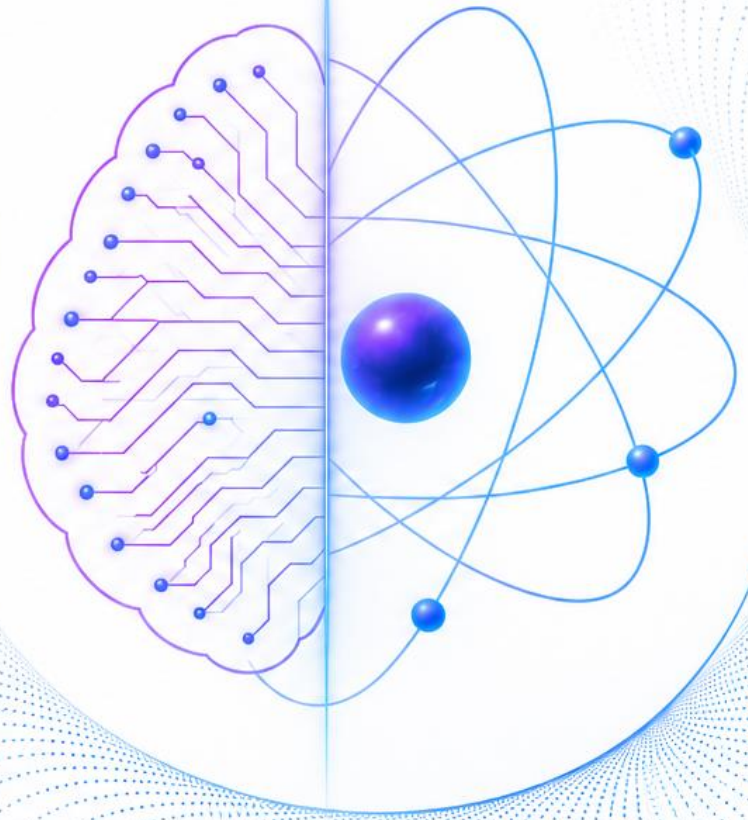
1

Quantum Computing for AI Engineers

Foundations, Limits, and Future Possibilities



Alireza Rahmani

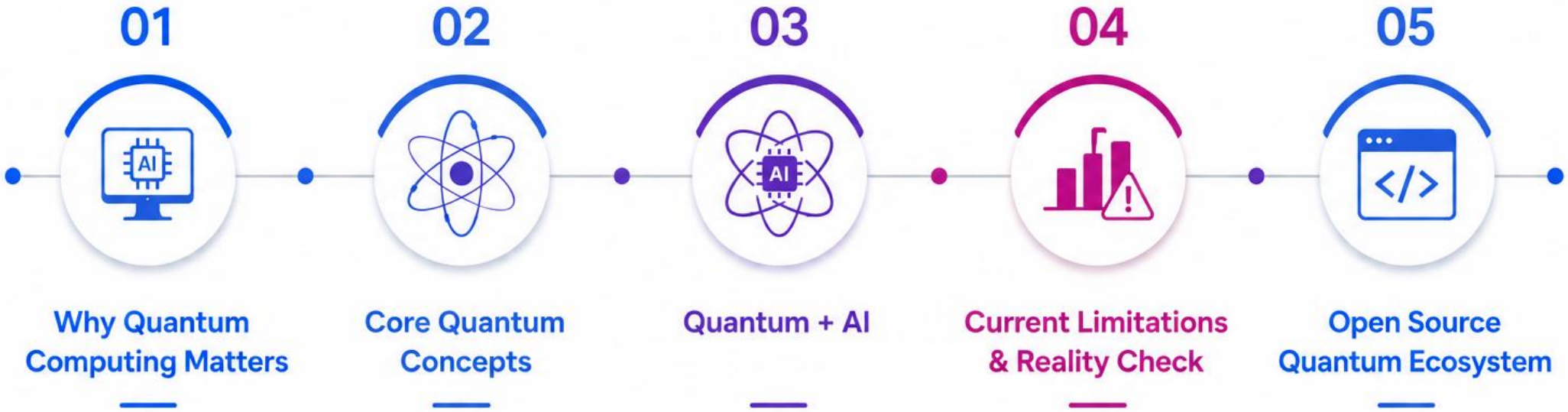
Senior cloud Architect – Red Hat

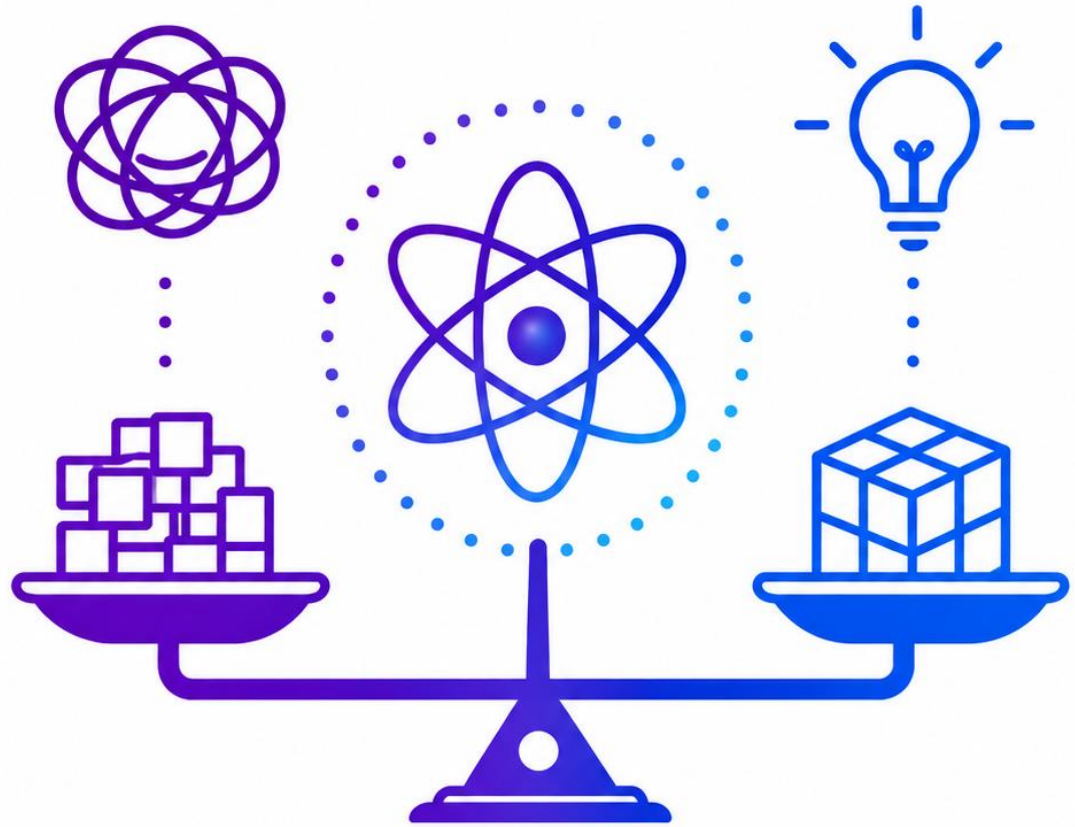
GOLDEN Kubestronaut

OPEN SOURCE SUMMIT NORTH AMERICA | 18–20 MAY 2026

Minneapolis

What We'll Explore





WHY QUANTUM COMPUTING IS MATTER

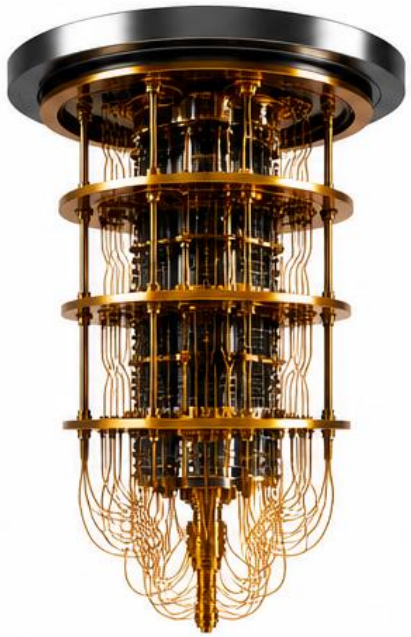
Evolution of Computing: Classical to Quantum

- Classical (Early)

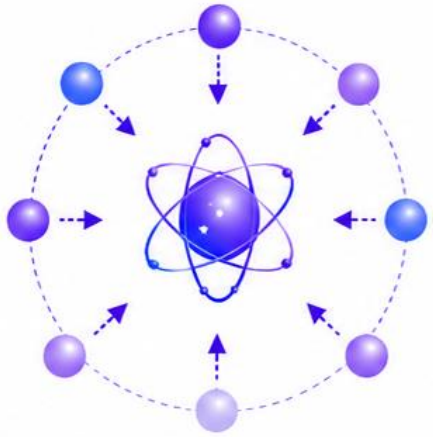
- Classical (Modern / AI Infrastructure)

- Quantum (New Paradigm)

QUANTUM COMPUTING VS CLASSICAL COMPUTING

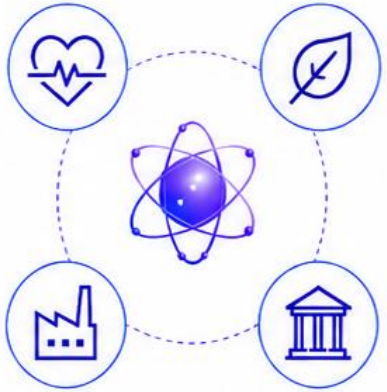


Why does quantum computing matter?

