

Basics of Quantum Computing

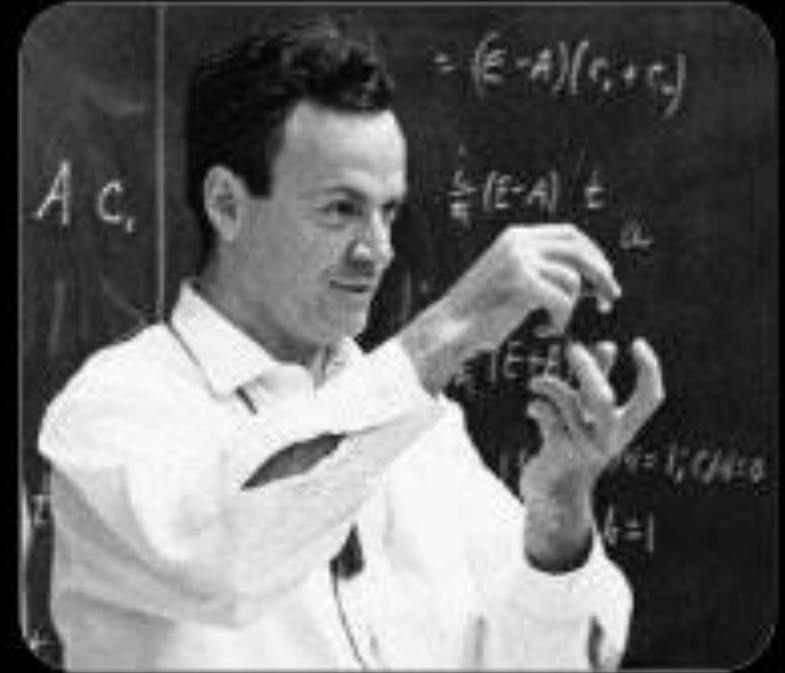
Contents

Engineering Physics Module 3, Unit 3.4

- Basic idea of a quantum computer
- Qubits and qubit operations
- Quantum logic gates and Quantum circuits

Feynman's Proposal of a Quantum Computer

1981 - Richard Feynman determines that it is impossible to efficiently simulate an evolution of a quantum system on a classical computer.

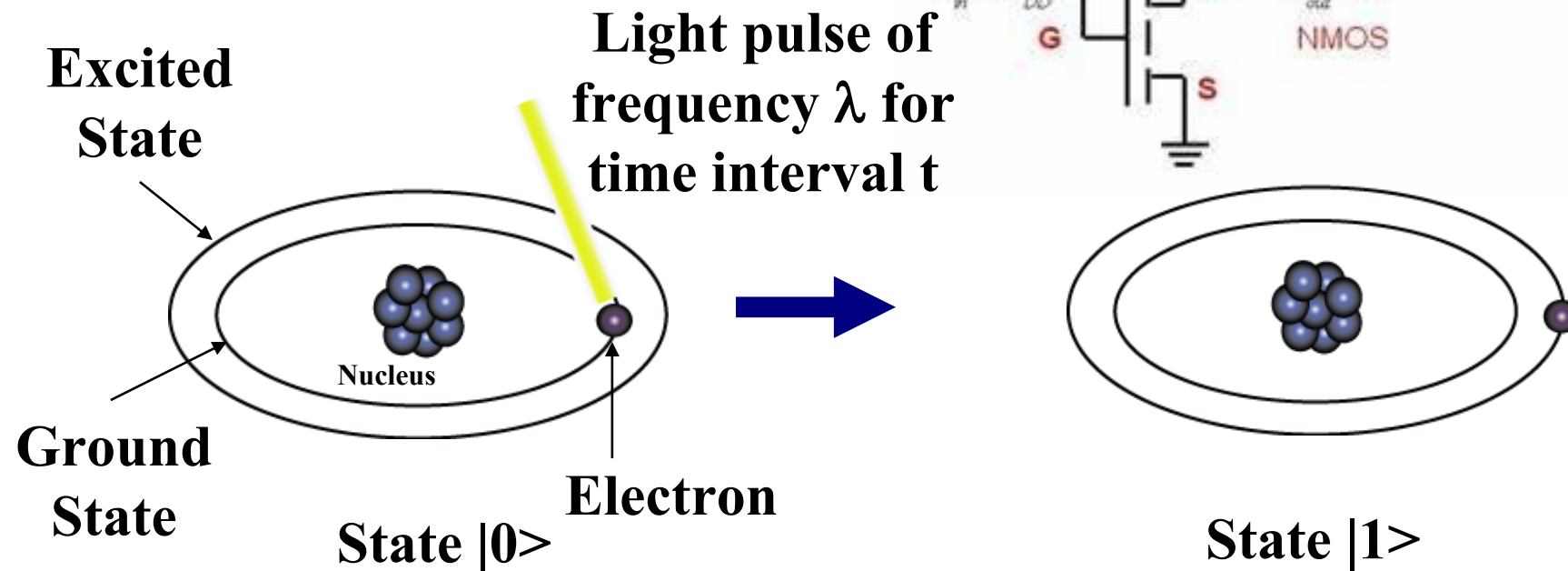


Message – go and build a machine/hardware which uses laws of quantum mechanics and which has “quantum mechanically prepared system” like microscopic objects.

