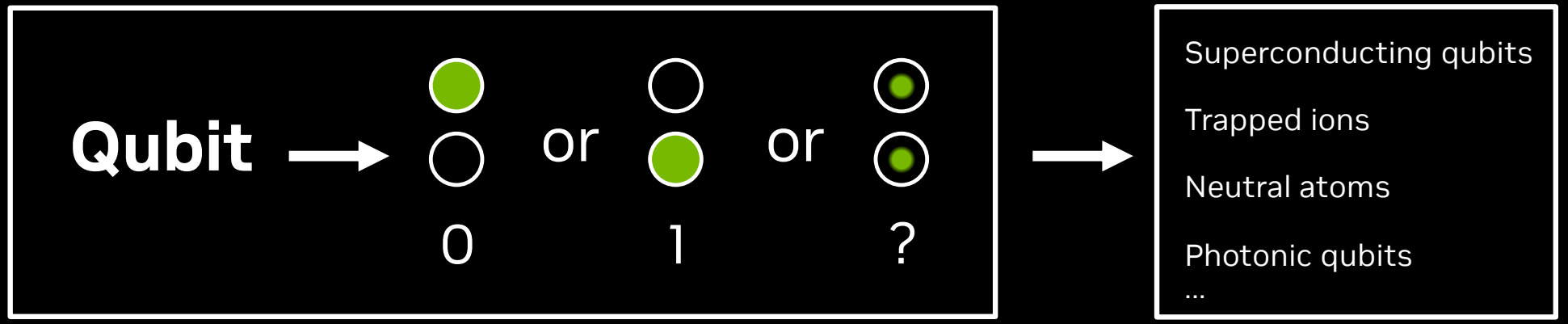
- Quantum circuits and quantum kernels
- AI for Accelerated Quantum Supercomputing
- Variational Algorithm and Adaptive Circuit Knitting
- Resources to learn more about Accelerated Quantum Supercomputing

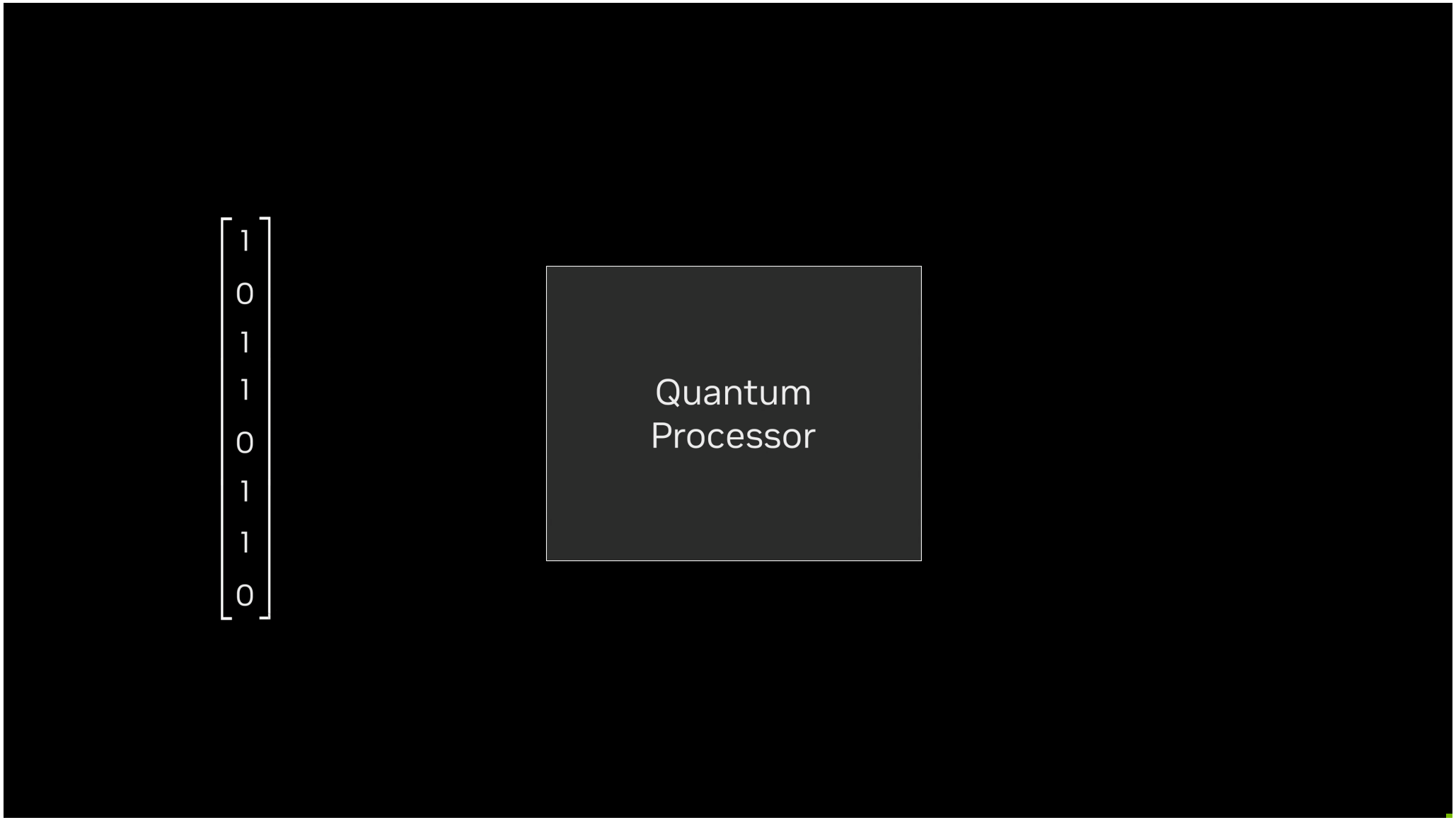
What is a Quantum Computer?