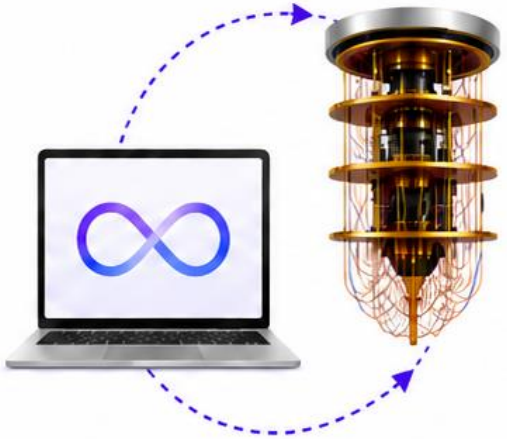


Parallel Exploration

Faster Discovery



Industry Applications



Future Innovation

QUANTUM COMPUTING USE CASES

DRUG DISCOVERY

OPTIMIZATION

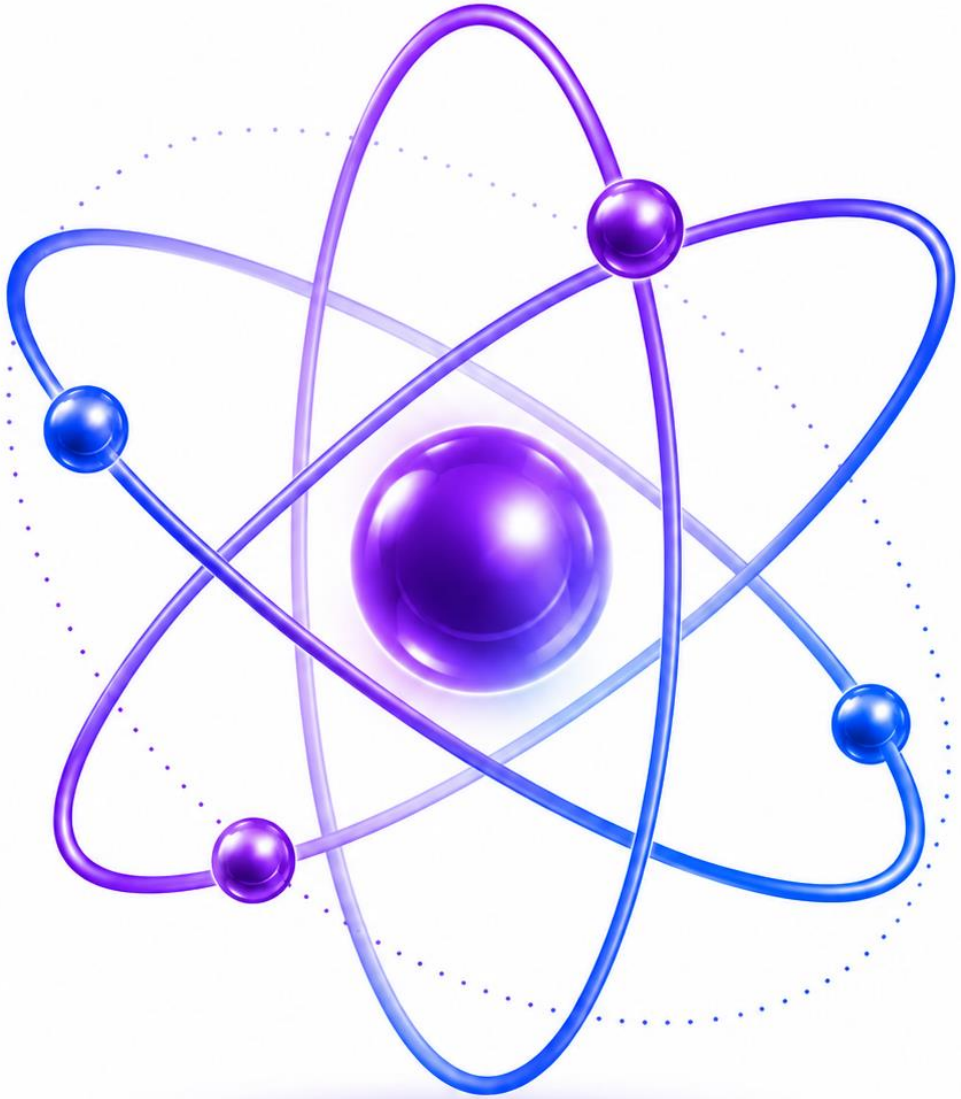
SIMULATION

MACHINE LEARNING (AI)

FINANCIAL MODELING

CRYPTOGRAPHY / SECURITY

ENERGY / TRAFFIC



CORE QUANTUM CONCEPTS

QUBIT: MORE THAN A BIT

CLASSICAL BIT

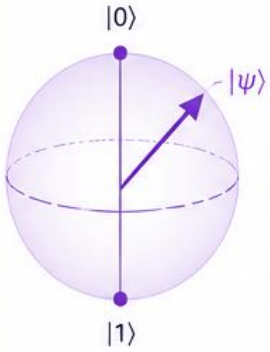
A bit can be only 0 or 1.

0 OR 1

State $|0\rangle$ State $|1\rangle$

QUBIT

A qubit can be in superposition of 0 and 1.



$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$

where $\alpha, \beta \in C$ and

$|\alpha|^2 + |\beta|^2 = 1$

Classic bit: definite 0 or 1

Qubit: probabilistic superposition of 0 and 1

CLASSICAL BIT

If the coin is on the table →
Heads $|0\rangle$ or Tails $|1\rangle$

Heads $|0\rangle$

Tails $|1\rangle$

A classical bit can be either 0 or 1,
It is in only one state at a time.

QUBIT

If the coin is spinning in the air →
it is both heads and tails
at the same time

Heads $|0\rangle$ and Tails $|1\rangle$

A qubit can be 0, 1, or both 0 and 1
at the same time (superposition).

Superposition

Qubits Can Exist in Multiple Probabilistic States Simultaneously

Classical Bit

In a classical system, a bit is **either 0 or 1.**

0

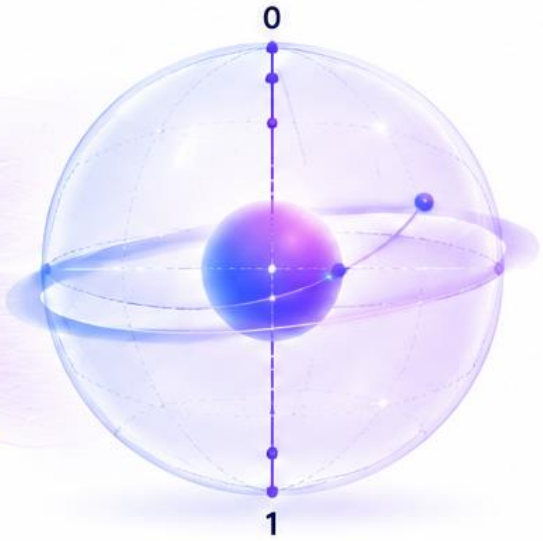
1

One state at a time

Superposition enables a qubit to be in **multiple states at once.**

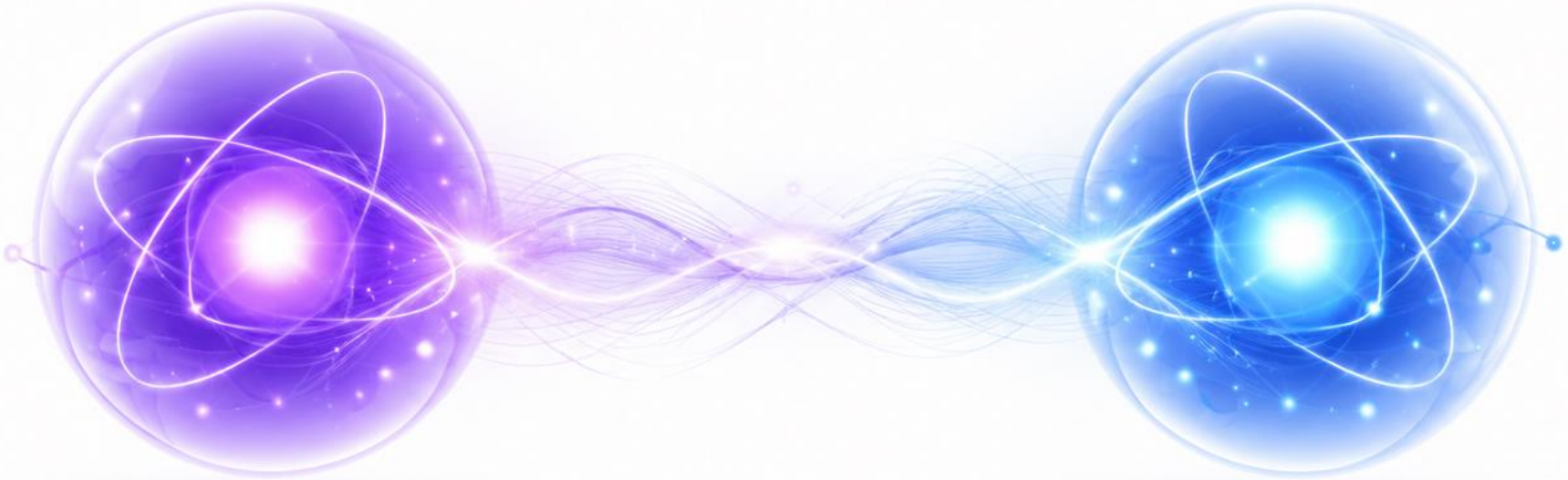
Qubit

In a quantum system, a qubit can be **0 and 1 at the same time.**



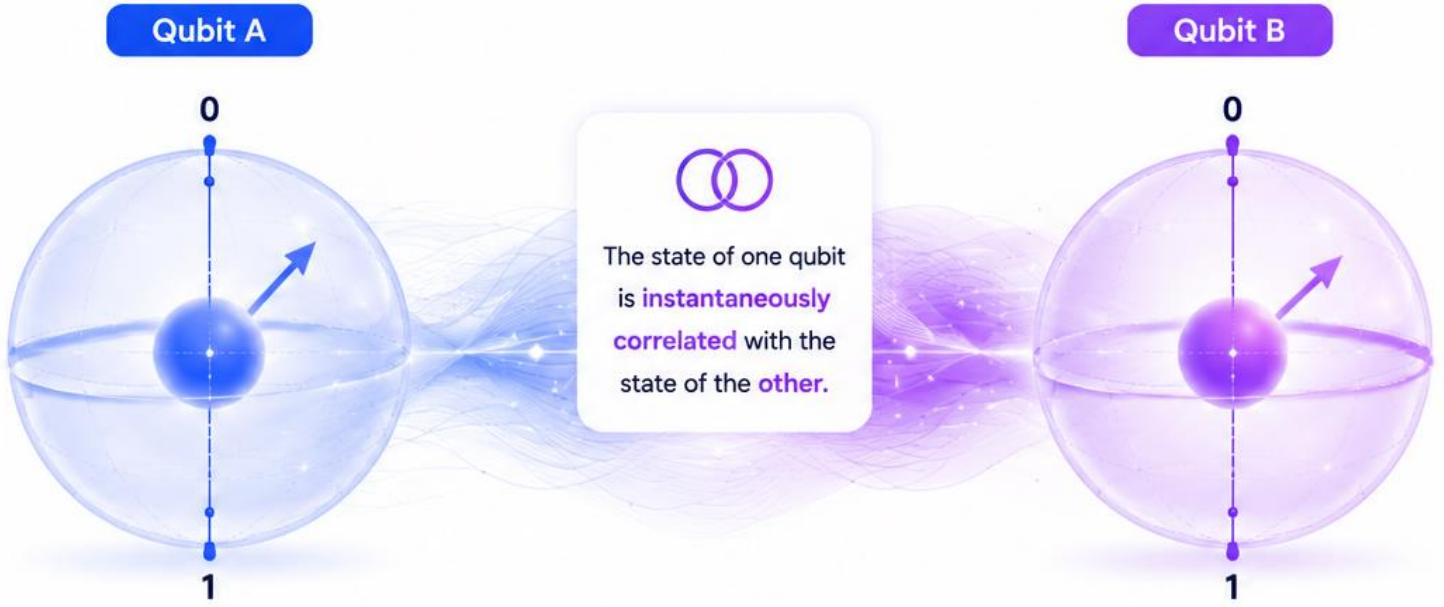
Multiple states simultaneously

ENTANGLEMENT



Entanglement

Entangled Qubits Are Deeply Connected, No Matter the Distance



Measure Qubit A

When measured, it collapses to **0 or 1.**

The state of one qubit is **instantaneously correlated** with the state of the **other.**

Qubit B Instantly Correlates

Its state is **instantly** determined, no matter how **far apart** they are.

Non-Local Correlation

Entangled qubits remain connected, regardless of the distance.

Stronger Than Classical

Entanglement has no classical explanation and enables unique quantum advantages.

Powerful Applications

Enables quantum communication, distributed computing, and advanced sensing.

Foundation of Quantum Power

Many quantum algorithms and protocols rely on entanglement to deliver exponential impact.