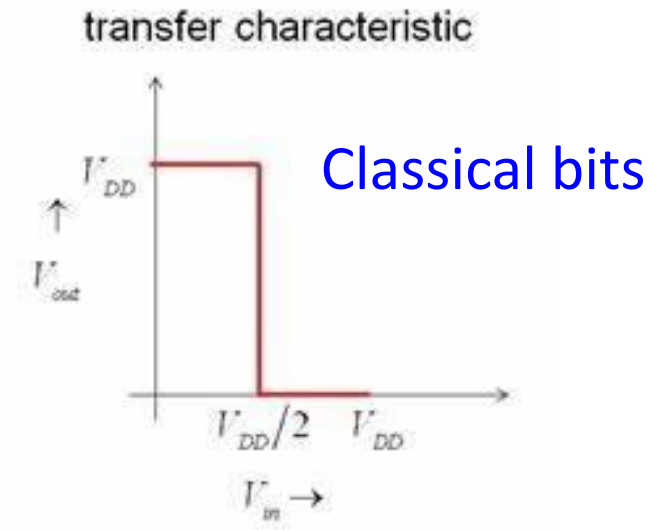
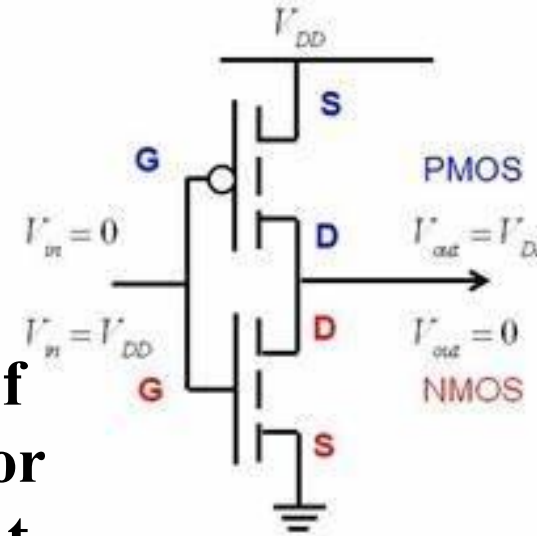
How Does A Quantum Computer Differ From Today's Computers?

It is based upon using

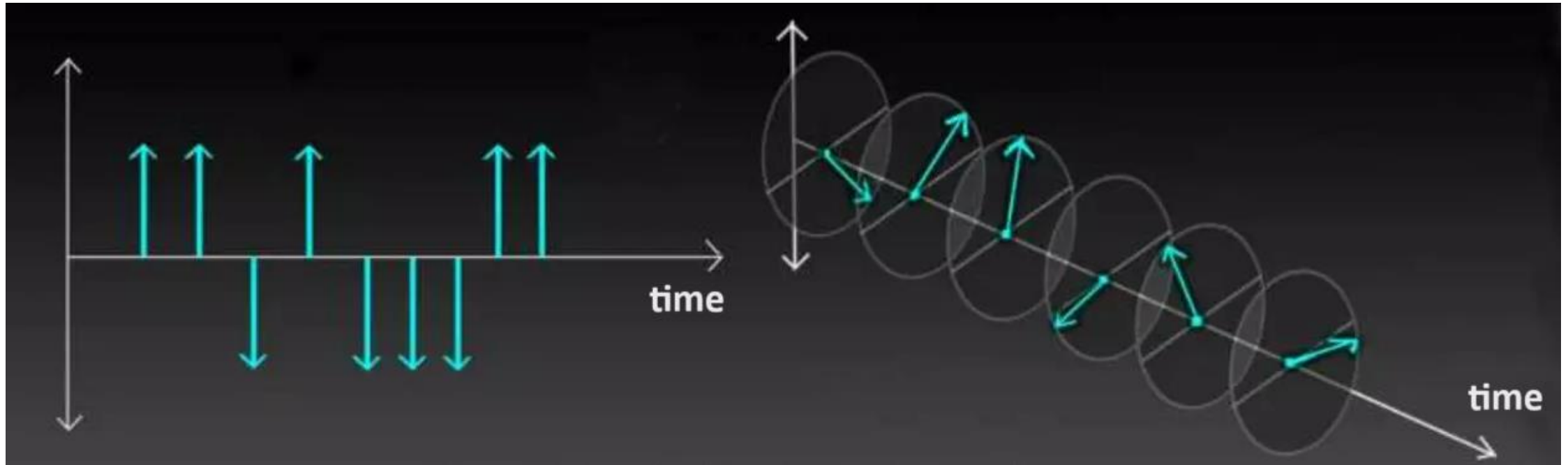
- Qubits
- Superposition/interference
- Entanglement