Conventional computer

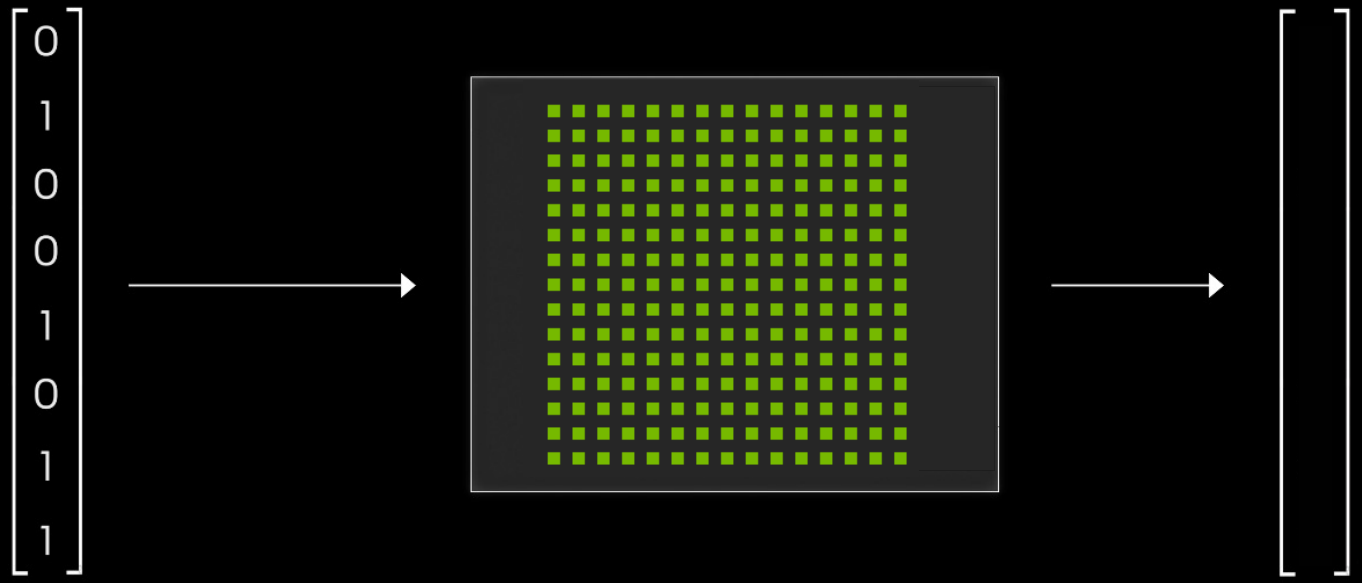


Quantum computer



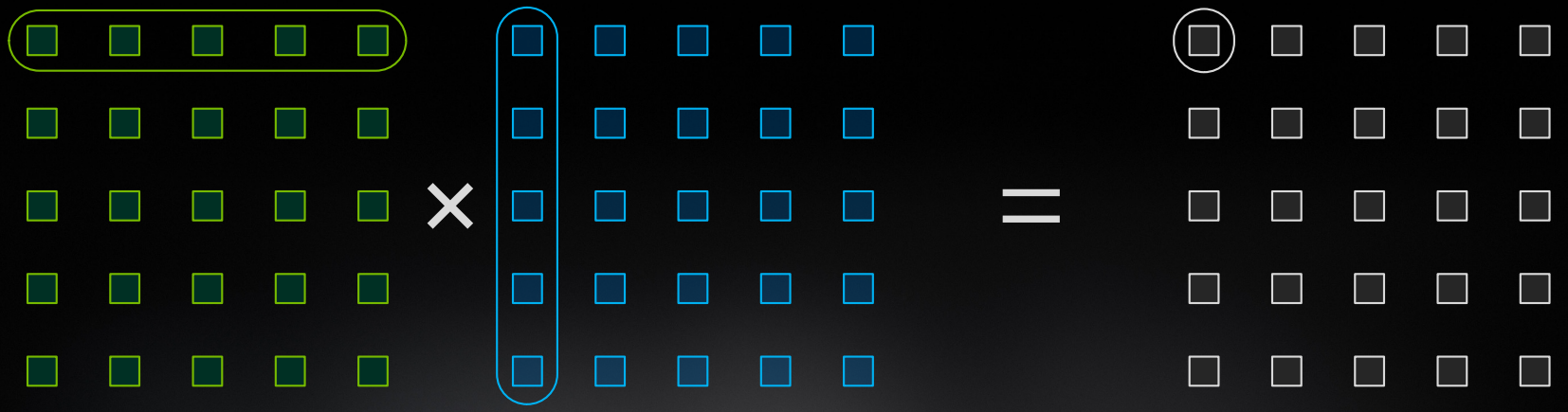

1
0
1
1
0
1
1
0
Quantum
Processor

Matrix Multiplication

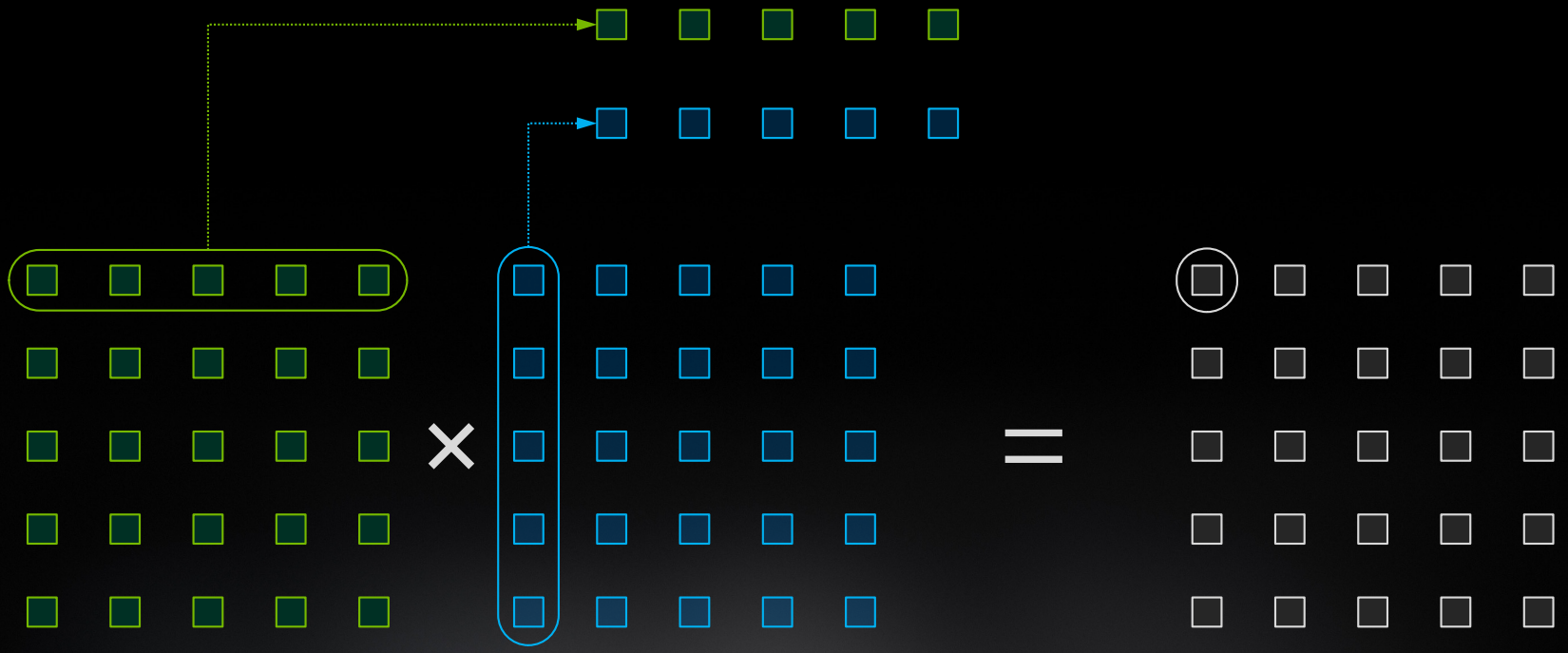


A quantum processor acting on N qubits can be modeled by a $2^N x 2^N$ matrix

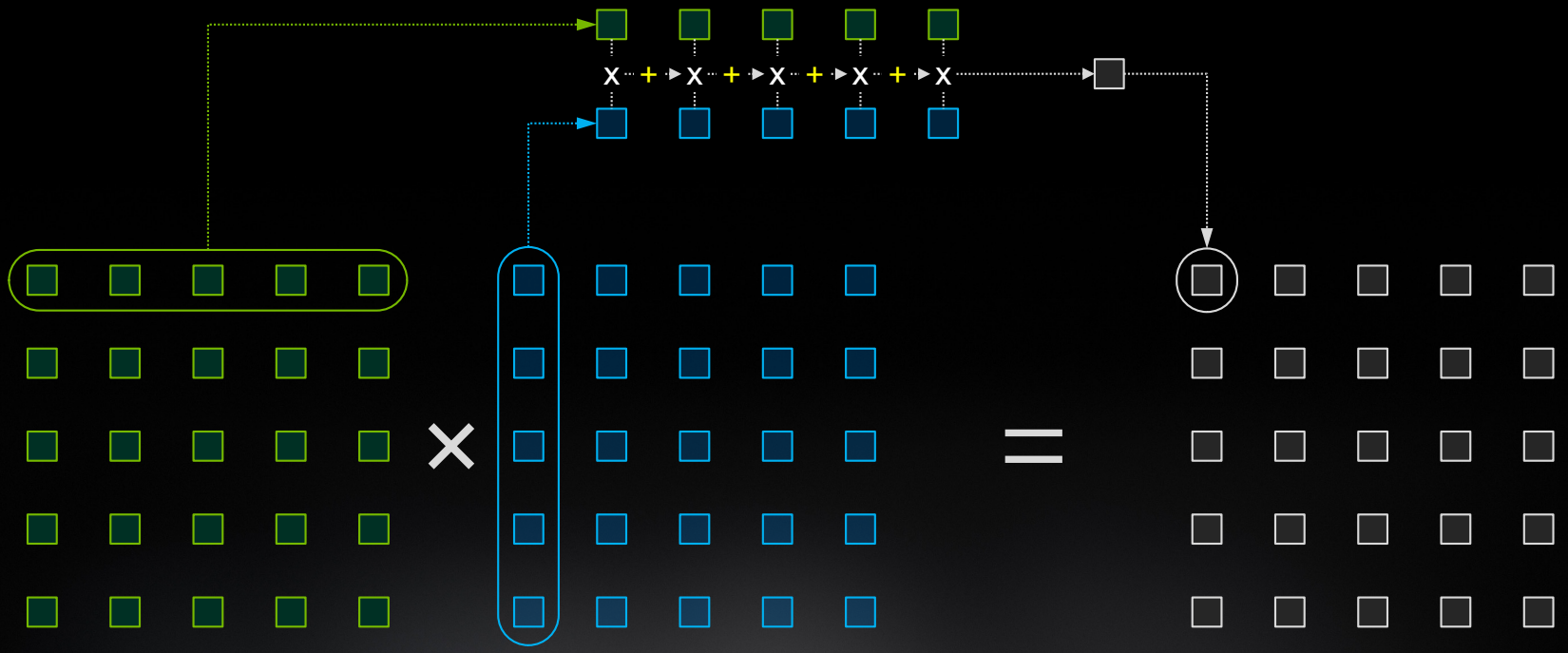
Matrix Multiplication



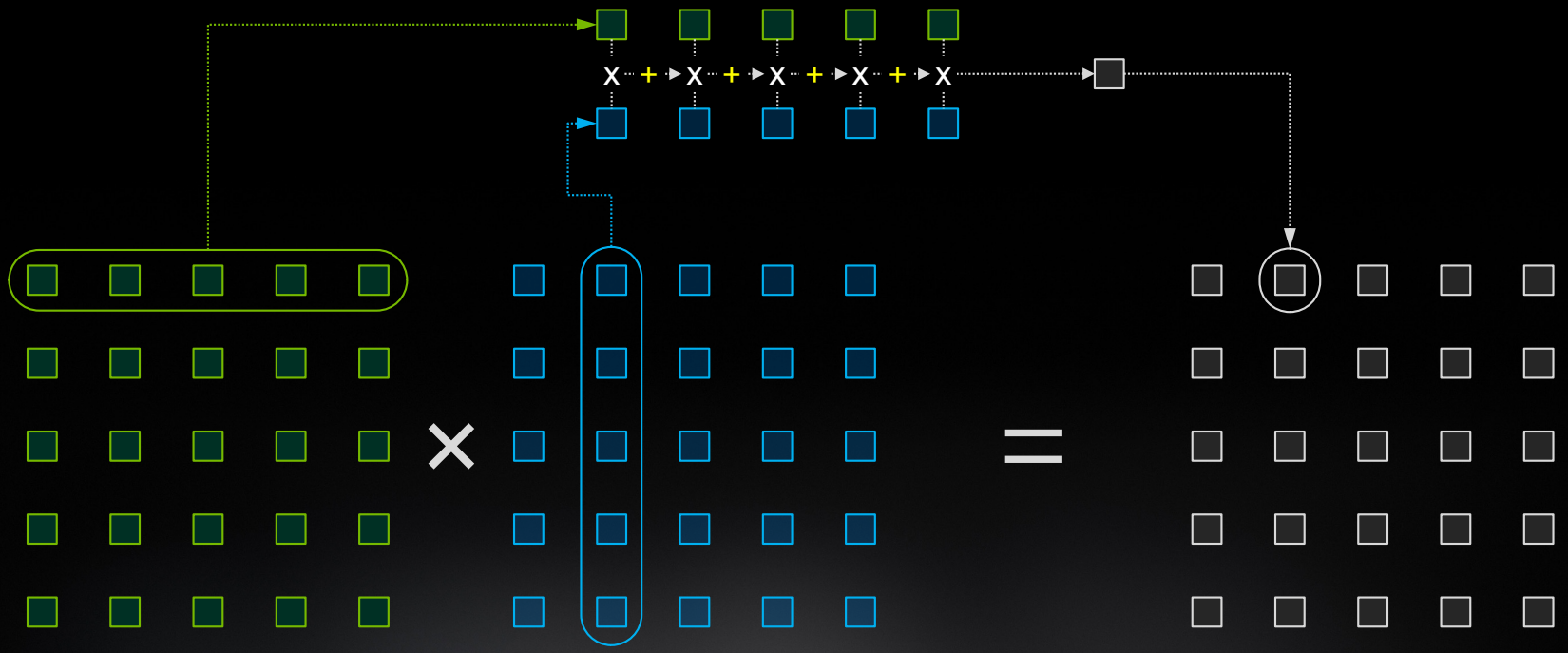
Matrix Multiplication



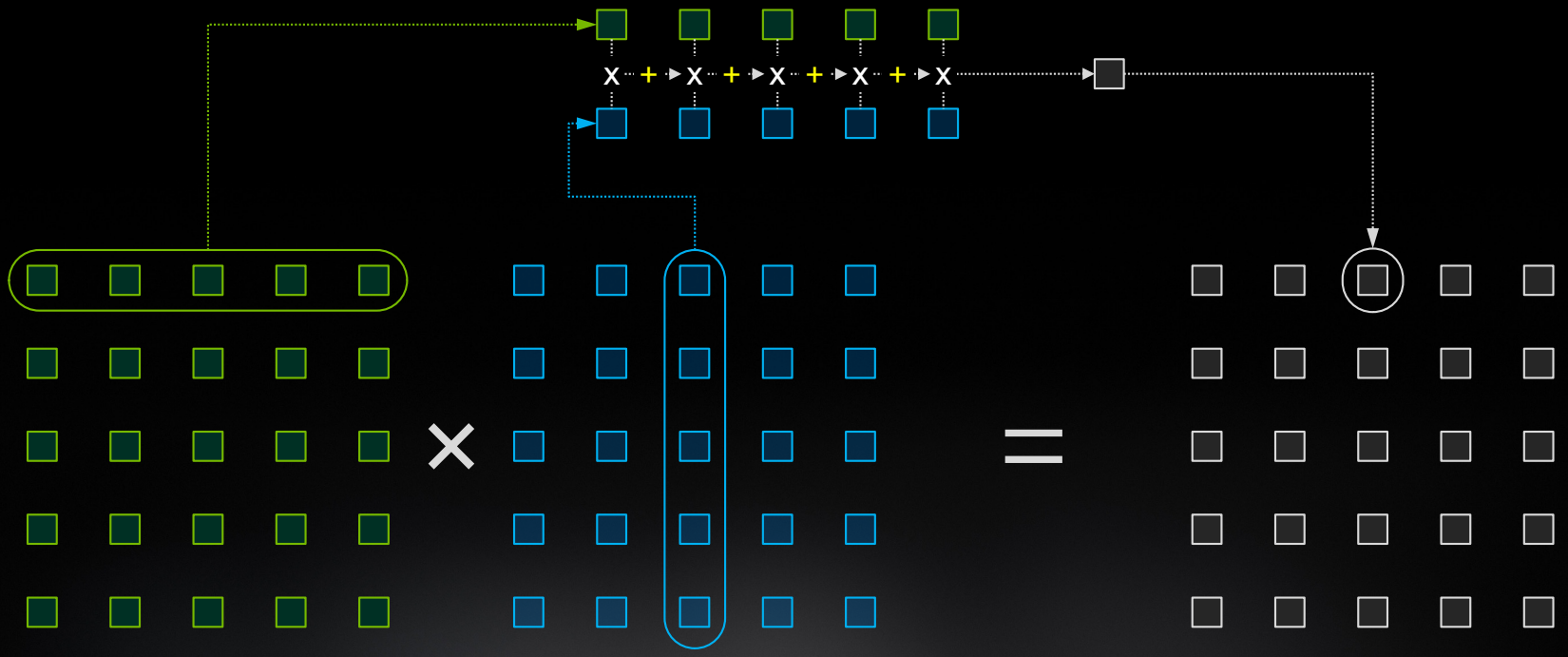
Matrix Multiplication



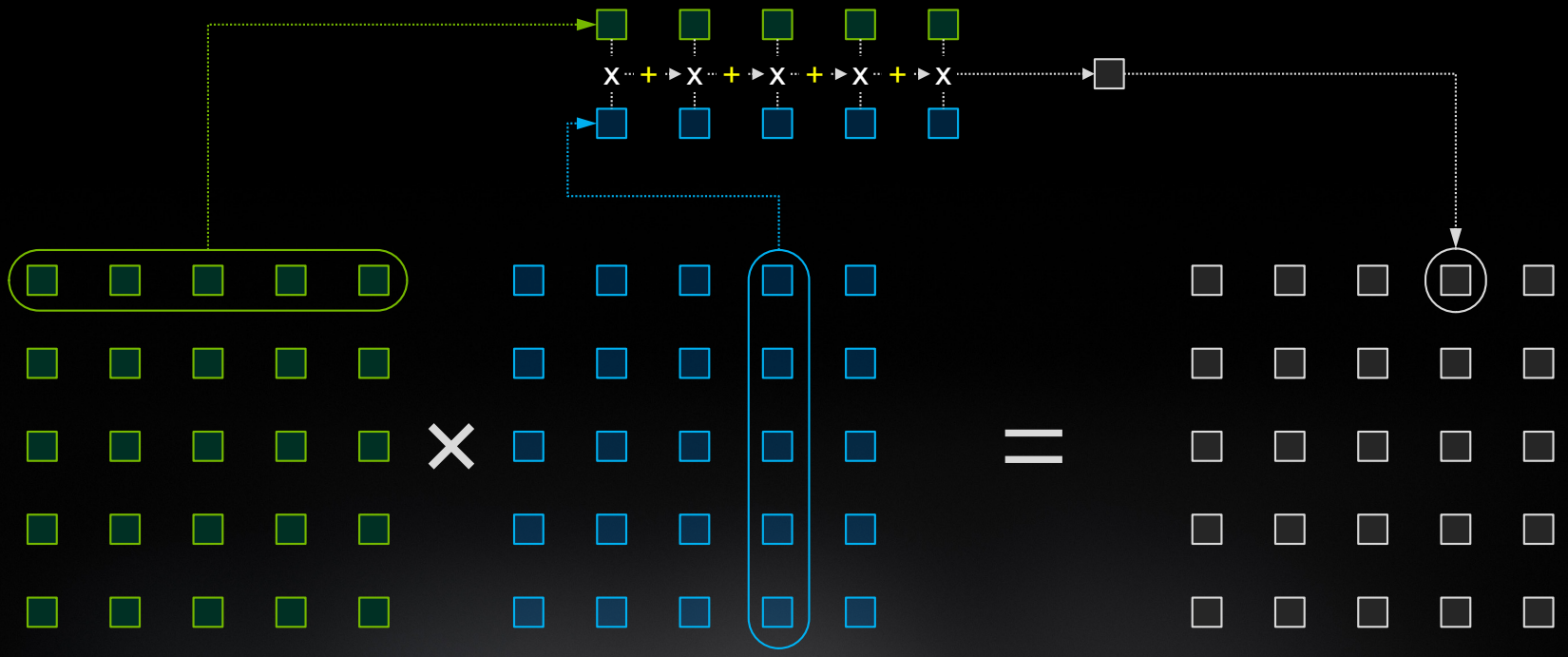
Matrix Multiplication



Matrix Multiplication

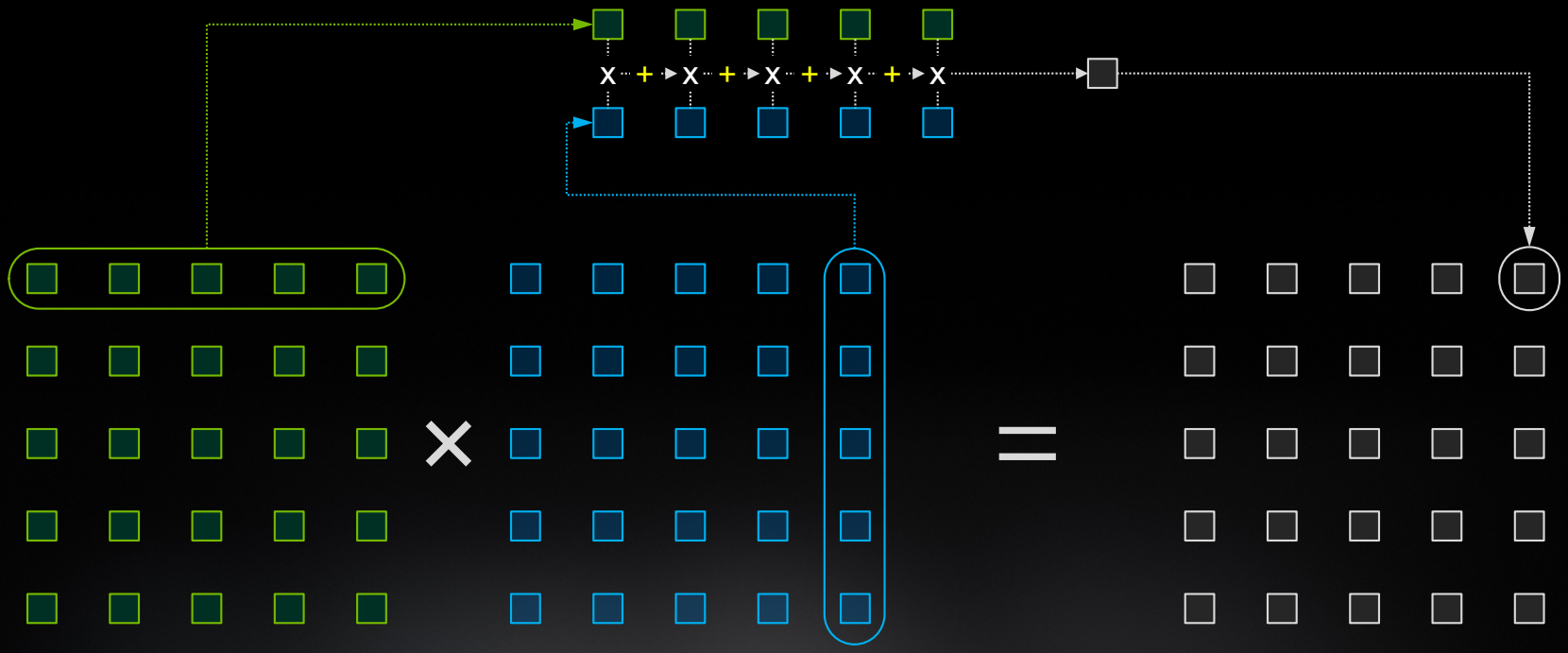


Matrix Multiplication



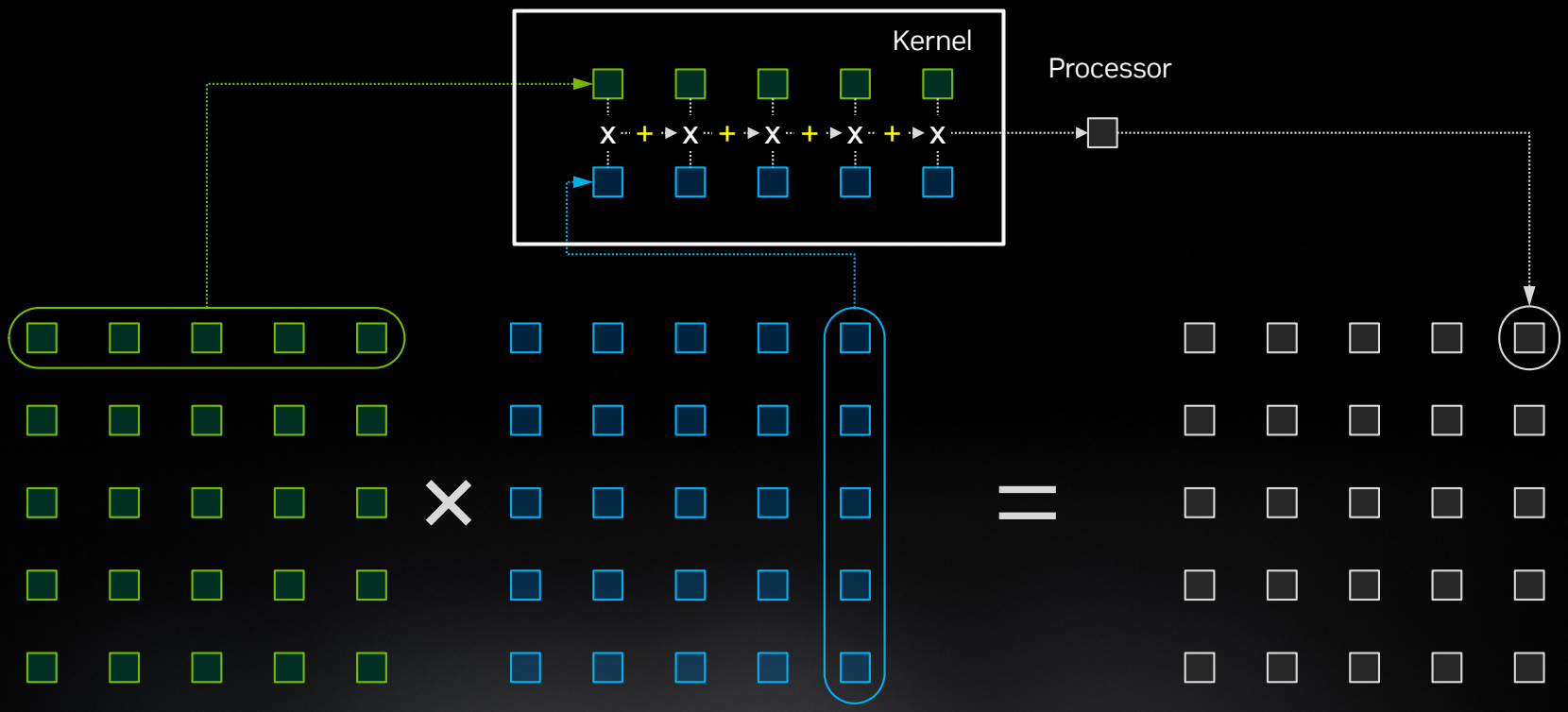
Matrix Multiplication

Can be carried out in parallel



Matrix Multiplication

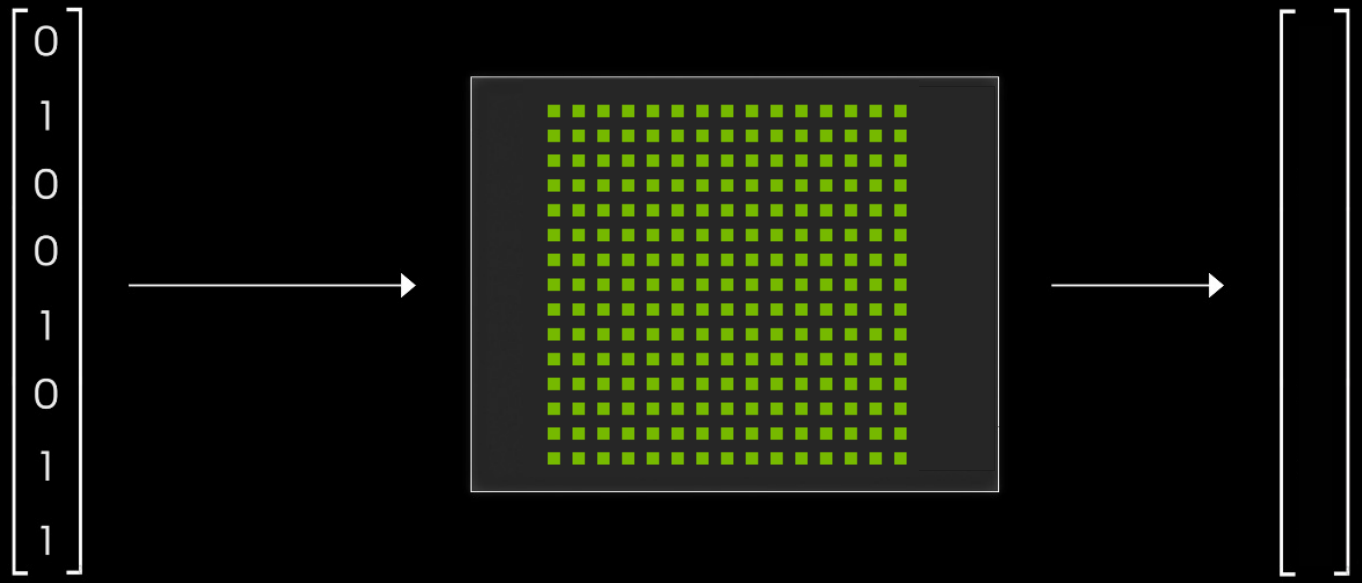
Can be carried out in parallel



Synchronous

Asynchronous

Matrix Multiplication

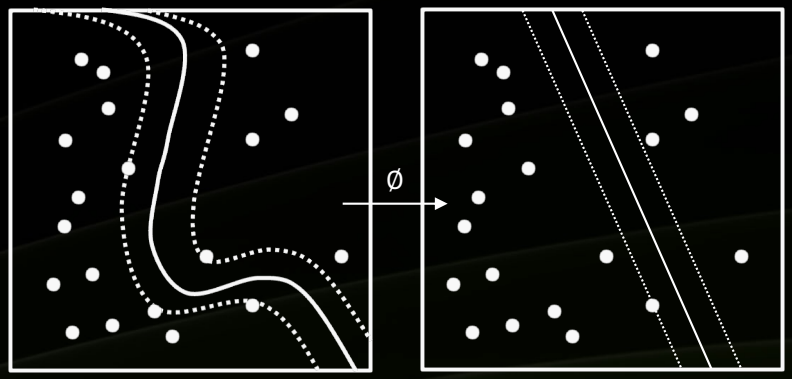


A quantum processor acting on N qubits can be modeled by a $2^N x 2^N$ matrix

Fraud Detection

HSBC Leverages CUDA-Q to Develop Improved Fraud Detection

- Fraudulent transactions: loss of $1.9BN per year for UK alone