COMMON QUANTUM GATES

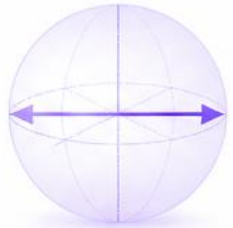
1

HADAMARD (H)

Superposition

2

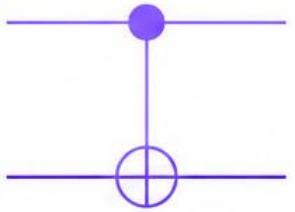
PAULI-X (X)



Flip

3

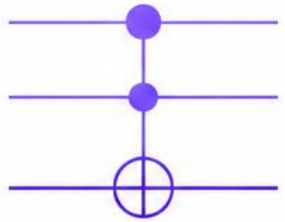
CNOT

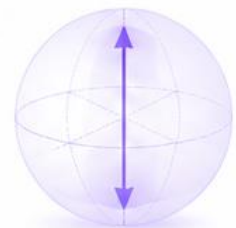


Control

4

TOFFOLI (CCNOT)

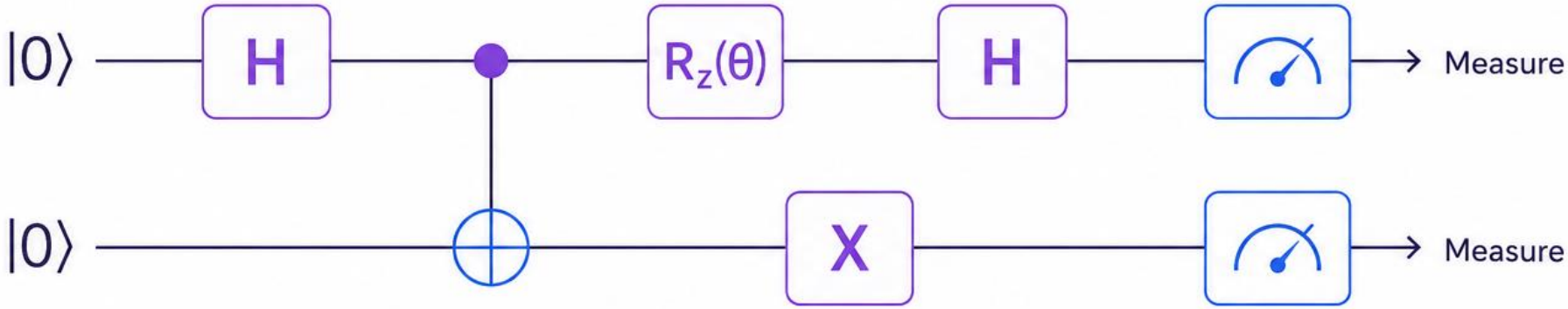




Controlled-Controlled-NOT

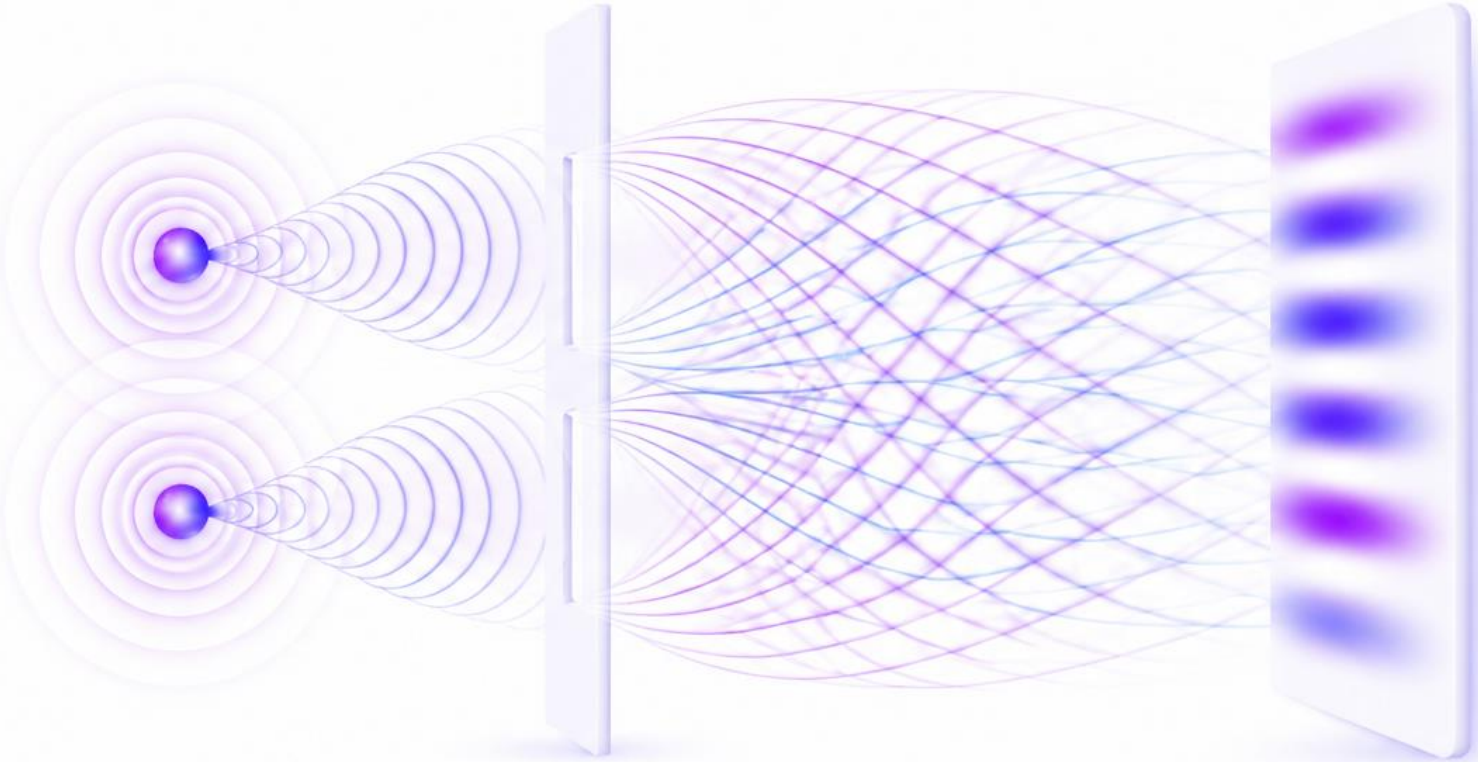
QUANTUM CIRCUIT

Sequence of quantum gates

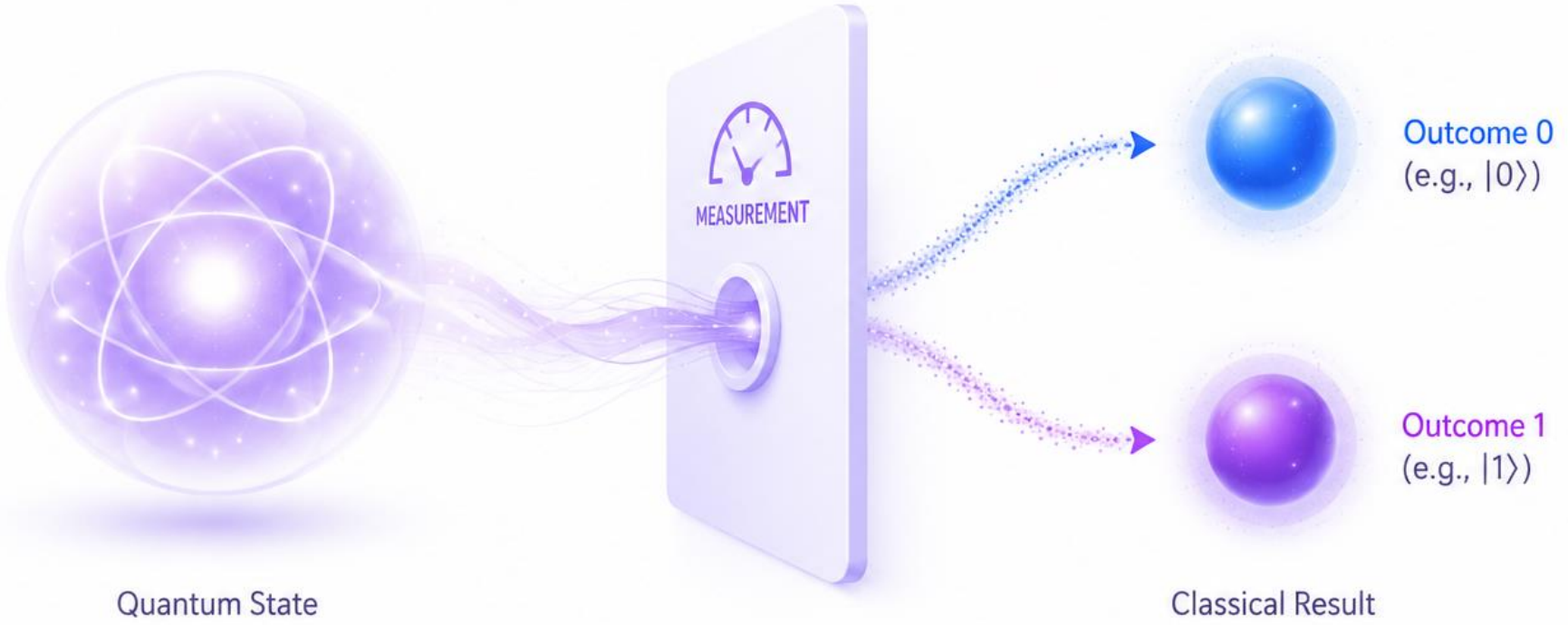


H	$R_z(\theta)$	X	⊕	
Hadamard (H)	Rotation Z (Rz)	Pauli-X (X)	CNOT	Measurement

INTERFERENCE



MEASUREMENT

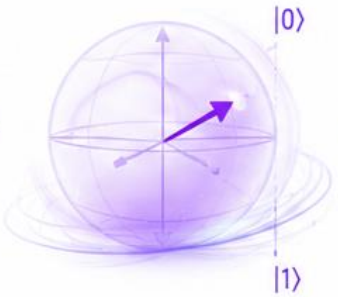


HOW DO QUBITS WORK IN QUANTUM COMPUTING?

1 INITIALIZATION

Qubits start in a known state, typically |0⟩.

2 SUPERPOSITION

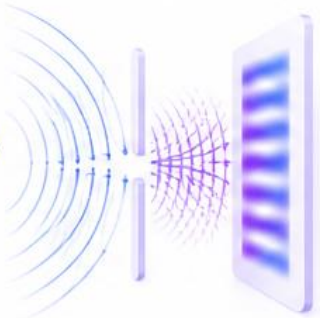


Qubits are put into superposition of |0⟩ and |1⟩.

3 ENTANGLEMENT

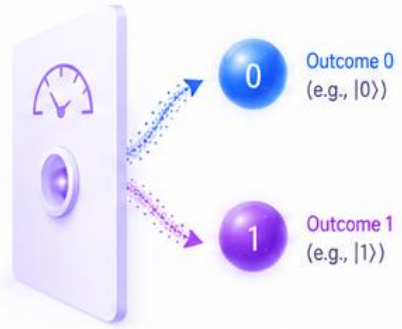
Qubits become entangled, correlating their states instantaneously.

4 INTERFERENCE



Probabilities interfere—amplifying correct outcomes and canceling incorrect ones.