Ideal CMOS inverter



Defining A Quantum Computer



Quantum computer is a machine that works on the principles of quantum mechanics and executes programs in the same manner as microscopic objects behave

Which Special Quantum Mechanical Properties Are Used?

- Superposition – ON and OFF simultaneously!
- Entanglement – connection stays even taken at two corners of the milky way galaxy and they communicate instantaneously!!
- Teleportation – design here, appears there – “there” can be outside milky way and it is instantaneous!!!

Classical v/s. Quantum Computers

Classical Computer	Quantum Computer
Uses semiconductor-based CMOS logic gates	May use atomic, electronic, nuclear or photonic properties
ON/OFF state of CMOS transistor determines logic 1/0	Logic 1/0 represented by spin up/down, ground state/excited state, right/left circularly polarized light, parallel/anti-parallel magnetization etc.
Bit can be in state 1 or 0 at a given time	Bit (qubit) can be in both 1 and 0 states at a given time
Machine executes operations bit by bit	Machine executes operation on all qubits simultaneously*

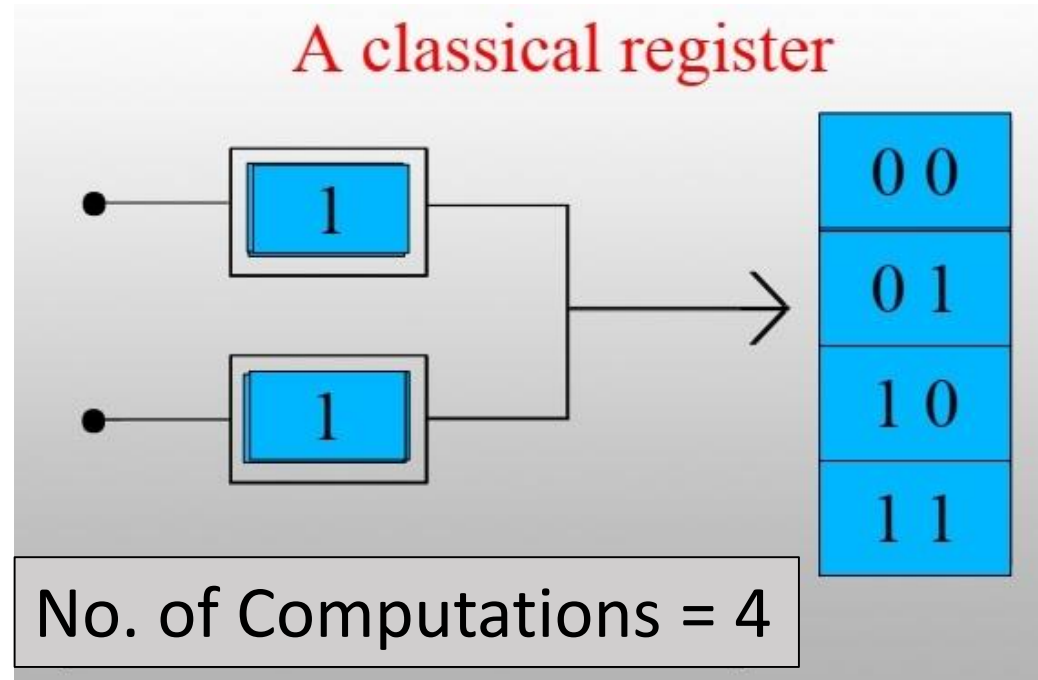
* This concept is different than parallel computing or super computing

