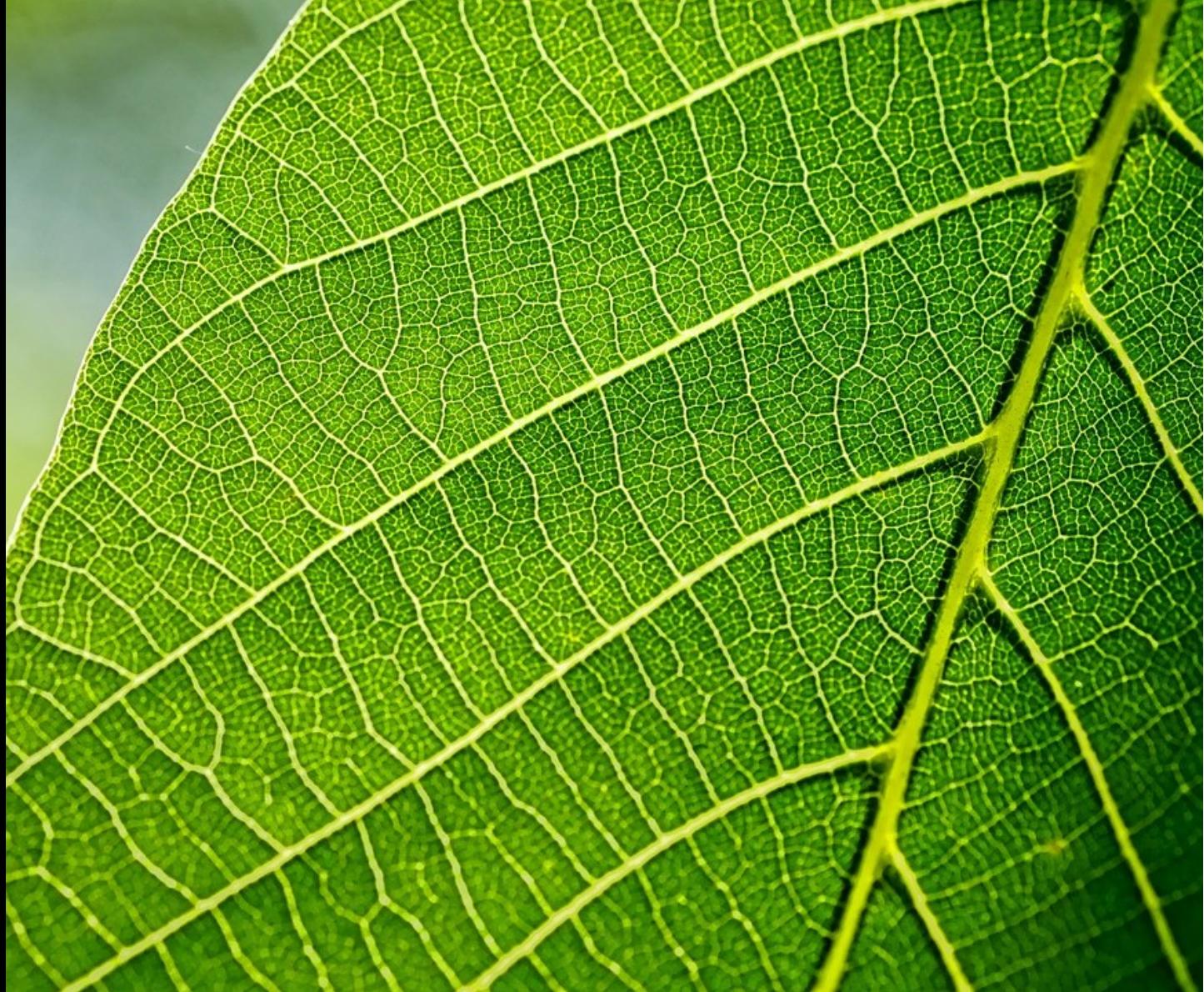
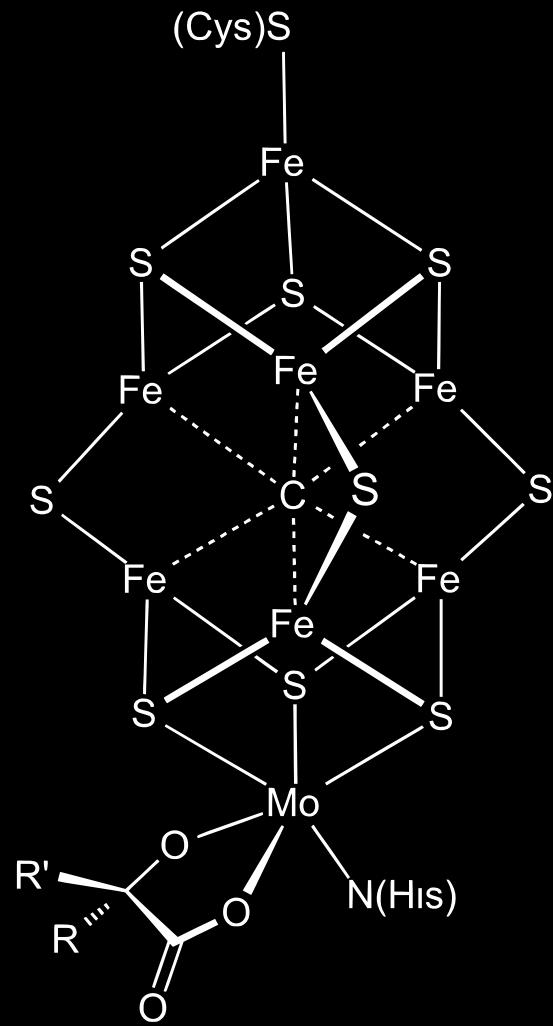




Ch1: Overview of Quantum Computing



Character

Bits

7

111

A

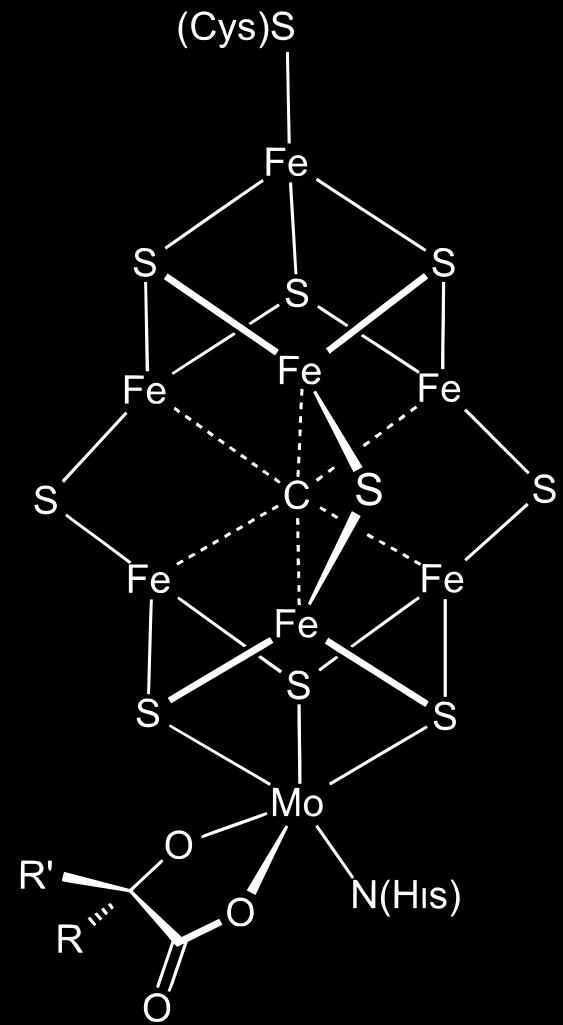
01000001

\$

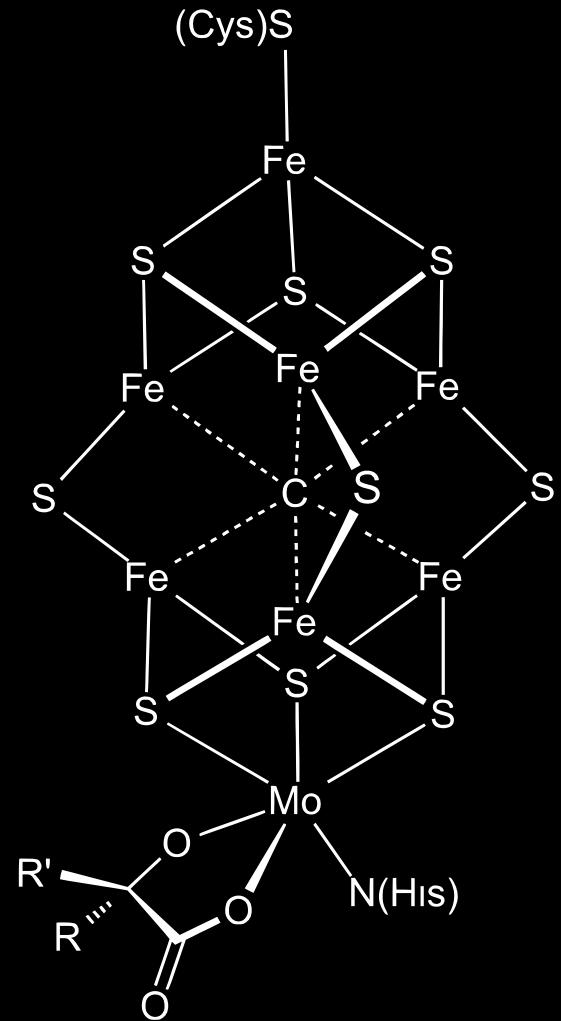
00100100

:)

0011101000101001



Classical
 $\sim 10^{32}$
bits



Classical

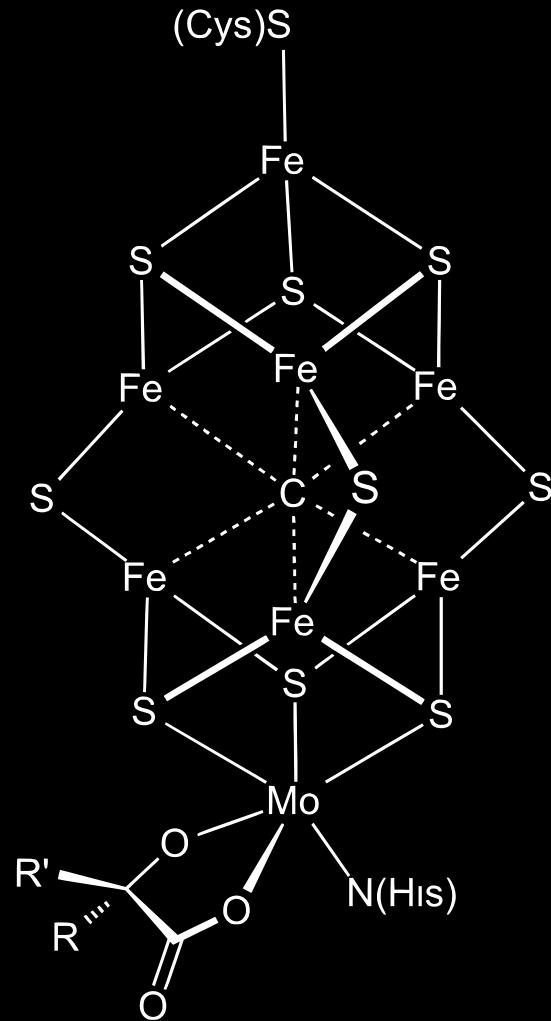
$\sim 10^{32}$

bits

Quantum

$\sim 10^8$

quantum bits



N bits $\rightarrow 2N$ bits

Doubling classical computers power

N qubits $\rightarrow N+1$ qubits

Doubling quantum computers power*

Quantum computing's potential is enormous !

*We will be more precise later in the course

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

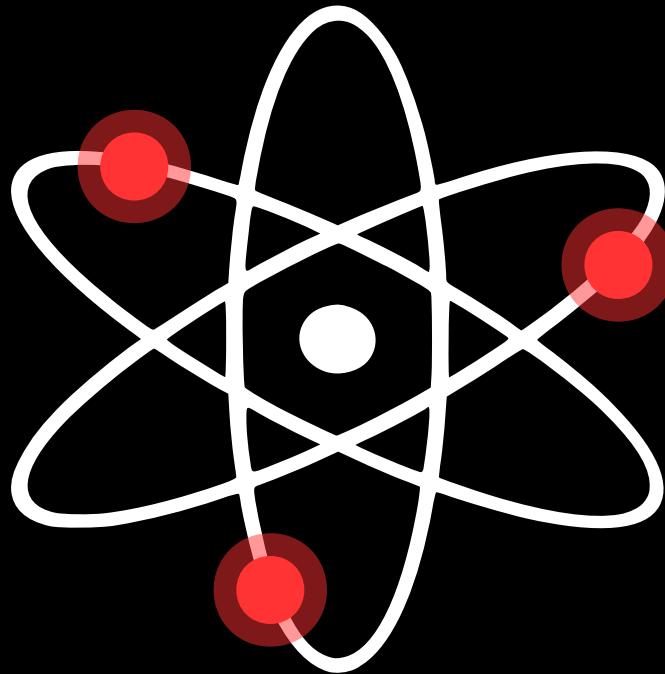
Industry Landscape

Prediction

Extracting information from data and using it to predict trends and behaviour patterns

Simulation

The imitation of the operation of a real-world process or system over time



Optimization

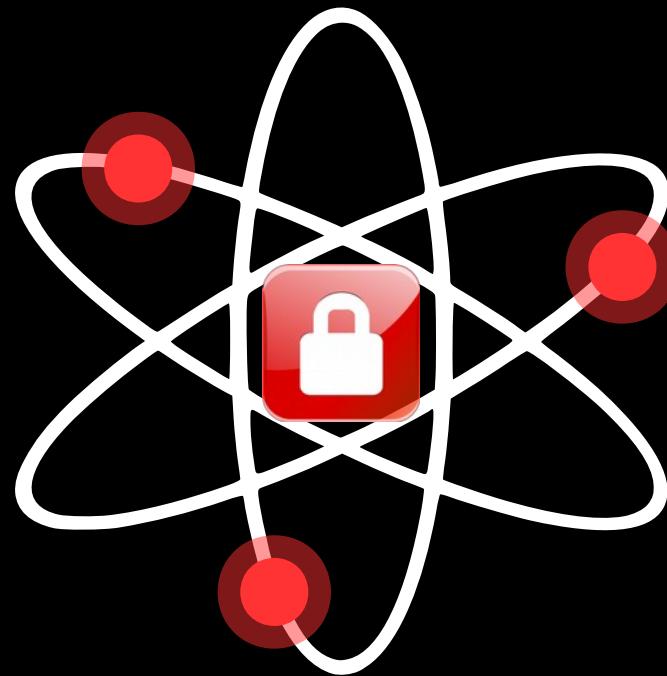
Finding the best solution with the least error from a multitude of possible solutions

Prediction

Extracting information from data and using it to predict trends and behaviour patterns

Simulation

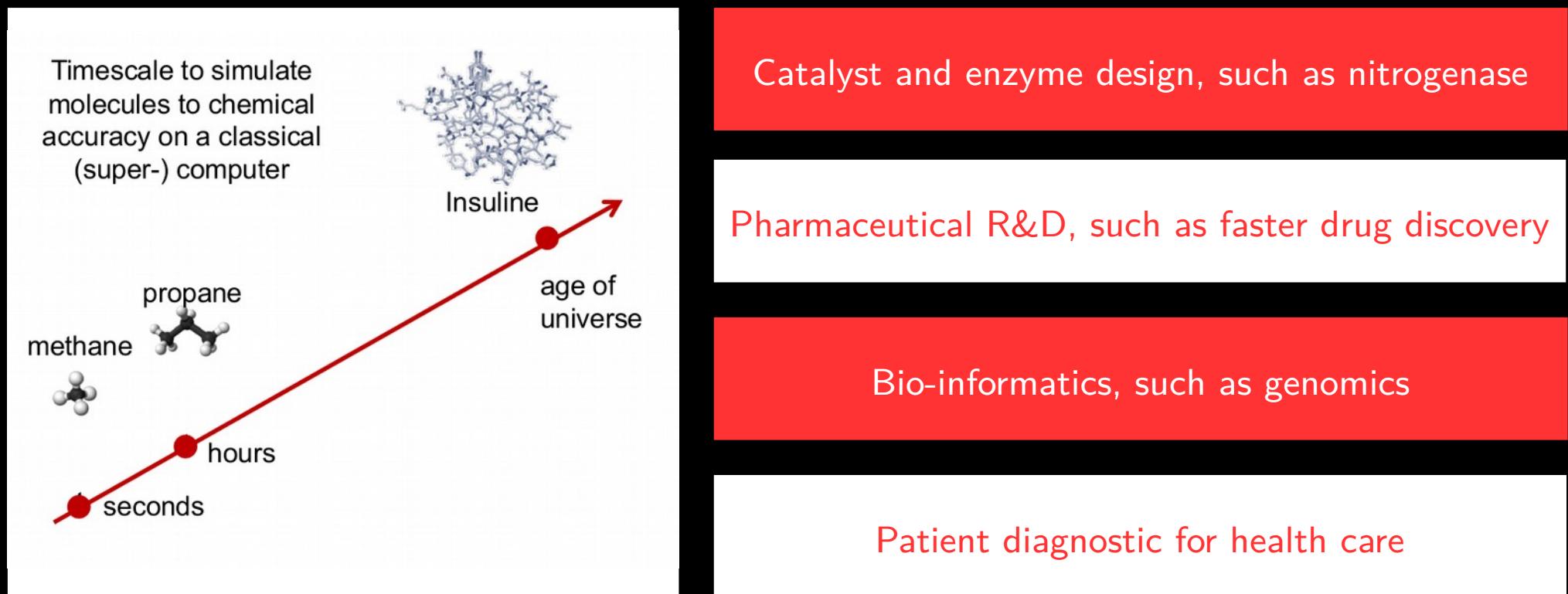
The imitation of the operation of a real-world process or system over time



Optimization

Finding the best solution with the least error from a multitude of possible solutions

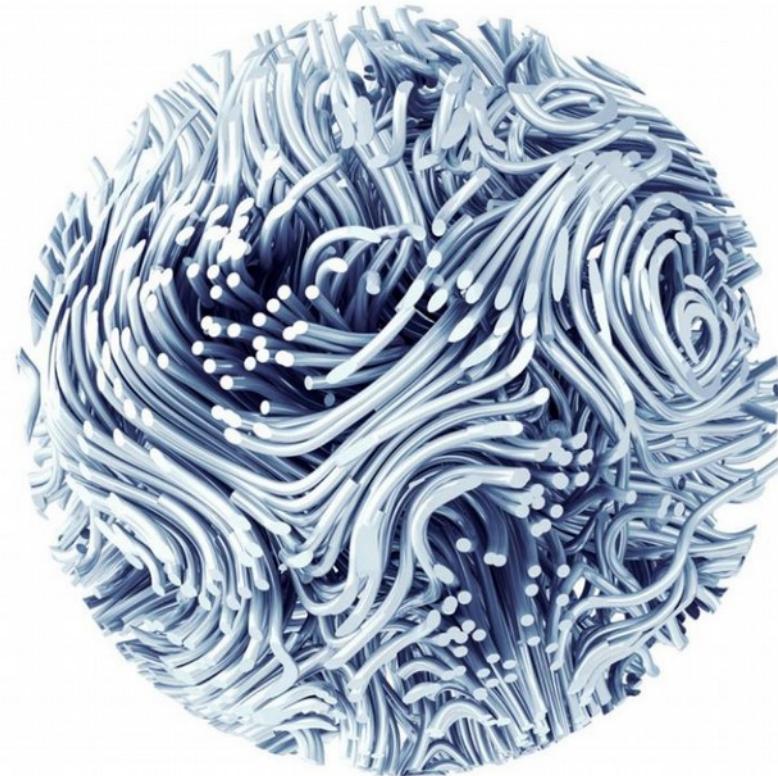
Computational-chemistry can be a highly valuable tool, but scales very poorly on classical computers; which is why in the 1980s the concept of quantum-computing was proposed.



McKinsey & Company report on Quantum Computing (2019)

The next big thing? Quantum computing's potential impact on chemicals

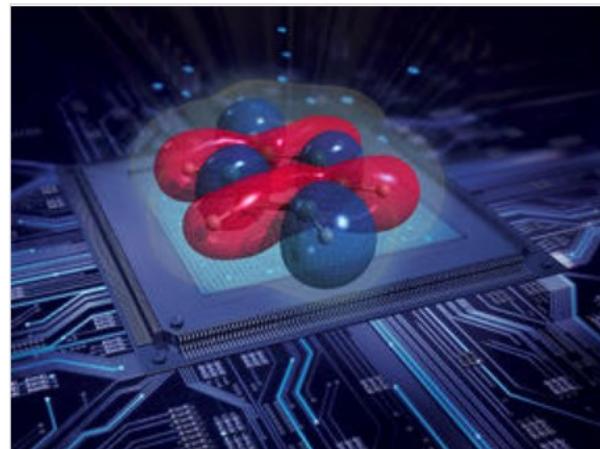
July 2019 | Article



Merck cooperates with start-up HQS Quantum Simulations

Unique approach to quantum chemistry on near-term quantum computers

06-Jun-2019



Merck announced a three-year cooperation with HQS Quantum Simulations, a start-up based in Karlsruhe, Germany. The cooperation between the startup and the Chief Digital Organisation of Merck will focus on applying and commercializing software for quantum chemical applications on quantum computers. Merck has the option for a distribution license.

“Quantum computing is poised to disrupt classical computing and enable a variety of unprecedented opportunities. The applications touch upon many fields with direct relevance to Merck and to our customers, for example materials research, drug discovery, artificial intelligence, and e-commerce,” said Philipp Harbach, Head of In Silico Research at the Chief Digital Organisation of Merck.

Merck KGaA
Merck and HQS Quantum Simulations Cooperate in
Quantum Computing

Atos, Bayer and RWTH Aachen University use Atos Quantum Learning Machine to study human disease patterns

Quantum computing to accelerate research in the Health sector

Paris, Leverkusen, Aachen, November 7, 2018

Atos, a global leader in digital transformation, Bayer, an international life science company, and RWTH Aachen University announce that they are working together to evaluate the use of Quantum Computing in research and analysis of human disease patterns. Computing and life science experts from these three institutions will use the Atos Quantum Learning Machine, the world's highest-performing quantum simulator, to research the evolution of multi-morbidity human diseases from large data repositories.

"Quantum Computing is one of the up and coming technologies that will have a game-changing impact on the life science industry, healthcare providers and of course treatment options for patients. While we consider it being early days for QC we want to make sure to learn how and in which areas it can best be used.", says Dirk Schapeler, VP G4A Digital Innovation from Bayer.

The project is based on anonymized real-world data of intensive care patients, to analyze and identify correlations between comorbidities and relevant patterns of disease evolution. This concept complements the approach of clinical trial studies that usually focuses on a limited number of patients and well-structured data to analyze disease criteria.

"We need to better understand the health state of patients with more than one disease. The Atos Quantum Learning machine will help us analyze the evolution of a disease and the interaction with comorbidities.", says Dr. Ulf Hengstmann, G4A Digital Health Innovation Manager from Bayer. "We already know that patients with specific diseases like heart failure can have several typical comorbidities. Now we need to understand why this is happening and how it affects therapy".