5 MEASUREMENT



Measurement collapses the qubit state to |0⟩ or |1⟩ with certain probability.

QUANTUM ALGORITHMS

How they work

1

EXPLORE

Use superposition to explore many possibilities

2

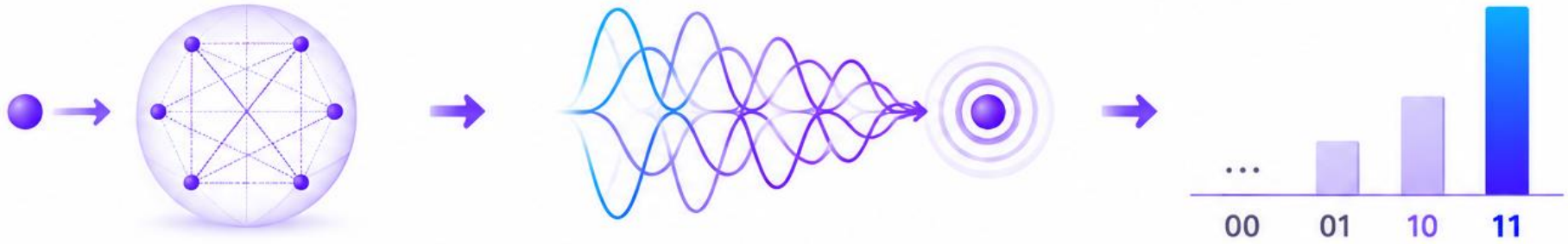
AMPLIFY

Use interference to amplify correct answers

3

SELECT

Measure to obtain the best solution



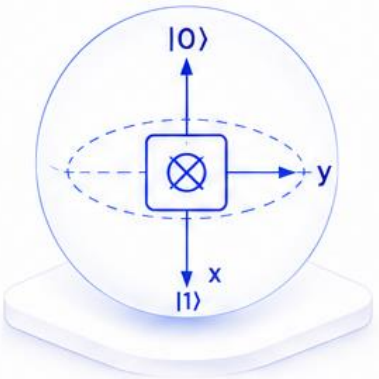
FAMOUS EXAMPLES

Shor's Algorithm
Factoring large numbers

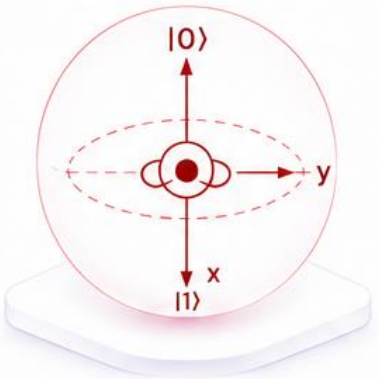
Grover's Algorithm
Unstructured search

QAOA (Variational)
Optimization problems

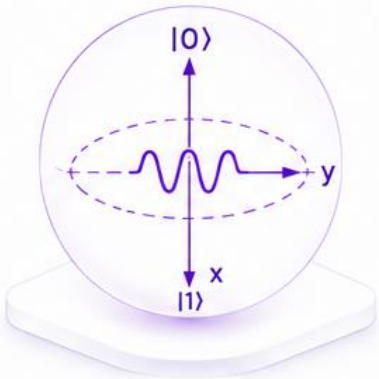
TYPES OF QUBITS



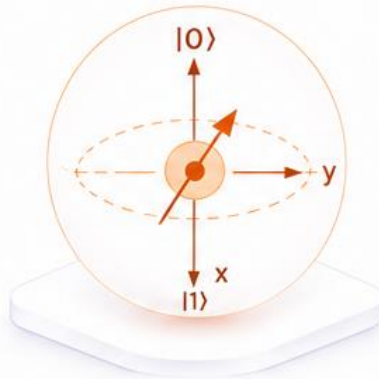
Superconducting Qubit



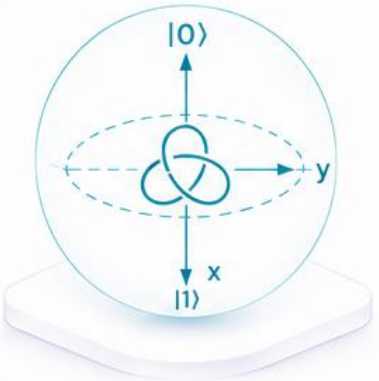
Trapped Ion Qubit



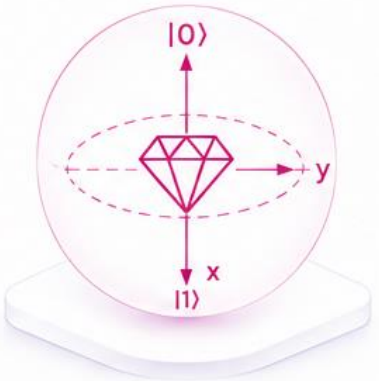
Photonic Qubit



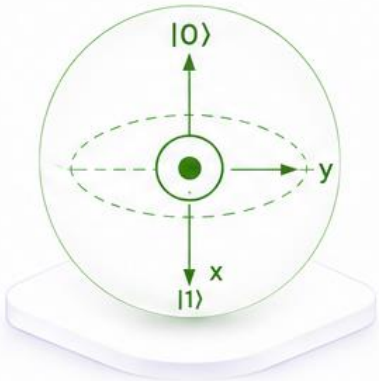
Spin Qubit
(Semiconductor)



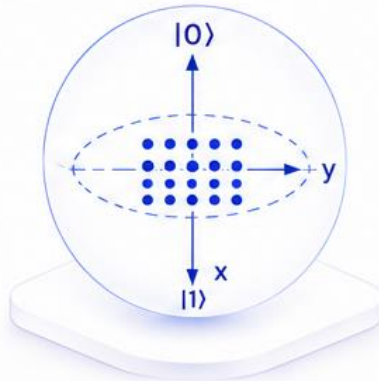
Topological Qubit



Diamond Vacancy
Qubit (NV Center)