Advantage of a Quantum Computer

A classical computer

- Each register has unique input

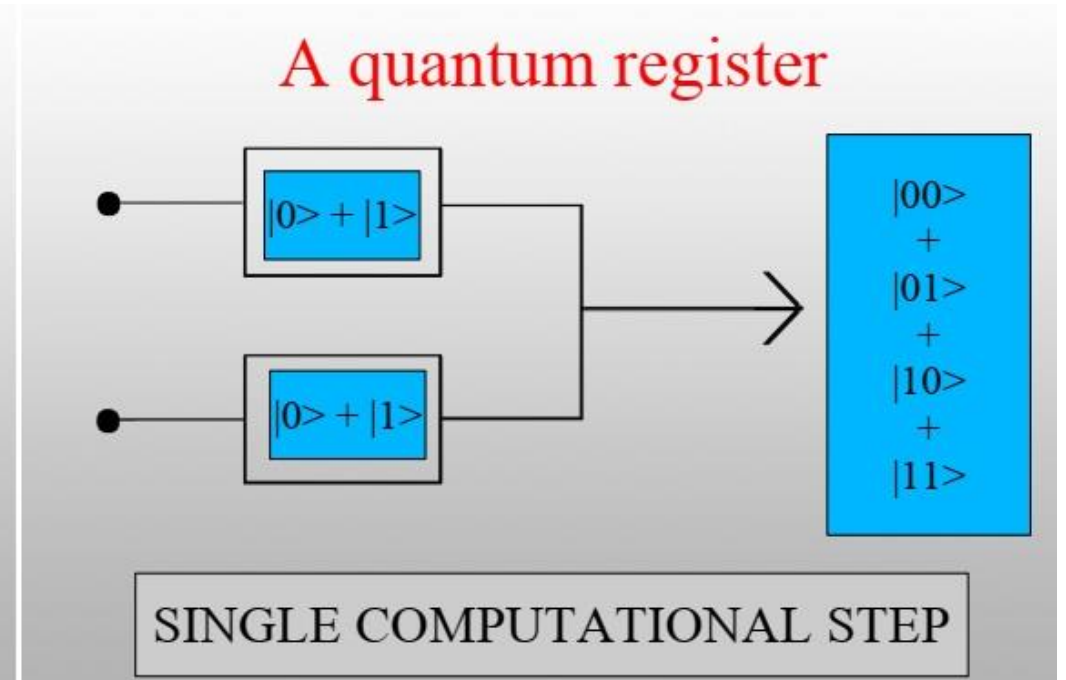
Executes one operation at a time



A quantum computer

- Each register has both inputs

Executes all operations in one go



Advantage of a Quantum Computer

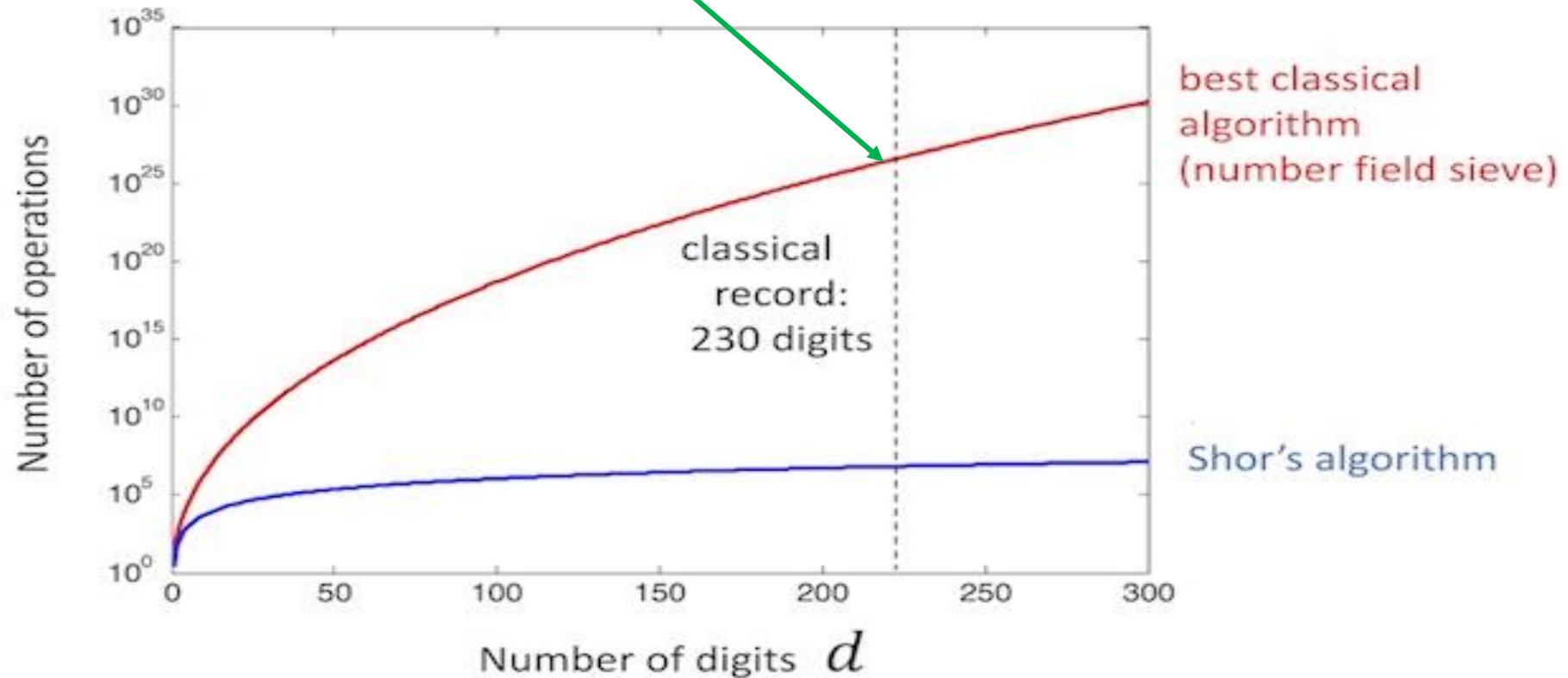
- Encode more information
- Powerful
- Massively parallel
- Easily crack secret codes
- Fast in searching databases
- Hard computational problems become tractable

