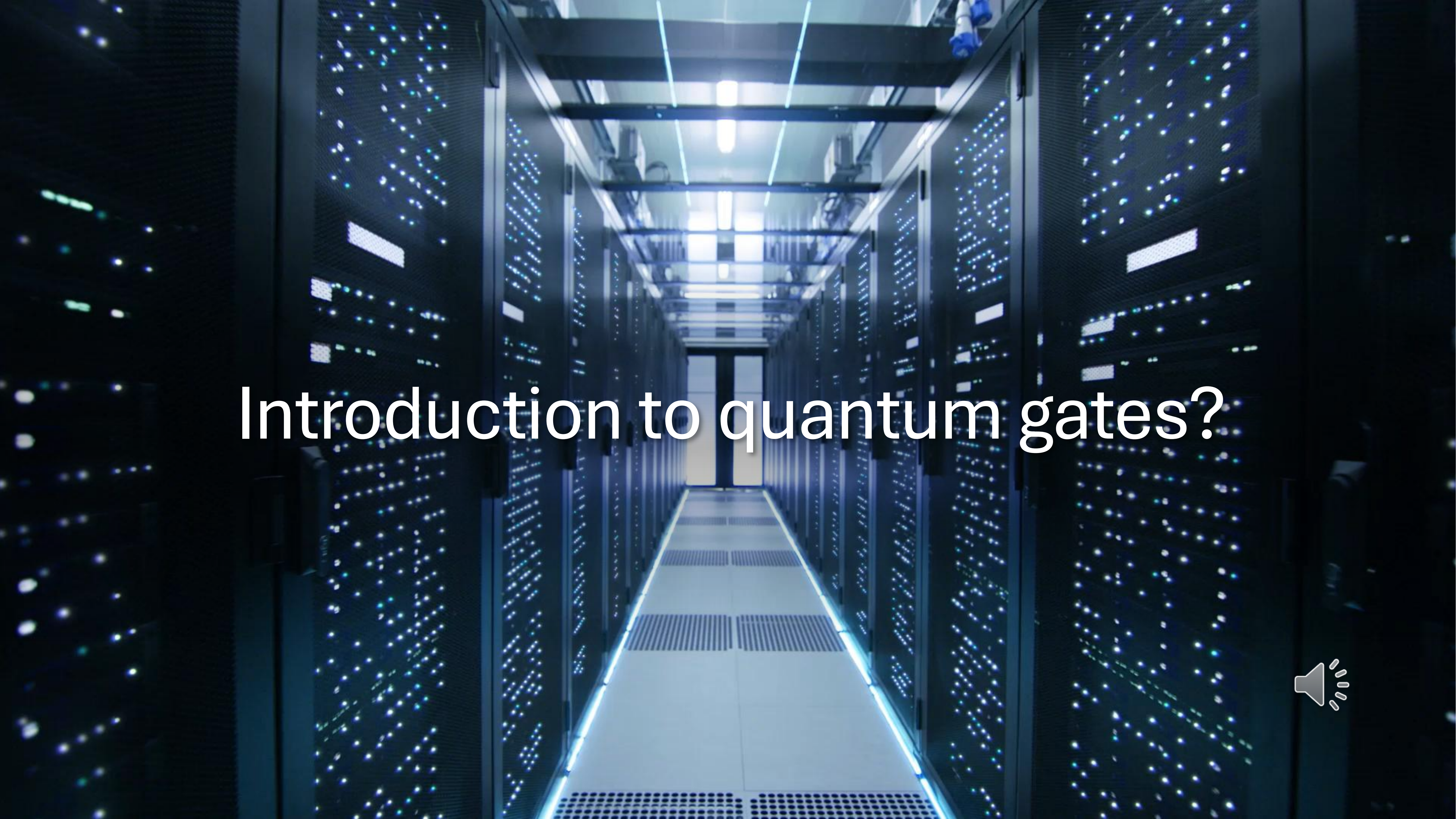

Introduction to quantum gates?

What is quantum gates?

Key Differences from Classical Gates

Feature	Classical Gates	Quantum Gates
Basic Unit	Bits (0 or 1)	Qubits (Superposition of 0 and 1)
Operation Type	Boolean Logic	Linear Algebra (Matrices)
Reversibility	Irreversible (e.g., AND gate loses info)	Always reversible (unitary operations)
Parallelism	One computation at a time	Superposition allows multiple computations

Fundamental Quantum Gates

- Pauli Gates (X, Y, Z)
- These are basic **single-qubit gates** that rotate qubits along the **X, Y, or Z axes**.

```
from qiskit import QuantumCircuit

qc = QuantumCircuit(1)  # One qubit circuit
qc.x(0)  # Apply X (NOT) gate
qc.draw()
```

Gate	Matrix Representation	Effect
X (NOT Gate)	$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$	Flips (
Y	$\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$	Rotates along the Y-axis
Z	$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$	Phase flip (flips sign of (

Hadamard Gate (H) – Creates Superposition

Gate	Matrix Representation	Effect
H (Hadamard)	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$	Creates **equal superposition** of (

- **Example**: Applying Hadamard on $\vert 0\rangle$ creates:

$$H\vert 0\rangle = \frac{1}{\sqrt{2}}(\vert 0\rangle + \vert 1\rangle)$$

```
qc.h(0)  # Apply Hadamard gate
qc.draw()
```

CNOT Gate (Controlled-X) – Entanglement

- A **two-qubit gate** that flips the second qubit **only if the first qubit is |1⟩**.
- Used in **quantum entanglement**.

```
qc = QuantumCircuit(2)
qc.h(0)  # Put first qubit in superposition
qc.cx(0, 1)  # CNOT: Entangle qubits
qc.draw()
```

Gate	Matrix Representation	Effect
CNOT	$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$	Creates **entanglement** between two qubits

Other Important Gates

Gate	Purpose
T & S Gates	Phase-shifting operations
Swap Gate	Swaps the states of two qubits
Toffoli (CCNOT) Gate	Three-qubit gate for quantum logic (used in quantum circuits)

Why Are Quantum Gates Important?

ENABLE SUPERPOSITION

CREATE ENTANGLEMENT

PERFORM REVERSIBLE COMPUTATION

ESSENTIAL FOR QUANTUM ALGORITHMS