Neutral Atom Qubit

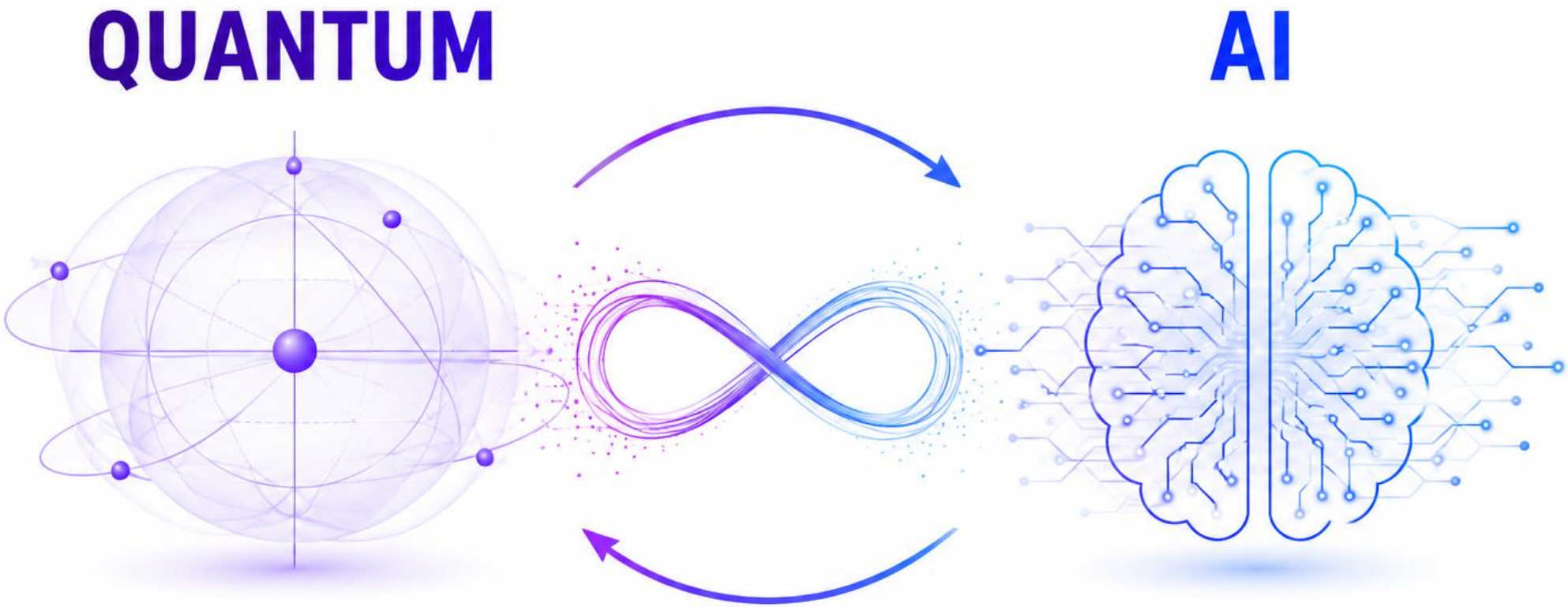


Quantum Dot Qubit

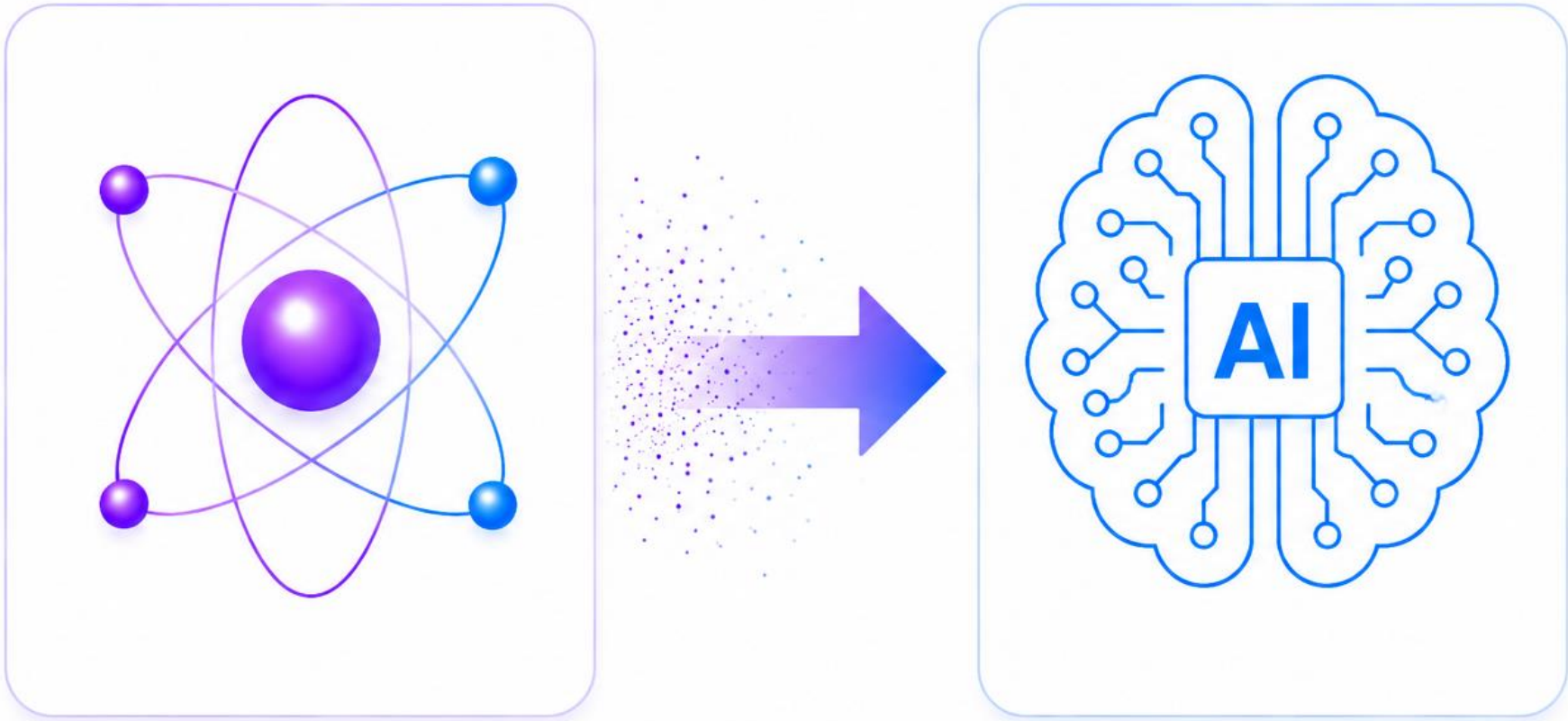
Qubit Technologies & Their Use Cases

Qubit Technology	Best Use Case	Key Strength	Example Company
Superconducting	General quantum computing	Fast today	IBM
Trapped Ion	Chemistry & simulation	Very accurate	IonQ
Photonic	Quantum networking	Scalable with light	PsiQuantum
Neutral Atom	Large-scale systems	Many qubits	QuEra
Spin Qubit (Semiconductor)	Chip-based scaling	Semiconductor compatible	Intel
Topological (Experimental)	Fault tolerance	Error-resistant	Microsoft
Quantum Annealing	Optimization	Specialized solver	D-Wave

No single qubit technology dominates all use cases today.


QUANTUM
AI

How Quantum Computing Helps AI



Faster Optimization

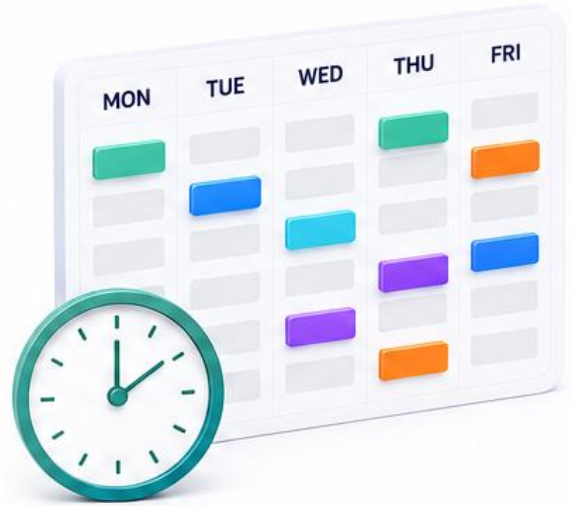
LOGISTICS

- Optimize delivery routes
- Reduce fuel and operational costs
- Handle real-time constraints

PORTFOLIO OPTIMIZATION

- Find optimal asset allocation
- Balance risk vs. return
- Process huge datasets efficiently

SCHEDULING

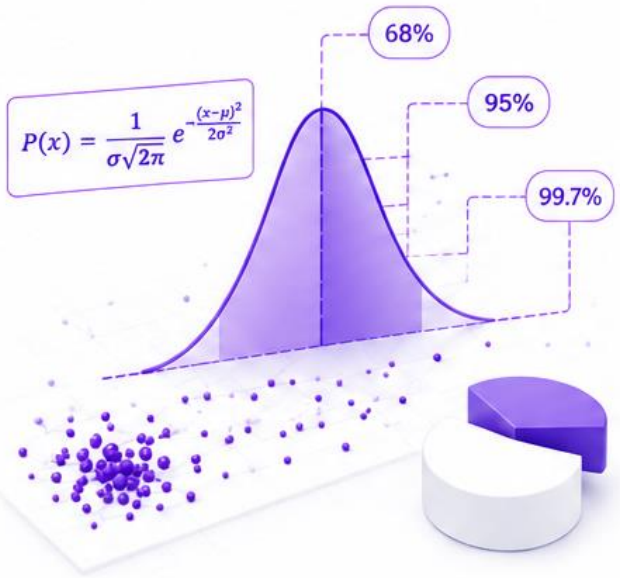


- Optimize employee shifts
- Allocate machines & resources
- Minimize delays and conflicts

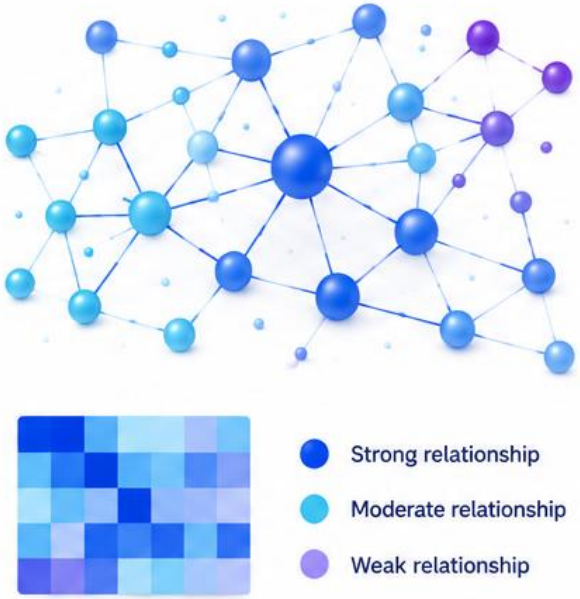
Quantum computing explores many possibilities simultaneously to find better solutions faster for complex optimization problems.