Quantum Algorithms

- Programs that would run on a quantum machine
- Currently, there are no genuine quantum algorithms
- We have Algorithms running on virtual machines that mimic quantum effects
- All use cloud based computing e.g. IBM's [Qiskit](#)

Advantage of Quantum Algorithm

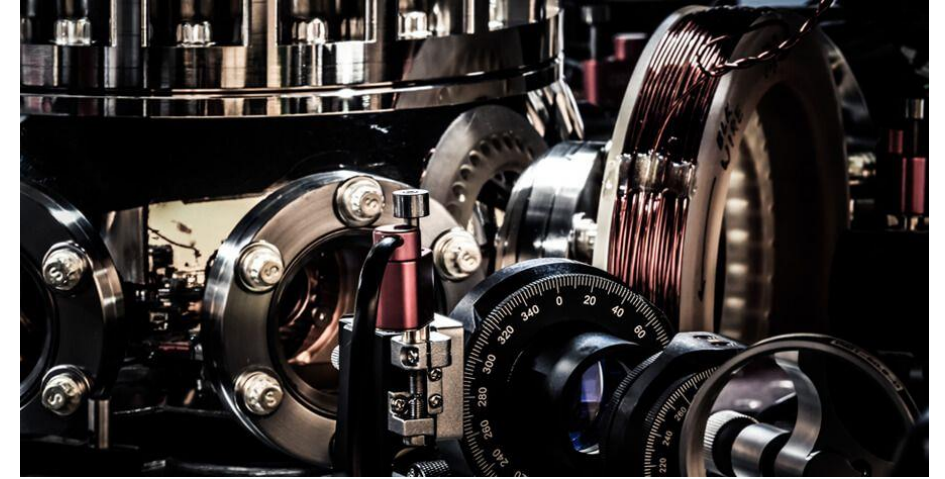
Took ≈ 2000 CPU years (OR 2000 parallel processors x 1 year)



Graph credit: IBM Quantum Computing

Quantum Hardware

- Ion trap – uses atomic energy levels
- SQUIDs – uses magnetisation
- NMR – uses nuclear spin
- QD/SET – uses electron energy states