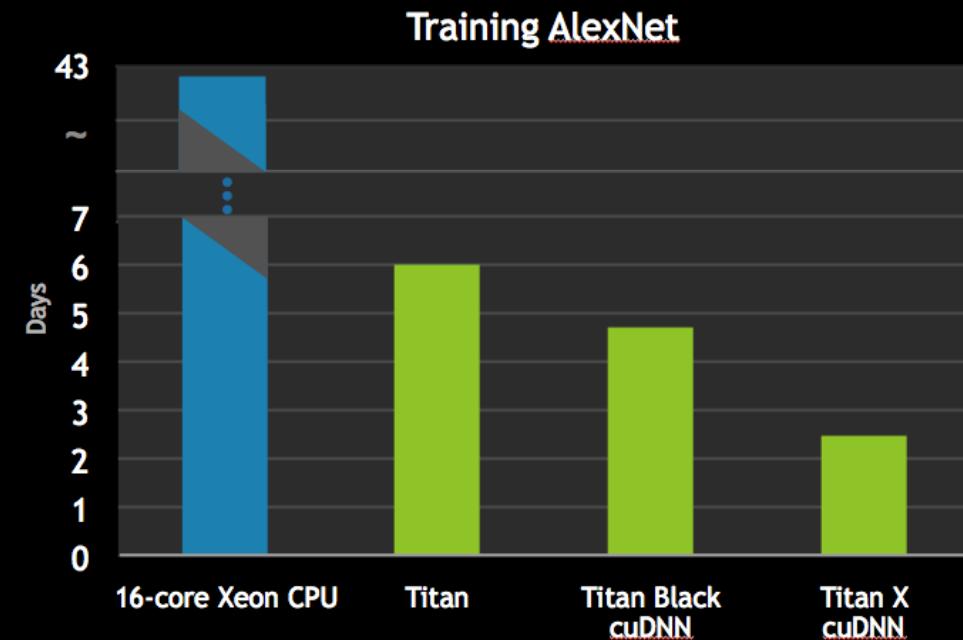
While artificial intelligence is a natural test bed for quantum computing, large scale quantum computers are expected to be threats for cybersecurity.

Machine learning and artificial intelligence

Search

Cybersecurity

Software verification and validation





PENNYLANE

A cross-platform Python library for quantum machine learning, automatic differentiation, and optimization of hybrid quantum-classical computations

Learn

Tutorials to introduce core QML concepts, including quantum nodes, optimization, and devices, via easy-to-follow examples.

[Quantum machine learning »](#)

Develop

Read the documentation, see the source code, make a bug report, and contribute directly to PennyLane.

[GitHub »»](#)

Hack

QHACK, our hardware focused QML hackathon, is now over. Check out our blog for a retrospective of the talks, projects, and winners!

[Blog »»](#)

PennyLane supports a growing ecosystem, including a wide range of quantum hardware and machine learning libraries





Information Technology Laboratory

COMPUTER SECURITY RESOURCE CENTER

Search CSRC

≡ CSRC MENU

CSRC

PROJECTS

Post-Quantum Cryptography

[f](#) [G+](#) [t](#)

Project Overview

NIST has initiated a process to solicit, evaluate, and standardize one or more quantum-resistant public-key cryptographic algorithms. [Full details can be found in the Post-Quantum Cryptography Standardization page.](#)

The Round 2 candidates were announced January 30, 2019. [NISTIR 8240, Status Report on the First Round of the NIST Post-Quantum Cryptography Standardization Process](#) is now available.

Background

In recent years, there has been a substantial amount of research on quantum computers – machines that exploit quantum mechanical phenomena to solve mathematical problems that are difficult or intractable for conventional computers. If large-scale quantum computers are ever built, they will be able to break many of the public-key cryptosystems currently in use. This would seriously compromise the confidentiality and integrity of digital communications on the Internet and elsewhere. The goal of *post-quantum cryptography* (also called quantum-resistant cryptography) is to develop cryptographic systems that are secure against both quantum and classical computers, and can interoperate with existing communications protocols and networks.

PROJECT LINKS

[Overview](#)[FAQs](#)[News & Updates](#)[Events](#)[Publications](#)[Presentations](#)

ADDITIONAL PAGES

[Post-Quantum Cryptography Standardization](#)[Call for Proposals](#)[Example Files](#)[Round 1 Submissions](#)



[Partner Portal](#) [Shop Online](#)

[Random Number Generation](#) [Quantum-Safe Security](#) [Single-Photon Systems](#) [News & Events](#) [Resource Library](#) [About IDQ](#)



ID Quantique, SK Telecom & Nokia Secure Optical Transport System Using Quantum Key Distribution (QKD)

> Learn More

SWISS QUANTUM

Contact Us

• • •

ID Quantique (IDQ) is the world leader in quantum-safe crypto solutions, designed to protect data for the long-term future. The company provides quantum-safe network encryption, secure quantum key generation and quantum key distribution solutions and services to the financial industry, enterprises and government organisations globally.

IDQ also commercializes a quantum random number generator, which is the reference in the security, simulation and gaming industries.

Product development and process optimization are among the manufacturing areas likely to witness major innovations with quantum computing.



Logistics: scheduling, planning, product distribution, routing

Automotive: traffic simulation, e-charging station
and parking search, autonomous driving

Material science: effective catalytic converters for cars,
battery cell research, more efficient material for solar cells,
and property engineering uses such as OLEDs

THE WALL STREET JOURNAL.

Home World U.S. Politics Economy Business Tech Markets Opinion Life & Arts Real Estate WSJ. Magazine

Subscribe | Sign In

Search (X)

CIO JOURNAL

Mercedes Enlists Quantum Computing to Build a Better Electric Vehicle Battery

Auto maker, working with IBM quantum experts, sees 'huge opportunity' in the technology

SHARE AA TEXT COMMENTS 4



Mercedes-Benz is working with IBM on the goal of deploying the next-generation computing power. Above, a quantum scientist walks across the IBM Q computation center in Yorktown Heights, N.Y. PHOTO: CONNIE ZHOU/IBM

RECOMMENDED VIDEOS

1. Impeachment Inquiry: Why High Crimes Is Inherently Subjective 
2. Dissecting the Vaping Illness Mystery 
3. Timeline: Interactions Between Trump's Camp and Ukraine 
4. U.S. Begins Withdrawal of Troops From Northern Syria 
5. Anatomy of an IPO Valuation 

MOST POPULAR ARTICLES

1. Appeals Court Stays Order That Trump Release Tax Returns 
2. WeWork Investors Turned Off by 'Sloppy' IPO Filings 

VOLKSWAGEN
AKTIENGESELLSCHAFT

GROUP BRANDS & MODELS SUSTAINABILITY INVESTOR RELATIONS CAREER MEDIA SOCIAL MEDIA

Minimal Waiting Time

Route Optimization

Intelligent traffic control with quantum computers

Traffic control is one of the many areas where quantum computers could be used.
An innovative project by Volkswagen: Avoiding traffic jams and shortening waiting times using quantum algorithms.

Traditionally, financial players have relied on the power of computing to reduce the risk. This has led to a computing arms race among them, where bigger profits result from analyzing a situation faster and in more detail.

Trading strategies

Portfolio optimization

Asset pricing

Fraud detection

Risk analysis

Market simulation



AMERICAN BANKER

All Sections ▾

NOW READING: [The Latest](#)[Why banks like Barclays are testing quantum computing](#)[Morning Scan Deutsche Bank plans new tech division; bitcoin ...](#)[BankThink Streamlined Volcker Rule could encourage some ...](#)[Subprime card lender introduces ex-Barclays exec as CEO](#)[Warren: Trump DOJ settles case against Wells Fargo; let big banks off easy](#) >

Why banks like Barclays are testing quantum computing

By
Penny CrosmanPublished
July 16 2018, 4:12pm EDTMore in
[High performance computing](#)
[Bank technology](#)
[Barclays](#)
[Morgan Stanley](#)
[IBM](#)[Print](#) [Reprint](#)

Quantum computing — technology based on the principles of quantum theory — is increasingly attracting the interest of financial services firms that are seeking to process transactions, trades and other types of data as fast as possible.

Barclays and JPMorgan Chase have been experimenting with IBM's quantum computing technology since December, [when they joined the tech company's Q network](#). Salvatore Cucchiara at Morgan Stanley last week articulated the bank's hope of speeding up portfolio optimizations like Monte Carlo simulations with the help of quantum computing.

Trending

Does it really matter where Wells Fargo's CEO is based?

The Most Powerful Women in Banking

A battle royal for online deposits

Energy optimization, for example, requires far too much traditional computing power to identify the ideal balance of resources from different energy sources to meet ever-changing consumption needs in real time.



Network design

Energy distribution

Oil well optimization

[Energy](#)[Technology](#)[Current issues](#)[Environment](#)[Community](#)[Company](#)

News and updates › **News releases**

[News](#)

Jan 8, 2019 - 12:01 a.m. EST

ExxonMobil and IBM to Advance Energy Sector Application of Quantum Computing

- Strategic commitment to advance joint research into quantum computing for energy
- ExxonMobil becomes first energy company to join the IBM Q Network
- Technology could further enhance ExxonMobil's own research and development capabilities

Atos fournit à Total le simulateur quantique le plus performant au monde

Paris, le 16 mai 2019

Atos, leader international de la transformation digitale, annonce aujourd'hui la livraison au groupe Total de son Atos Quantum Learning Machine (QLM), le **simulateur quantique le plus performant au monde**. Dans le cadre d'un projet de recherche transverse ambitieux, le groupe Total compte ainsi mettre l'Atos QLM au service de l'ensemble de ses métiers.

L'Atos Quantum Learning Machine associe une machine ultra compacte et puissante à un langage de programmation universel, permettant aux chercheurs et ingénieurs de développer et tester des algorithmes quantiques. Elle simule les lois de la physique qui sont au cœur même de l'informatique quantique pour calculer l'exécution exacte d'un programme quantique avec une précision à la double décimale.

Le calcul quantique trouvera des applications concrètes au sein du Groupe Total, pour la chimie moléculaire et des matériaux, l'optimisation de réseaux énergétiques, de flottes de véhicules, ou encore d'outils industriels et à plus long terme, l'imagerie sismique ou bien la mécanique des fluides.

« Monter en compétence sur le calcul quantique, avec cette solution d'Atos, l'un des leaders du secteur, c'est démontrer une fois encore notre esprit pionnier. Nous allons développer une approche quantique sur différentes problématiques de recherche couvrant l'ensemble de nos métiers pour explorer de nouvelles voies de résolution et gagner en performance et en efficacité », a déclaré Marie-Noëlle Semeria, directrice recherche & développement groupe de Total.

Microsoft and DEWA bringing quantum computing to Dubai

June 28, 2018 | Microsoft News Center



DEWA will work with Microsoft and access new quantum Microsoft Azure services to create quantum-inspired solutions to power energy optimization and improve sustainability efforts in Dubai and the United Arab Emirates

DUBAI, United Arab Emirates — June 28, 2018 — The Dubai Electricity and Water Authority (DEWA) on Thursday announced plans to work with Microsoft Corp. to develop new quantum-based solutions to address energy optimization and other challenges where classical computers have serious limitations, making it the first organization outside the U.S. to participate in the Microsoft Quantum program.

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Task:

Integer Factorization

Applications

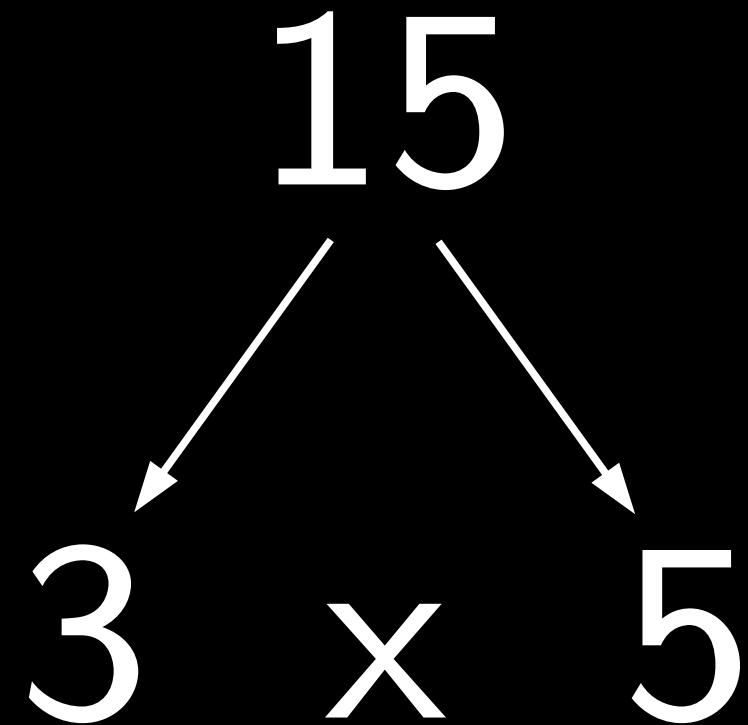
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

Q-Algorithms

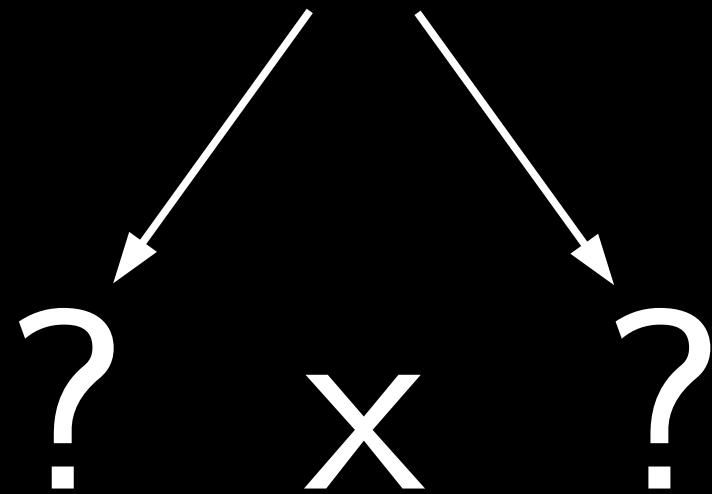
Q-Bits

Q-Circuits

Hardware

Industry

7110379909909823469971673725424473064353882489427176741102057973000889379665565049610836498148428158908772246304866860943192
0907344516262190407768933383377381407878353760499455979319960700906894699032445175759904798500685134300942629461309714010525
8451183638689370751031611701475016230049806026342053176134099092008619376369645670455584888994220854383100330689198272181971
464627398981966424692315074087395450462661785555515740733919354799058011416327121389973469757674185303667619128805768897233
3216854588089690421544040301537811000428377757537533165315590643914173011914509168646819605343438902256216469789162186128



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Classical

$\sim 10^{14}$

years

Quantum*

~ 10

seconds

*assuming a quantum computer with 4096 perfectly stable qubits

Task:

Integer Factorization

Quantum algorithm:

Shor's Algorithm

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

1 digit

Enter Passcode



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

Number of digits

Number of tries

1



10

Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

4 digits

Enter Passcode

0 0 0 0

1

2

3

4

5

6

7

8

9

0

Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Number of digits

1



10

4



10,000

Applications

Q-Algorithms

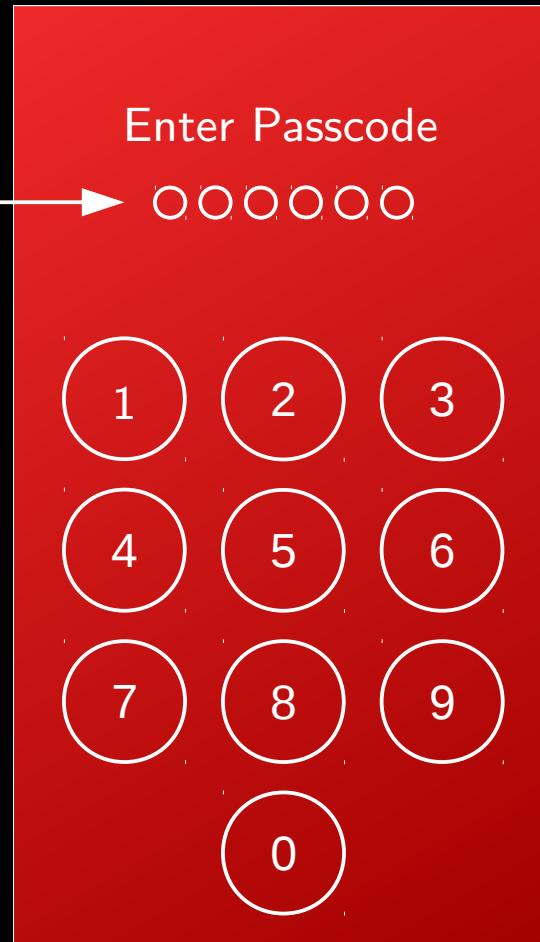
Q-Bits

Q-Circuits

Hardware

Industry

6 digits



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Number of digits

Number of tries

1



10

4



10,000

6



1,000,000

Applications

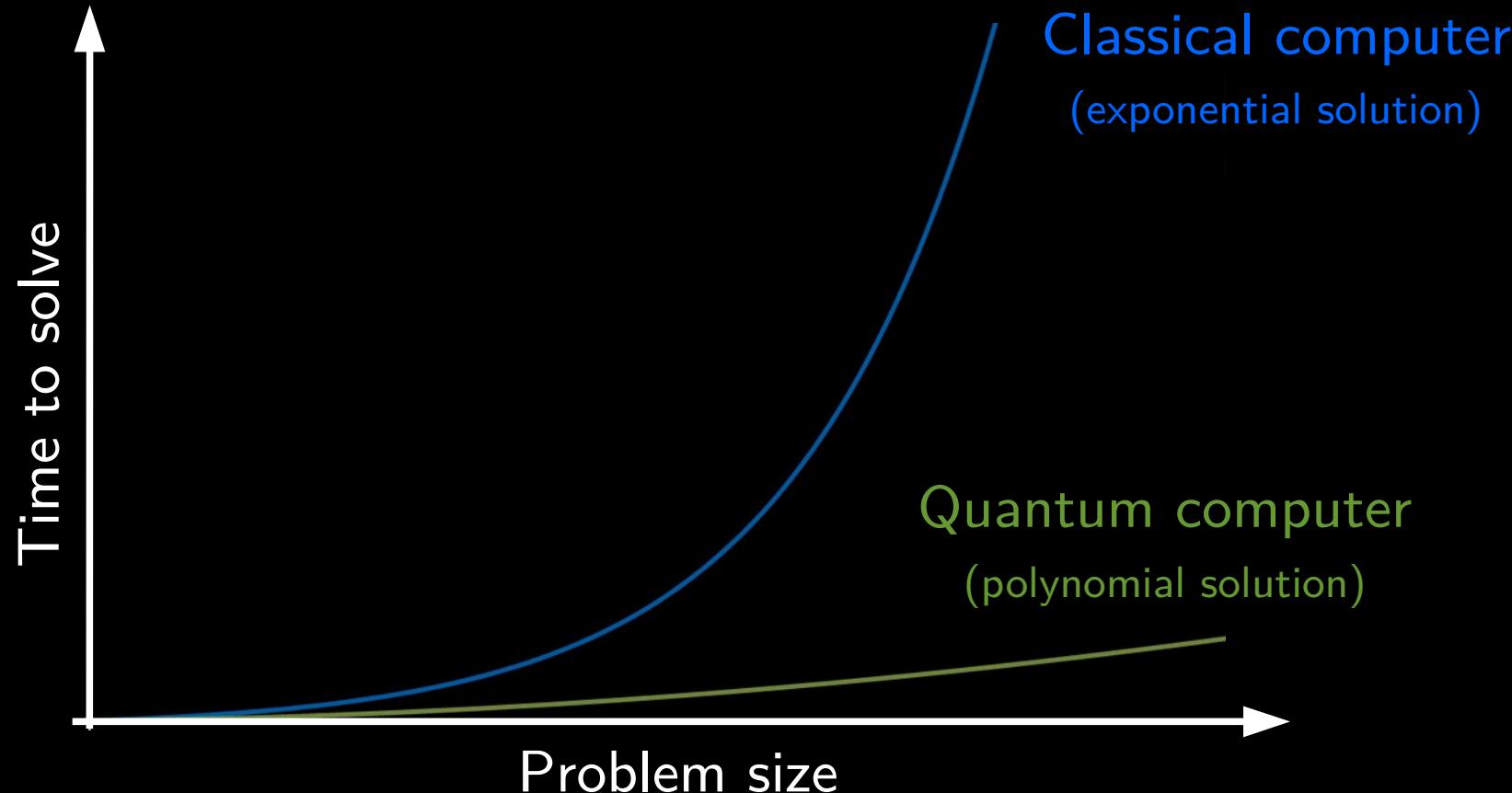
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

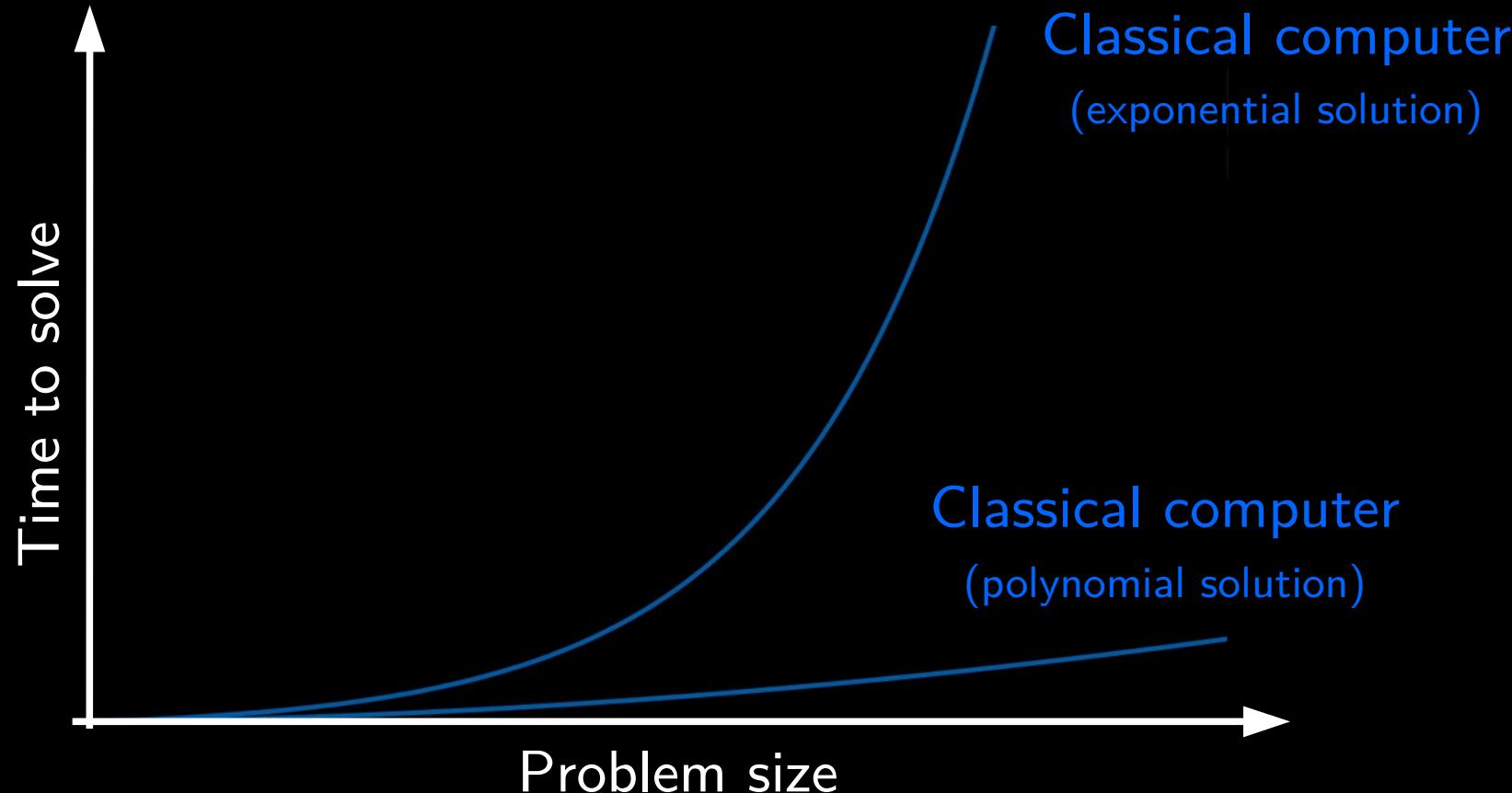
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