Better Pattern Discovery

PROBABILISTIC MODELING



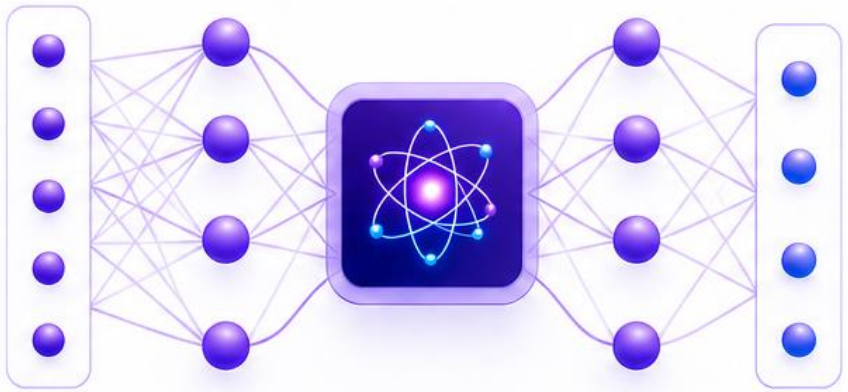
COMPLEX DATA RELATIONSHIPS



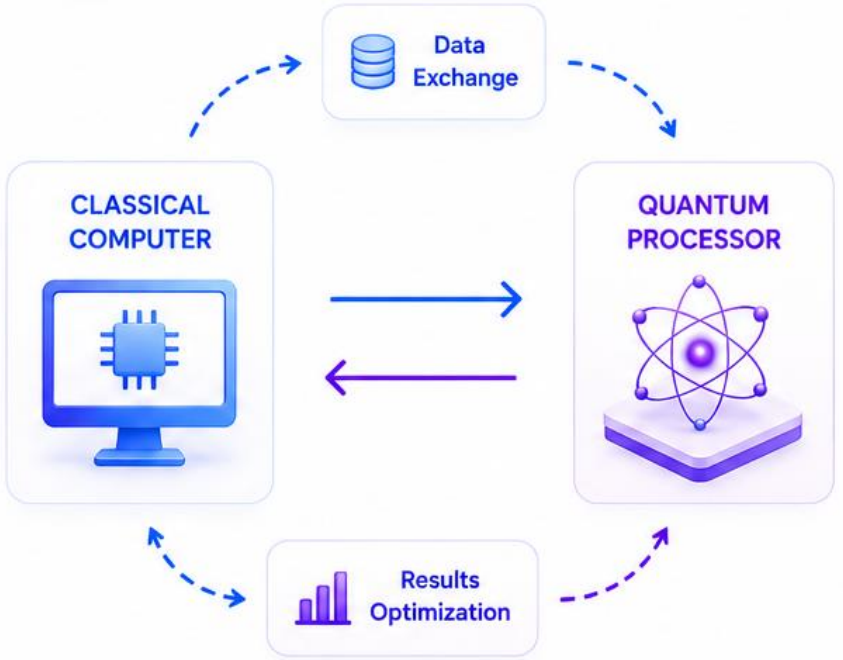
BETTER PATTERN DISCOVERY

Improved AI Models

QUANTUM NEURAL NETWORKS

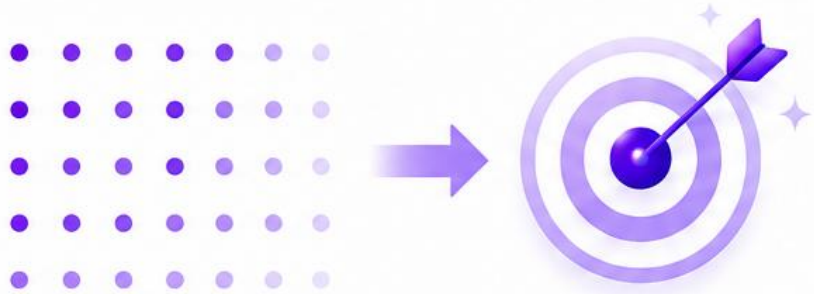


HYBRID AI SYSTEMS

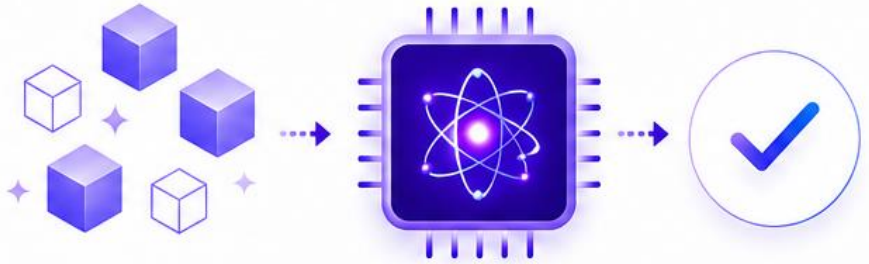


Faster Training & Sampling

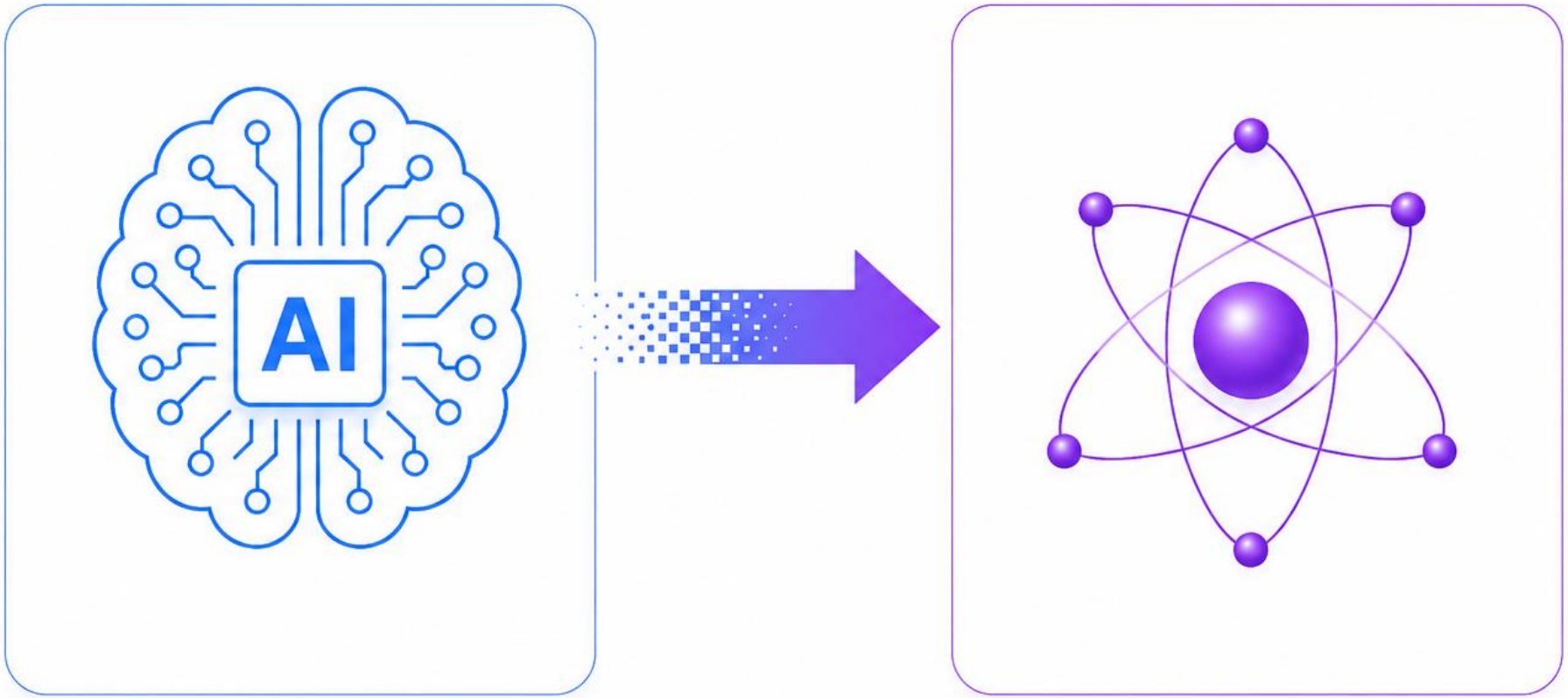
Parameter Tuning



Simulation Acceleration



How AI Helps Quantum Computing



Noise Reduction & Stability

Noisy Quantum System

Environmental noise causes decoherence and signal distortion

Qubits

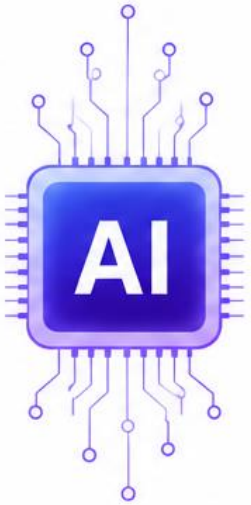
Noisy / Distorted Signal

Thermal Noise

EM Interference

Vibrations

Radiation

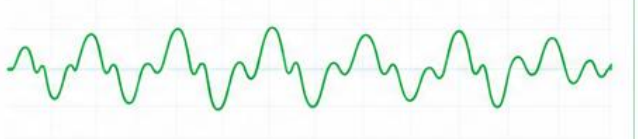


Stable Quantum System

Reduced decoherence results in stable qubits and reliable operations

Qubits

Clean / Clear Signal



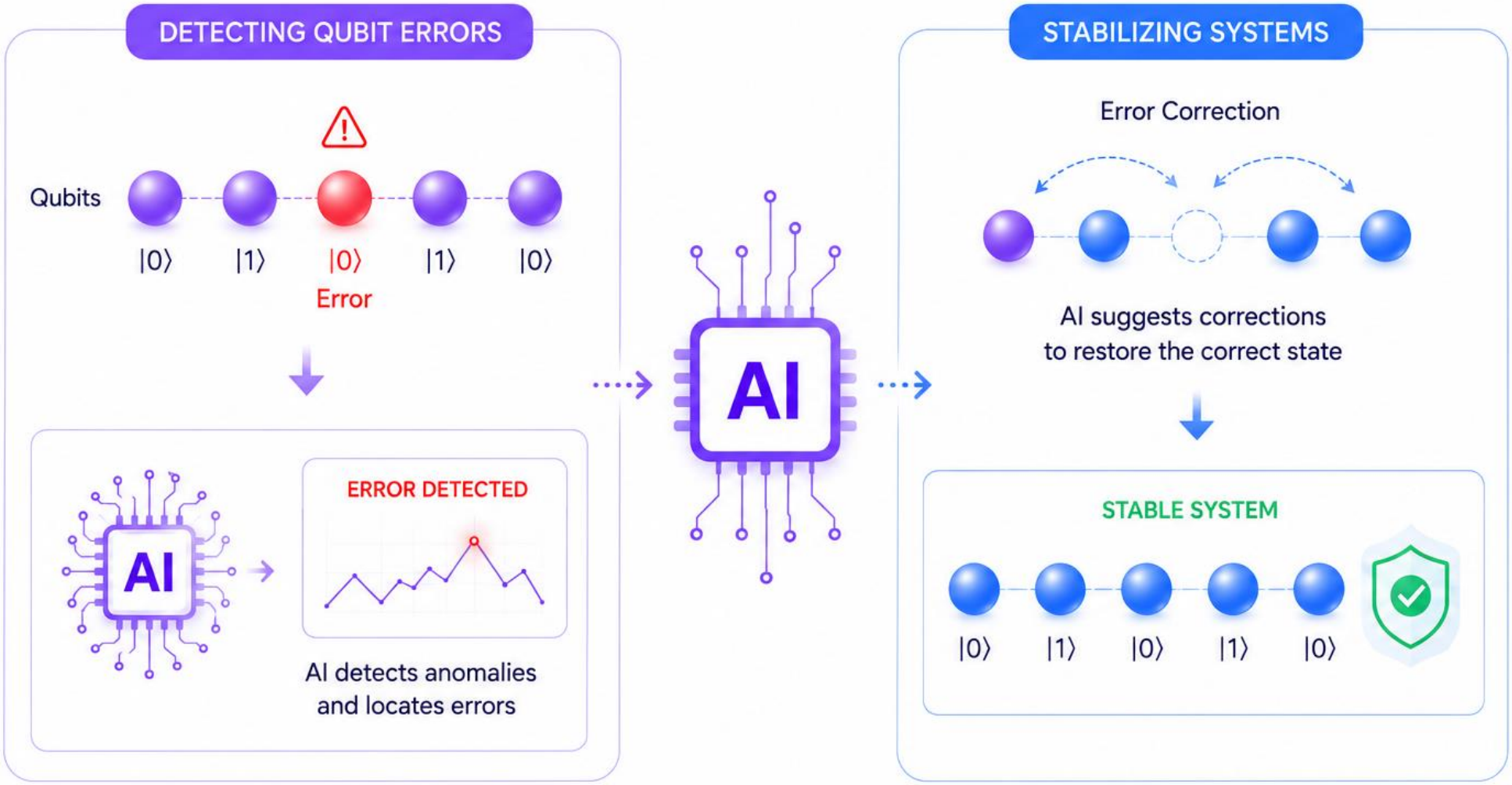
Reduced Decoherence

Higher Fidelity

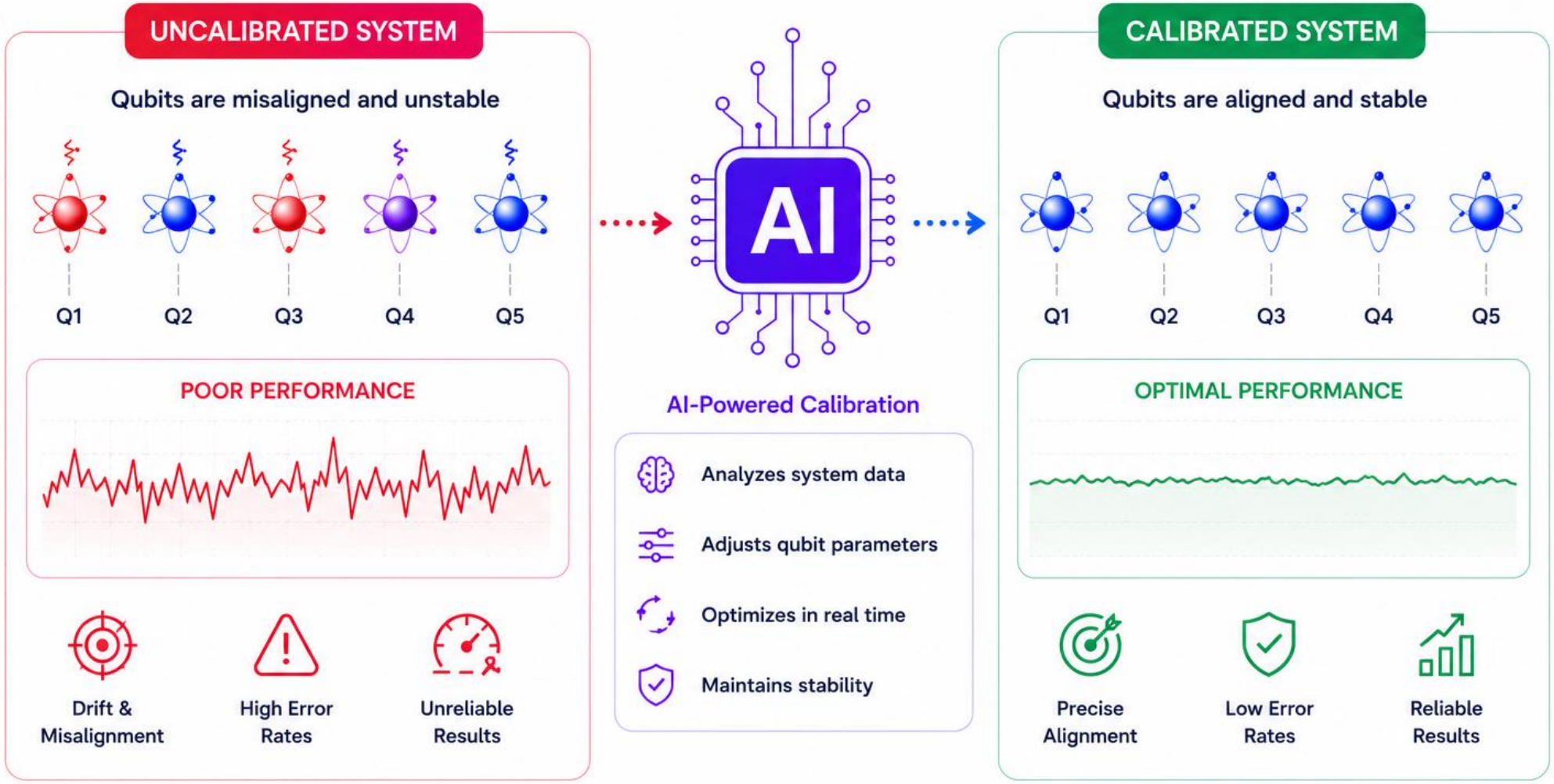
Better Performance

System Stability

Quantum Error Correction

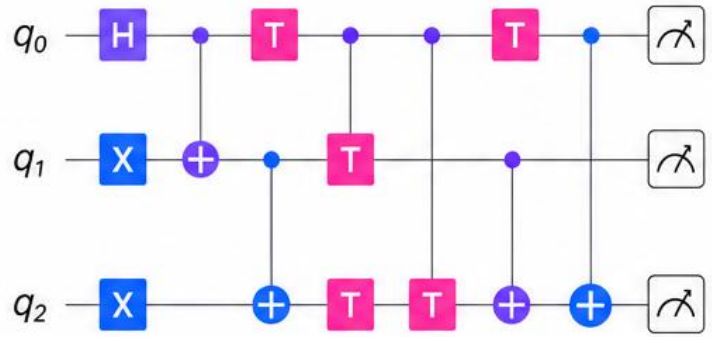


Hardware Calibration

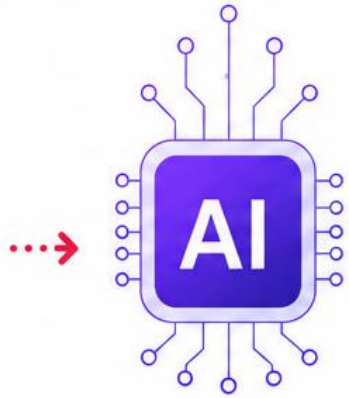


Quantum Circuit Optimization