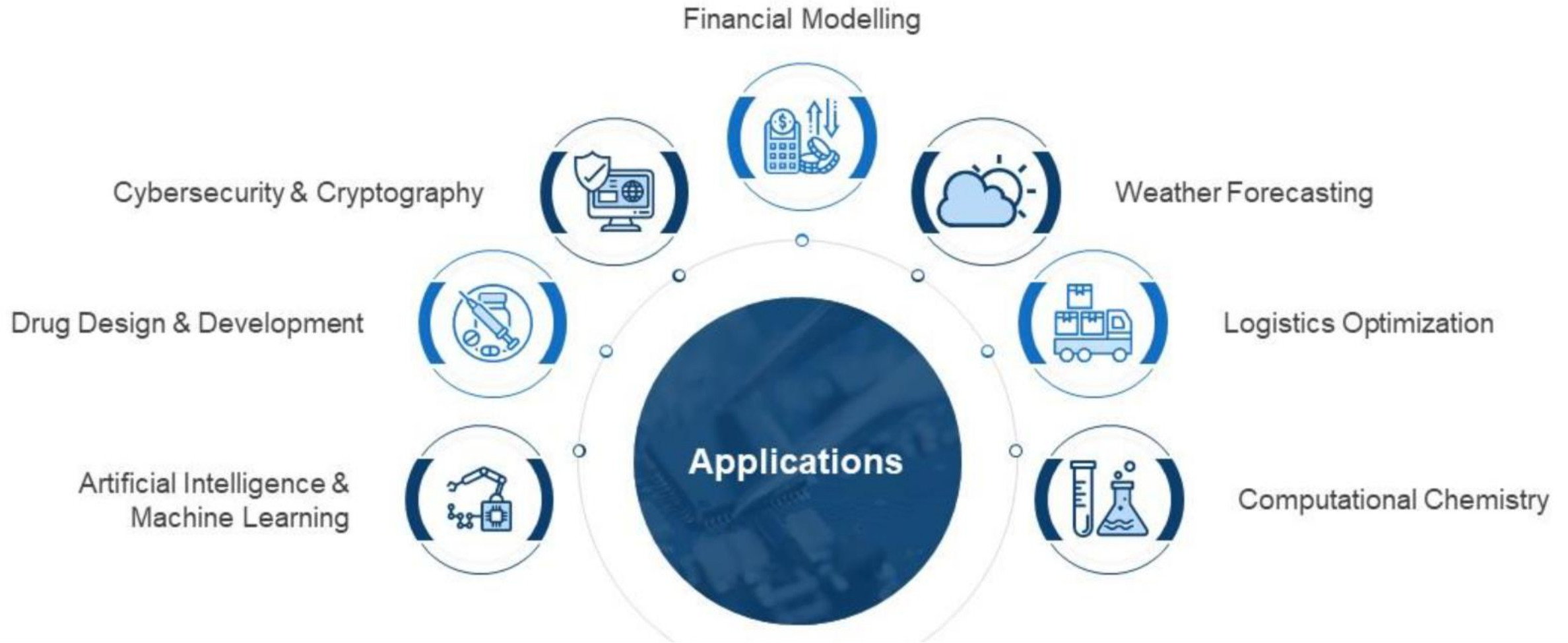


Examples:

- Honeywell using Ion trap
- D-wave Technologies using SQUID
- IBM using NMR
- Google using superconductors



Applications of Quantum Computing



Applications of Quantum Computing

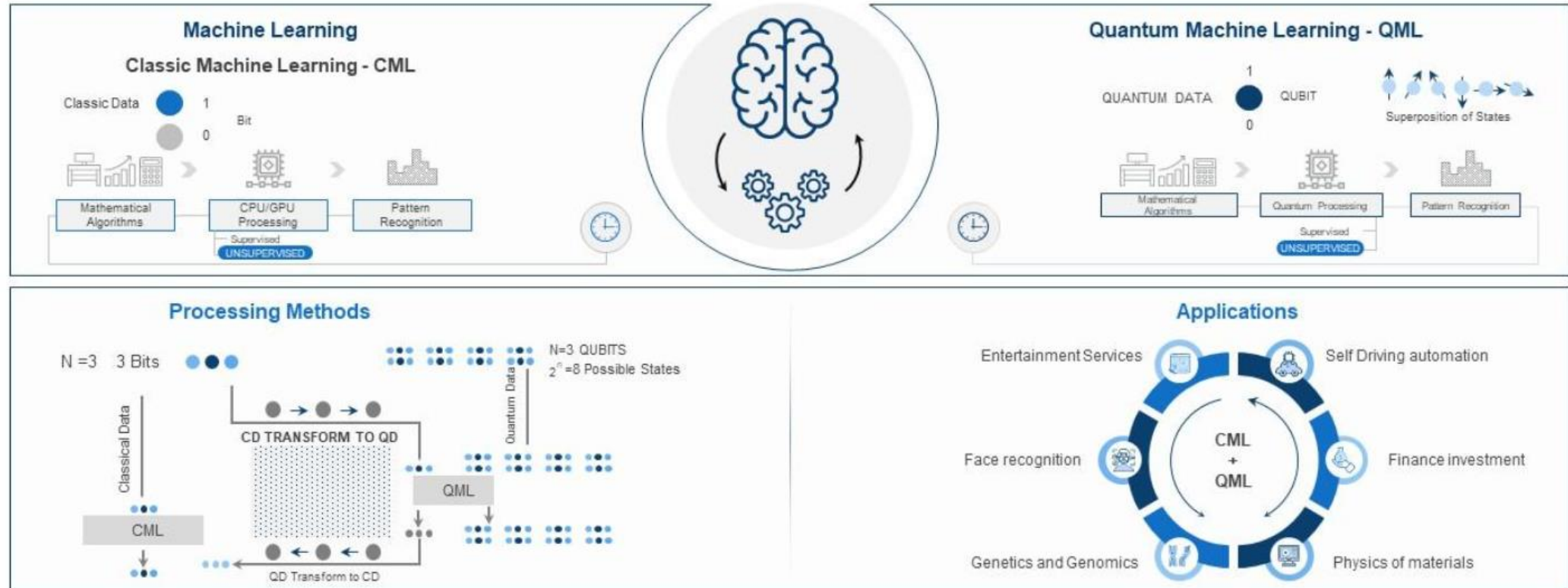
Artificial Intelligence & Machine Learning with Quantum Computing

This slide depicts how quantum computing would be beneficial when using artificial intelligence and machine learning. It also shows that how data is processed in classic machine learning and quantum machine learning.