- Quantum-inspired methods may improve fraud detection
- Reduced false positives by 4%, improved true positives by 2%
- Run as 165 qubit classification problem on GPUs with CUDA-Q



HSBC

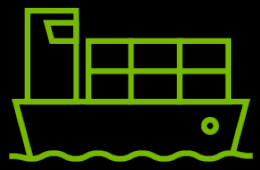
Agenda

- Quantum circuits and quantum kernels – CUDA-Q Lab 2
- AI for Accelerated Quantum Supercomputing
- Variational Algorithm and Adaptive Circuit Knitting
- Resources to learn more about Accelerated Quantum Supercomputing

Quantum Computing's Broad Impact

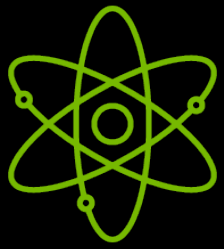
EV chemistry

Drug discovery

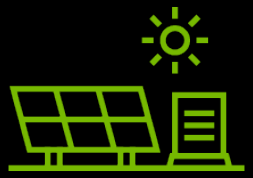


Logistics

Finance



Physics modelling

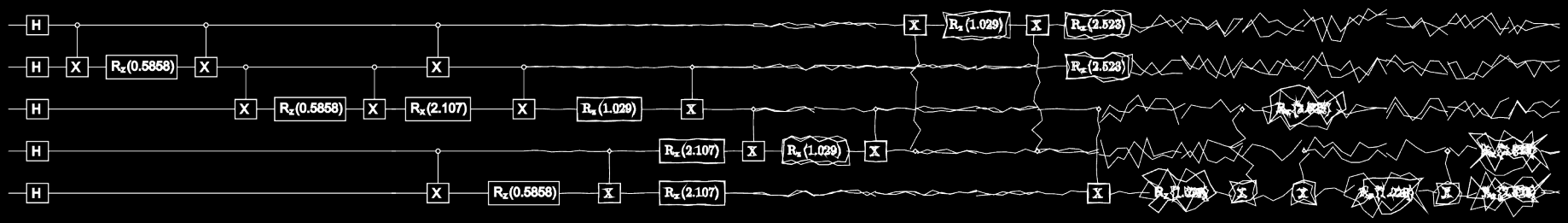


Materials

Nitrogen fixation

AI and ML

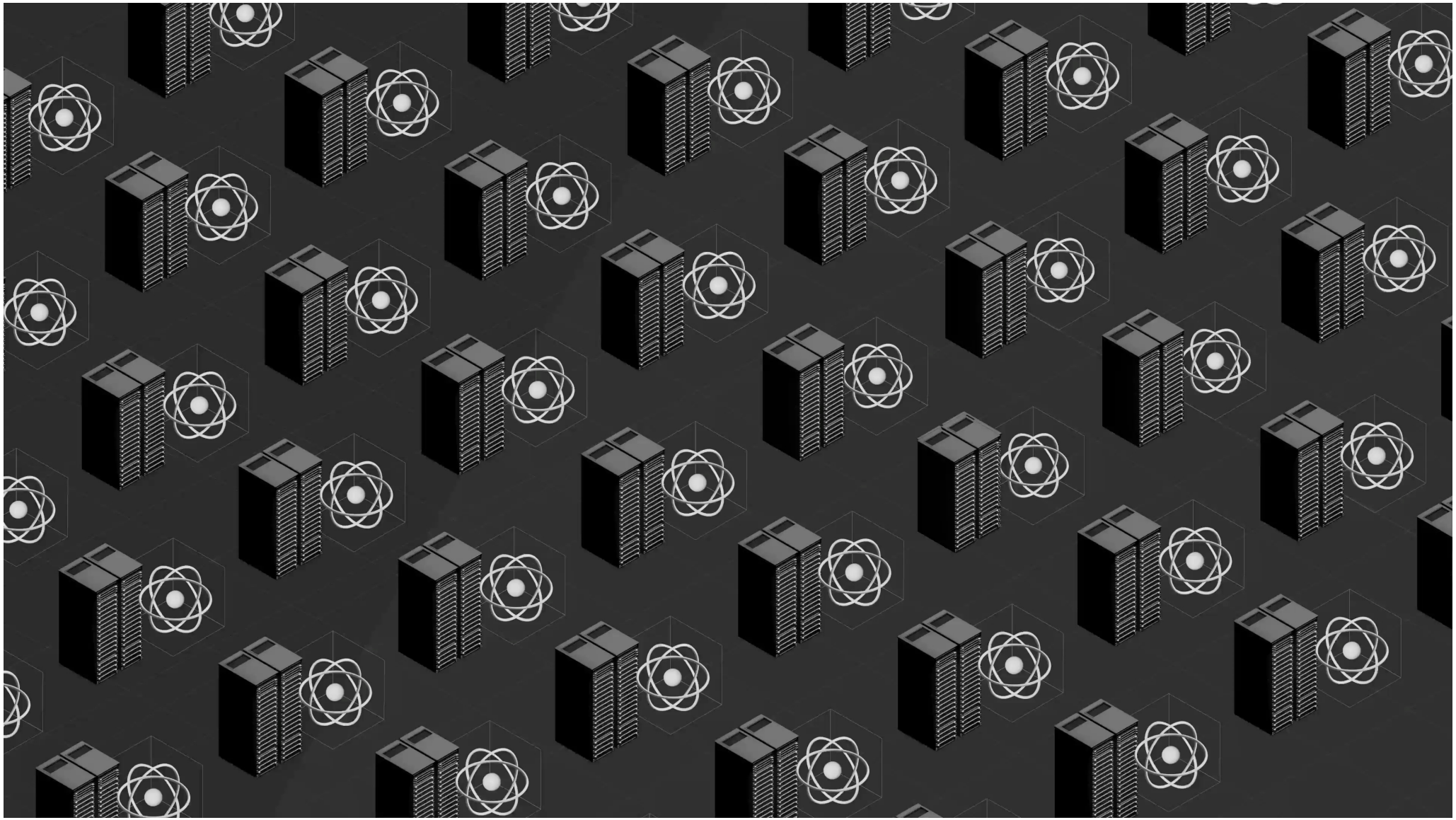
Noise Limits Today's Quantum Hardware



Noise limits computations on today's quantum hardware to just hundreds of operations

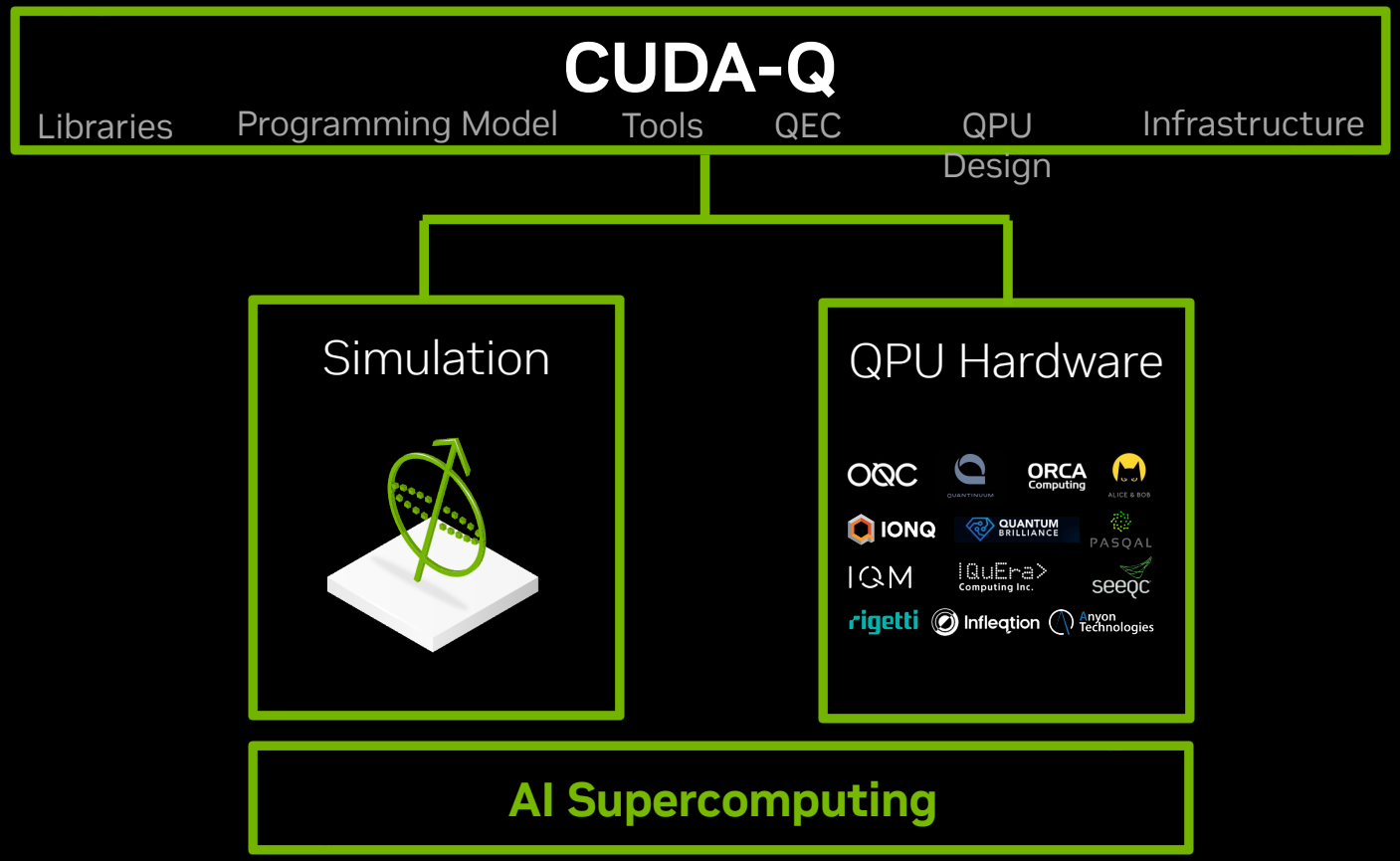
Agenda

- Quantum circuits and quantum kernels
- AI for Accelerated Quantum Supercomputing
- Variational Algorithm and Adaptive Circuit Knitting
- Resources to learn more about Accelerated Quantum Supercomputing