UNOPTIMIZED CIRCUIT



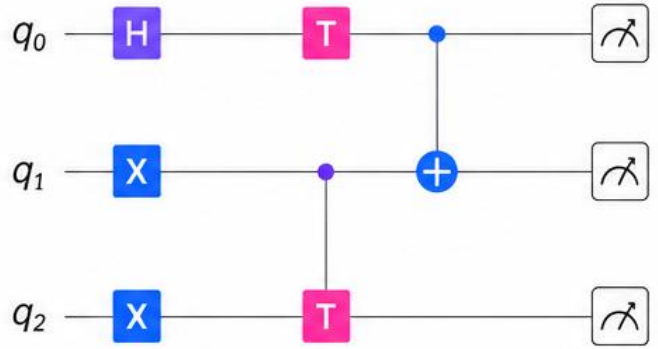
Depth	Gates	Cost
28	42	High



AI-Powered Optimization

- Analyzes circuit structure
- Identifies redundancies
- Applies transformation rules
- Minimizes depth and gates

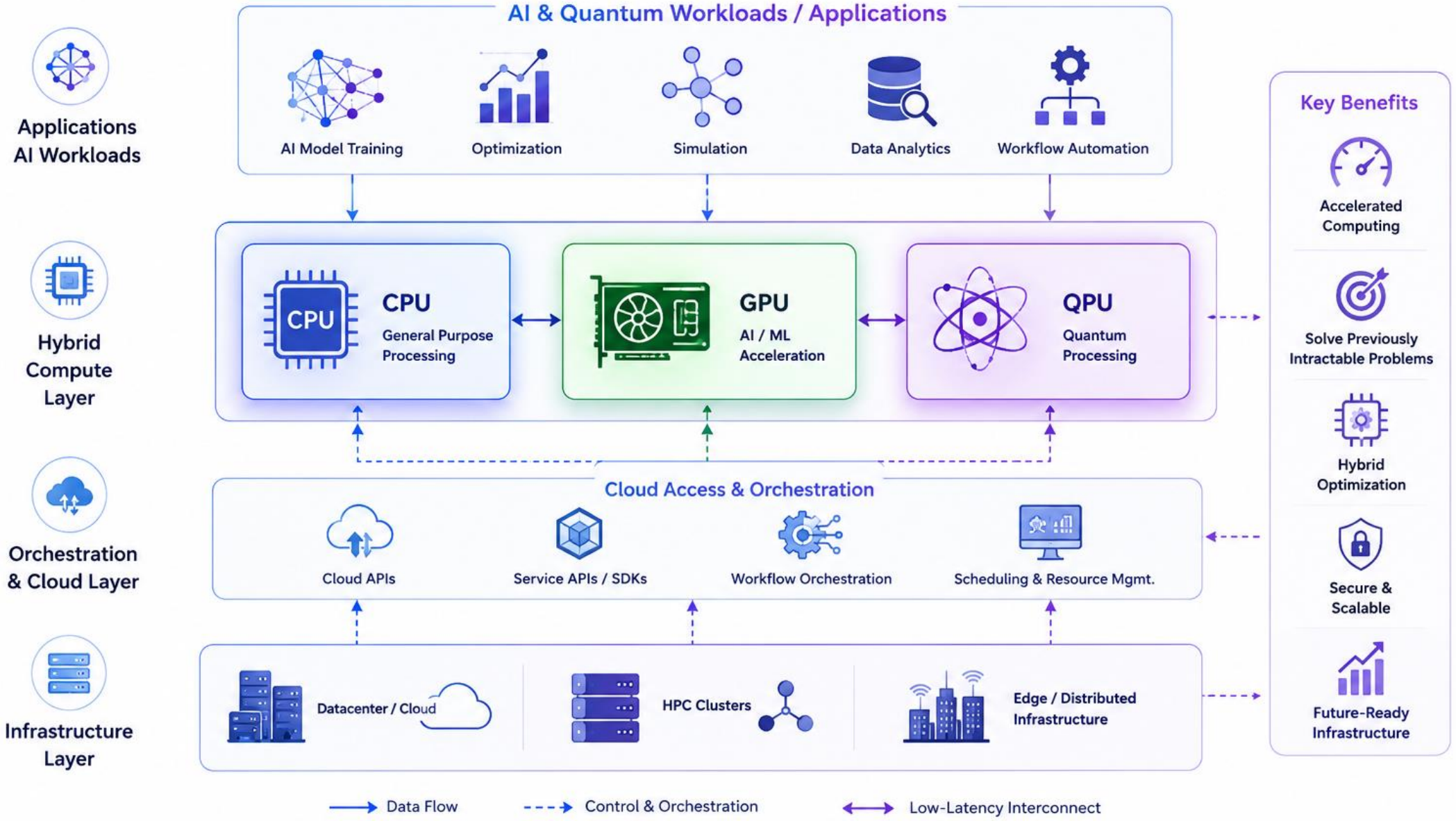
OPTIMIZED CIRCUIT



Depth	Gates	Cost
11	18	Low

Future Hybrid Infrastructure

Classical and Quantum Systems Working Together



Industry Examples

How Leading Organizations are Building the Future Quantum Stack

IBM

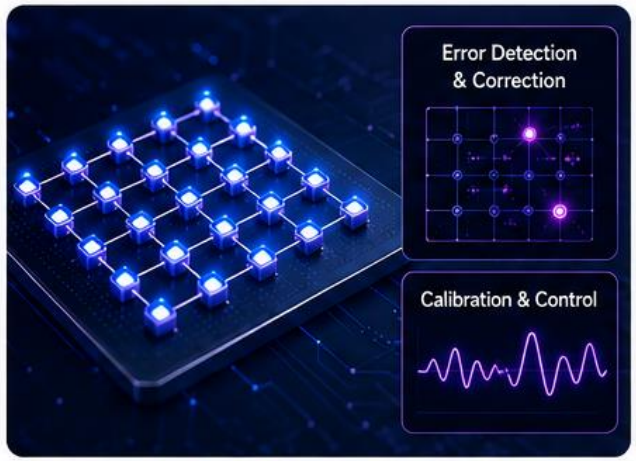
Real Quantum Hardware

- Superconducting Qubits
- Cryogenic Systems
- Cloud Access (IBM Quantum)
- Enterprise Integration

Focus: Real quantum hardware and cloud-accessible systems

Google Quantum AI

System Engineering & Error Correction



- Qubit Scaling
- Error Correction & Stability
- Calibration & Control
- Hardware–Software Co-Design

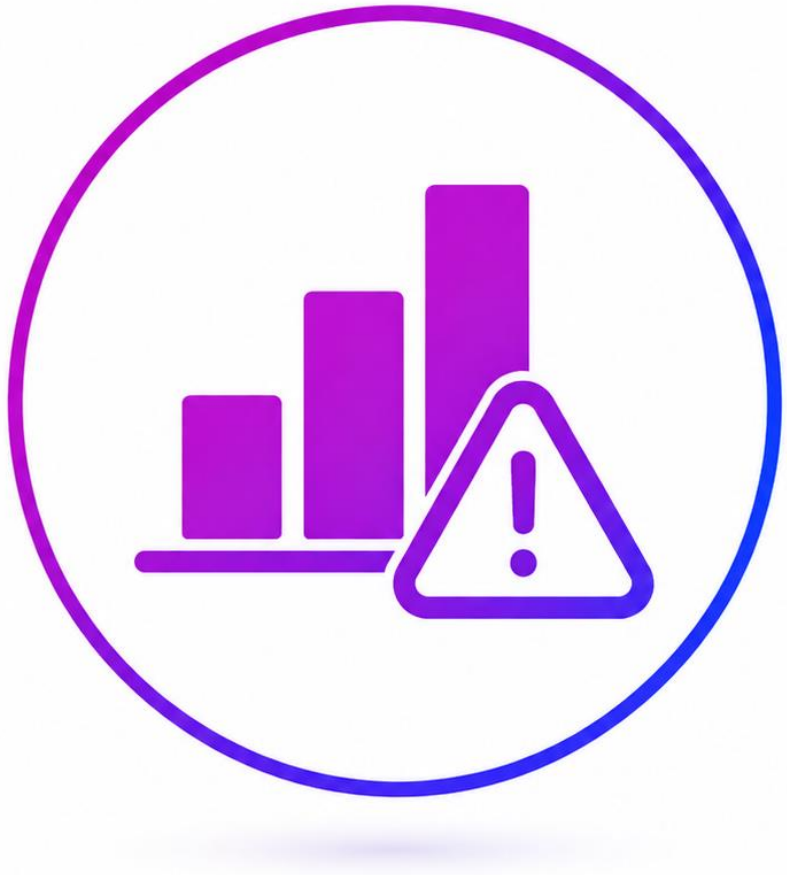
Focus: Scaling, stability and full-system engineering for fault-tolerant quantum computing

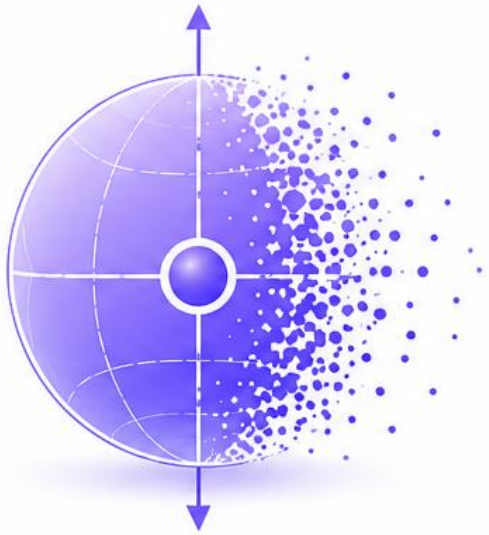
NVIDIA NVQLink

Hybrid Infrastructure & AI + Quantum Integration

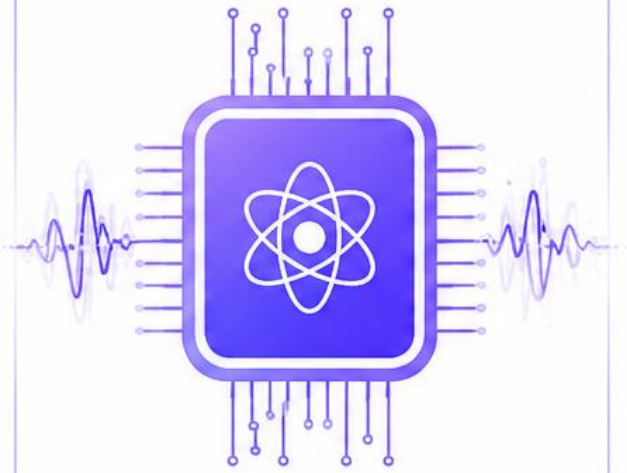
- AI Workloads
- Hybrid Algorithms
- Orchestration & Runtime
- Results & Insights