Artificial intelligence and machine learning are growing faster, and it becomes difficult for classical computers to carry out complex problems in a short period

Quantum computers will be helpful to execute complex problems and provide results in a concise period

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Applications of Quantum Computing

Drug Design & Development with Quantum Computing

This slide represents drug design and development through quantum computing and how it would be time-saving and cost-saving for the medical industries.



To design and develop a drug, using traditional computers is very difficult since it is a costly, time-consuming, and risky process



Quantum computing can be a powerful method of understanding the medications and their reactions on people, which will save lots of money and time for medical companies

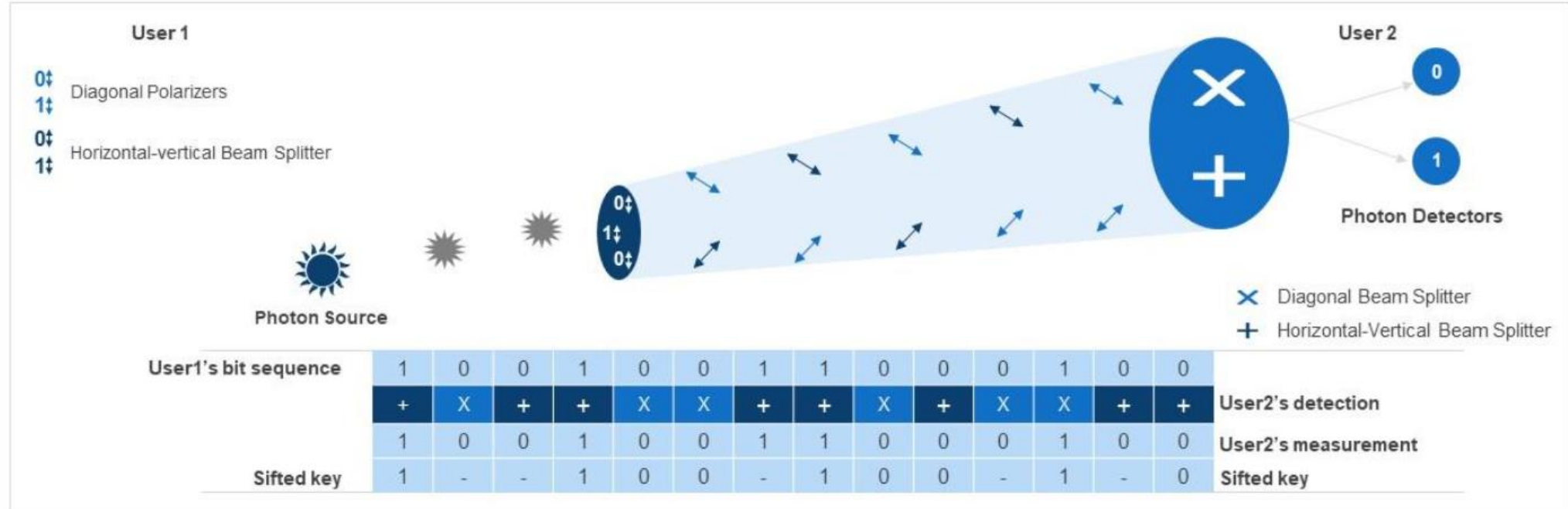


Will allow companies to carry out more medication discoveries to find new clinical treatments for the better drug industry

Applications of Quantum Computing

Cybersecurity & Cryptography with Quantum Computing

This slide shows quantum computing in cybersecurity and cryptography and how data will be encrypted through quantum algorithms.



Cyber Security is the primary concern globally as the number of cyberattacks increases day by day. It is difficult for classic computers to combat these threats



Quantum computing with the combination of machine learning can help for building encryption methods known as quantum cryptography



Quantum cryptography utilizes the standards of quantum mechanics to send secure messages, and dissimilar to mathematical encryption is un-hackable



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Applications of Quantum Computing

Financial Modelling with Quantum Computing

This slide represents the application of quantum computing in financial modeling, and it also depicts how current models are not sufficient for financial services.