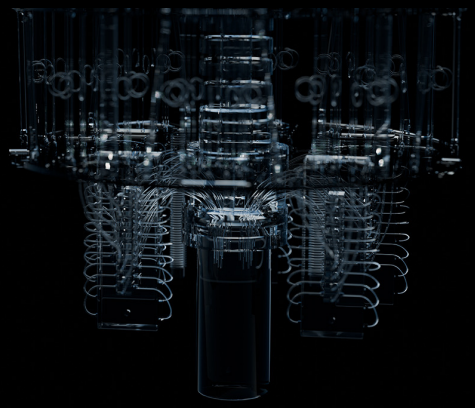


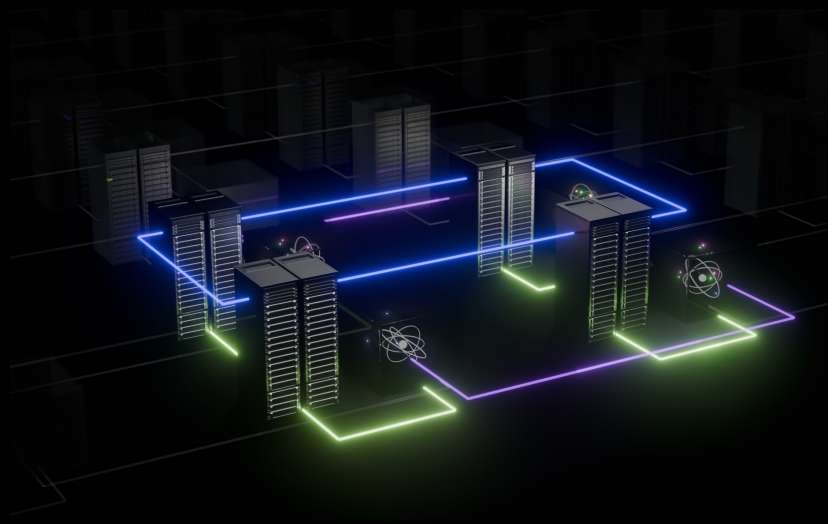
CUDA-Q

The platform for accelerated quantum computing



Accelerating the Journey From Qubits to Supercomputers

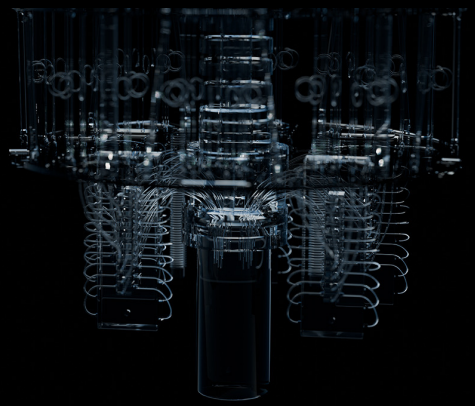


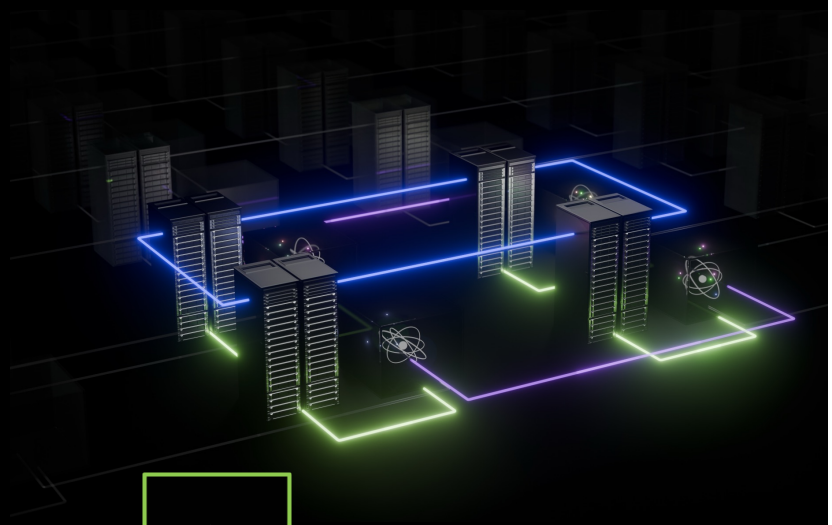


Qubits

Accelerated Quantum Supercomputers

Accelerating the Journey From Qubits to Supercomputers





Qubits

Better quantum hardware

Hybrid algorithms

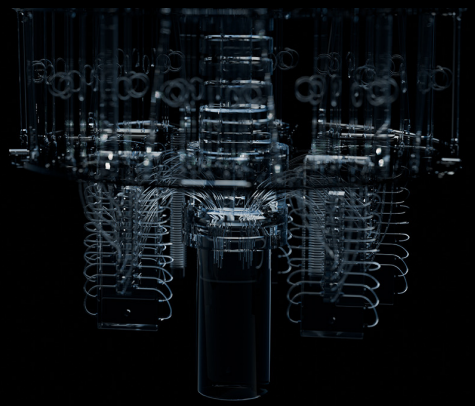
Implementing QEC

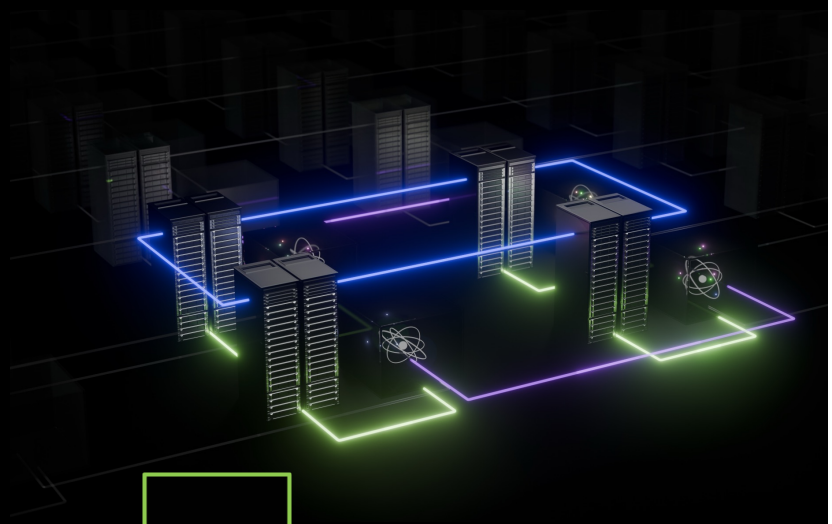
Infrastructure challenges

Accelerated Quantum Supercomputers

NVIDIA

Accelerating the Journey From Qubits to Supercomputers





Qubits

Better quantum hardware

Hybrid algorithms

Implementing QEC

Infrastructure challenges

Accelerated Quantum Supercomputers

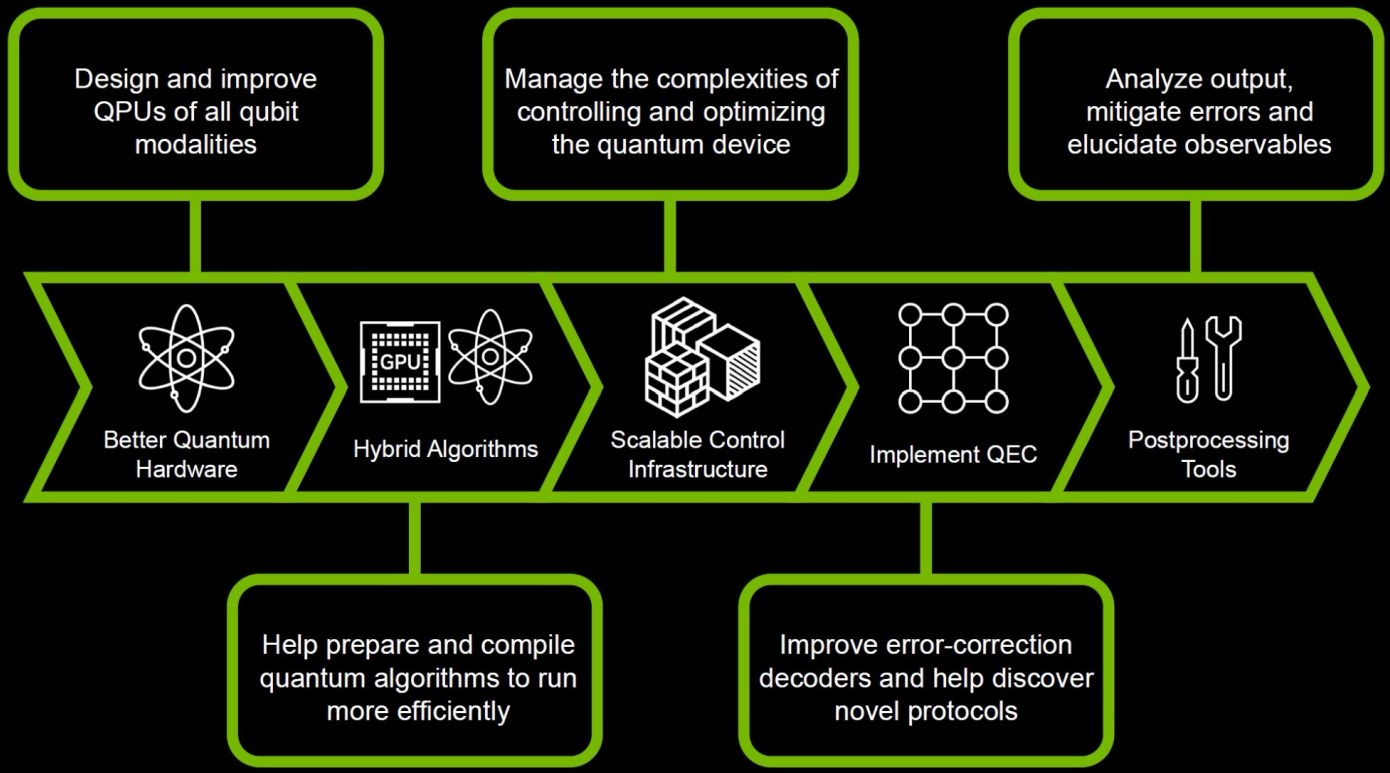
NVIDIA

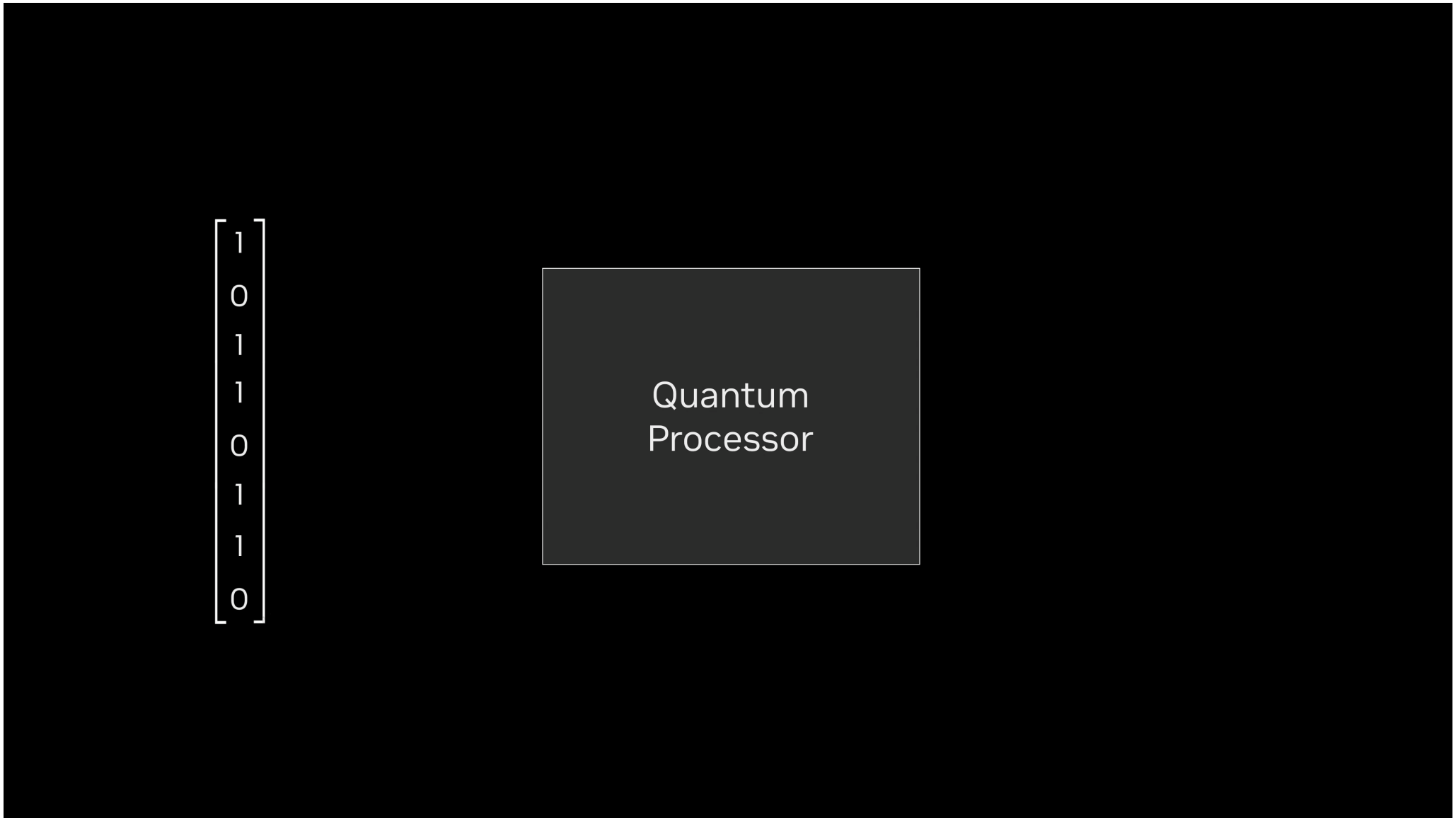
AI supercomputing

NVIDIA

Artificial Intelligence for Quantum Computing

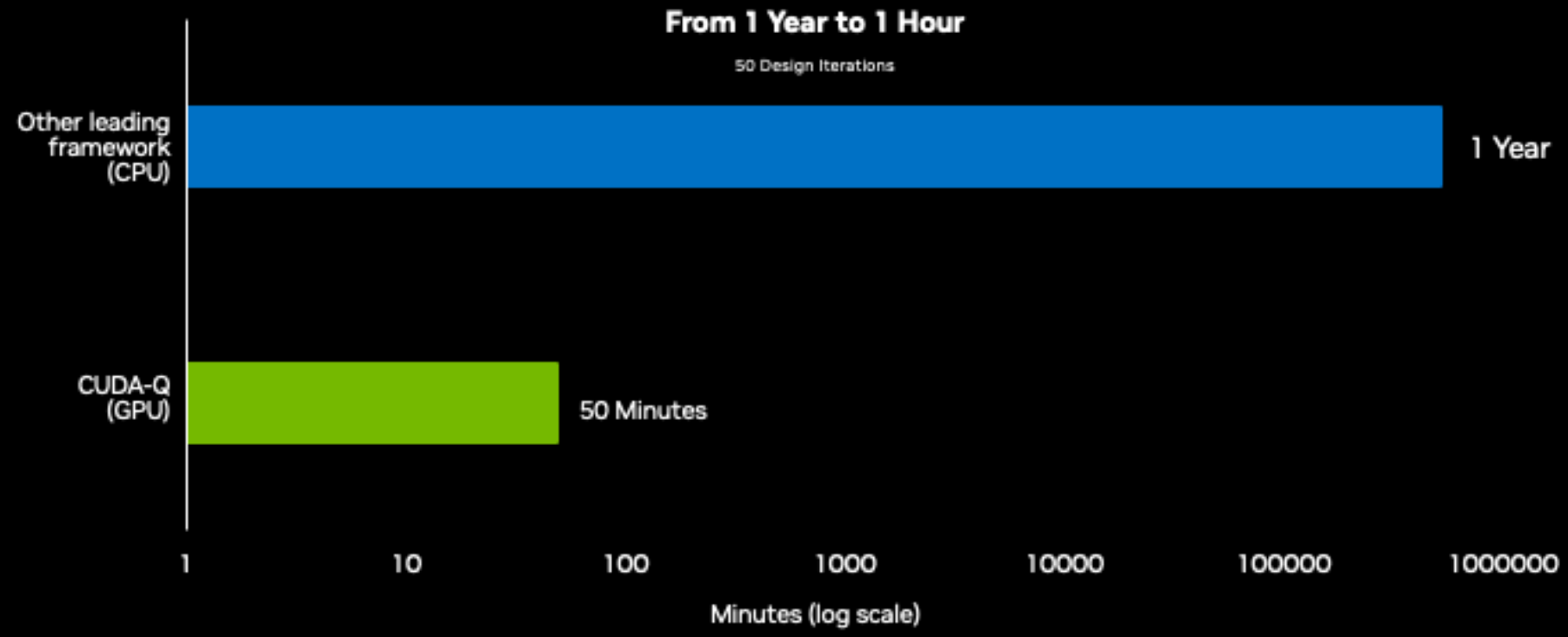
arXiv:2411.09131




1
0
1
1
0
1
1
0
Quantum
Processor

Dynamics in CUDA-Q

Enabling QPU developers everywhere to accelerate their design process

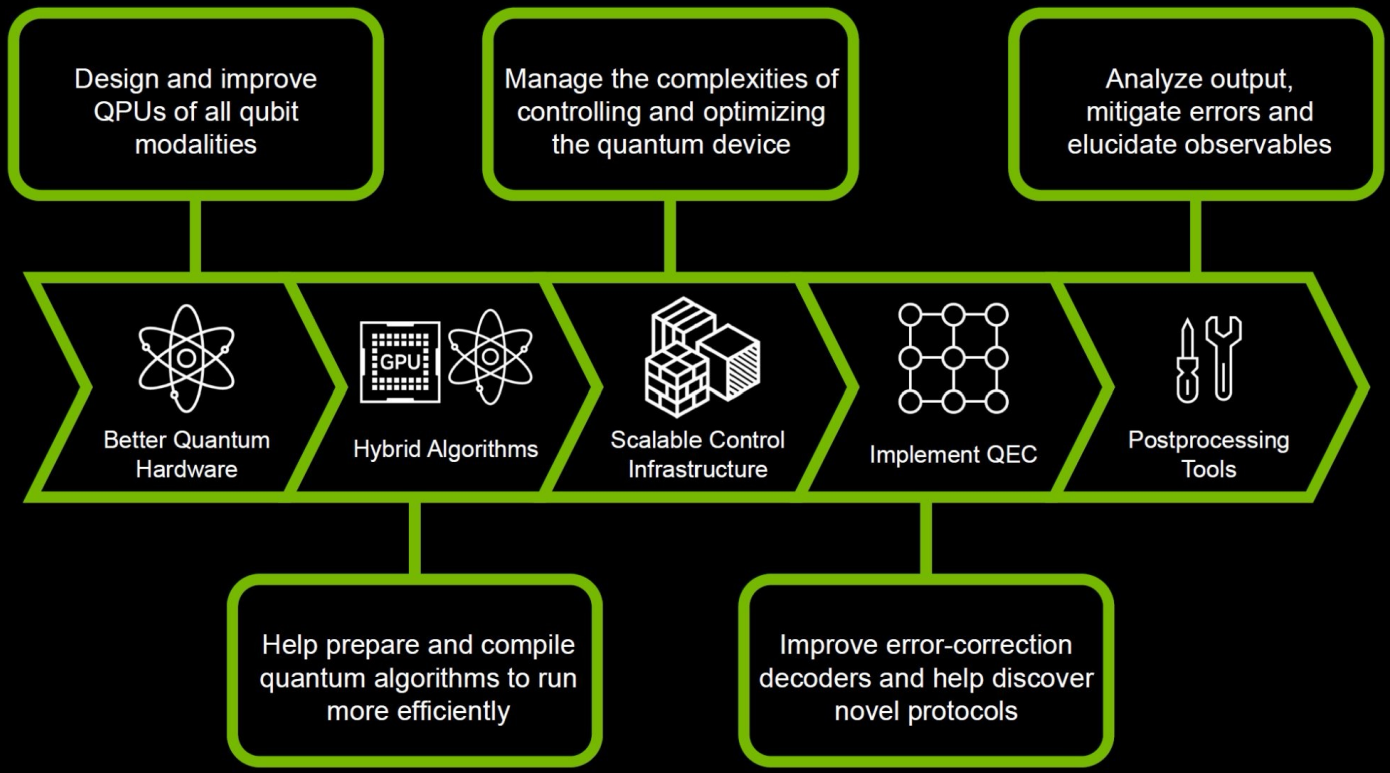


CPU: Intel Xeon 8480CL | GPU: DGX H100
Energy levels: 32 Transmon x 128 Resonator x 4 Purcell Filter