Focus: Connecting GPUs and QPUs for hybrid AI + quantum workflows





Decoherence



Noise (NISQ)

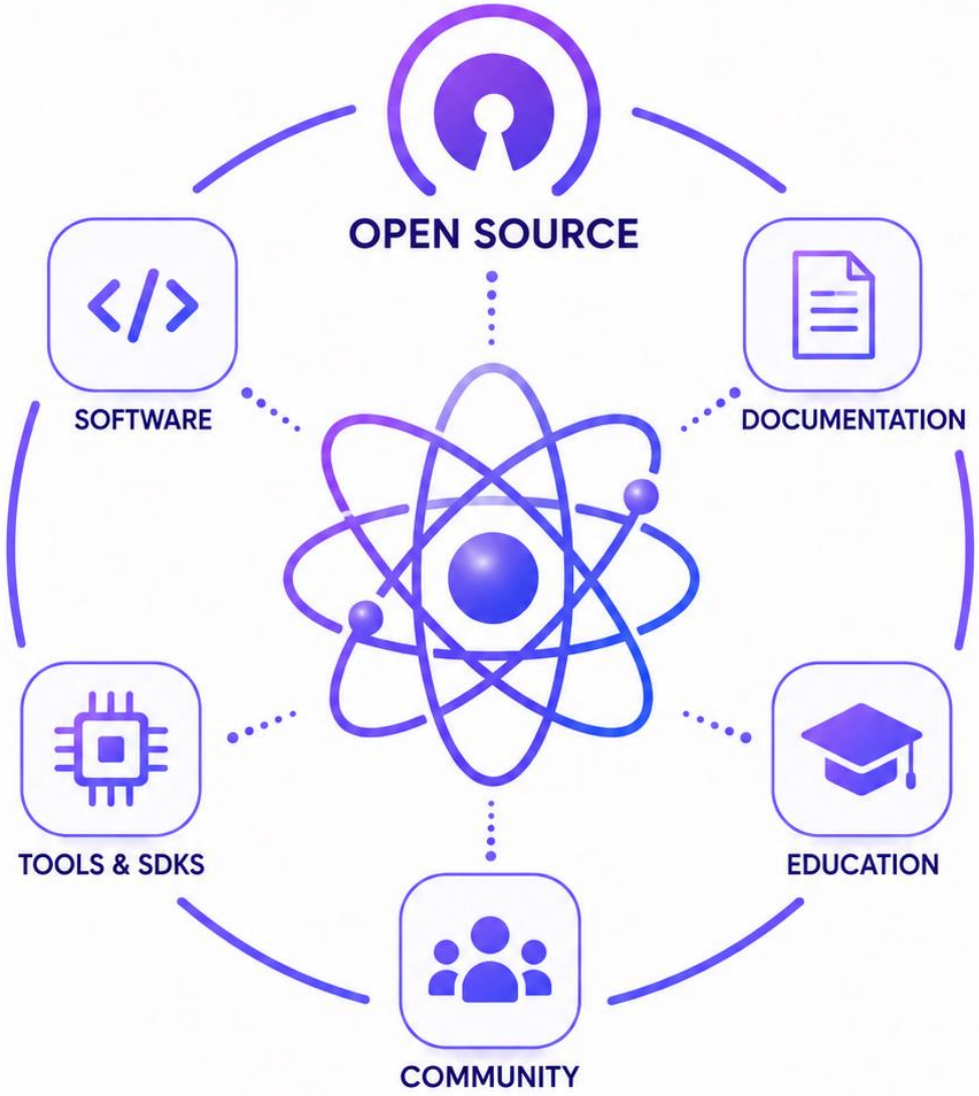
Error Correction

The Security Side of Quantum Computing

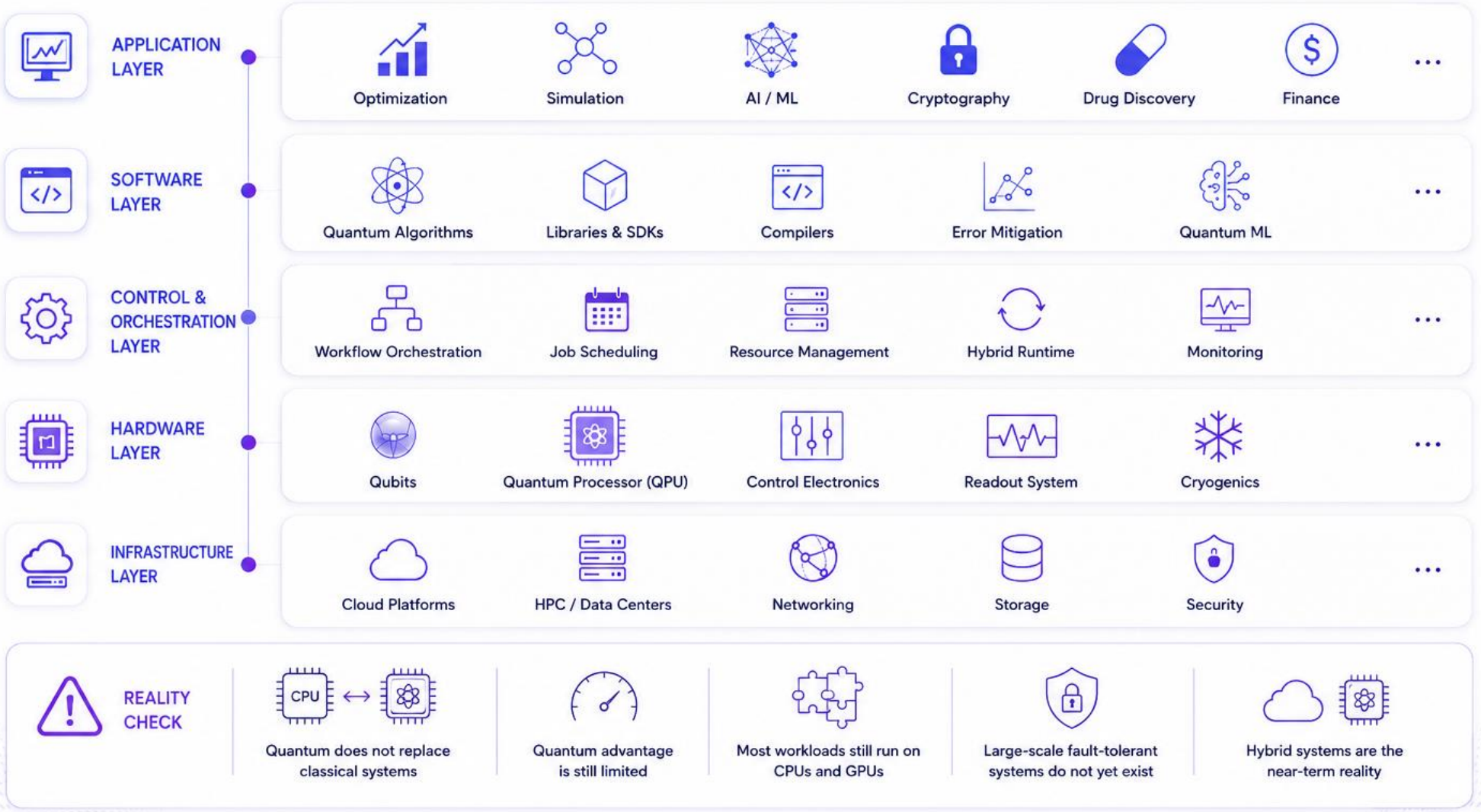
NIST
PQC Standards

Shor's Algorithm
Threat to RSA & ECC

FIPS 140-3
Cryptographic Modules


OPEN SOURCE
SOFTWARE
DOCUMENTATION
TOOLS & SDKS
EDUCATION
COMMUNITY

Quantum Computing Stack



Quantum Computing Ecosystem:
Who Builds What

HARDWARE LEADERS (QUANTUM PROCESSORS)

IBM	Superconducting qubits
Google	Superconducting qubits
IONQ	Trapped ions
rigetti	Superconducting qubits
PsiQuantum	Photonics
PASQAL	Neutral atoms

CLOUD & PLATFORM PROVIDERS (QAAS)

aws	Amazon Braket
	Azure Quantum
IBM	IBM Quantum

SOFTWARE & DEVELOPMENT ECOSYSTEM

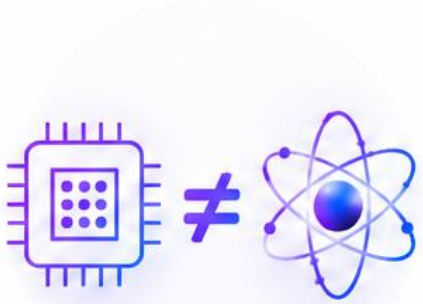
Qiskit	IBM
Cirq	Google
Q#	Microsoft
NVIDIA	CUDA-Q, cuQuantum

Open-Source Quantum Software Projects

Category	IBM	Google	Microsoft	NVIDIA	AWS
SDKs & Frameworks	Qiskit	Cirq	QDK (Q#)	CUDA-Q	Braket SDK
Quantum Machine Learning	Qiskit Machine Learning	TensorFlow Quantum	Azure Quantum + QML integrations	CUDA-Q + cuQuantum	Braket Hybrid Jobs
Simulators	Qiskit Aer	qsim	Quantum Simulators in QDK	cuQuantum	Local & Managed Simulators
Cloud Quantum Platforms	IBM Quantum Platform	Google Quantum AI	Azure Quantum	DGX Quantum Integrations	Amazon Braket
Compilers & Runtime	Qiskit Runtime, Qiskit Terra	Cirq Compiler Stack	Quantum Runtime / QIR	CUDA-Q Compiler	Braket Runtime
Primary Focus	Enterprise Quantum Ecosystem	Quantum AI Research	Hybrid Cloud Quantum Workflows	GPU-Accelerated Hybrid Quantum Computing	Multi-Provider Quantum Cloud Access

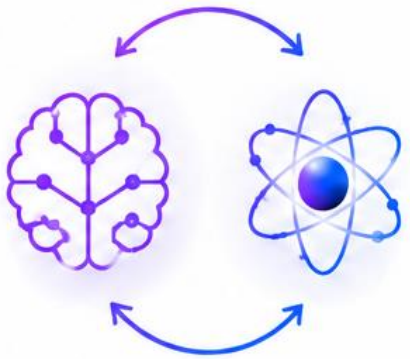
https://github.com/qosf/awesome-quantum-software

Key Takeaways



Not a replacement

Specialized



Hybrid AI + Quantum

Start learning today

Thank you!

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