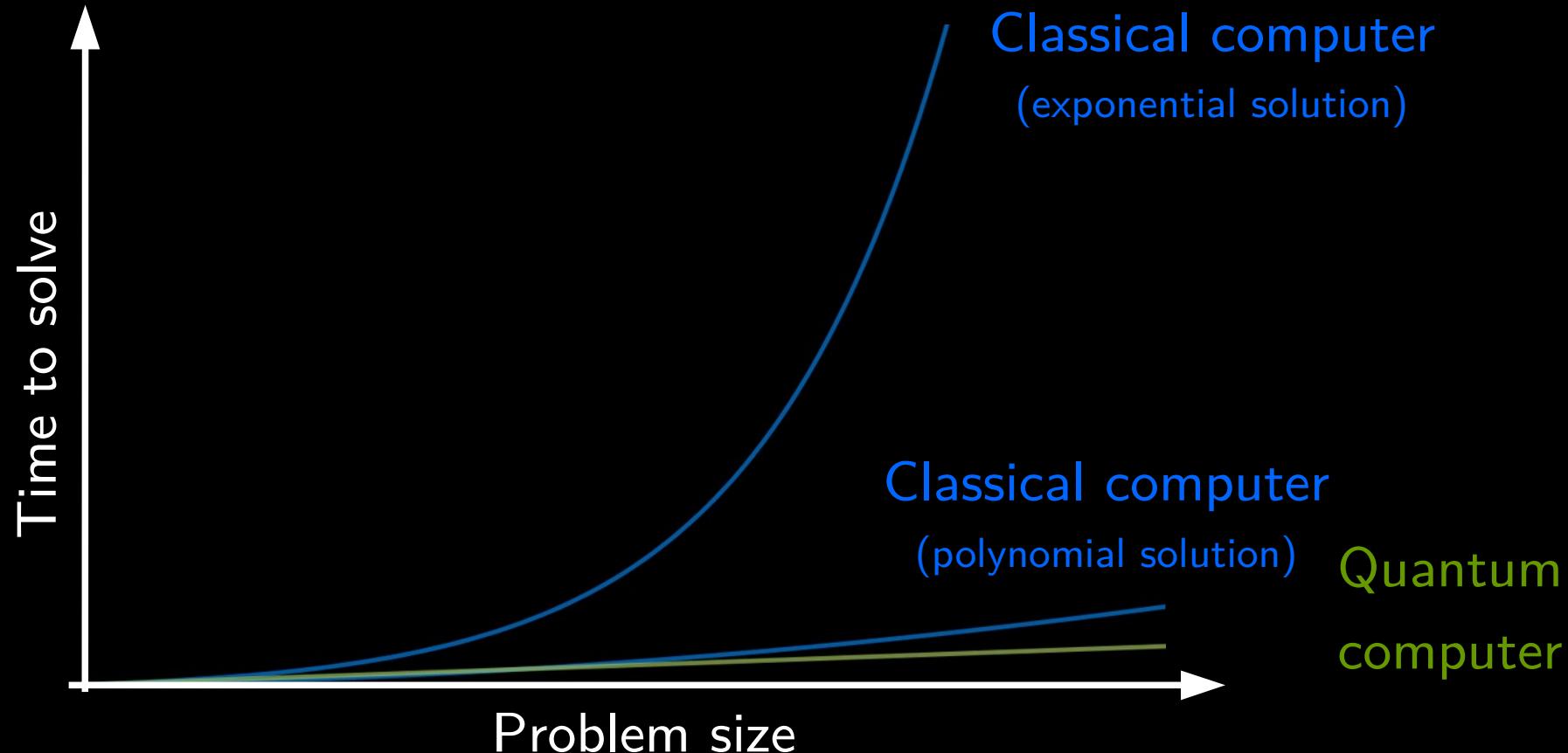
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

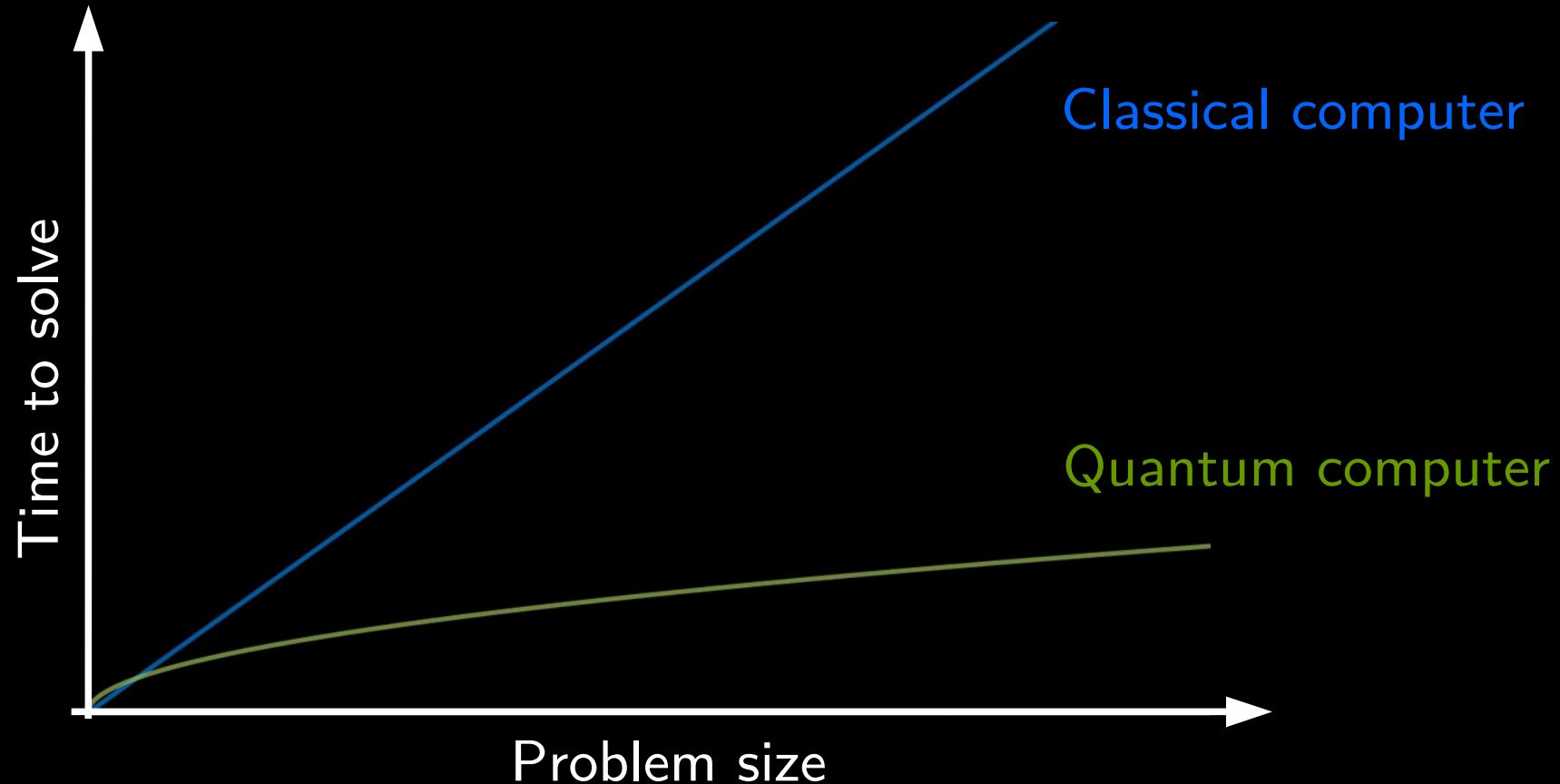
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

1 digit

1 number

Enter Passcode

1

Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

1 digit

4 numbers

Enter Passcode



1

2

3

4

Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

1 digit

6 numbers

Enter Passcode



1

2

3

4

5

6

Shor's algorithm

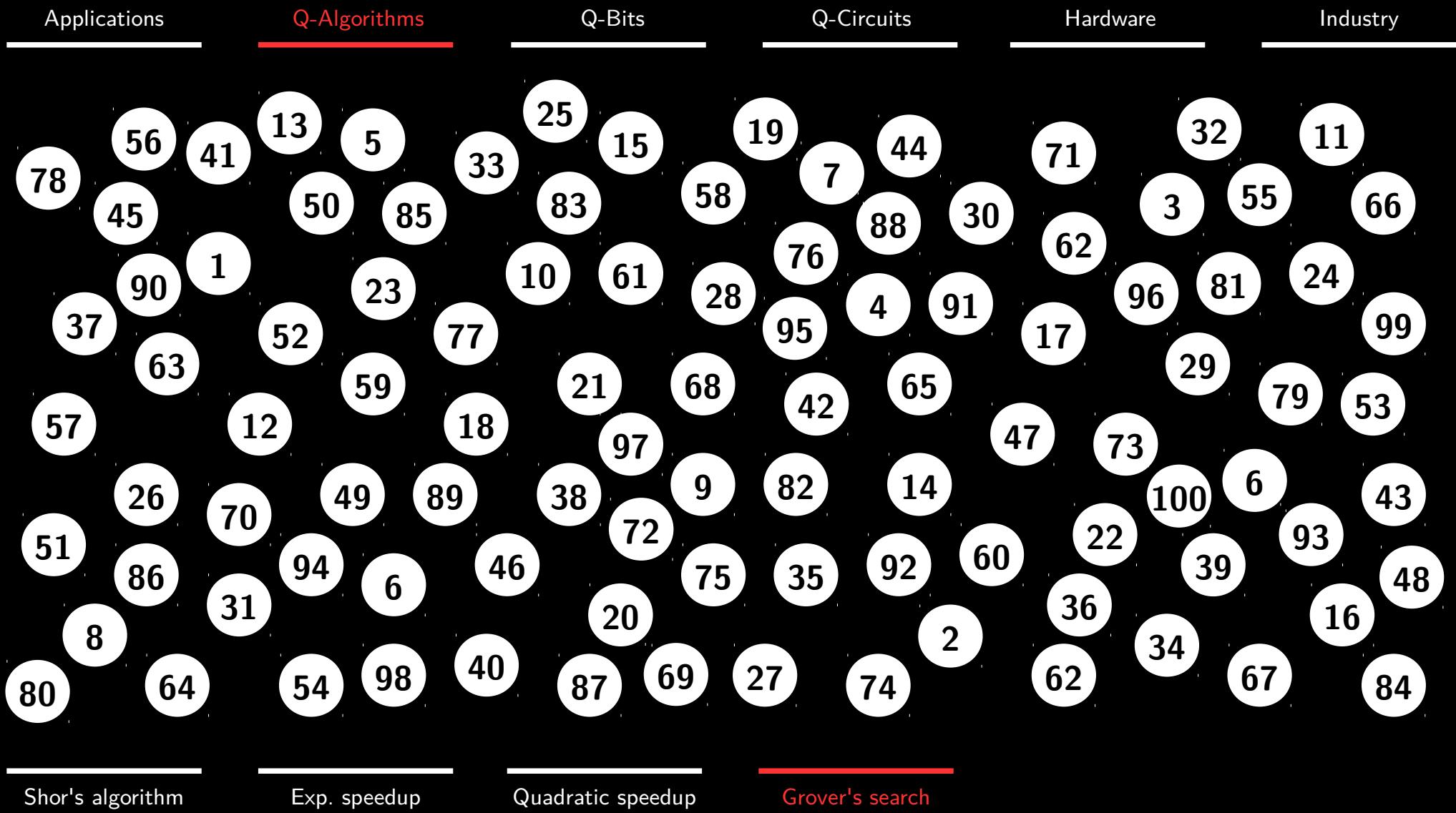
Exp. speedup

Quadratic speedup

Grover's search

Task:

Searching unsorted database



Applications

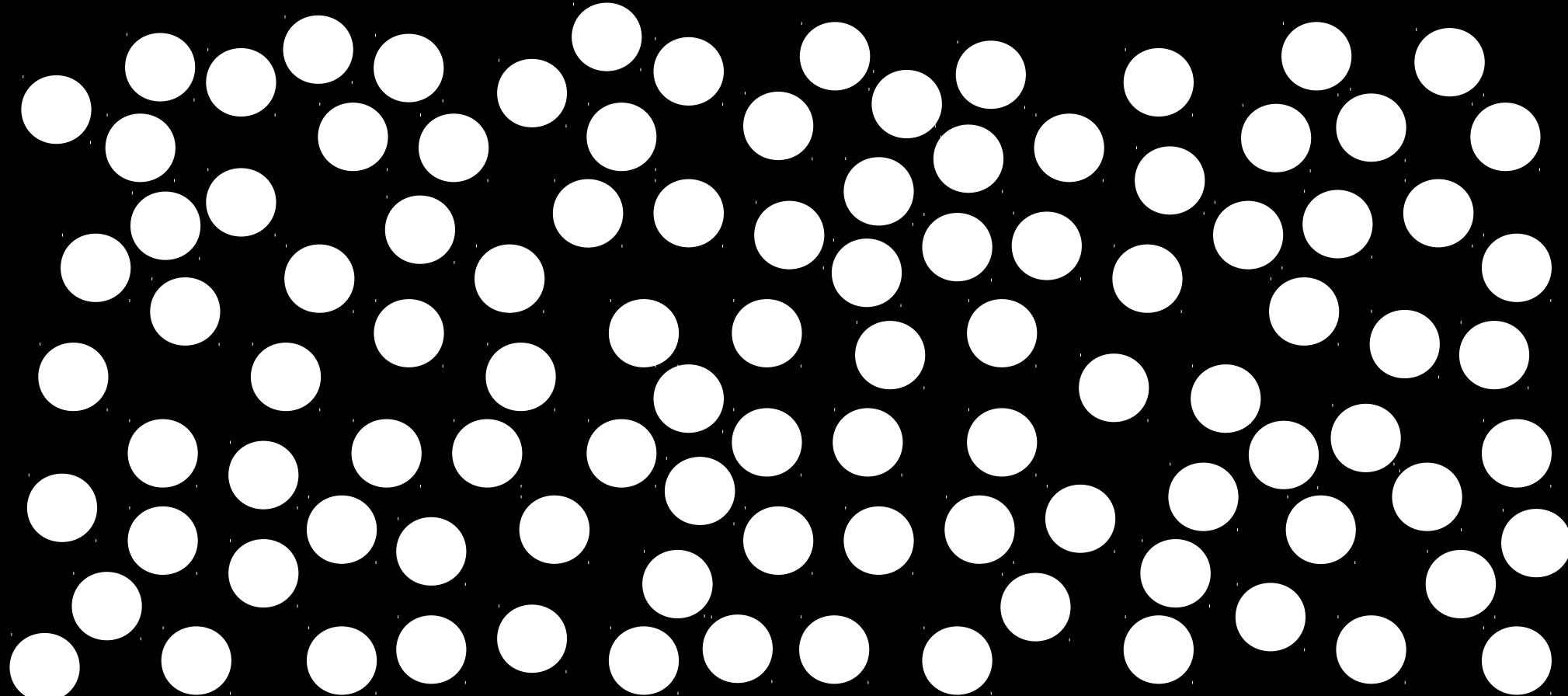
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Shor's algorithm

Exp. speedup

Quadratic speedup

Grover's search

Classical

100

tries

Quantum

8

tries

Classical

n

tries

Quantum

\sqrt{n}

tries

Task:

Searching unsorted database

Quantum algorithm:

Grover's Search

Task:

Searching unsorted database

Quantum algorithm:

Grover's Search



Later in talk

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

1. Superposition

2. Entanglement

1. Superposition

2. Entanglement

Applications

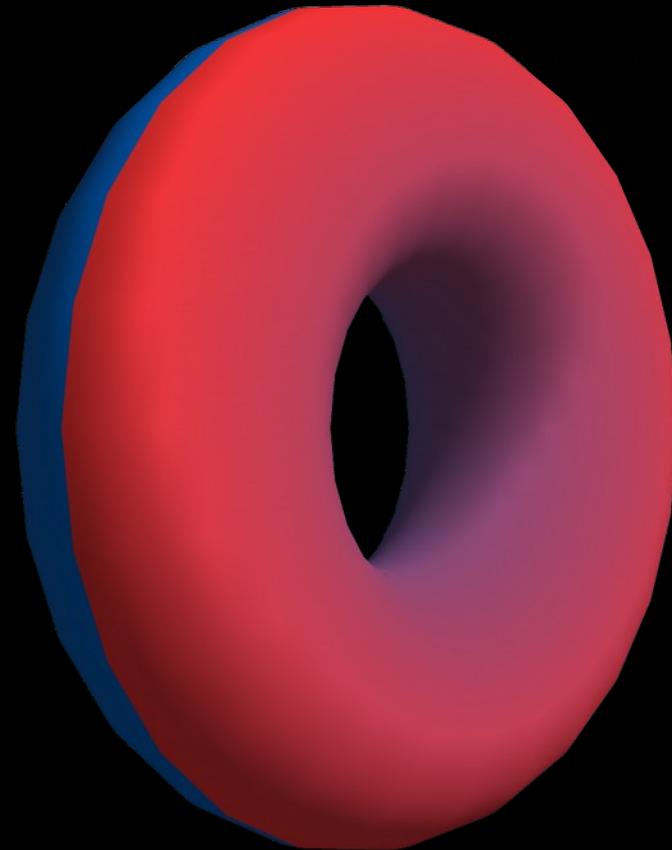
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Superposition

Entanglement

Summary

Applications

Q-Algorithms

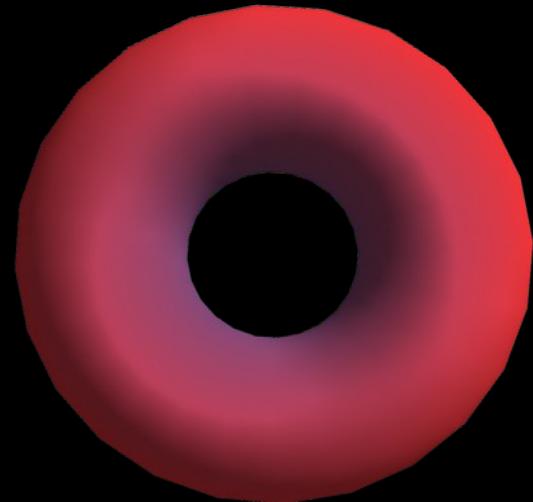
Q-Bits

Q-Circuits

Hardware

Industry

Classical bit:



0

Superposition

Entanglement

Summary

Applications

Q-Algorithms

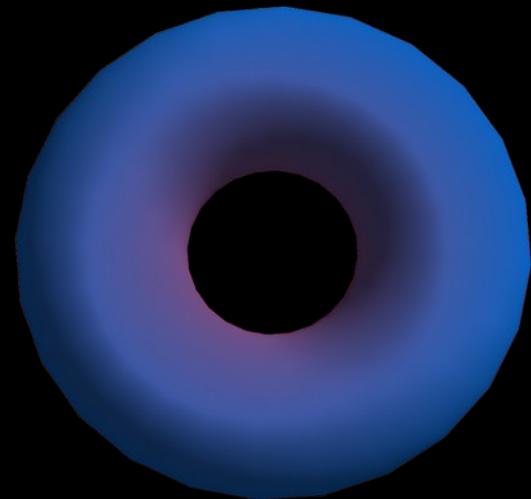
Q-Bits

Q-Circuits

Hardware

Industry

Classical bit:



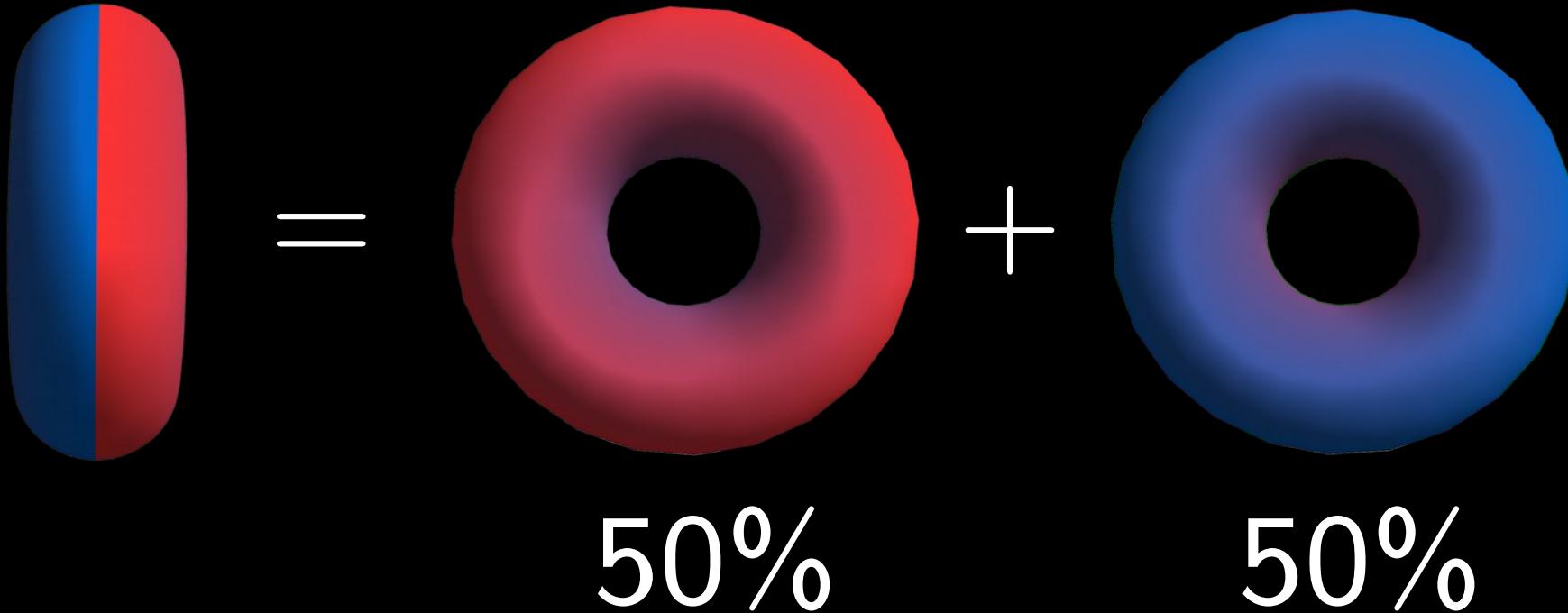
1

Superposition

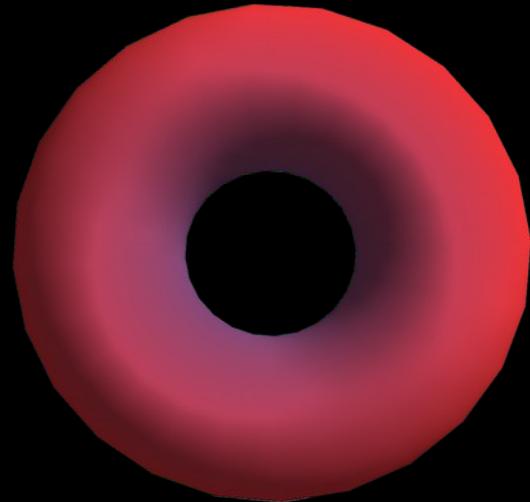
Entanglement

Summary

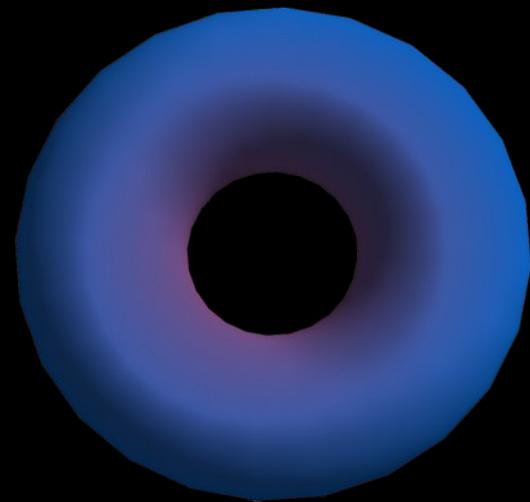
Superposition:



Measurement:

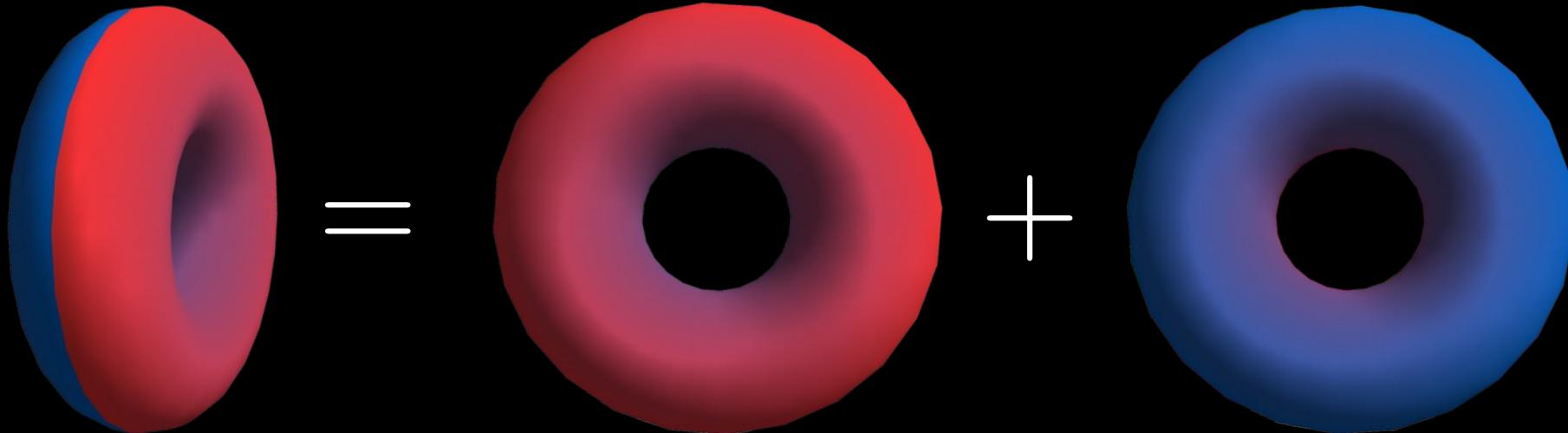


50%



50%

Superposition:



70%

30%

Applications

Q-Algorithms

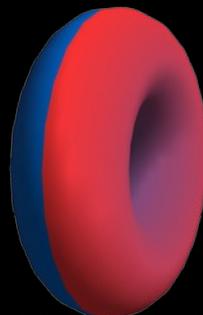
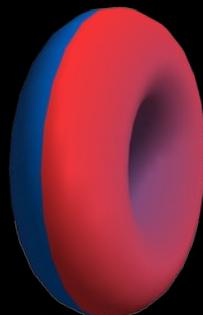
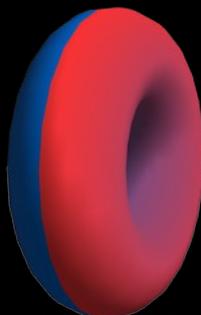
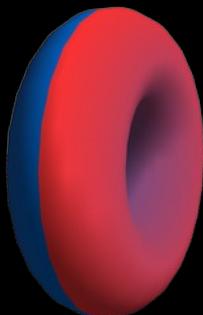
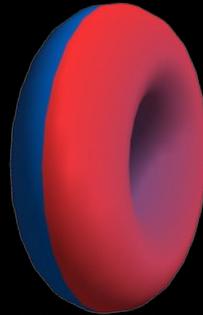
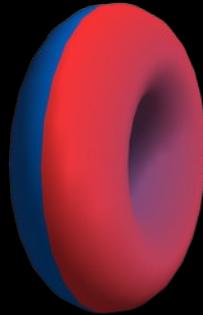
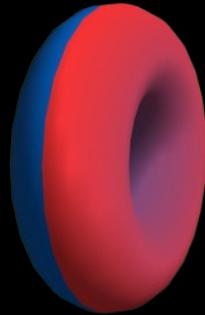
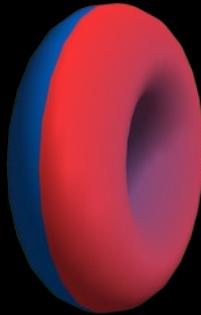
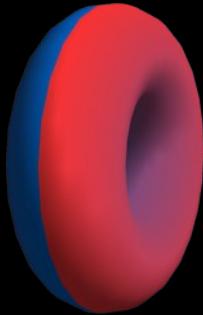
Q-Bits

Q-Circuits

Hardware

Industry

Multiple qubits:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

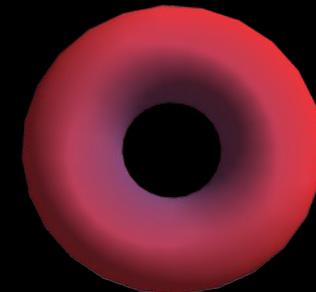
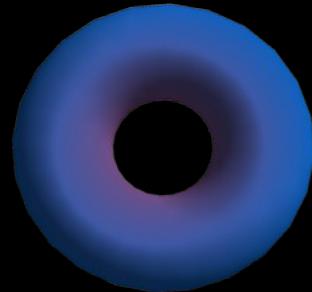
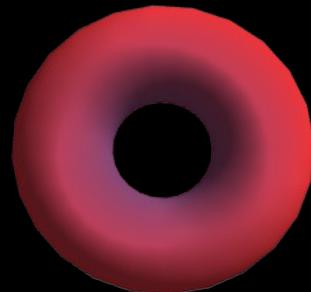
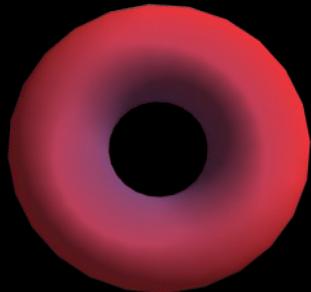
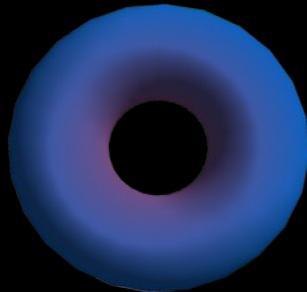
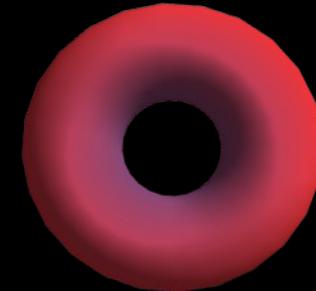
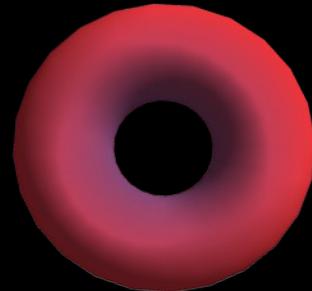
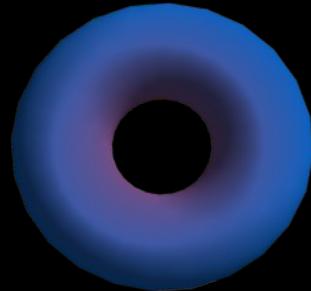
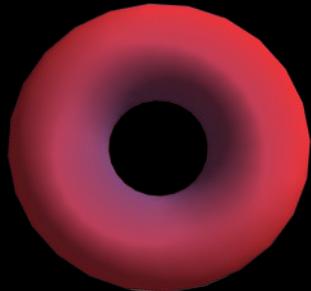
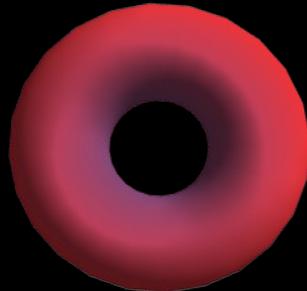
Q-Bits

Q-Circuits

Hardware

Industry

Multiple measurements:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

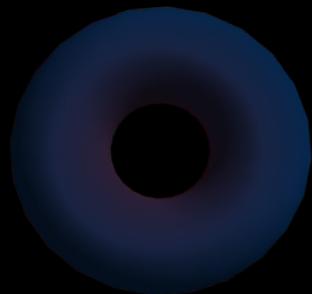
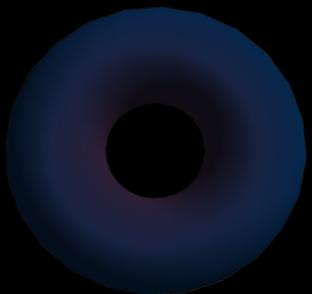
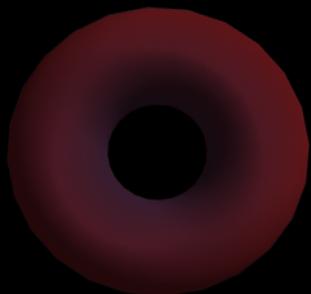
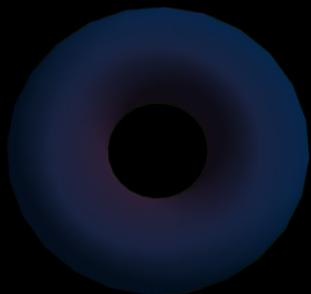
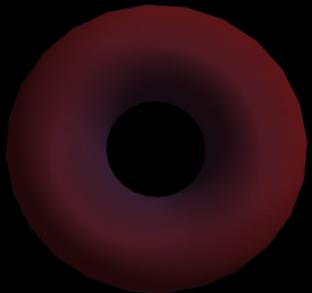
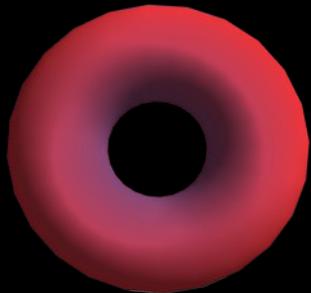
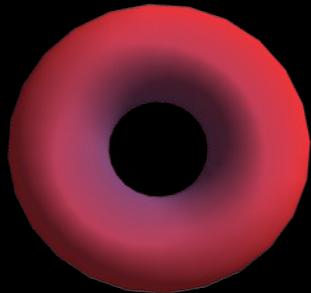
Q-Bits

Q-Circuits

Hardware

Industry

2 (classical) bits:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

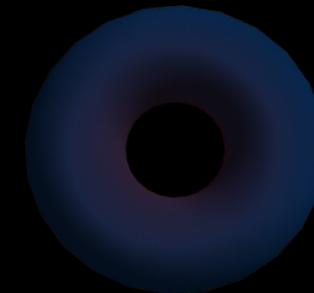
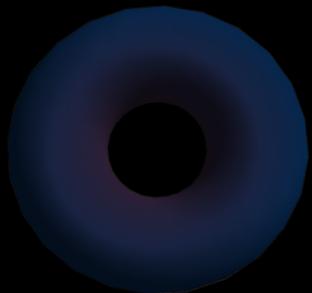
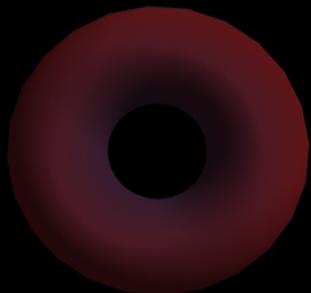
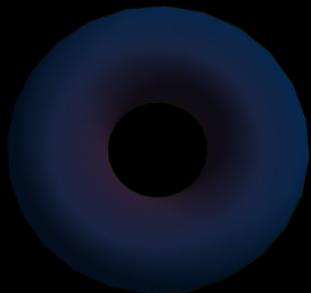
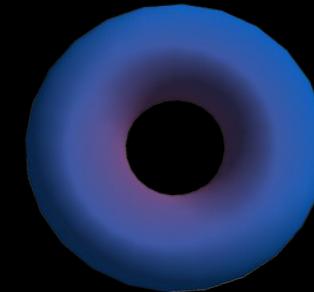
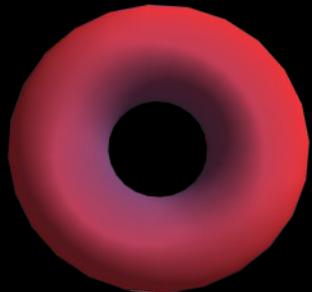
Q-Bits

Q-Circuits

Hardware

Industry

2 (classical) bits:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

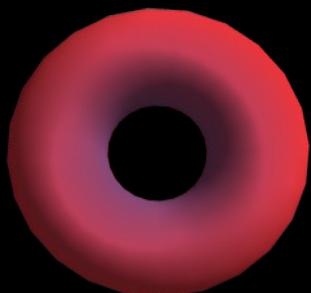
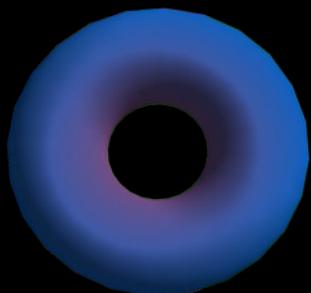
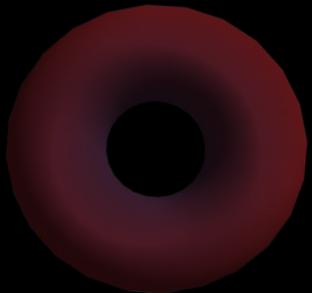
Q-Bits

Q-Circuits

Hardware

Industry

2 (classical) bits:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

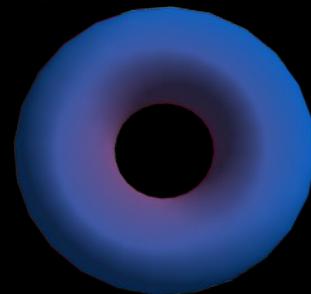
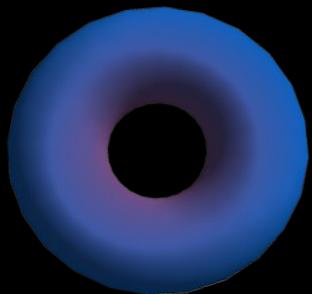
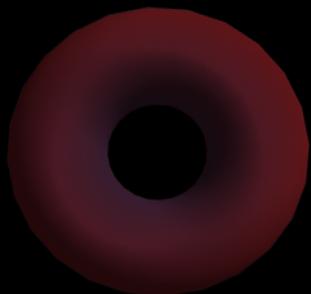
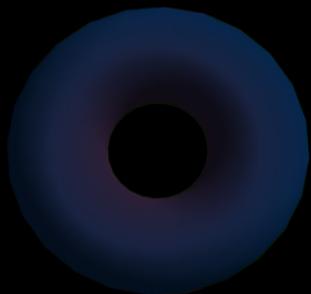
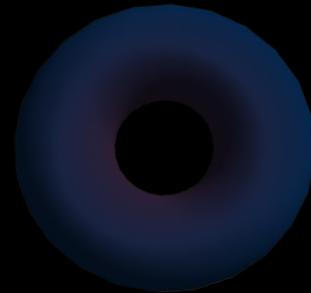
Q-Bits

Q-Circuits

Hardware

Industry

2 (classical) bits:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

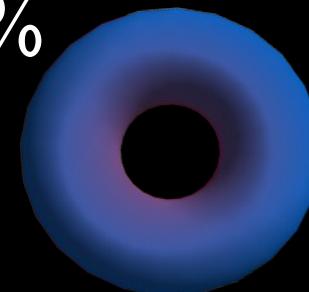
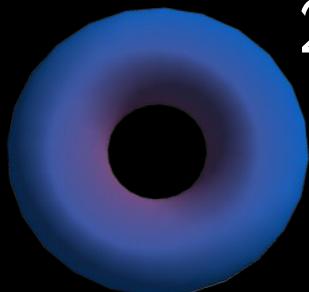
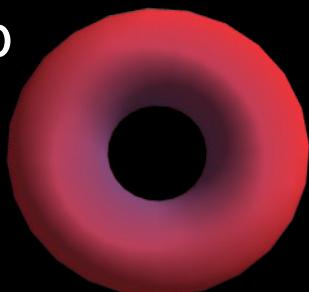
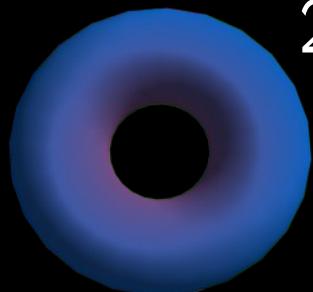
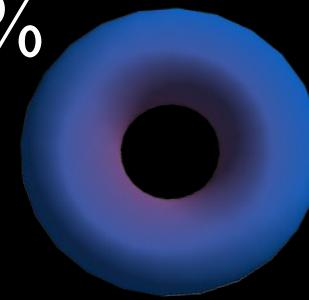
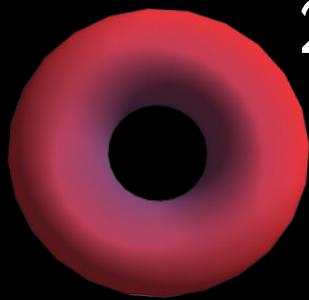
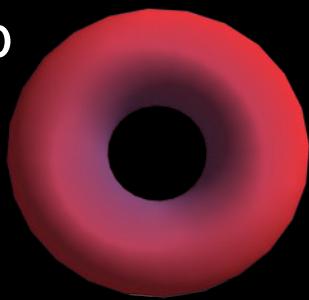
Q-Bits

Q-Circuits

Hardware

Industry

2 qubits:

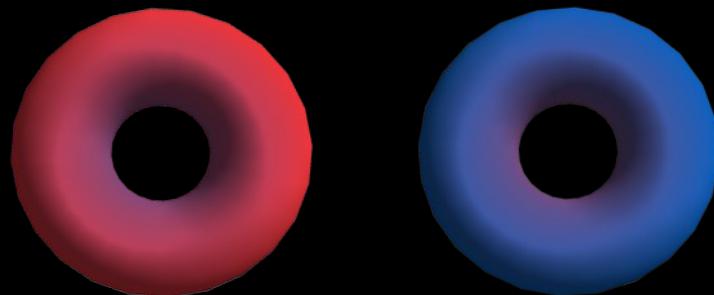


Superposition

Entanglement

Summary

2 (classical) bits:



1st bit



2nd bit

of information

of information

Applications

Q-Algorithms

Q-Bits

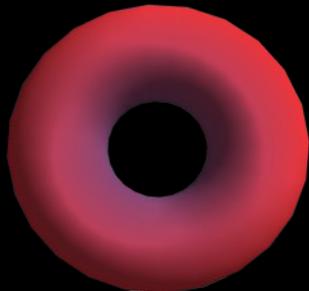
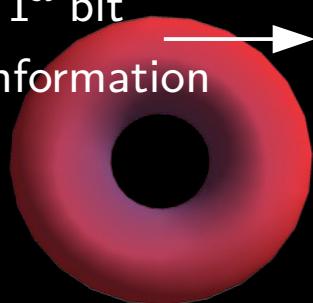
Q-Circuits

Hardware

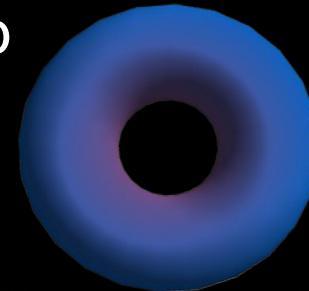
Industry

2 qubits:

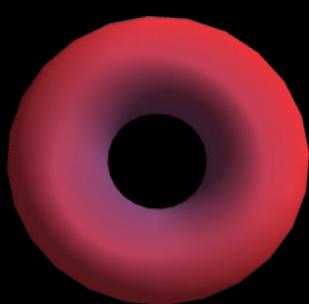
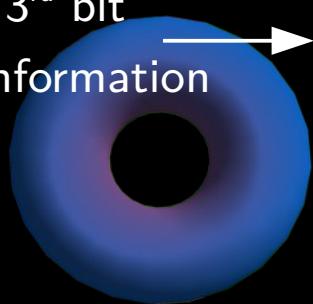
1st bit
of information → ?%



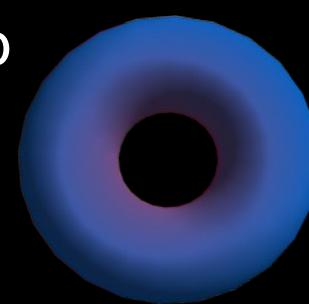
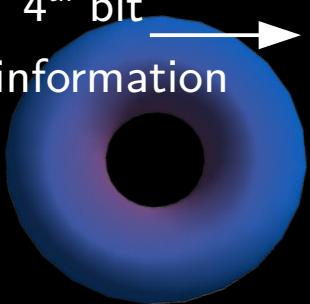
2nd bit
of information → ?%



3rd bit
of information → ?%



4th bit
of information → ?%

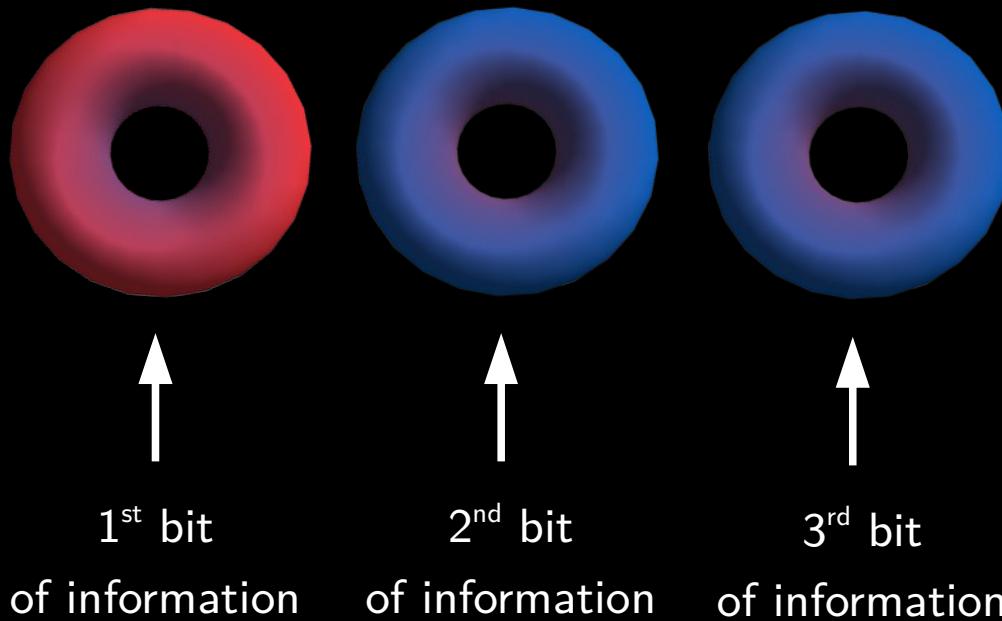


Superposition

Entanglement

Summary

3 (classical) bits:



Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

3 qubits:

1st bit
of information → ?%



2nd bit
of information → ?%



3rd bit
of information → ?%



4th bit
of information → ?%



Superposition

Entanglement

Summary

5th bit
of information → ?%



6th bit
of information → ?%



7th bit
of information → ?%



8th bit
of information → ?%



Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

n

qubits

2^n

bits

Applications

Q-Algorithms

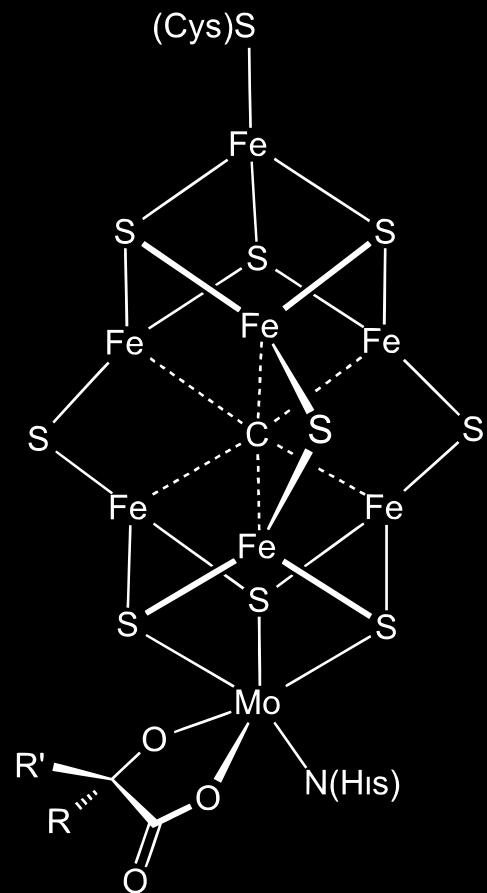
Q-Bits

Q-Circuits

Hardware

Industry

108
qubits



2^{108}

$\approx 10^{32}$
bits

Superposition

Entanglement

Summary

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

1. Superposition

2. Entanglement

Superposition

Entanglement

Summary

Applications

Q-Algorithms

Q-Bits

Q-Circuits

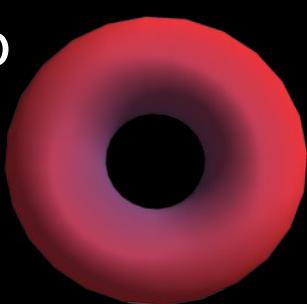
Hardware

Industry

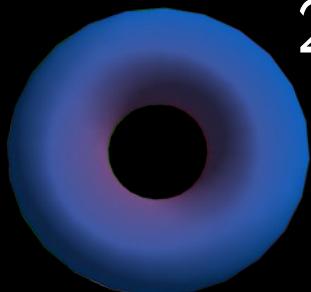
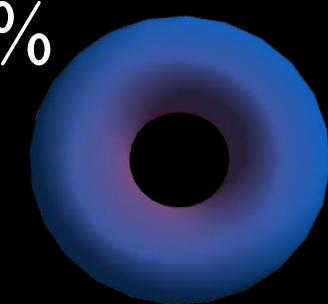
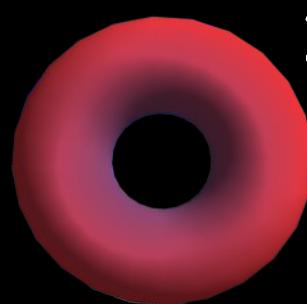
Superposition:



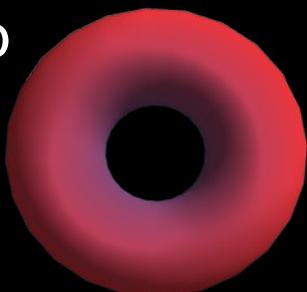
25%



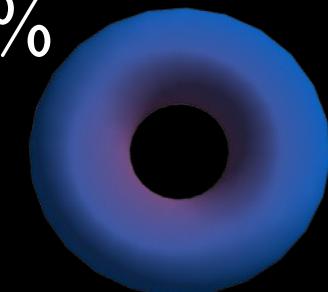
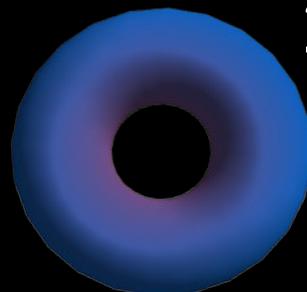
25%



25%



25%



Superposition

Entanglement

Summary

Applications

Q-Algorithms

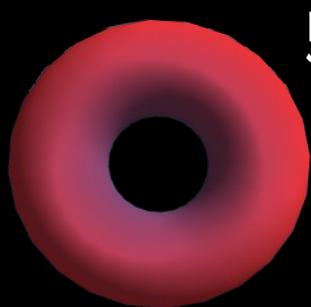
Q-Bits

Q-Circuits

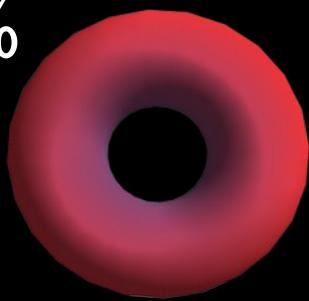
Hardware

Industry

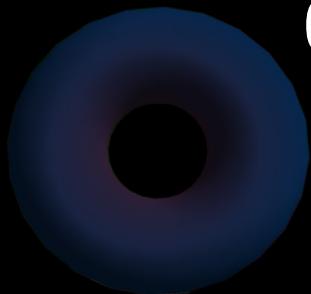
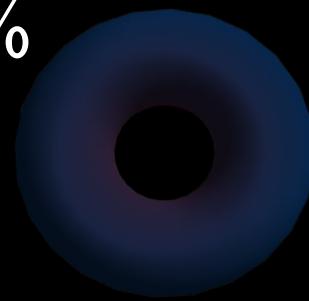
Entanglement:



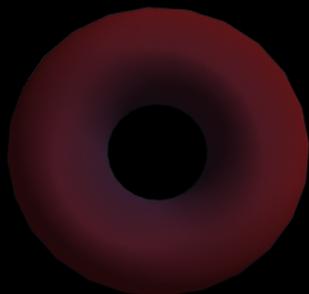
50%



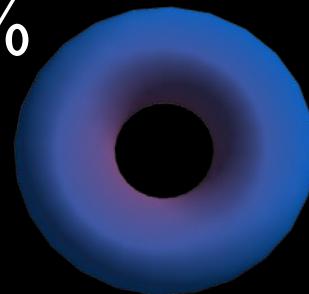
0%



0%



50%



Superposition

Entanglement

Summary

Applications

Q-Algorithms

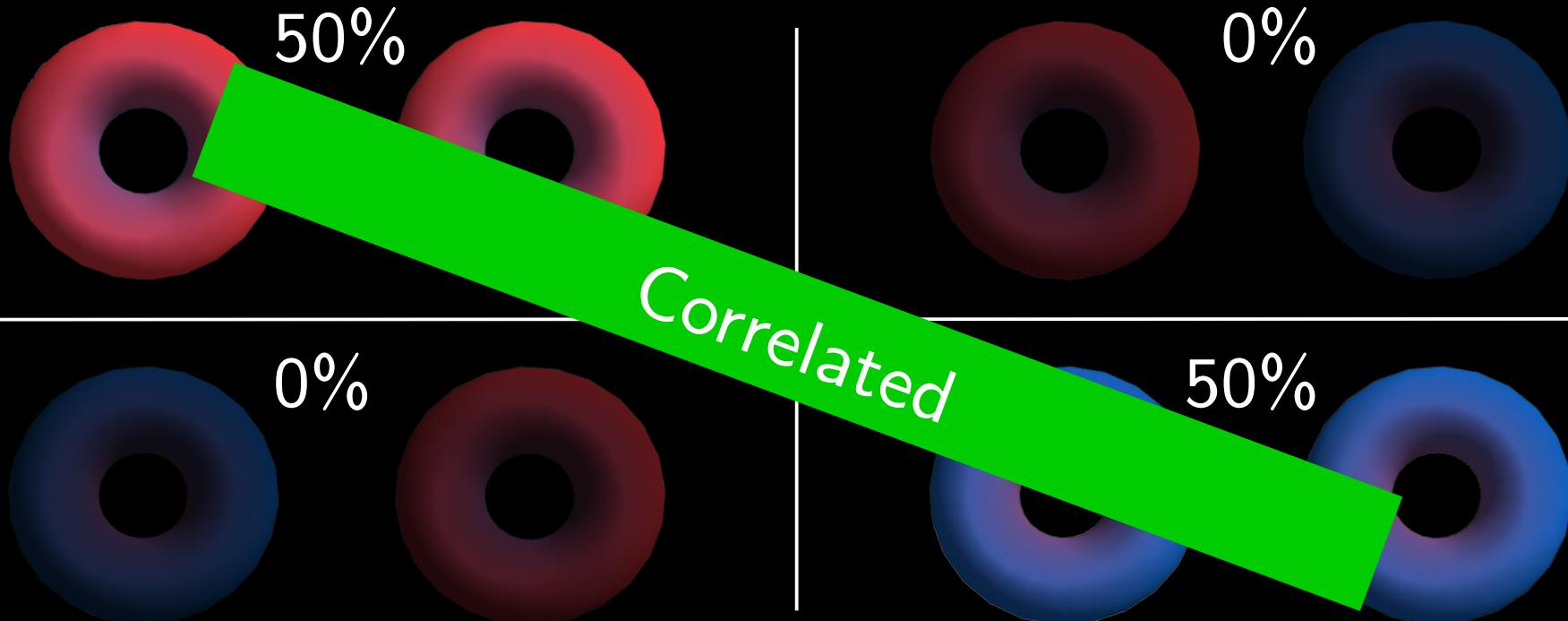
Q-Bits

Q-Circuits

Hardware

Industry

Entanglement:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

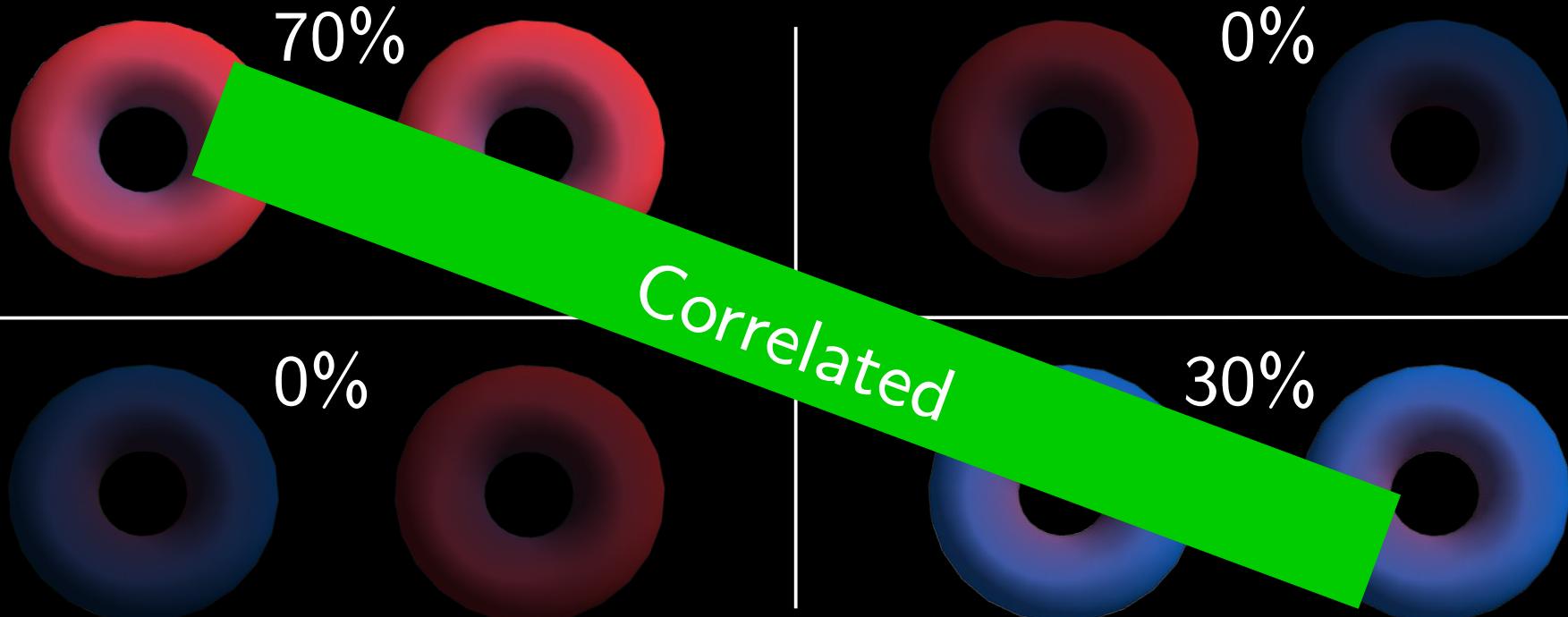
Q-Bits

Q-Circuits

Hardware

Industry

Entanglement:



Superposition

Entanglement

Summary

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

Entanglement:

0%



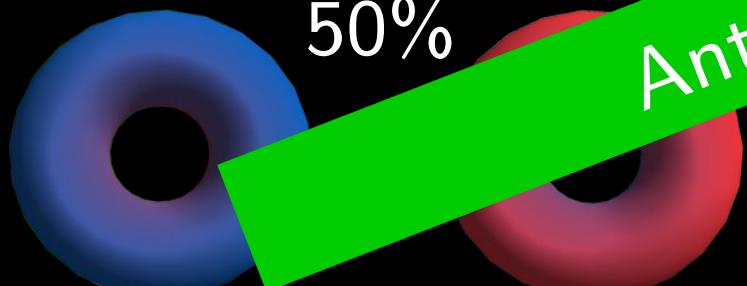
0%



50%

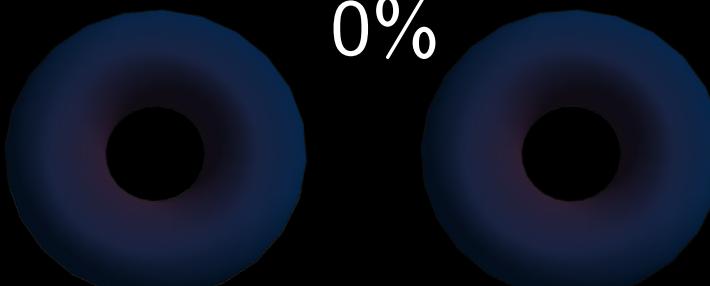


50%



Anti-Correlated

0%



Superposition

Entanglement

Summary

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

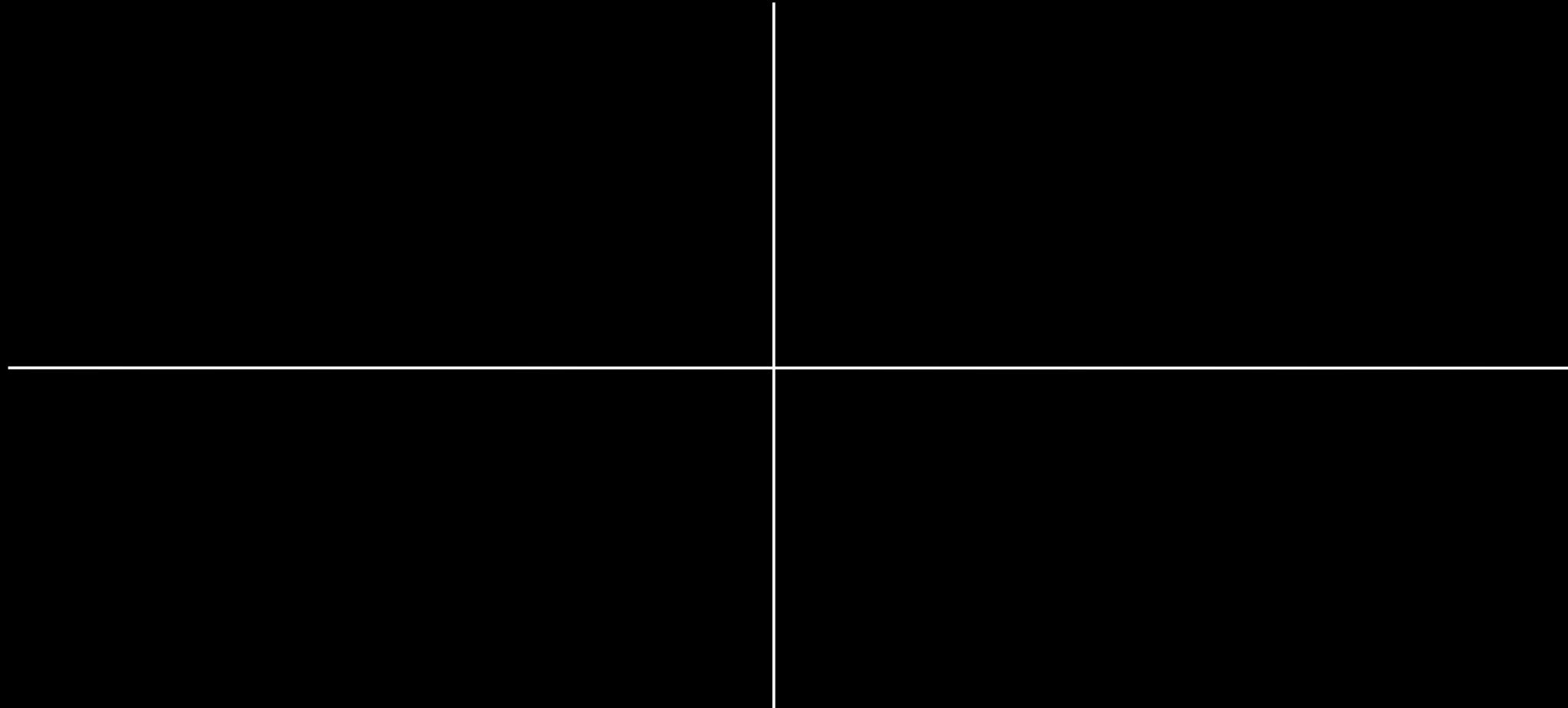
Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

Superposition



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

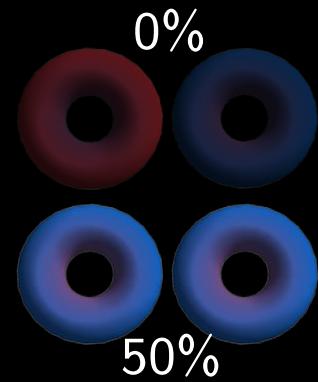
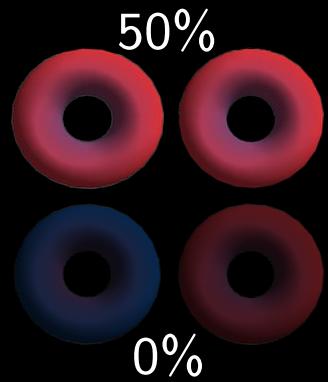
Hardware

Industry

Superposition



Entanglement



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

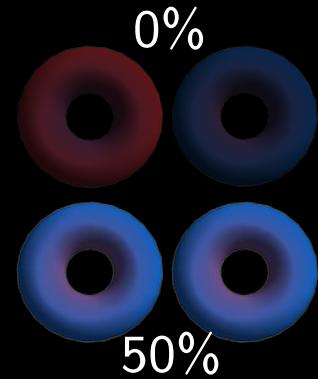
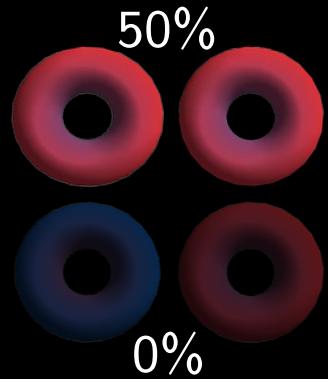
Hardware

Industry

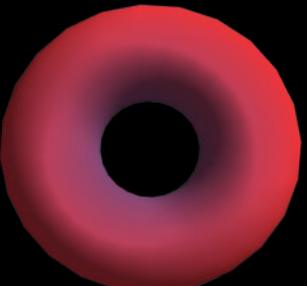
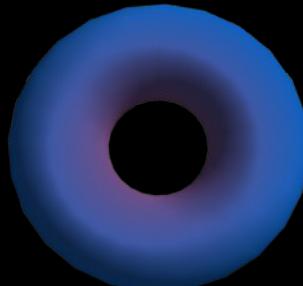
Superposition



Entanglement



Bit flip



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

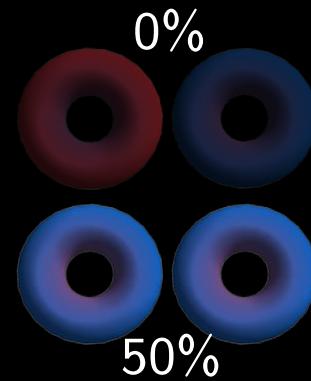
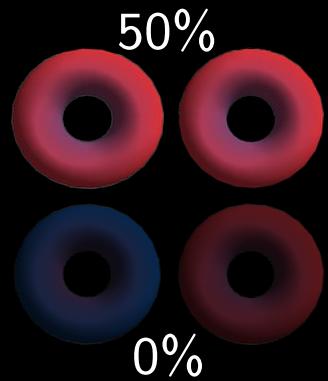
Hardware

Industry

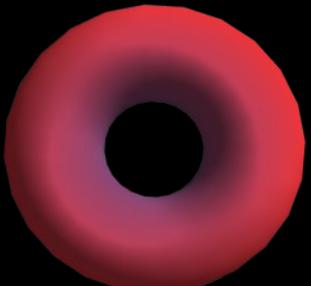
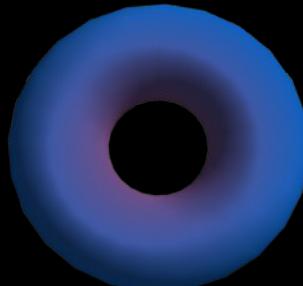
Superposition



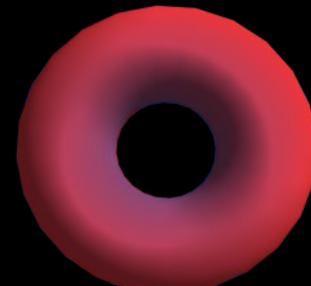
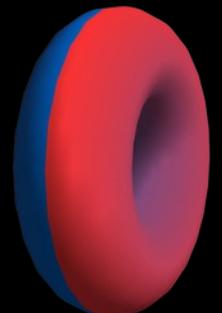
Entanglement