Monte Carlo' simulations are used by Finance companies on classical computers to track down the correct blend for productive investments dependent on expected returns and the risk associated, which is very time consuming

Quantum technology can enhance the solution quality and save development time by performing large and complex calculations

Financial pioneers spend billions of dollars in business; even a tiny improvement in the expected return can be worthy for them

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Applications of Quantum Computing

Weather Forecasting with Quantum Computing

This slide defines how quantum computing will be helpful in weather forecasting, and scientists will be able to predict extreme weather conditions in advance.

To analyze the weather conditions through the classic computers is time taking sometimes

Quantum computing's ability to process a large amount of data quickly will change the weather forecast modeling and will be helpful to provide climate change information accurately and in no time

Scientists will be able to predict extreme weather conditions accurately, and it will help to save lives

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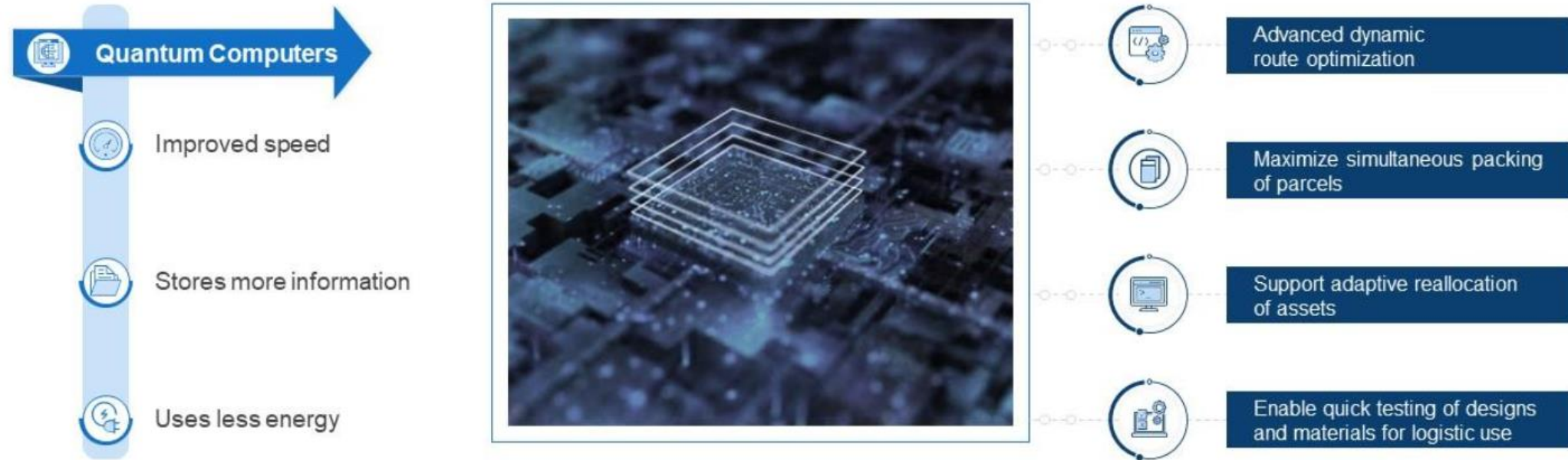


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+25 °c	+19 °c	+19 °c	+15 °c	+10 °c	+8 °c	+25 °c

Applications of Quantum Computing

Logistics Optimization with Quantum Computing

This slide depicts the logistic optimization through quantum computing and how it would be easy to know about traffic on a particular path in advance.



Conventional computing is used to sync with operating models that need to continuously compute and recalculate optimal routes of traffic management, fleet activities, airport regulation, cargo and distribution, and that could seriously affect applications

Some of these tasks are more complex for a classic computer but can perform quite efficiently with quantum computers

Two common approaches to solve these issues are – Quantum Annealing and Universal Quantum

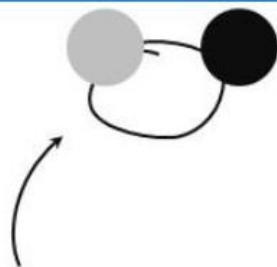
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Applications of Quantum Computing

Computational Chemistry with Quantum Computing

This slide represents the computation chemistry with quantum computing and how it would enhance the technology to carry out complex molecule experiments without testing on humans or animals.

Classical computers can simulate



Small molecule with a few atoms

Quantum computers could simulate



Large molecule with many atoms



Quantity of quantum states, even in a smallest of a molecule, is tremendous, and in this manner, complex for traditional computing memory to handle that



Ability of quantum computers to focus on the presence of both 1 and 0 at the same time could give massive power to the machine to effectively map the molecules, which, thus, possibly opens opportunities for drug research



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