NVIDIA

Artificial Intelligence for Quantum Computing

arXiv:2411.09131

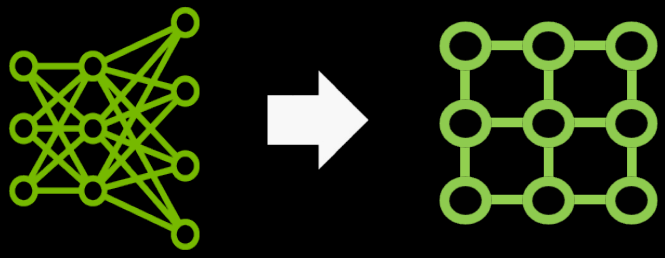


AI for Error Correction

AI-driven code generation and decoding

AI for code generation

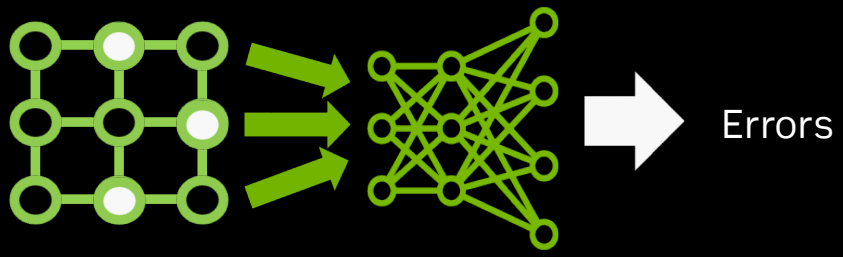
Error correcting code with specific properties are generated by reinforcement learning



Error correcting code

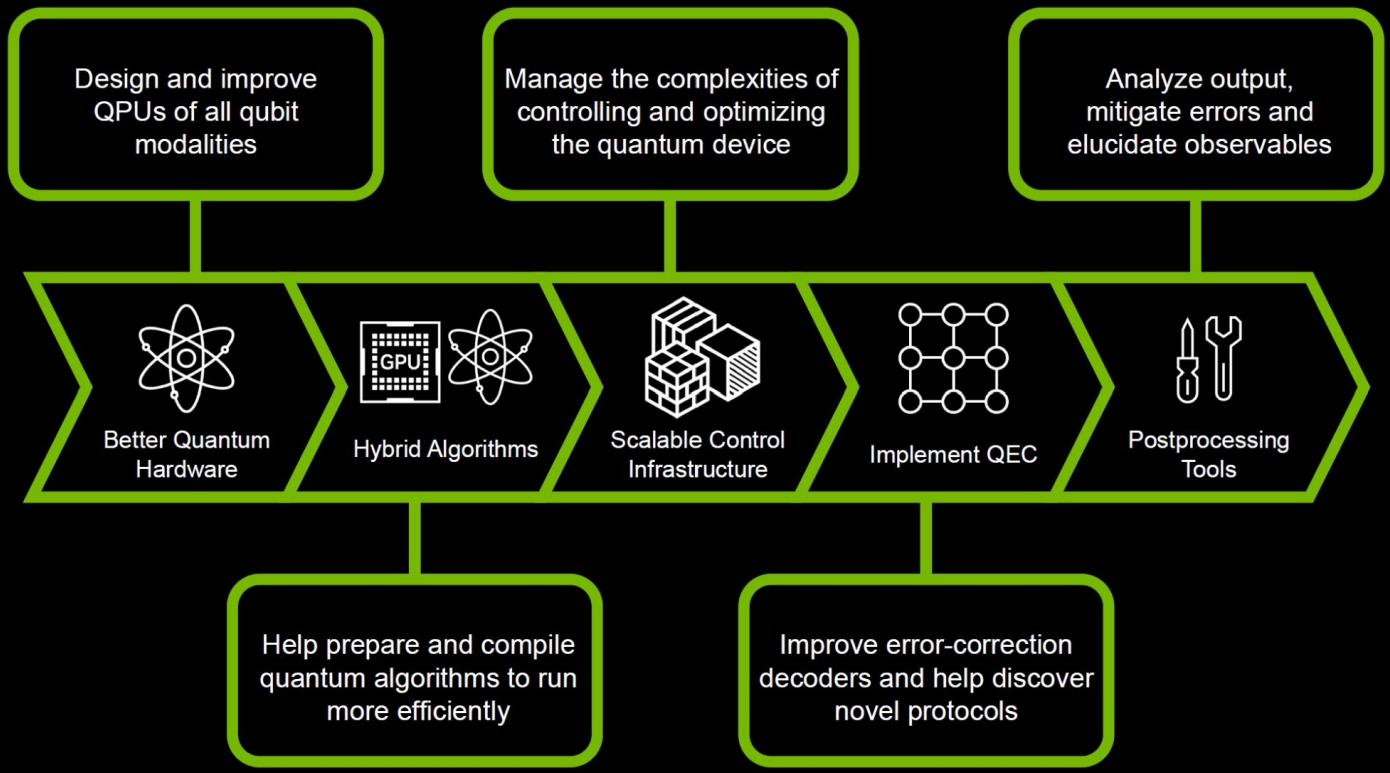
AI for decoders

The result of syndrome measurements are decoded by machine learning models



Artificial Intelligence for Quantum Computing

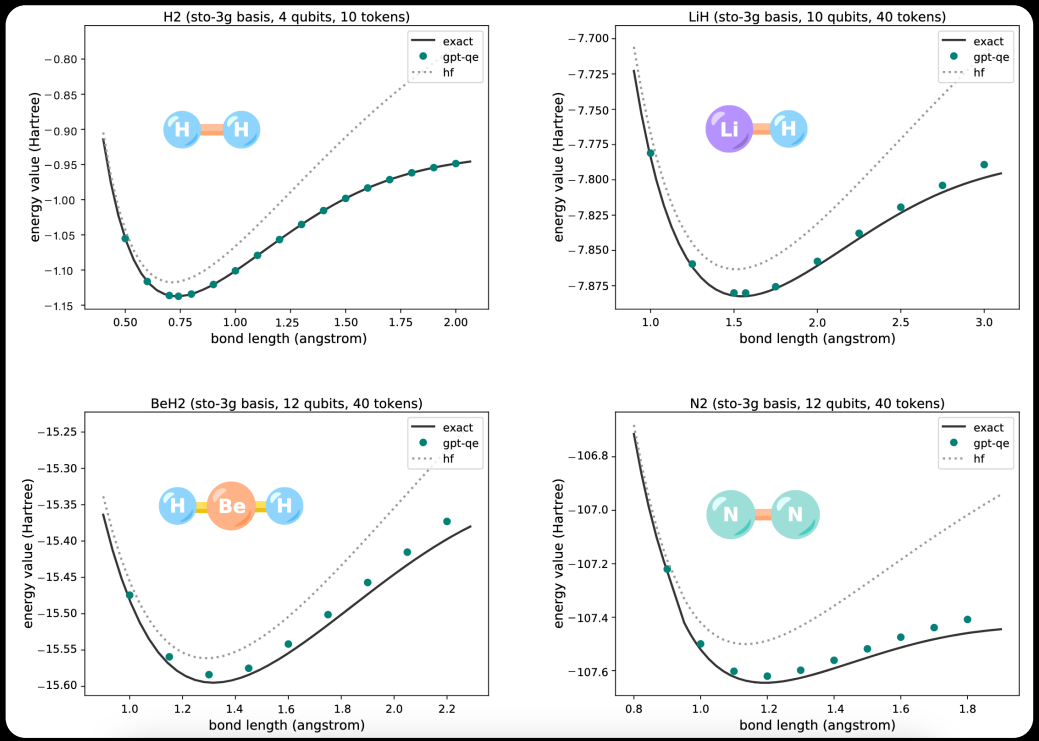
arXiv:2411.09131



Application to Ground State Search

GTP-QE used to generate circuits producing a molecular ground state

- **Clear example of leveraging AI for QC**
- **Executed using CUDA-Q on A100 GPUs in Perlmutter supercomputer**
- **Can be extended to variety of novel Generative Quantum Algorithms (GQAs)**
  - Potential extensions in drug discovery, materials science, and environmental applications.



UNIVERSITY OF TORONTO

St. Jude Children's Research Hospital
Finding cures. Saving children.

https://arxiv.org/pdf/2401.09253.pdf

NVIDIA

The Generative Quantum Eigensolver

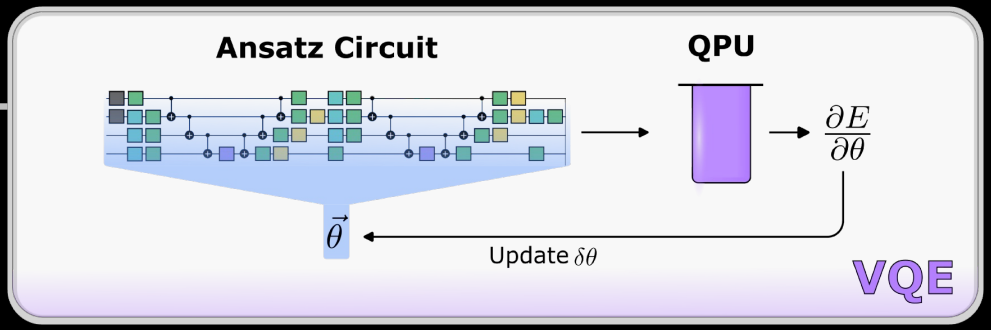
First demonstration of GPT-generated circuits in the literature

Goal: Find a circuit producing e.g. ground state
Optimization of some possible space of circuits for desired output

VQE

Optimization parameters are *part of quantum circuit*

- Leads to issues with local minima and barren plateaus



UNIVERSITY OF TORONTO

St. Jude Children's Research Hospital
Finding cures. Saving children.

https://arxiv.org/pdf/2401.09253.pdf

NVIDIA

The Generative Quantum Eigensolver

First demonstration of GPT-generated circuits in the literature

Goal: Find a circuit producing e.g. ground state
Optimization of some possible space of circuits for desired output

VQE

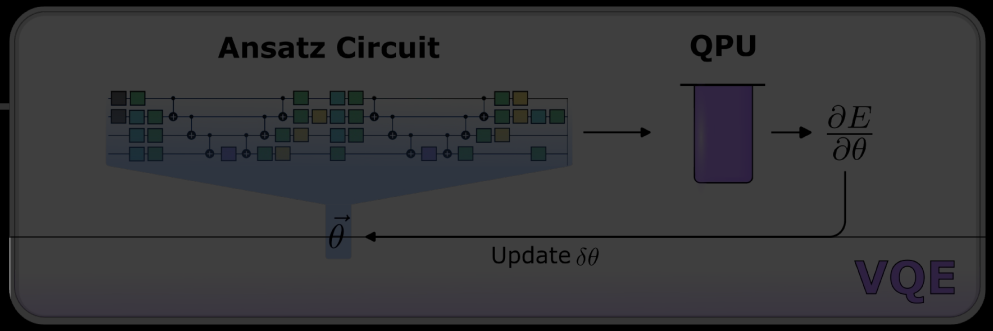
Optimization parameters are *part of quantum circuit*

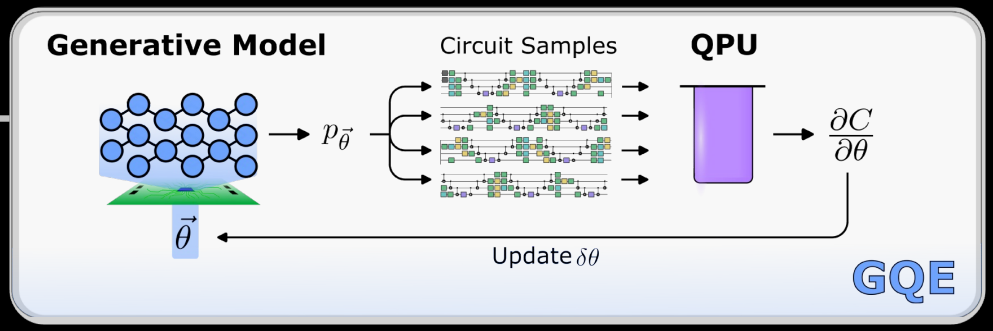
- Leads to issues with local minima and barren plateaus

GQE

Move cost-function *to DNN landscape*

- Training capabilities and scalability of classical models can overcome these limitations
- **GQE also allows potential of pretraining from database of circuit results**
  - Each training epoch creates more accurate circuits





UNIVERSITY OF TORONTO

St. Jude Children's Research Hospital
Finding cures. Saving children.

https://arxiv.org/pdf/2401.09253.pdf

NVIDIA

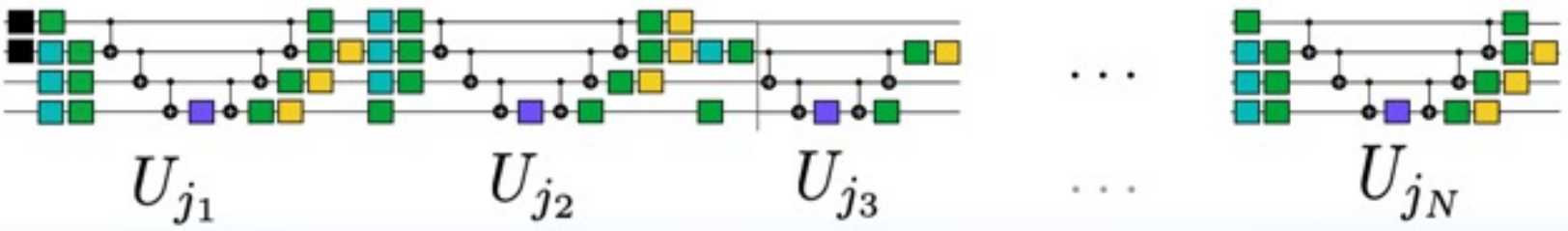
AI Assisted circuit design

$$\vec{j} \sim \text{"Once upon a time } \cdots \text{ happily ever after"}$$

$$\text{word}_{j_1}\ \text{word}_{j_2}\ \text{word}_{j_3}\ \text{word}_{j_4}\ \cdots\ \text{word}_{j_{N-2}}\ \text{word}_{j_{N-1}}\ \text{word}_{j_N}$$

LLM

$$\vec{j} \sim$$



GPT-QE

UNIVERSITY OF TORONTO

St. Jude Children's Research Hospital
Finding cures. Saving children.