Bit flip



Measurement



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry

Hadamard H-gate:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

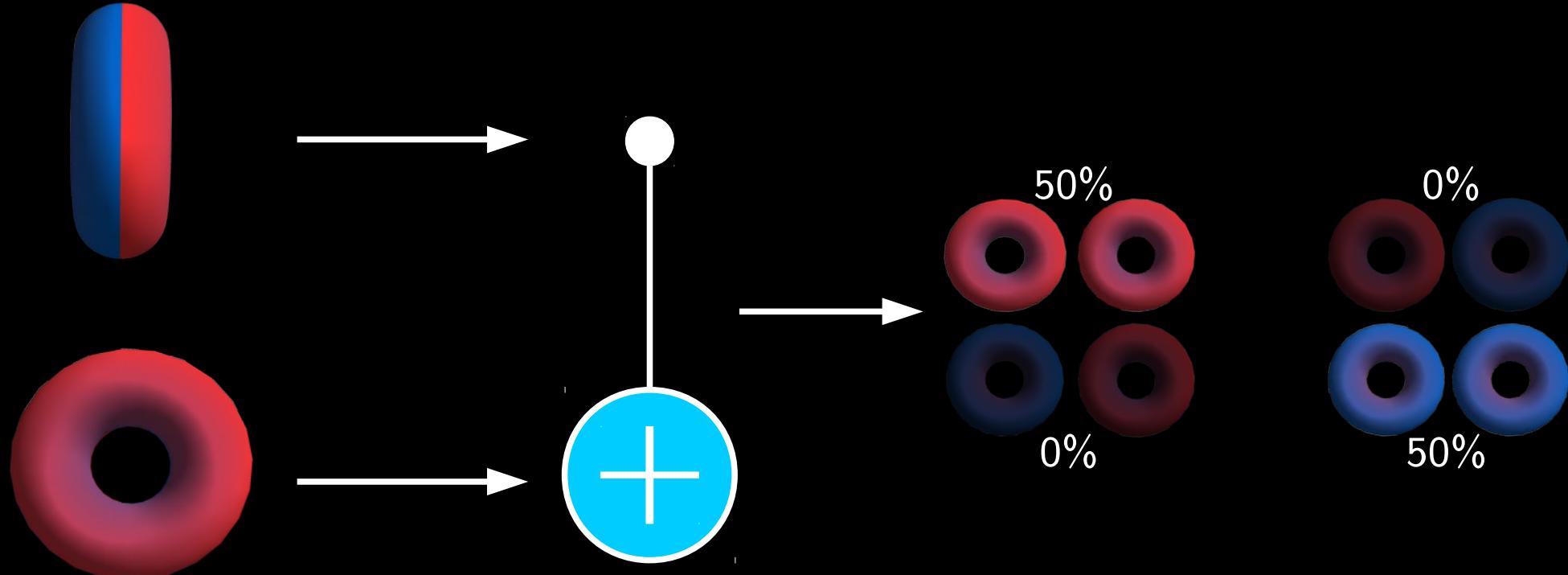
Q-Bits

Q-Circuits

Hardware

Industry

C-NOT gate:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

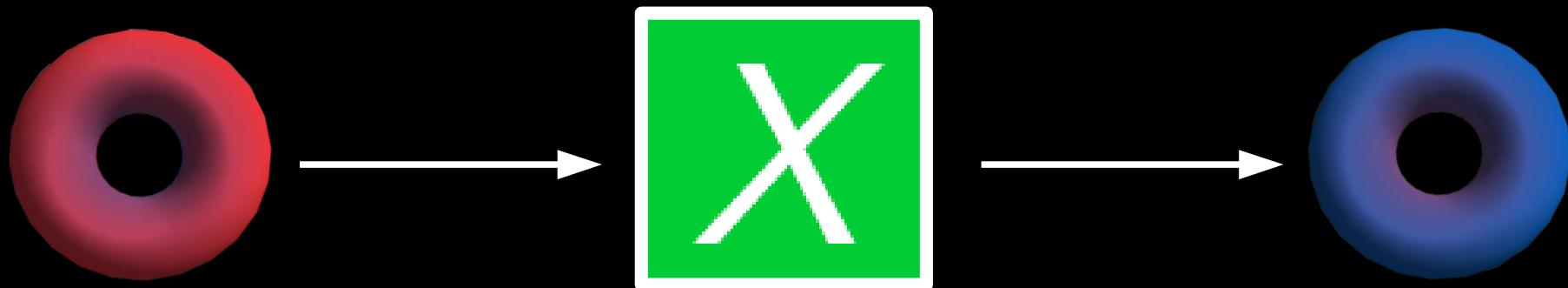
Q-Bits

Q-Circuits

Hardware

Industry

Bit flip X-gate:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

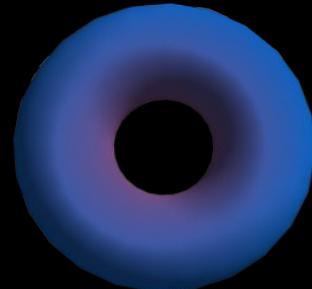
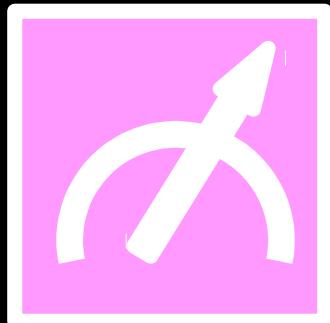
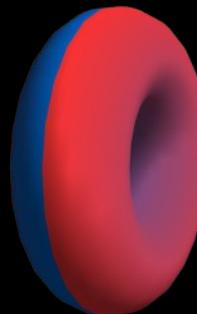
Q-Bits

Q-Circuits

Hardware

Industry

Measurement:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

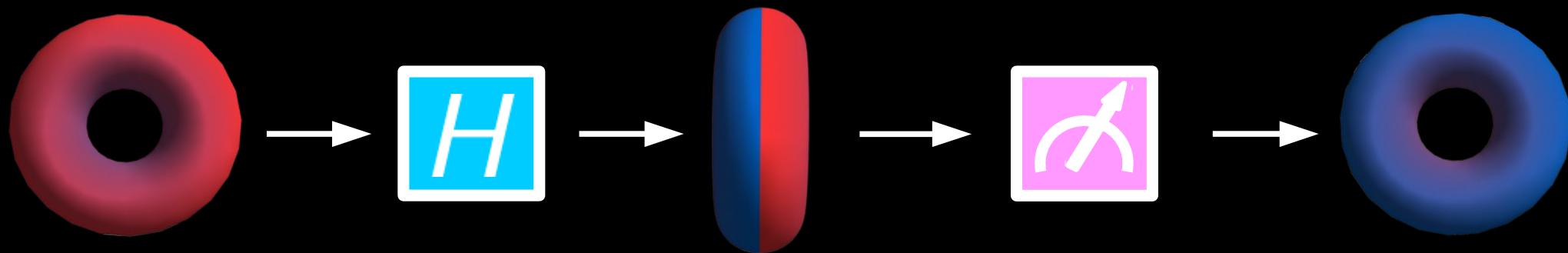
Q-Bits

Q-Circuits

Hardware

Industry

Quantum circuit:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

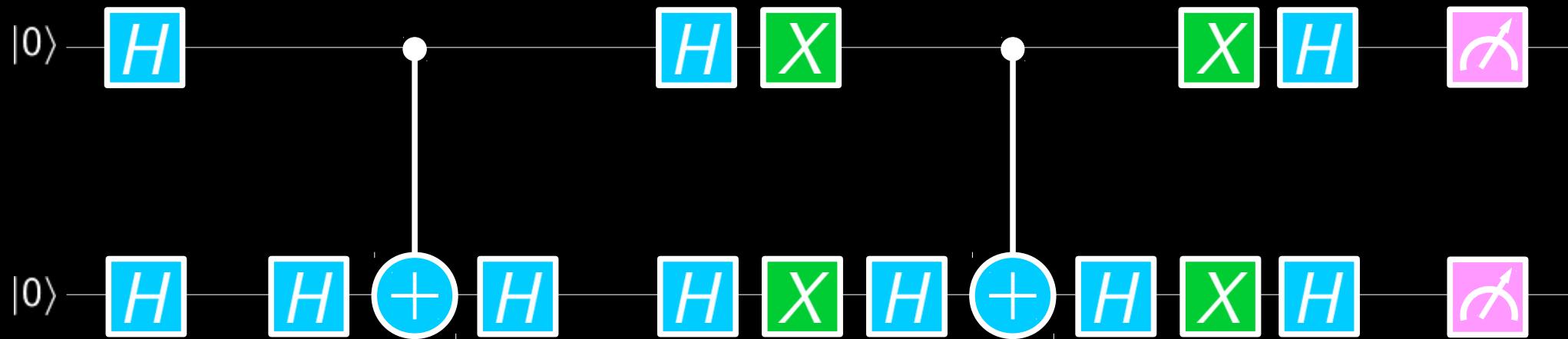
Q-Bits

Q-Circuits

Hardware

Industry

Grover's search:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

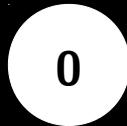
Q-Bits

Q-Circuits

Hardware

Industry

Grover's search:



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Grover's search:

0

2

3

1

Classical

Quantum

4

1

tries

try

Grover's search:

Number Bits

0

00

1

01

2

10

3

11

Grover's search:

Number Bits

0

00

1

01

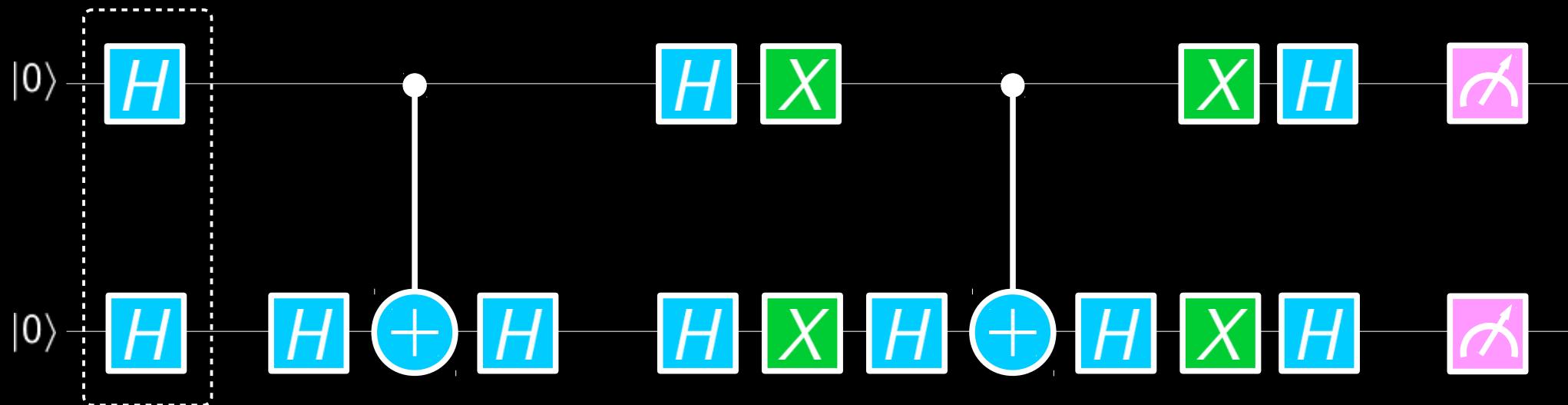
2

10

3

11

Grover's search: Step 1 – Superposition



Applications

Q-Algorithms

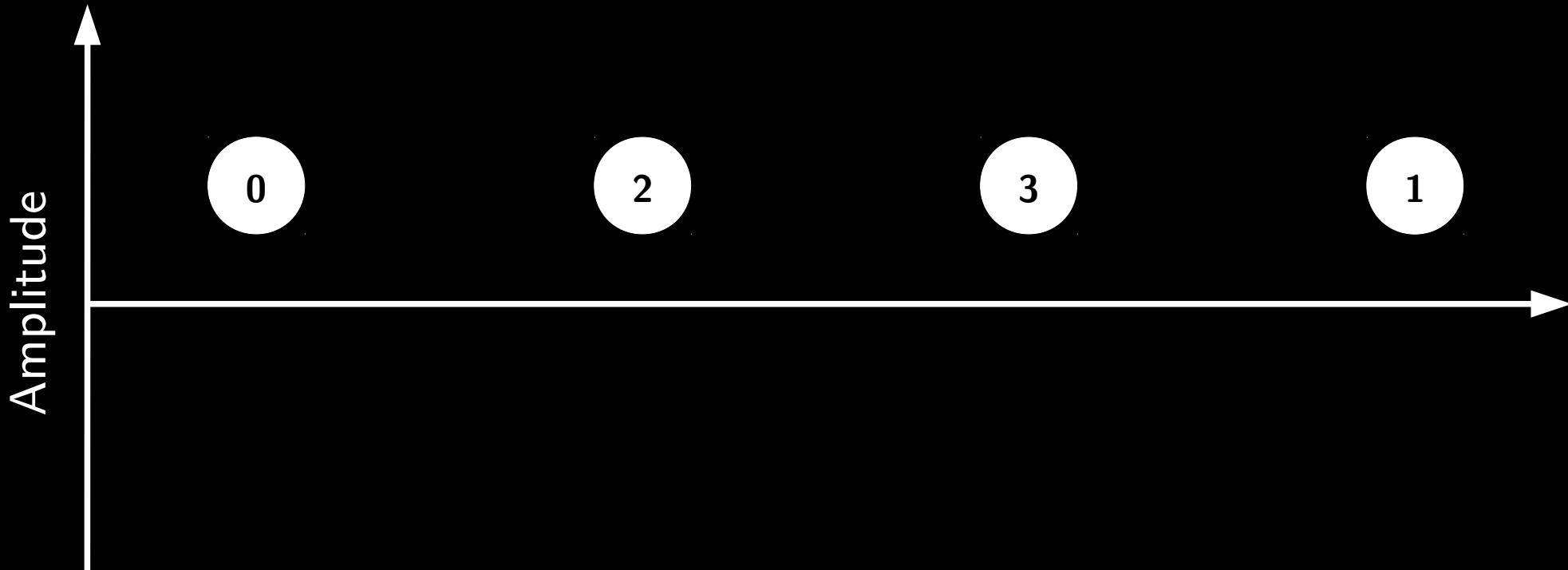
Q-Bits

Q-Circuits

Hardware

Industry

Grover's search: Step 1 – Superposition



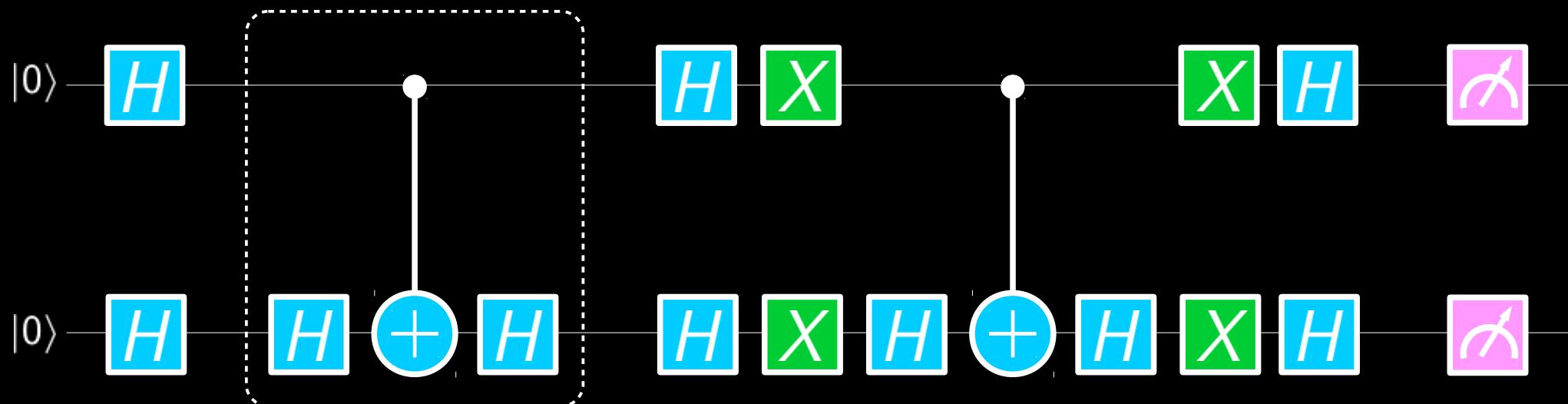
Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Grover's search: Step 2 – Oracle



Applications

Q-Algorithms

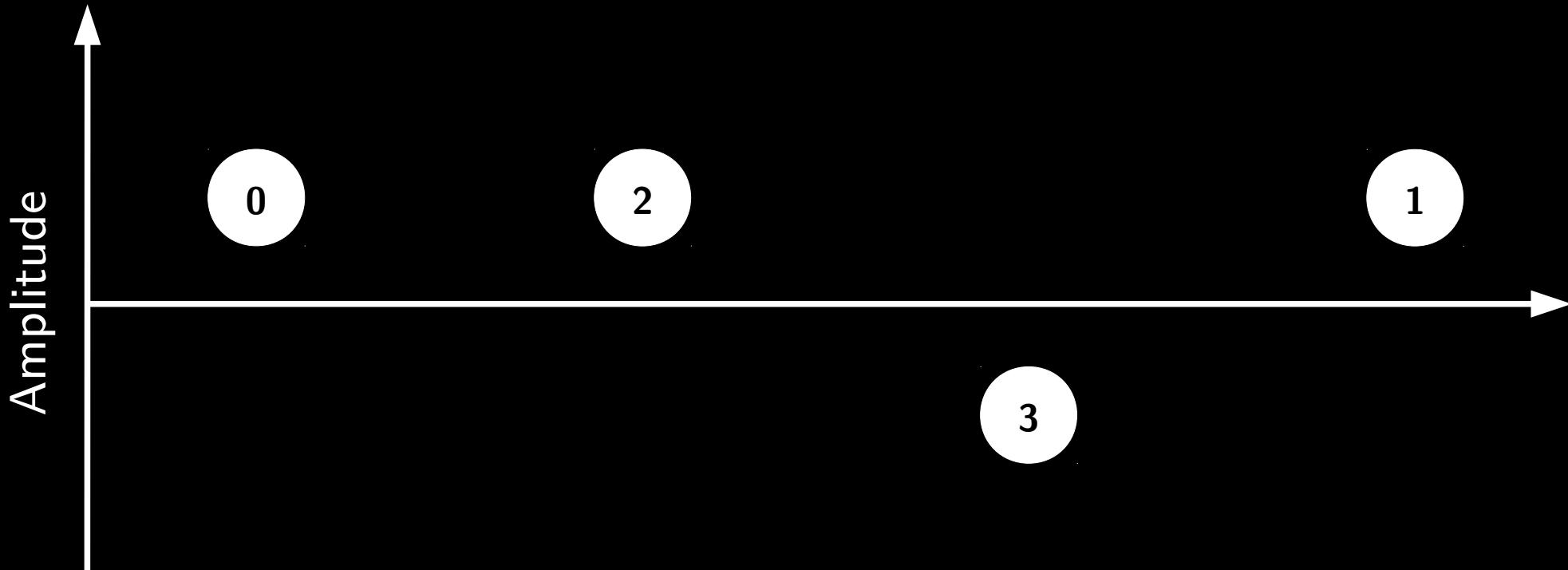
Q-Bits

Q-Circuits

Hardware

Industry

Grover's search: Step 2 – Oracle



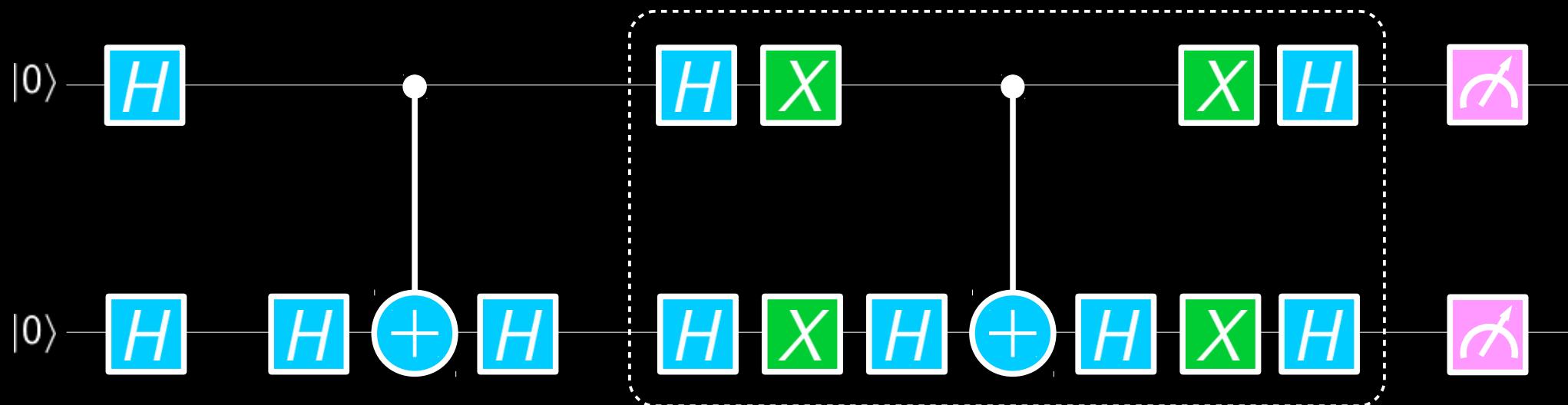
Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Grover's search: Step 3 – Reflection