https://arxiv.org/pdf/2401.09253.pdf

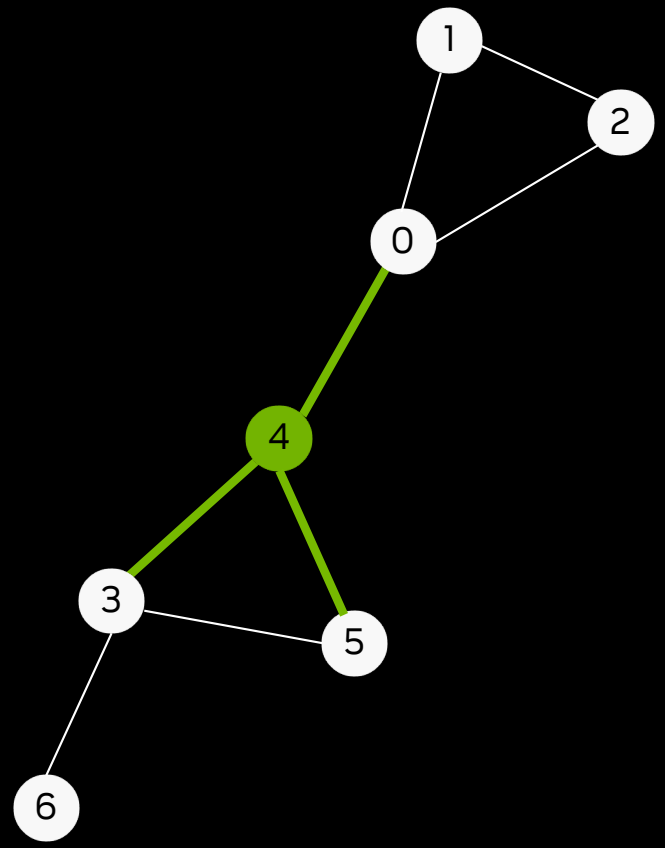
NVIDIA

Agenda

- Quantum circuits and quantum kernels
- AI for Accelerated Quantum Supercomputing
- Variational Algorithm Adaptive Circuit Knitting Example – QAOA Lab 1
- Resources to learn more

Max Cut Problem

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors



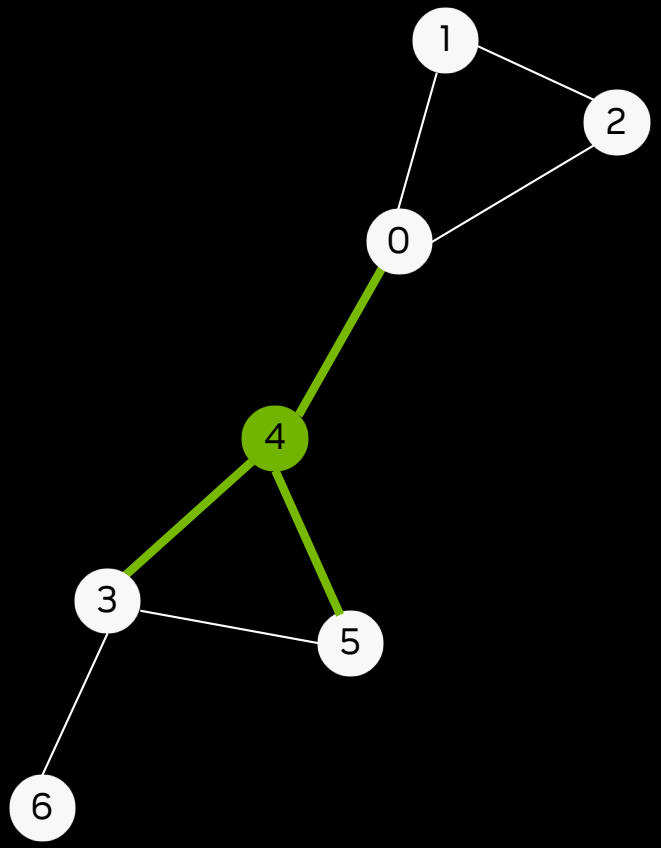
0
0
0
0
1
0
0

What's the max cut of this grah?

Max Cut Problem

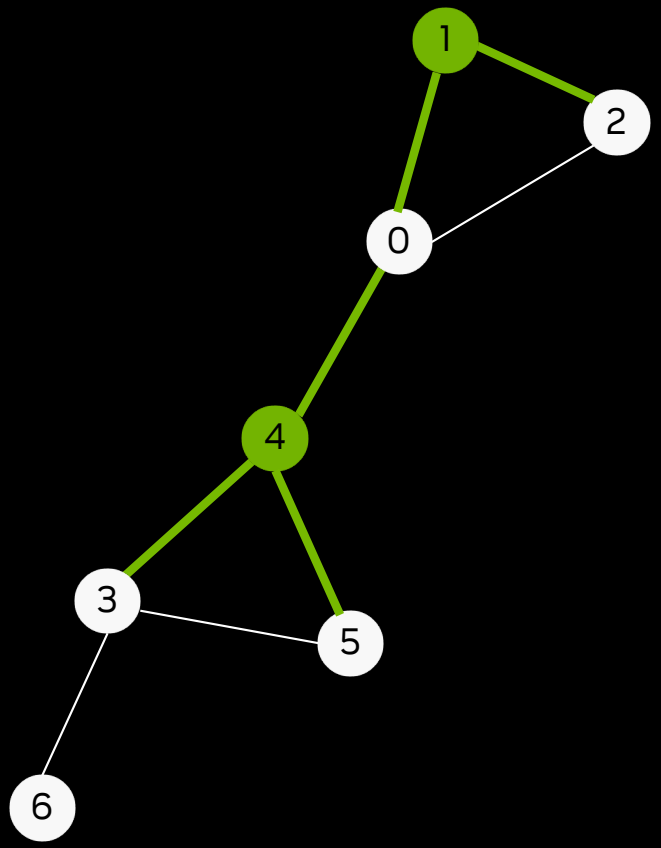
Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors

0
0
0
0
1
0
0



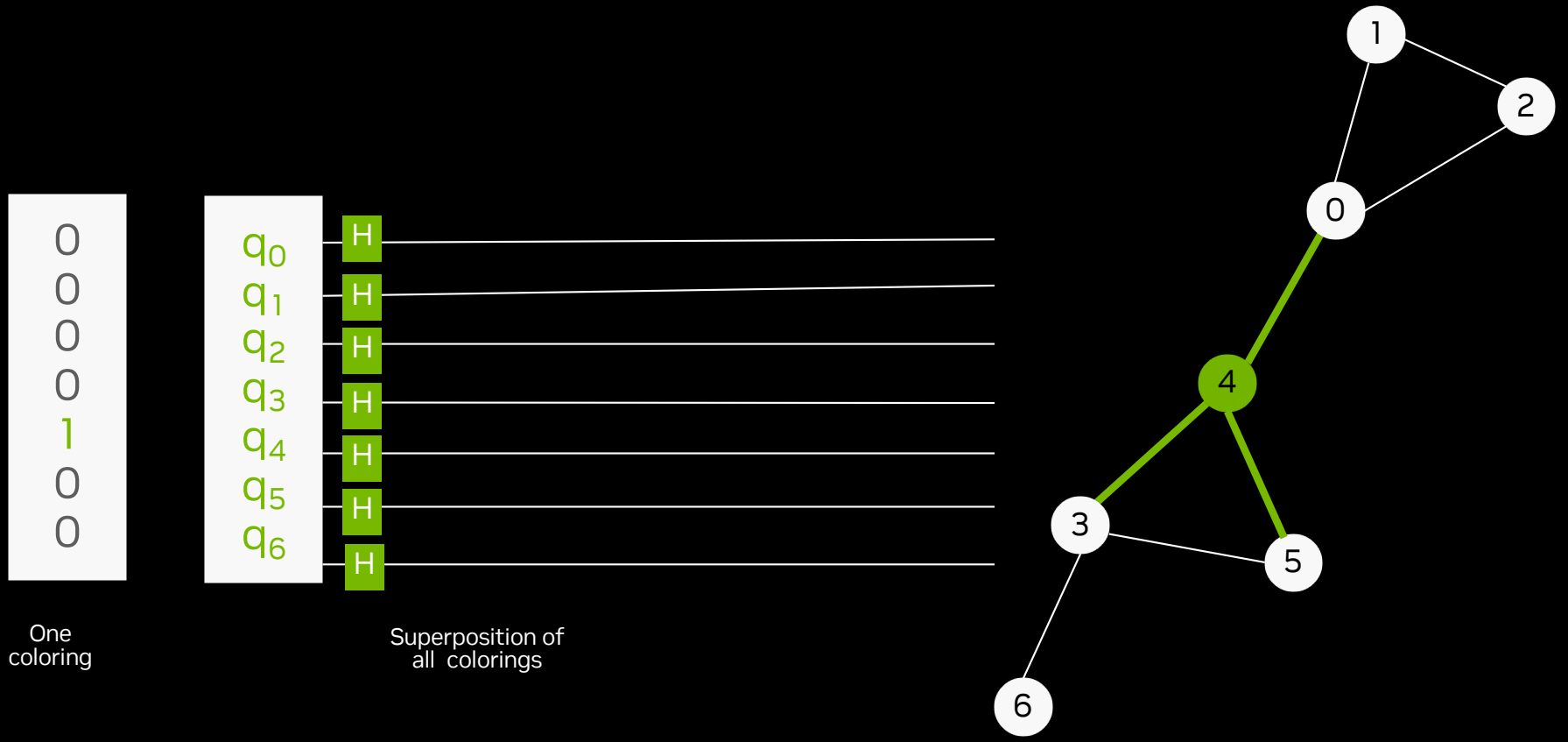
Max Cut Problem

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors



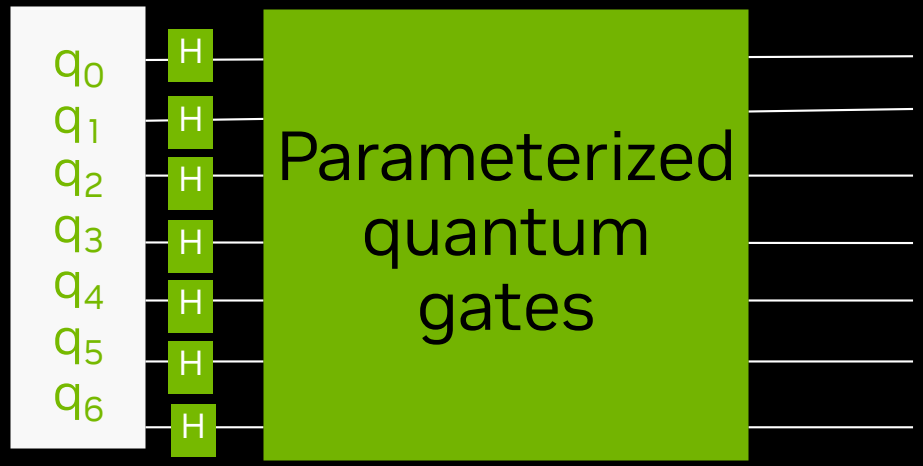
Max Cut Problem

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors

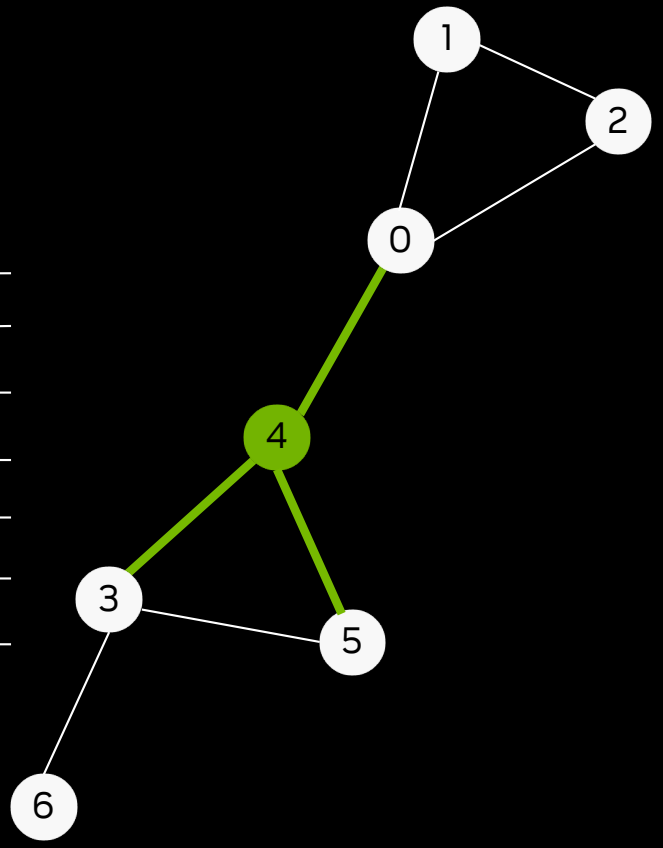


Max Cut Problem

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors

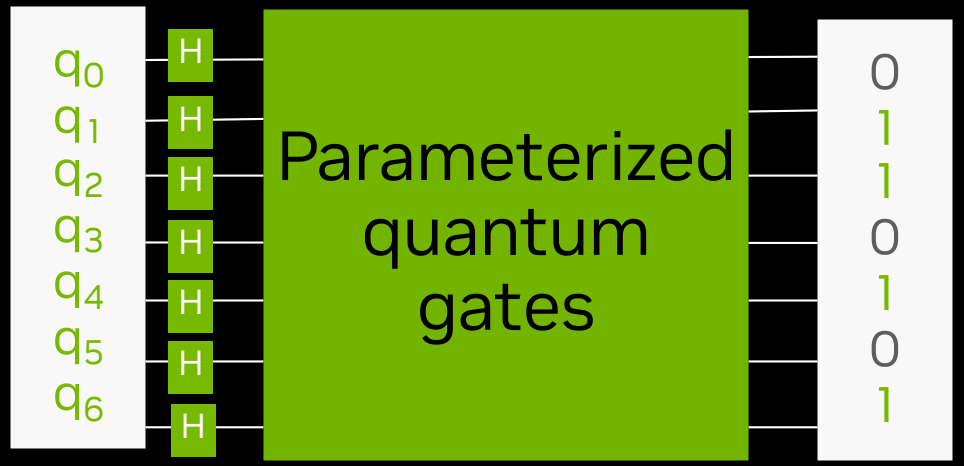


Apply gates to
amplify the good
colorings

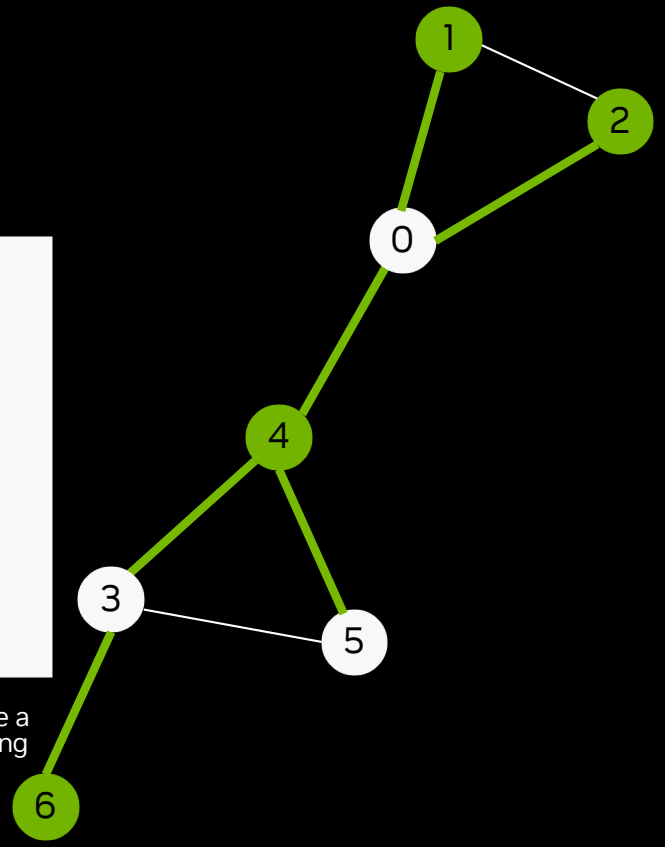


Max Cut Problem

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors



Aim: sample a good coloring

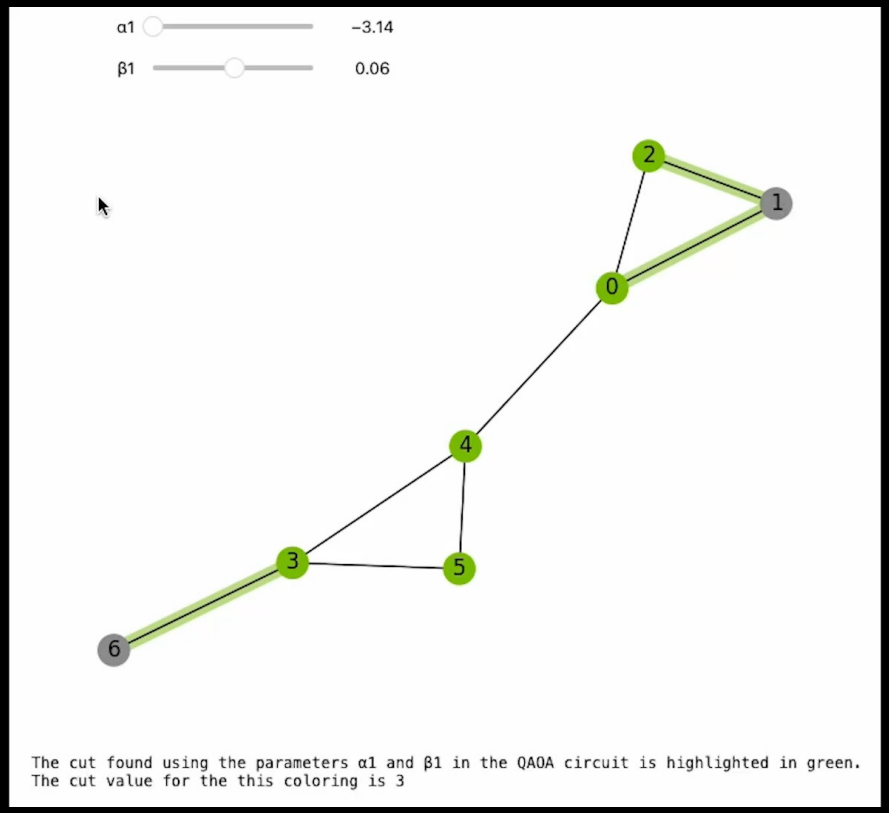


Learning the parameter values

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors

Quantum computation with parameters α1 and β1

0
1
0
0
0
0
1



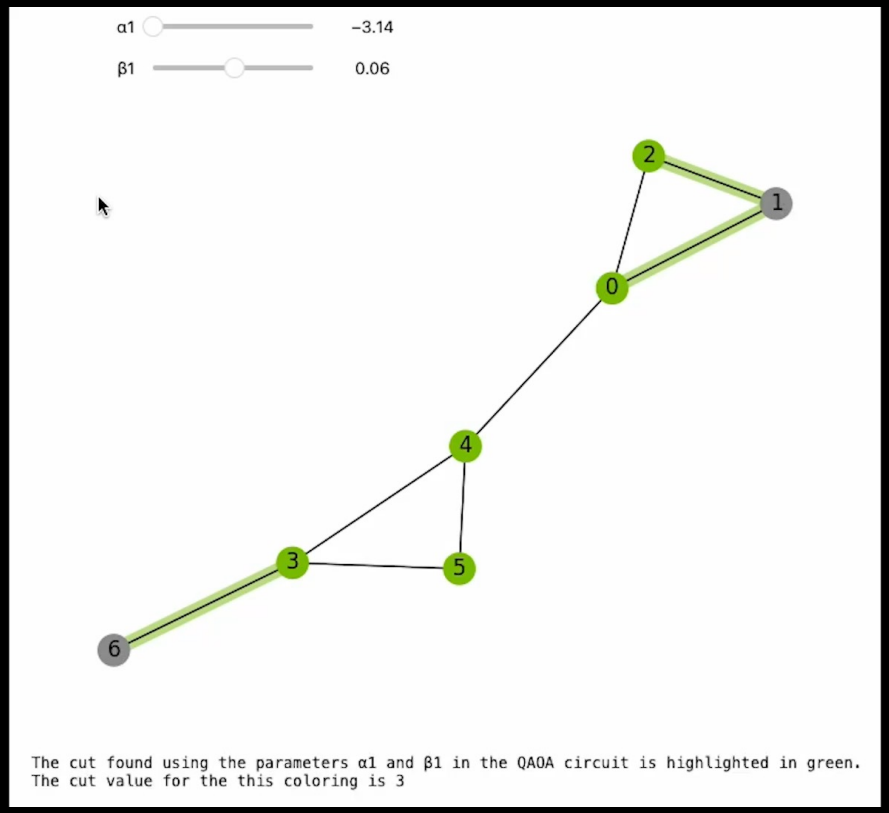
Learning the parameter values

Identify a 2-coloring of the vertices to
maximize the number of edges between vertices of different colors

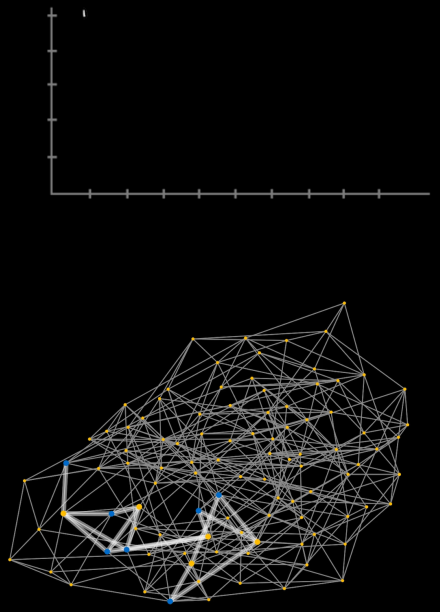
Quantum computation with parameters α1 and β1