Applications

Q-Algorithms

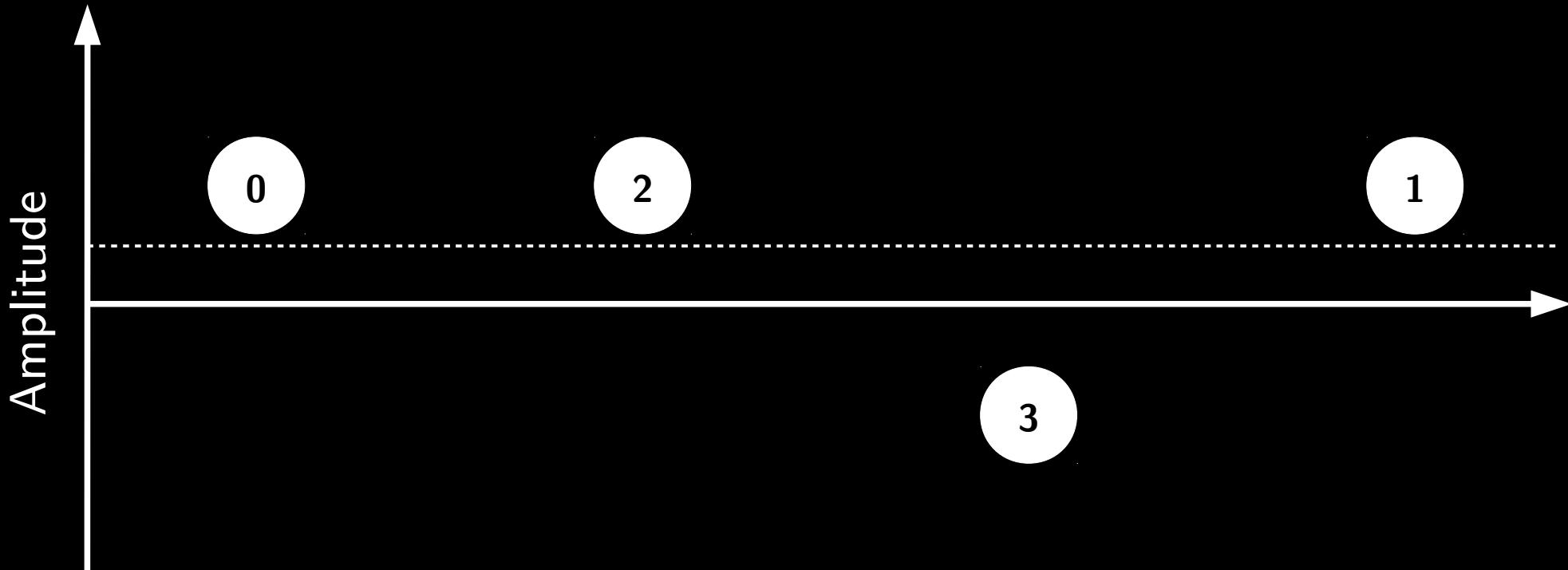
Q-Bits

Q-Circuits

Hardware

Industry

Grover's search: Step 3 – Reflection



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Q-Algorithms

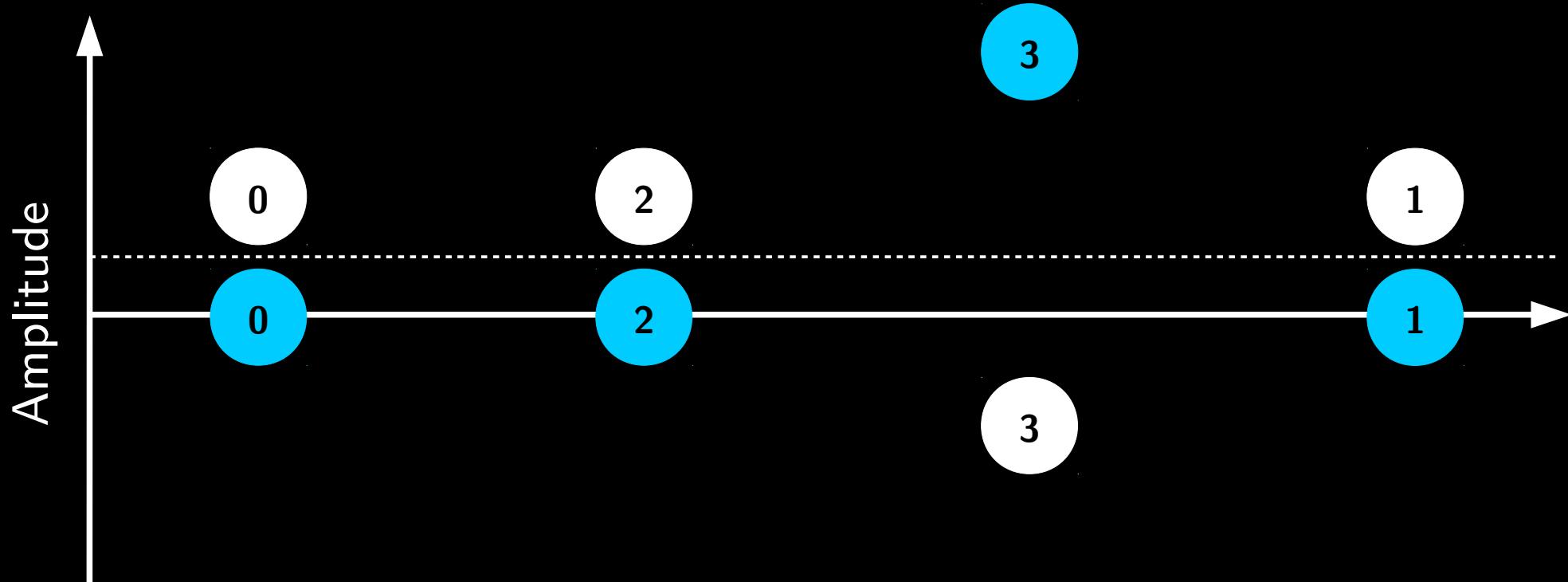
Q-Bits

Q-Circuits

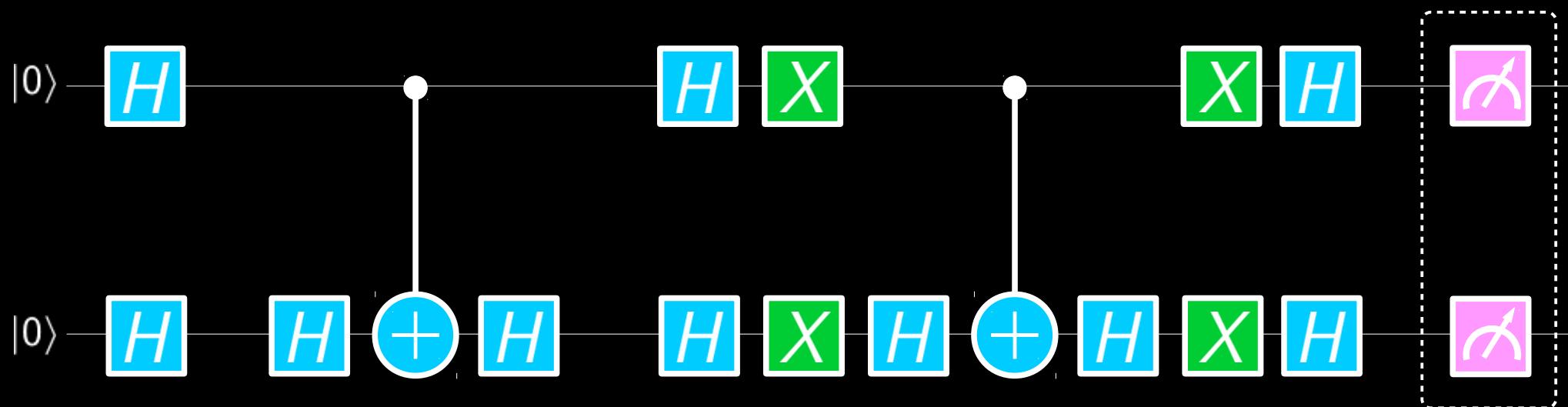
Hardware

Industry

Grover's search: Step 3 – Reflection



Grover's search: Step 4 – Measurement



Applications

Q-Algorithms

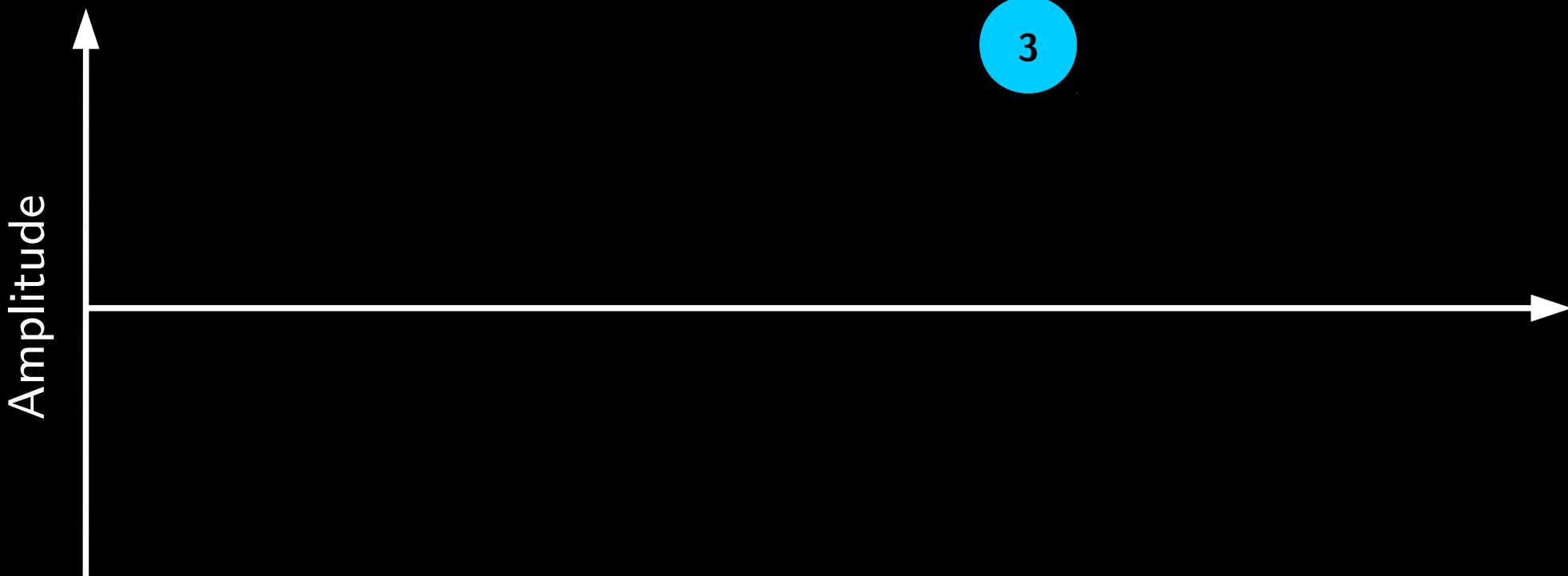
Q-Bits

Q-Circuits

Hardware

Industry

Grover's search: Step 4 – Measurement



Operations on Q-Bits

Q-Gates

Q-Circuit

Grover's search

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Why is quantum computing (so) hard ?

We want qubits to interact strongly with one another.

We don't want qubits to interact with the environment.

Until we measure them.

Applications

Q-Algorithms

Q-Bits

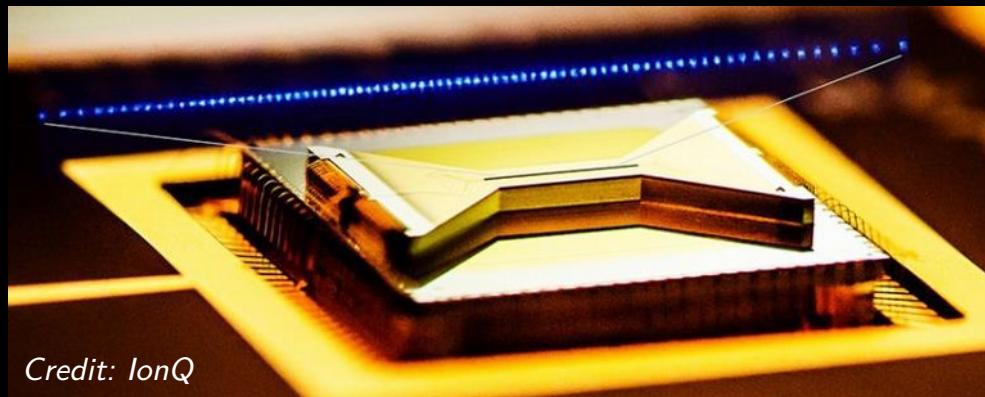
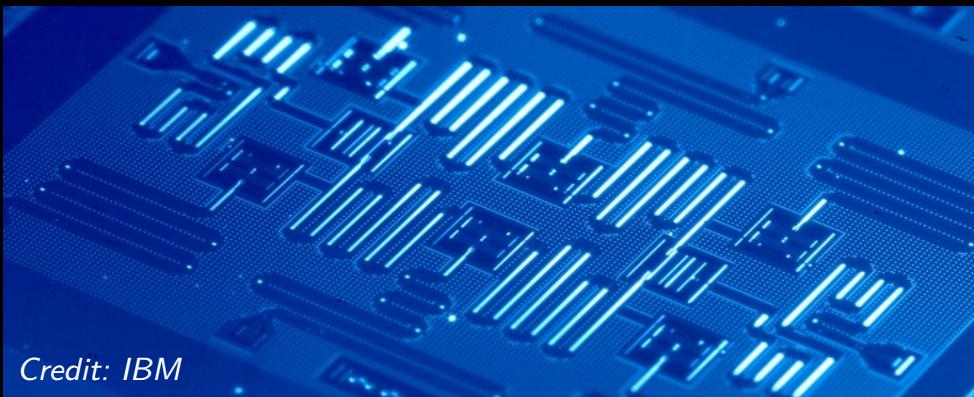
Q-Circuits

Hardware

Industry

Superconducting circuits

Trapped ions



Decoherence

Leading qubit platforms

Quantum supremacy

Other platforms

Error correction

NISQ era

Superconducting circuits

Trapped ions

Google, IBM, Rigetti, and others

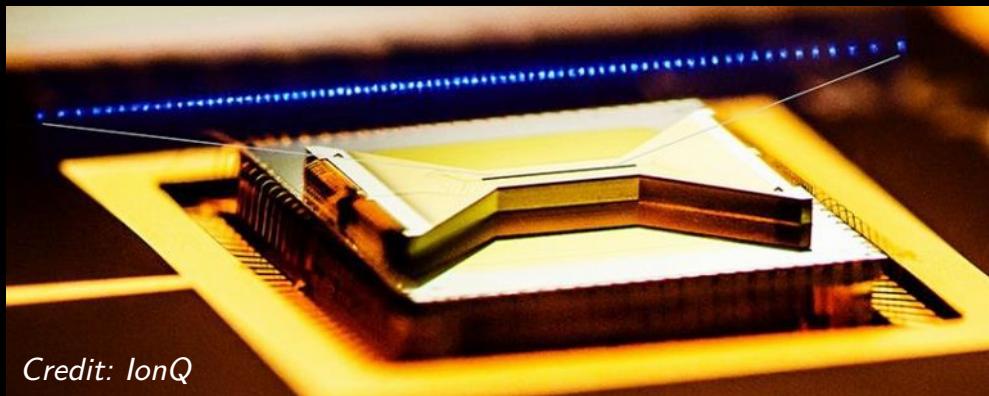
#Qubits: 72 (Google), 53 (IBM, Google)



Controllability, Semiconductor industry



Coherence time, Gate fidelities, Near absolute zero, Nearest neighbours connectivity



Credit: IonQ



Superconducting circuits

Google, IBM, Rigetti, and others

#Qubits: 72 (Google), 53 (IBM, Google)



Controllability, Semiconductor industry



Coherence time, Gate fidelities, Near absolute zero, Nearest neighbours connectivity



Trapped ions

AQT, IonQ, and others

#Qubits: 79 (IonQ)



Coherence time, Gate fidelities, All-to-all connectivity



Controllability, Vacuum operation

Volume 574 Issue 7779, 24 October 2019

[Subscribe](#)

Quantum supremacy

In this week's issue, [John Martinis and his colleagues](#) describe a significant step in the development of quantum computing. For the first time, the researchers have demonstrated experimentally that a programmable quantum computer can outperform the world's most powerful conventional processors – a state known as quantum supremacy. The team used a quantum processor made up of 53 functional qubits to tackle a task that involved sampling the output of a... [show more](#)

Applications

Q-Algorithms

Q-Bits

Q-Circuits

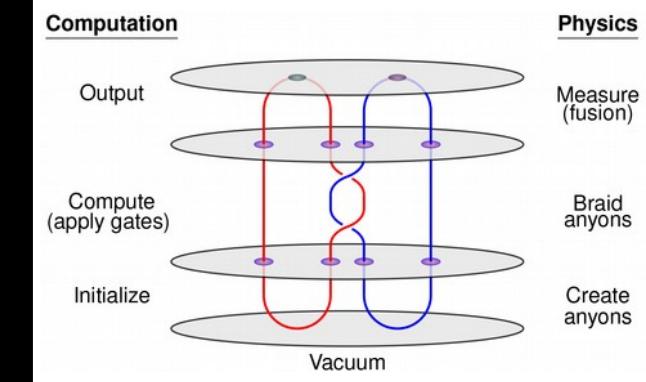
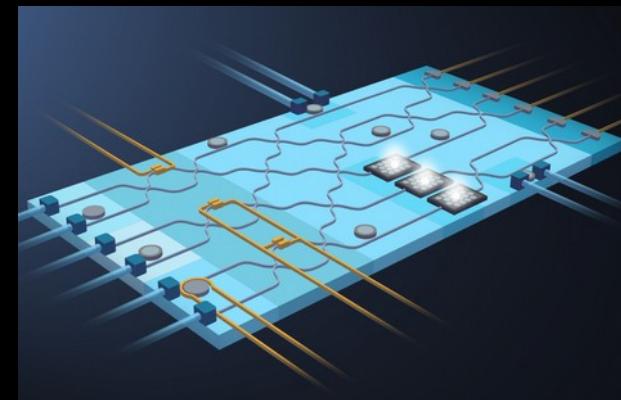
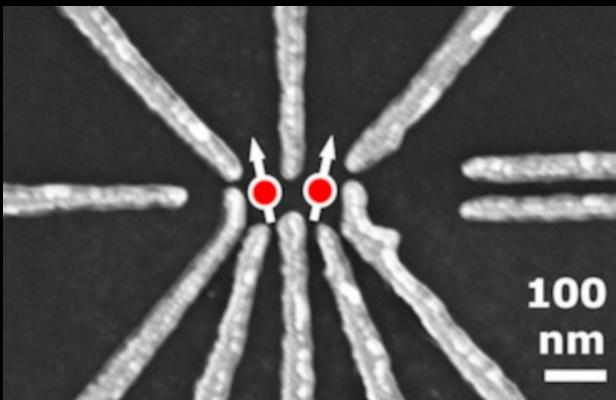
Hardware

Industry

Quantum dots

Photonic

Topological



Decoherence

Leading qubit platforms

Quantum supremacy

Other platforms

Error correction

NISQ era

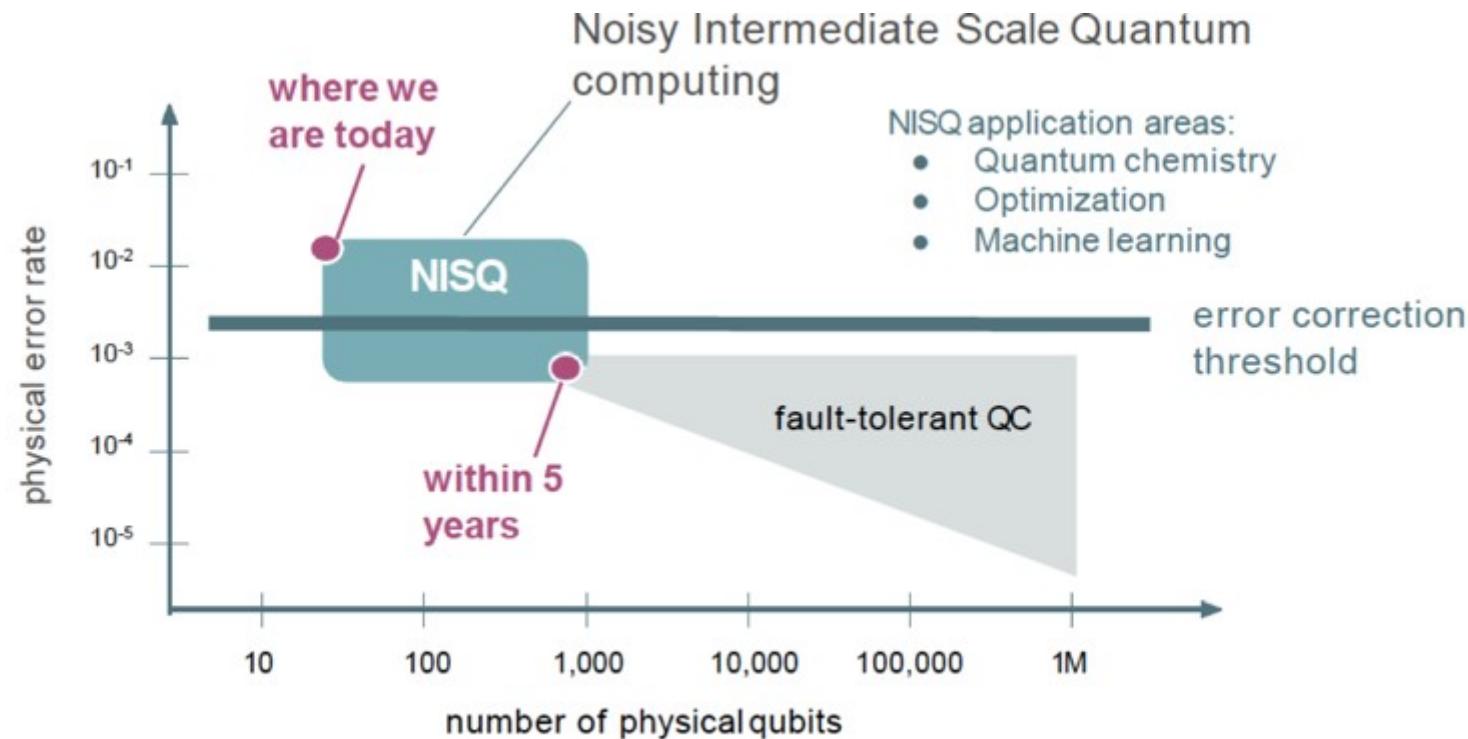
Quantum error correction

Long term goal → Fault-Tolerant QC

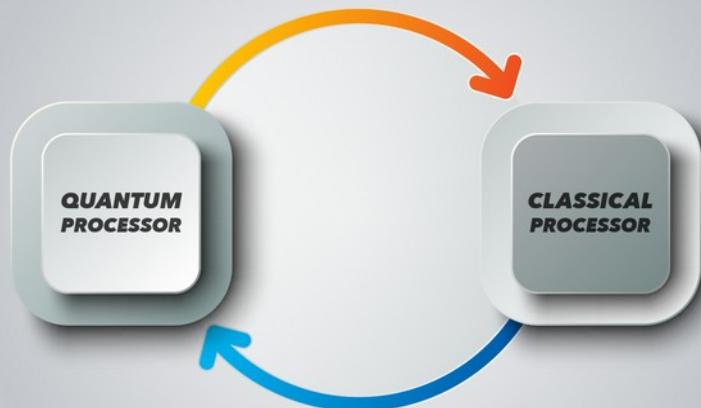
The protected “logical” quantum information is encoded in a highly entangled states of many physical qubits.

The environment can't access this information if it interacts locally with the protected system.

"Quantum computing in the NISQ era and beyond", J. Preskill (2018)



Hybrid quantum/classical approach in the NISQ era



Delegate the hard part of a computation to a (noisy) quantum processor.

→ e.g. computing the energy of a molecule for a given electronic configuration

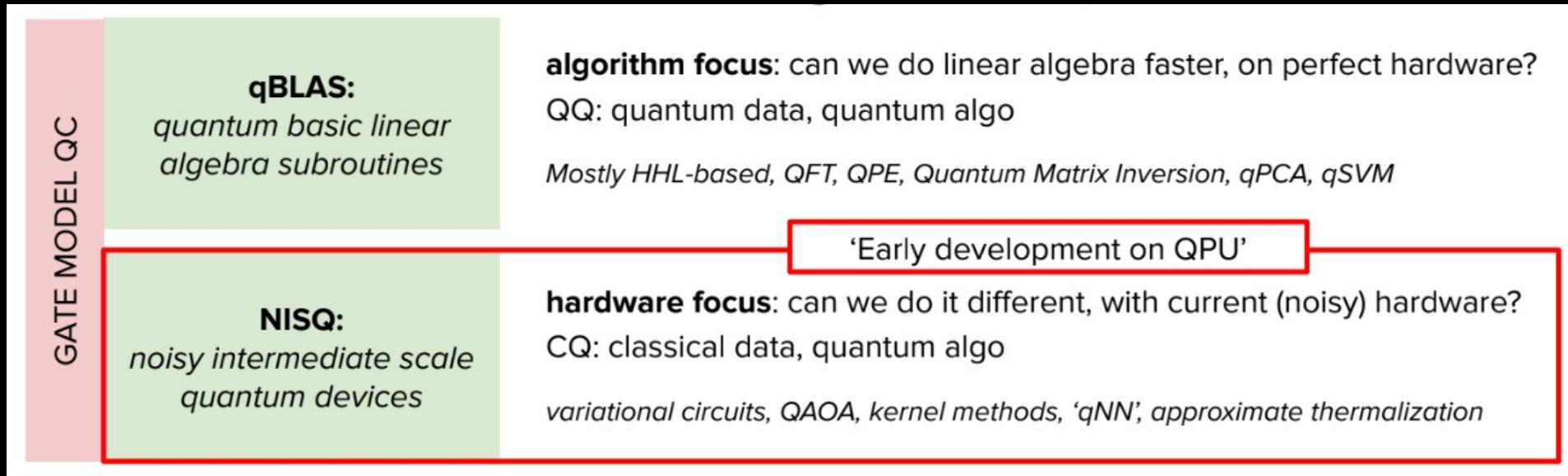
Delegate the easy part to a classical processor.

→ e.g. proposing a new electronic configuration that lower your molecule's energy

Iterate until optimal result is reached.