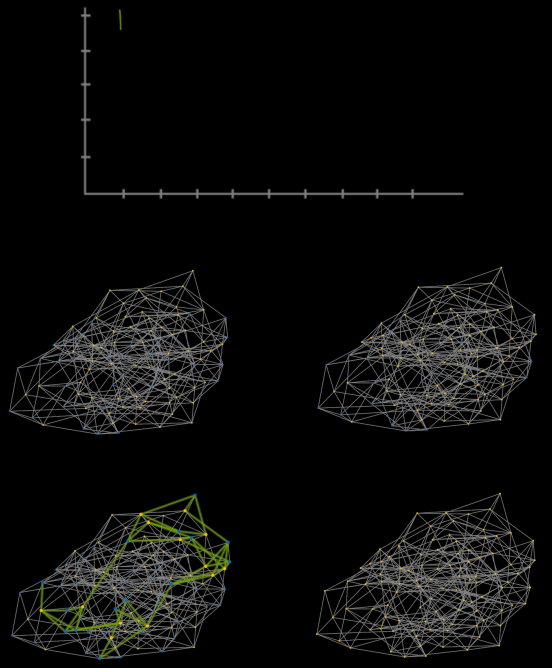
0
1
0
0
0
0
1

Classical optimizer to update parameter values

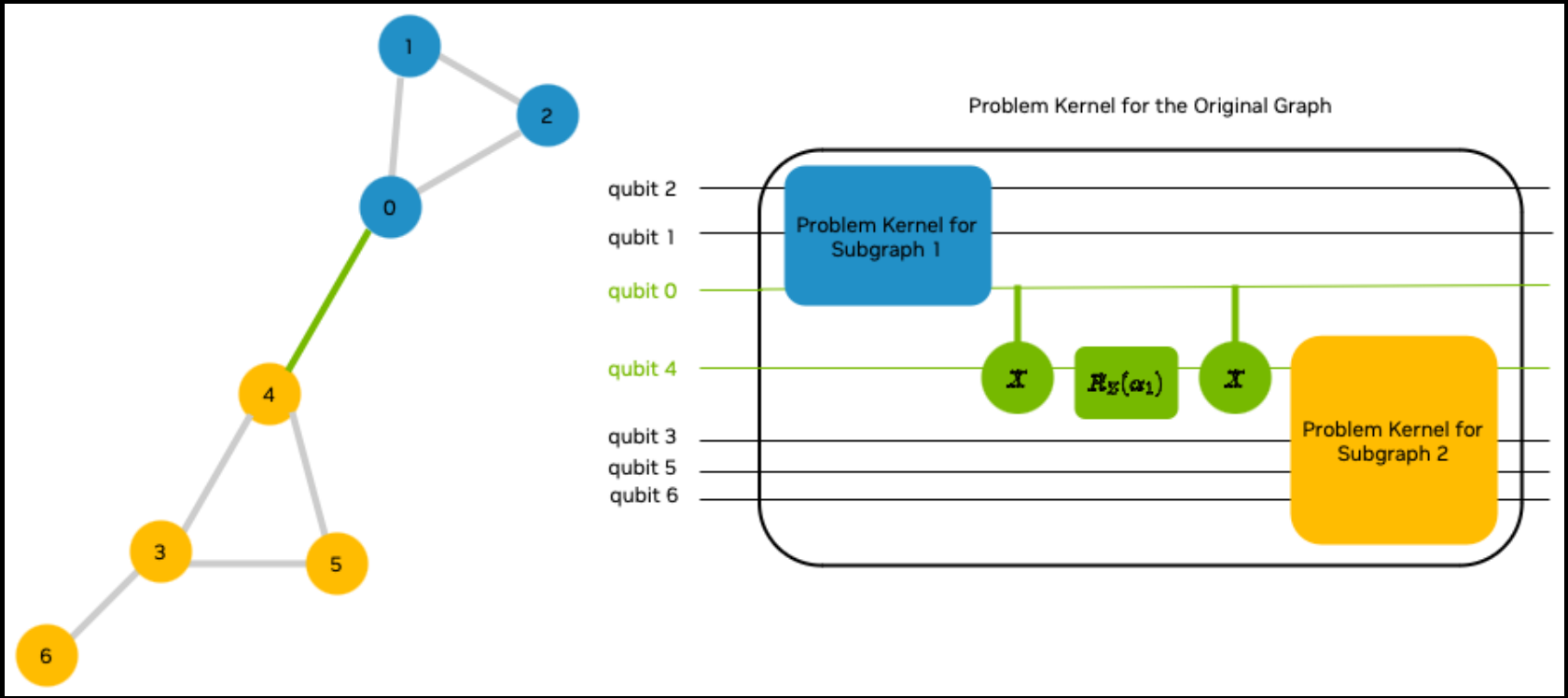


Max Cut Example to Illustrate Circuit Cutting

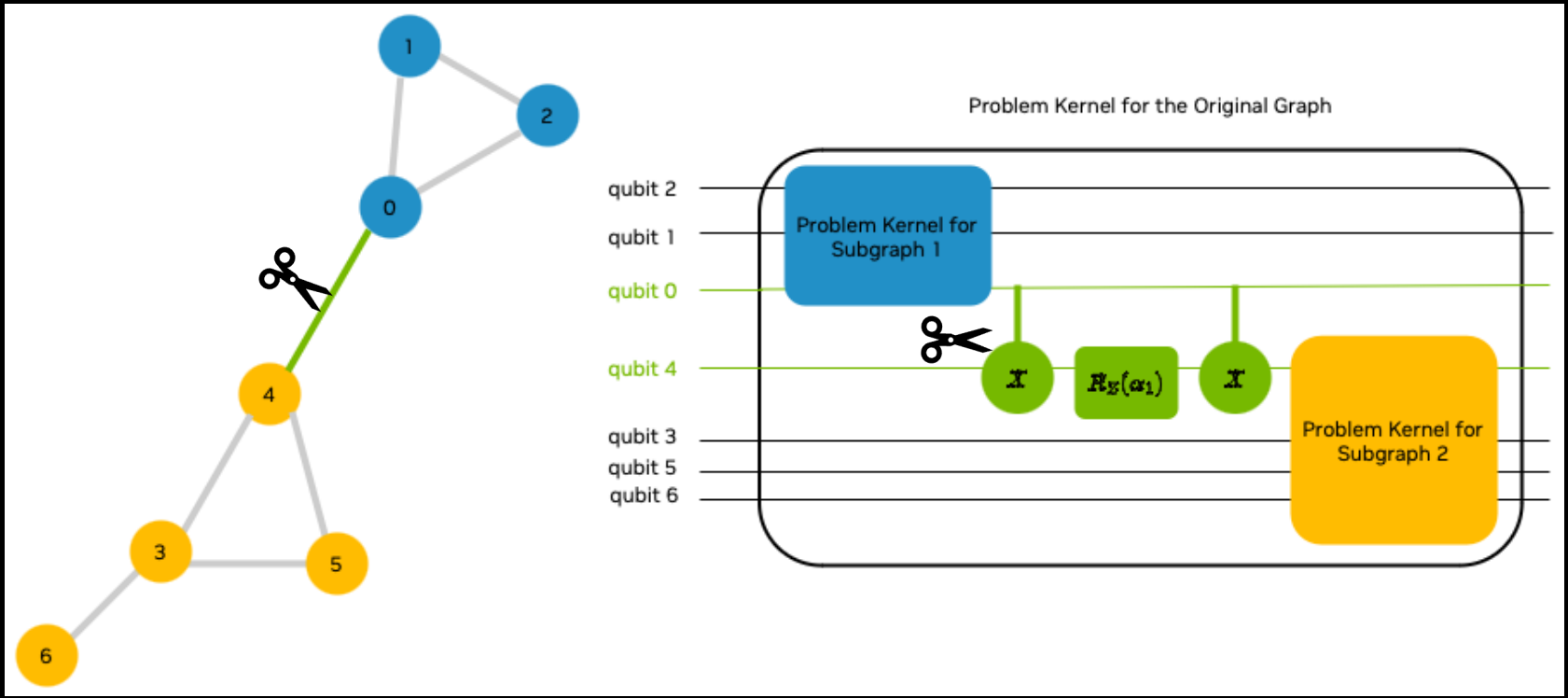




Visualizing Circuit Cutting



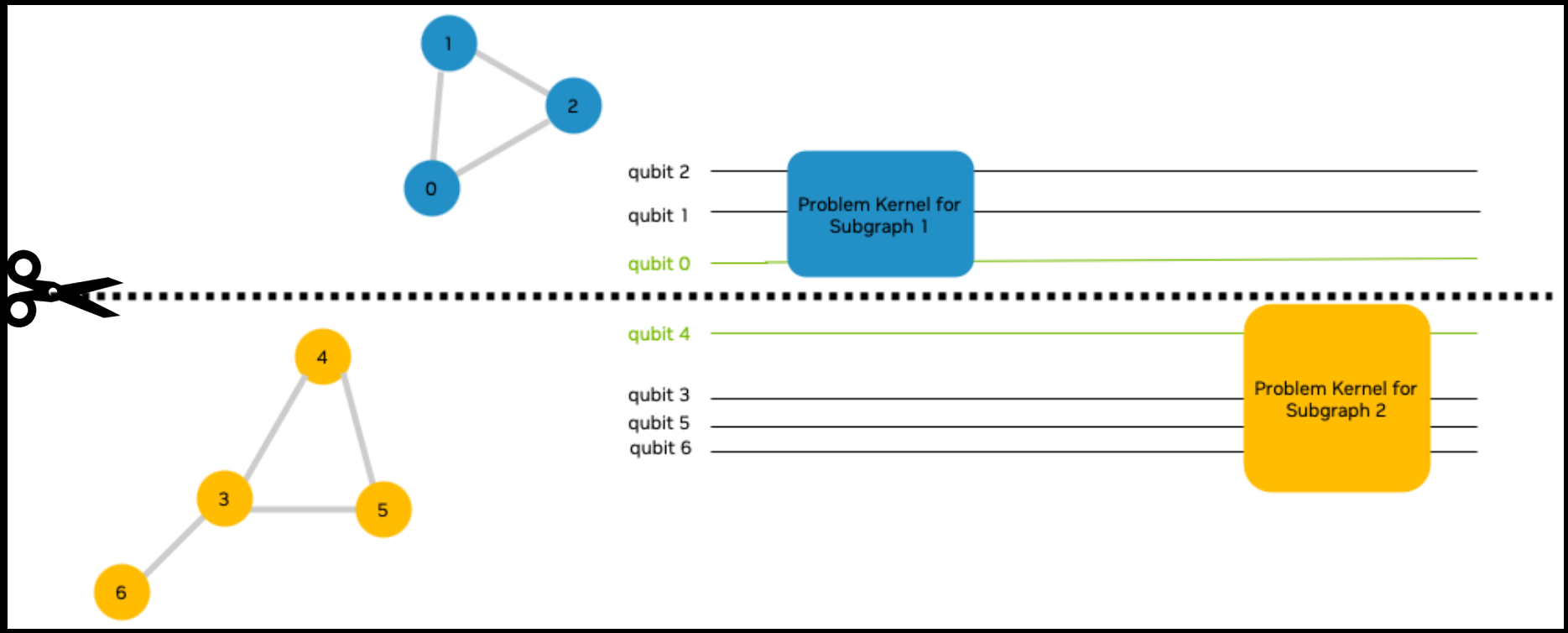
Visualizing Circuit Cutting



Dividing a Graph into Subgraphs

Cutting a Circuit into Subcircuits

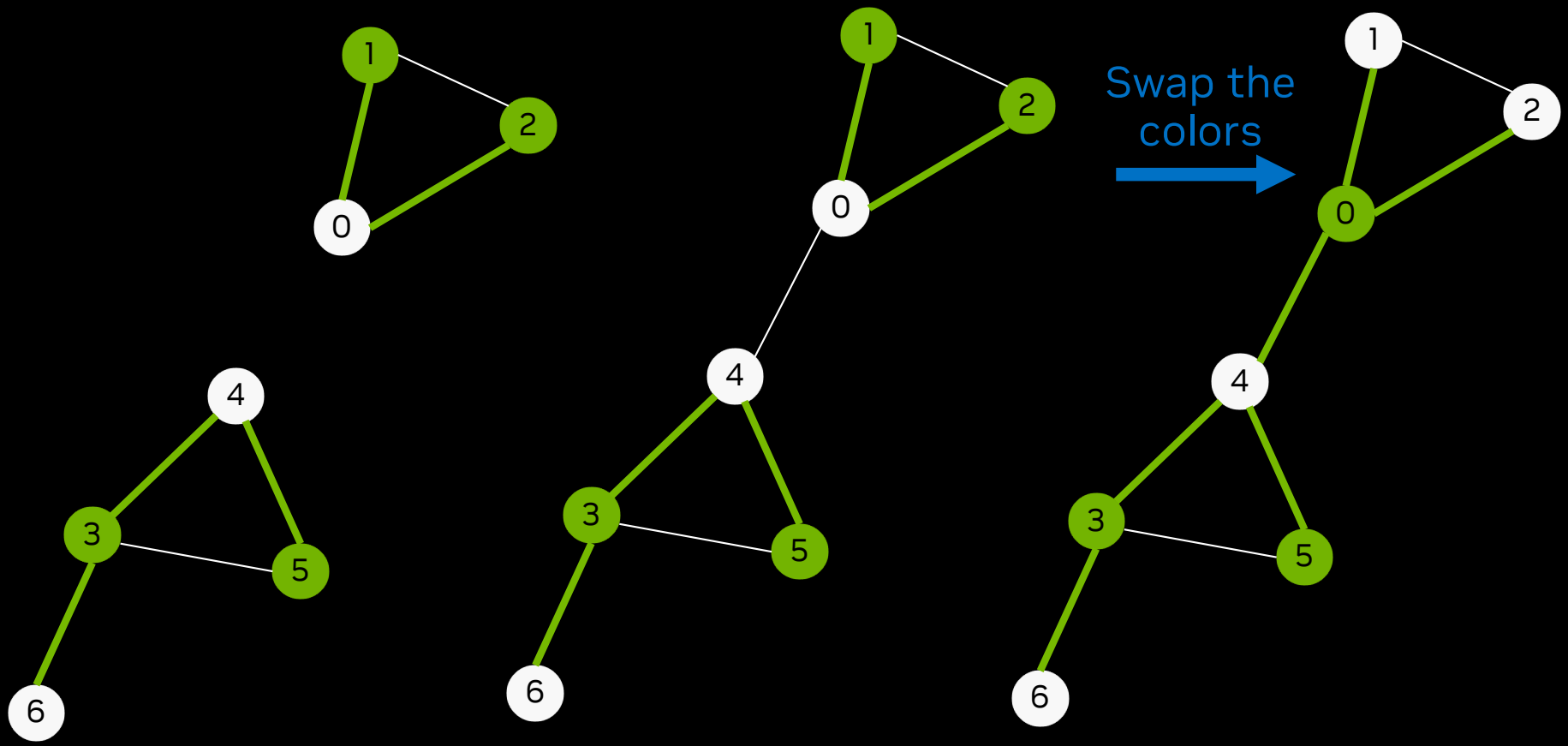
Visualizing Circuit Cutting



Dividing a Graph into Subgraphs

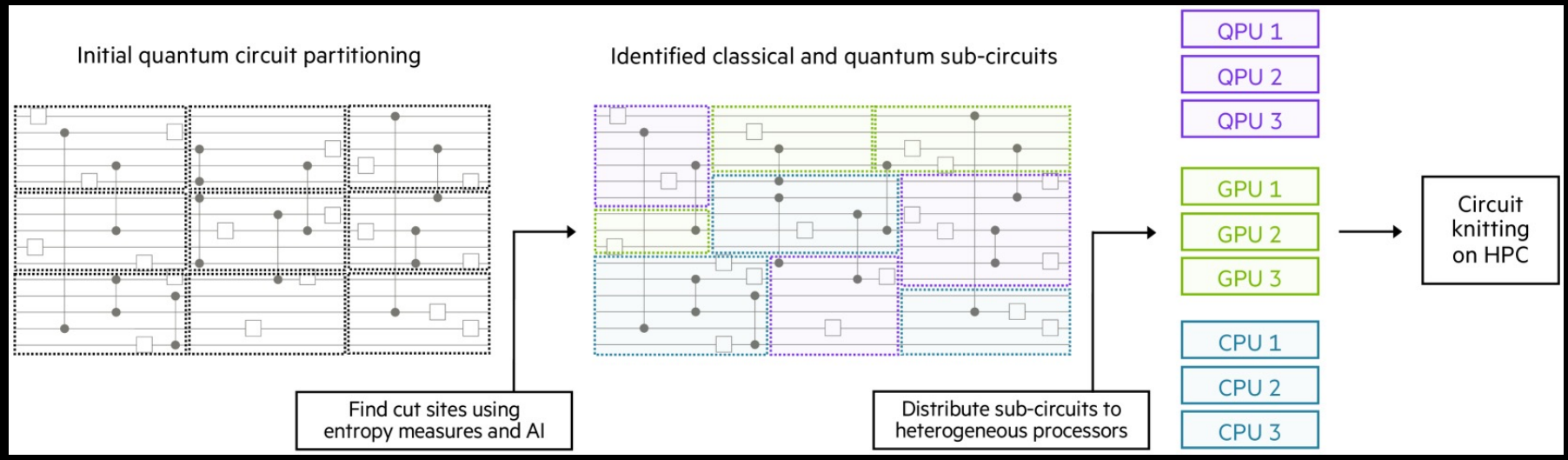
Cutting a Circuit into Subcircuits

Visualizing Circuit Knitting



Distributed Quantum Computing with Adaptive Circuit Knitting

To overcome the exponential overhead of traditional circuit knitting

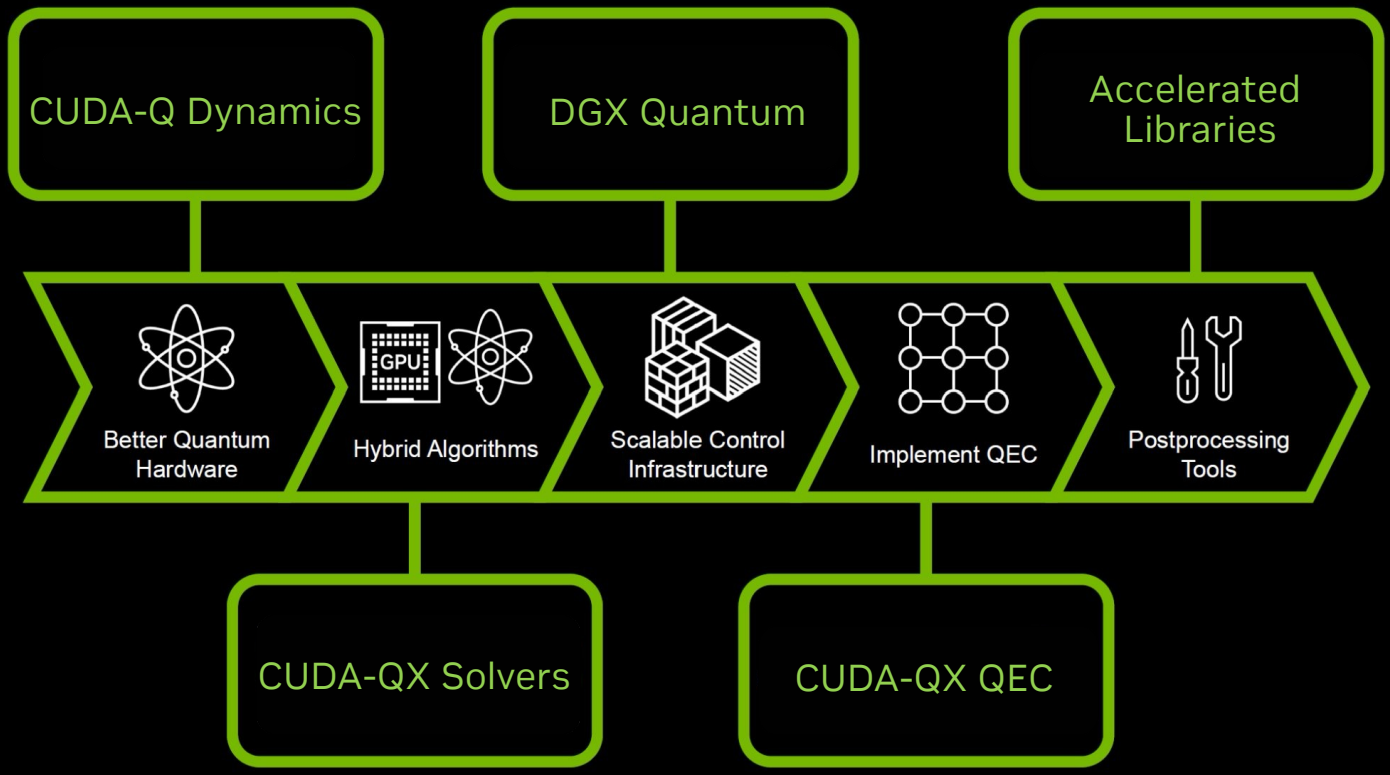


https://arxiv.org/abs/2411.10406

Agenda

- Quantum circuits and quantum kernels
- AI for Accelerated Quantum Supercomputing
- Variational Algorithm and Adaptive Circuit Knitting
- Resources to learn more about Accelerated Quantum Supercomputing

Artificial Intelligence for Quantum Computing

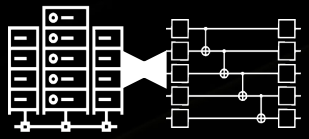


Quantum: Not Just for Physicists

Overcoming these challenges requires broad spectrum of expertise

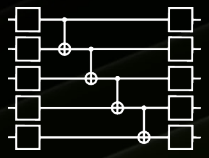
Qubit Fidelity
99.99% 2-Qubit Gate Fidelity

Qubit Scale
100k-1M+ Qubits for FTQC



HPC Integration
Sub-Microsecond HPC-QC Latency

Error Correction
Methods that Scale to Large Quantum Systems



Algorithms
Algorithms with Exponential Speed-up

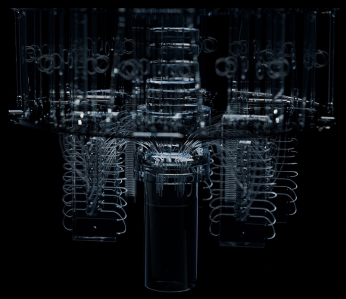
Developer Tools
Integrate with Scientific Computing
Familiar to non-Quantum Physicists

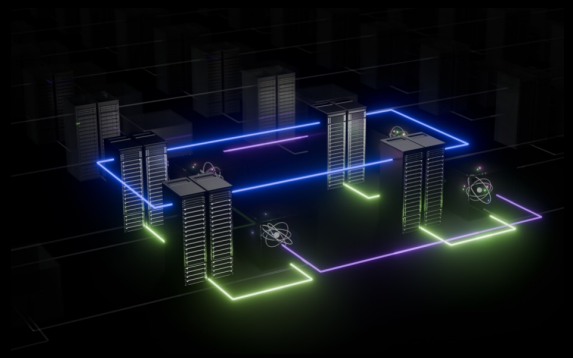
- Physicists
- Engineers
- Computer Scientists
- Developers
- Mathematicians
- Chemists
- Biologists
- Subject Matter Experts
- Students
- ...

NVIDIA

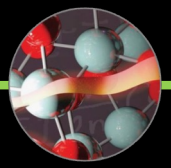
CUDA-Q Academic

https://github.com/NVIDIA/cuda-q-academic

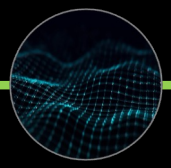




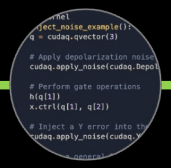
Today's Systems



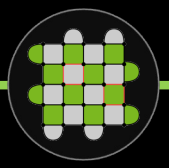
Quantum Algorithm and Hybrid Application Development



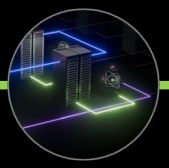
Qubit Design EDA



GPU Simulations to Generate Quantum Data



Quantum Error Correction



Quantum Computing Deployments

Accelerated Quantum Supercomputers

CUDA-Q Academic Modules

Quantum Applications to Finance	Dynamics 101	Quick Start to Quantum Computing	QEC 101	Divide and Conquer for Max Cut

NVIDIA

Find out more

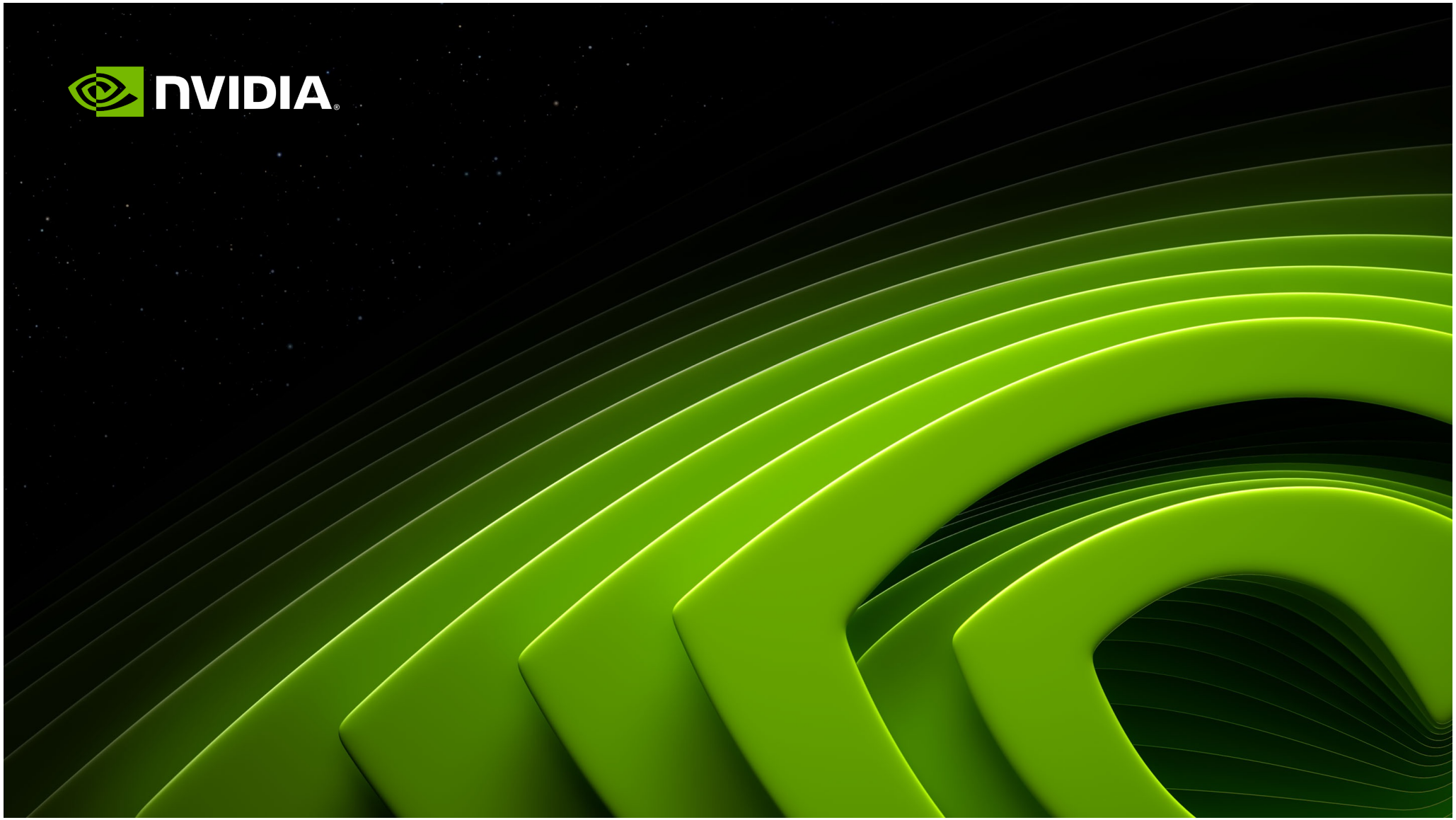
NVIDIA Quantum
https://www.nvidia.com/en-us/solutions/quantum-computing/

CUDA-Q v0.10 Now Available

Python – Install from PyPi
C++ – https://github.com/NVIDIA/cuda-quantum/releases

CUDA-Q Academic

Educational resources for CUDA-Q
(https://github.com/NVIDIA/cuda-q-academic)


NVIDIA