→ e.g. electronic configuration of lowest energy

Quantum Machine Learning (QML)



Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

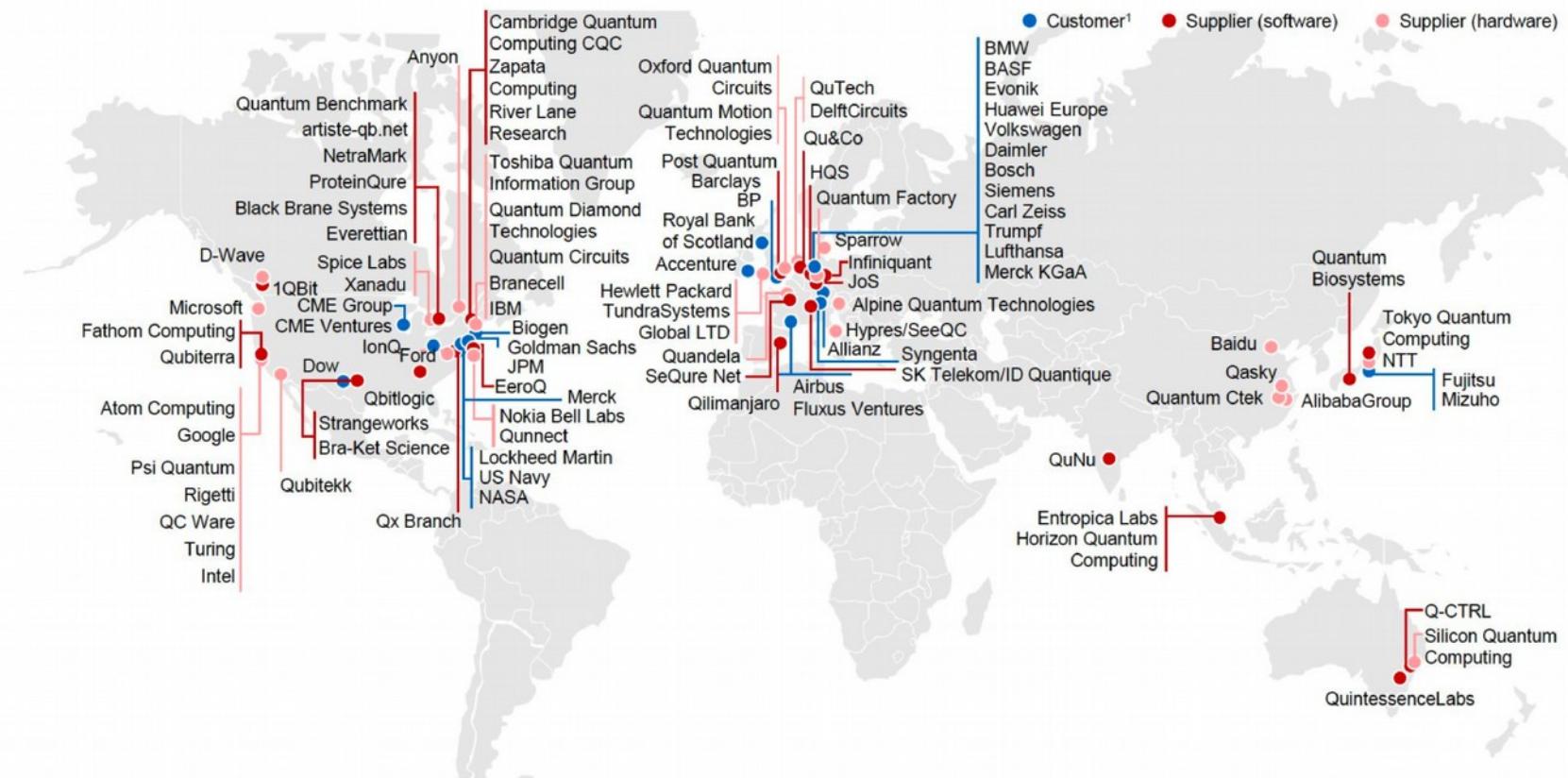
Quantum Bits

Quantum Circuits

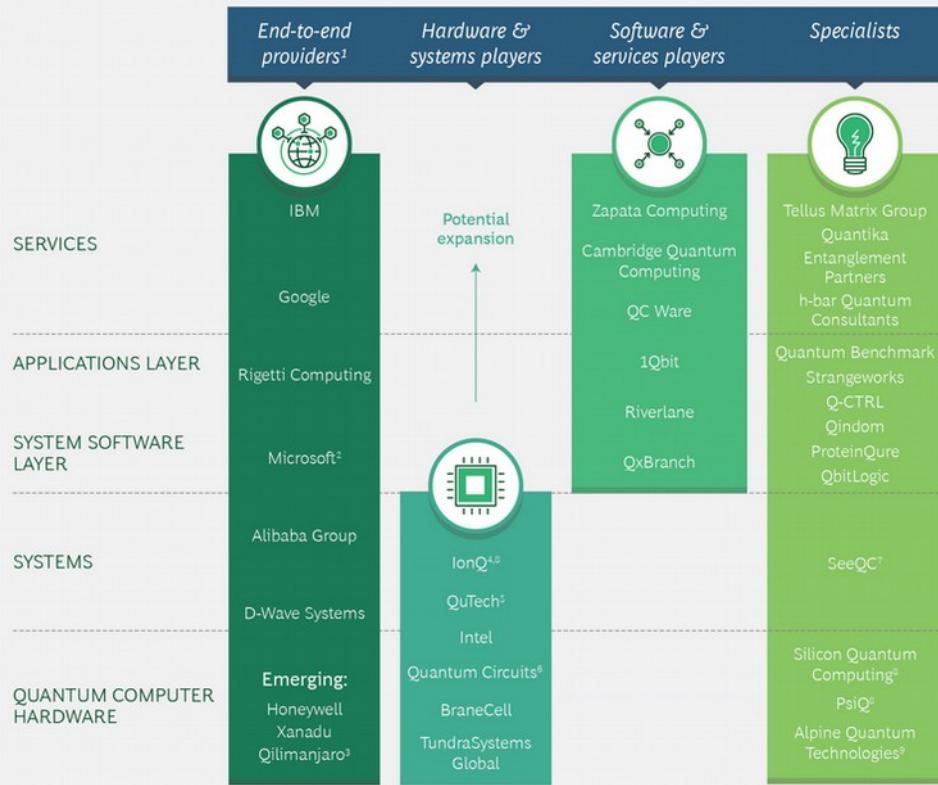
Hardware

Industry Landscape

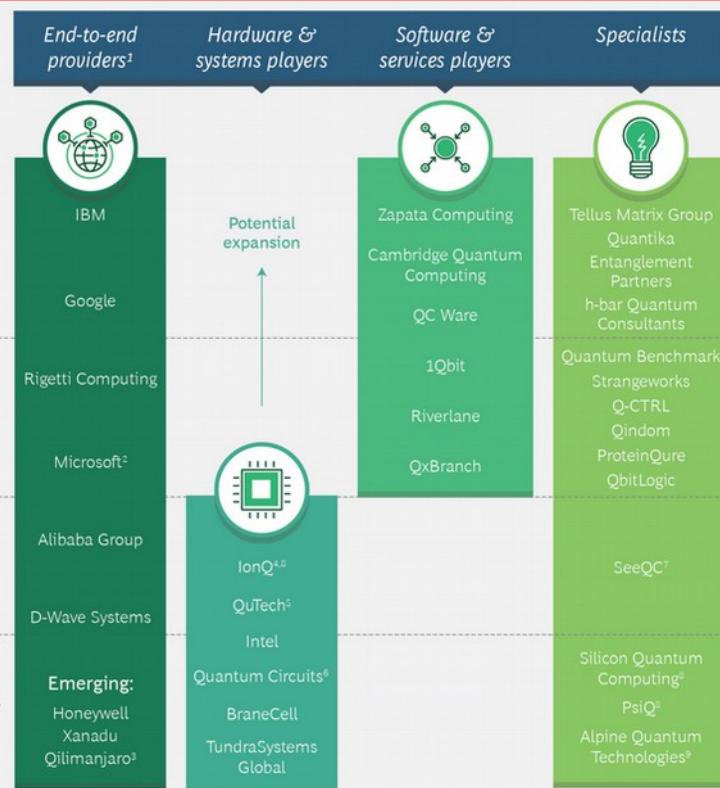
Non-exhaustive overview of quantum computing players (2019)



Boston Consulting Group report on Quantum Computing (2019)



Boston Consulting Group report on Quantum Computing (2019)



Startup	Total [US\$ millions]	Most recent funding	
		Date	Description
D-Wave Systems	205	June 1, 2018	US\$10.15 million of grant funding in a deal led by the Canadian Government
Rigetti Computing	119	March 28, 2017	Announced further US\$40 million in its series B round of funding
PsiQ	65	Undisclosed	Undisclosed
Silicon Quantum Computing	60	August 2017	AU\$83 million venture funded by: New South Wales Government (AU\$9 million), University of New South Wales (AU\$25 million), Commonwealth Bank of Australia (AU\$14 million), Telstra (AU\$10 million over two years), and the Australian Government (AU\$25 million over five years)
Cambridge Quantum Computing	50	August 26, 2015	US\$50 million of development capital
1QBit	35	November 28, 2017	CA\$45 million of development capital in Series B funding
IonQ	22	February 24, 2017	US\$20 million of Series B venture funding
Quantum Circuits	18	November 13, 2017	US\$18 million of Series A venture funding
Alpine Quantum Computing	12	February 8, 2018	€10 million of grant funding
QC Ware	8	July 5, 2018	US\$7 million of Series A venture funding
Optalysys	8	September 21, 2017	£3 million of seed funding from undisclosed investors
Nextremer	5	August 8, 2017	JP¥500 million of venture funding
Oxford Quantum Circuits	3	September 8, 2017	£2 million of venture funding

Canada

D-Wave, 1Qbit notable private investment. Creative Destruction Lab in Toronto accelerates market launch of deep tech startups in quantum technologies. Hundreds of millions of government funding invested (IQC, Perimeter Institute).

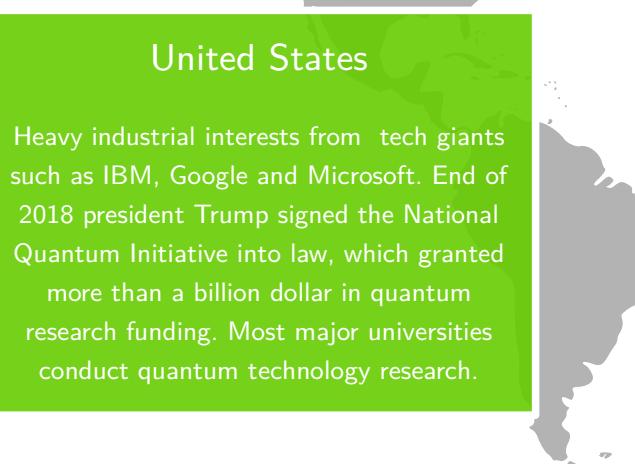


United States

Heavy industrial interests from tech giants such as IBM, Google and Microsoft. End of 2018 president Trump signed the National Quantum Initiative into law, which granted more than a billion dollar in quantum research funding. Most major universities conduct quantum technology research.

Europe

Numerous research groups funded over past 20 years through framework programs. 1 billion euro investment announced in 2016 (European flagship on Quantum Technologies).



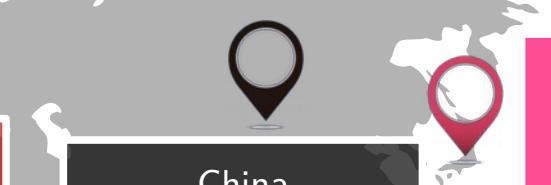
U.K.

U.K. National Quantum Technologies programme launched in 2013 with 270M pounds invested. Additional investment plan of 350M pounds from both government agencies (150M) and industrial players (200M) announced in 2019 with a focus on quantum computing.



China

Massive investments in quantum communication from government agencies with a 2.000 km long quantum key distribution network currently deployed. Alibaba is spending 10 billion dollars in research on quantum computing since 2017.



Japan

Japan has set aside more than 270M dollars in a 10-year research plan. Major Japanese tech players are following suit.



Australia

Center for quantum technology continuously funded for over 15 years, investment from national banks and telecommunications.



Applications

Q-Algorithms

Q-Bits

Q-Circuits

Hardware

Industry



 **LES NOTES SCIENTIFIQUES DE L'OFFICE**
OFFICE PARLEMENTAIRE D'ÉVALUATION DES CHOIX SCIENTIFIQUES ET TECHNOLOGIQUES 

Note n° **13** — **Les technologies quantiques : introduction et enjeux** Mars 2019

Résumé

- De nombreuses technologies de notre vie quotidienne se basent sur les principes de la physique quantique : lasers, transistors, dispositifs de positionnement par satellite (GPS)...
- Depuis quelques années, les technologies quantiques au sens large connaissent un intérêt marqué aussi bien de la part des industriels que des gouvernements, en parallèle de progrès techniques de rupture.
- Les nouvelles technologies quantiques concernent des applications telles que les capteurs, le calcul ou les communications. Ces domaines s'appuient sur les principes de la physique quantique, en particulier l'intrication et la superposition d'états.
- En Europe, un programme d'envergure de type « flagship » a été lancé en 2018 pour soutenir les projets européens dans la course mondiale aux technologies quantiques, dont les principaux concurrents établis sont la Chine et les États Unis.

M. Cédric Villani, Député, Premier vice-président


© monsij/ Adobe Stock



Paula Forteza 
@PaulaForteza

[Suivre](#)



Pouvons-nous démultiplier nos capacités de calcul ? Nos protocoles de chiffrement seront-ils tous rendus obsolètes du jour au lendemain ? Les technos quantiques sont-elles le futur de l'informatique ?

Me voilà en mission pour projeter la France dans cette nouvelle révolution !

Le Premier ministre,
Vu la Constitution ;
Vu le [code électoral](#), notamment son article LO 144,
Décrète :

Article 1 [En savoir plus sur cet article...](#)

Mme Paula FORTEZA, députée, est, en application de l'[article LO 144 du code électoral susvisé](#), chargée d'une mission temporaire ayant pour objet les technologies quantiques.

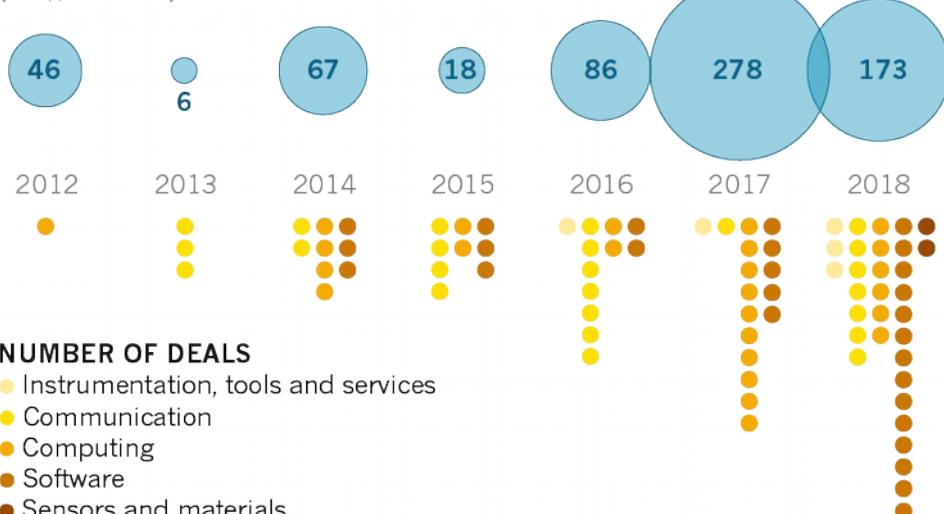
03:26 - 6 avr. 2019

67 Retweets 205 J'aime



Private investments (VC funds) - Nature's report on Quantum Technologies (2019)

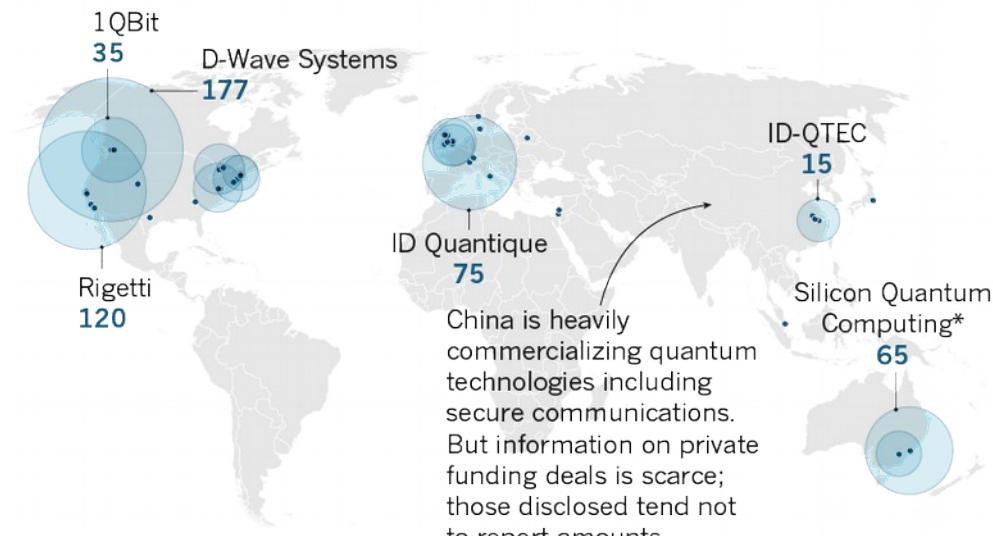
TOTAL VALUE OF DEALS
(US\$, millions)



NUMBER OF DEALS

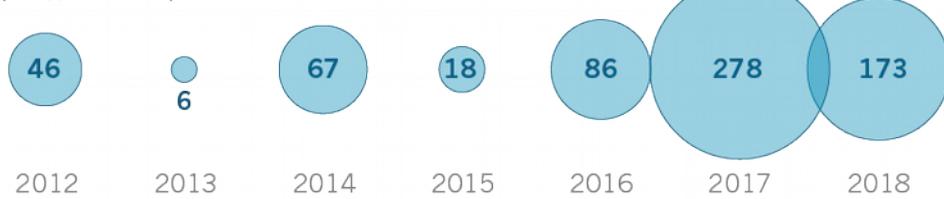
- Instrumentation, tools and services
- Communication
- Computing
- Software
- Sensors and materials

LOCATION OF INVESTMENTS 2012–18
(US\$, millions)

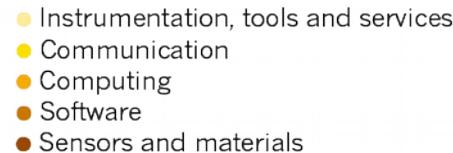


Private investments (VC funds) - Nature's report on Quantum Technologies (2019)

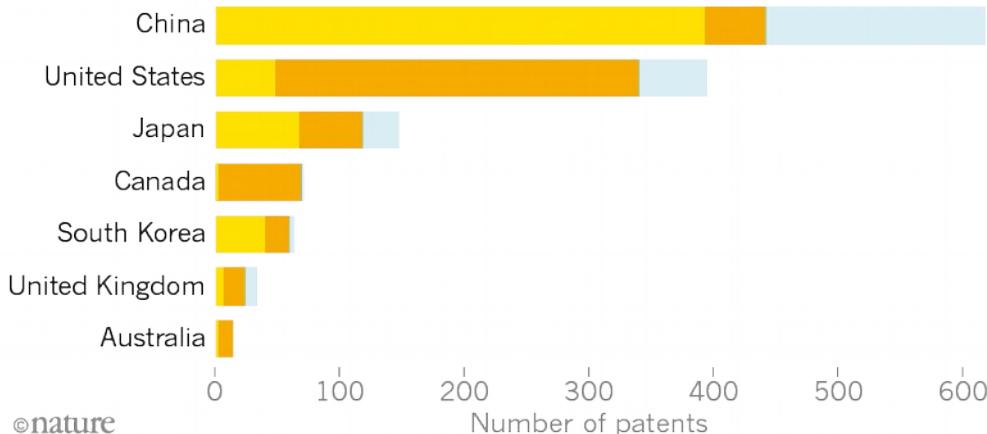
TOTAL VALUE OF DEALS (US\$, millions)



NUMBER OF DEALS



- Quantum key distribution (quantum communication)
- Quantum computing (including software)
- Other quantum technology



©nature

"Nous voulons faire émerger 5 à 6 start-up du quantique en France", annonce Christophe Jurczak, du fonds Quantonation

MANUEL MORAGUES

FRANCE , INVESTISSEMENT , INFORMATIQUE , ELECTRONIQUE , BONNE NOUVELLE

PUBLIÉ LE 16/11/2018 À 10H15

ENTRETIEN Lancé en mai 2018, Quantonation vient de réaliser sa première opération dans le quantique en investissant dans la start-up britannique Kets Quantum Security. Un début pour ce fonds d'investissement dédié aux technologies quantiques et plus généralement à "la physique de rupture". Son dirigeant, Christophe Jurczak, détaille à l'Usine Nouvelle ses ambitions et dresse le portrait d'une France du quantique forte de ses talents, mais encore peu mobilisée pour faire naître une industrie.

BPIFRANCE PRESENTS THE FIRST EDITION OF THE QUANTUM COMPUTING BUSINESS CONFERENCE, IN PARIS ON JUNE 20, 2019

Meet all the Quantum Computing ecosystem for a single day of conference in Paris.

Philippe NIEUWBOURG
April 26th 2019 | 492 readers



Photo bpifrance

Conclusion

Quantum computing is a promising technology for a number of industries in order to reach beyond the current limits of drug discoveries, data processing, etc.

Conclusion

Quantum computing is a promising technology for a number of industries in order to reach beyond the current limits of drug discoveries, data processing, etc.

Although quantum computers are currently small and noisy, a great way to exploit their non-classical properties is to adopt an hybrid approach which leverage both quantum and classical computation.

Conclusion

Quantum computing is a promising technology for a number of industries in order to reach beyond the current limits of drug discoveries, data processing, etc.

Although quantum computers are currently small and noisy, a great way to exploit their non-classical properties is to adopt an hybrid approach which leverage both quantum and classical computation.

Direct collaboration with a software provider or an end-to-end provider allows partners to take early advantage of rising technology maturity. However, at this stage companies should avoid locking into a particular technology or approach.

Conclusion

Quantum computing is a promising technology for a number of industries in order to reach beyond the current limits of drug discoveries, data processing, etc.

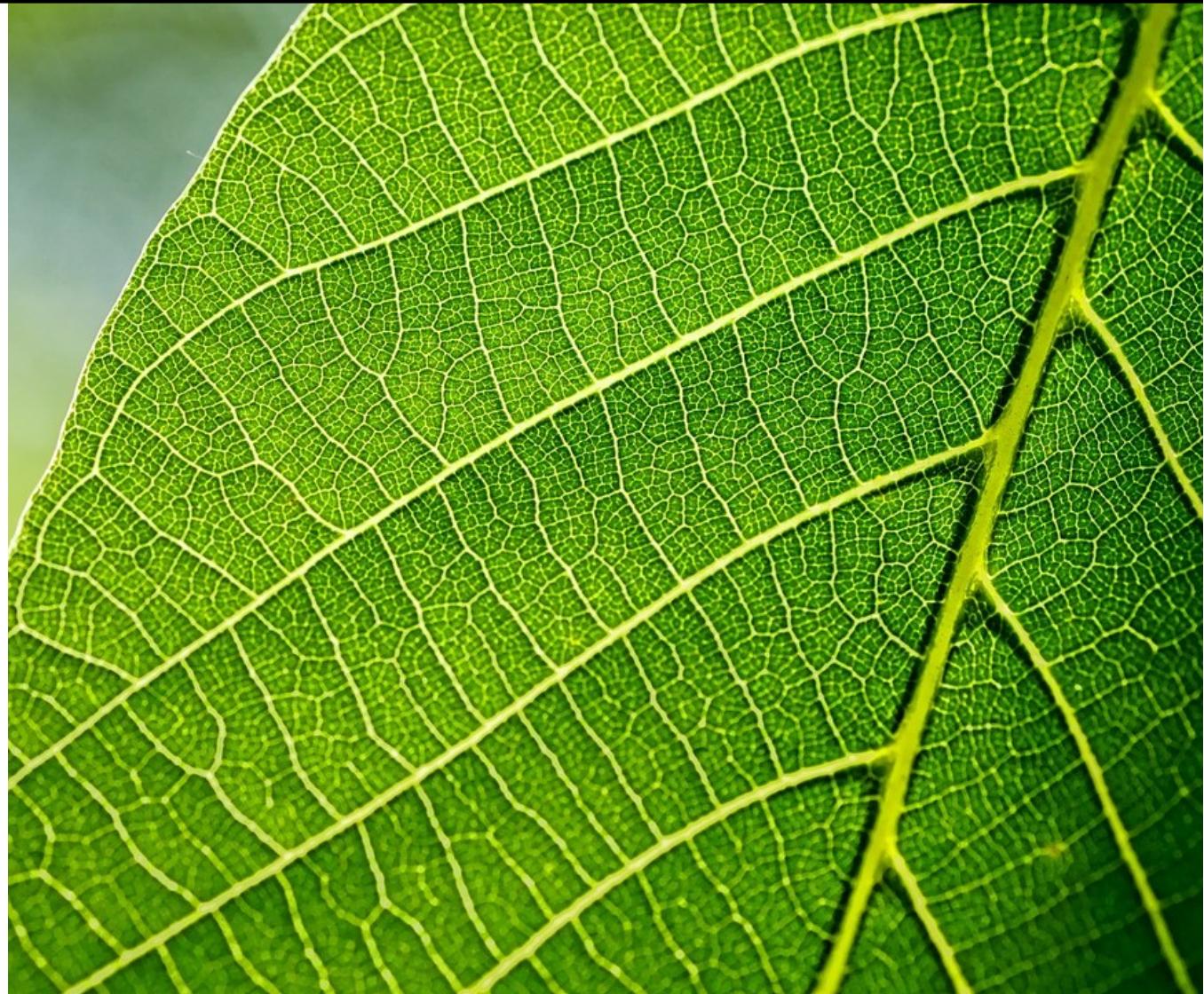
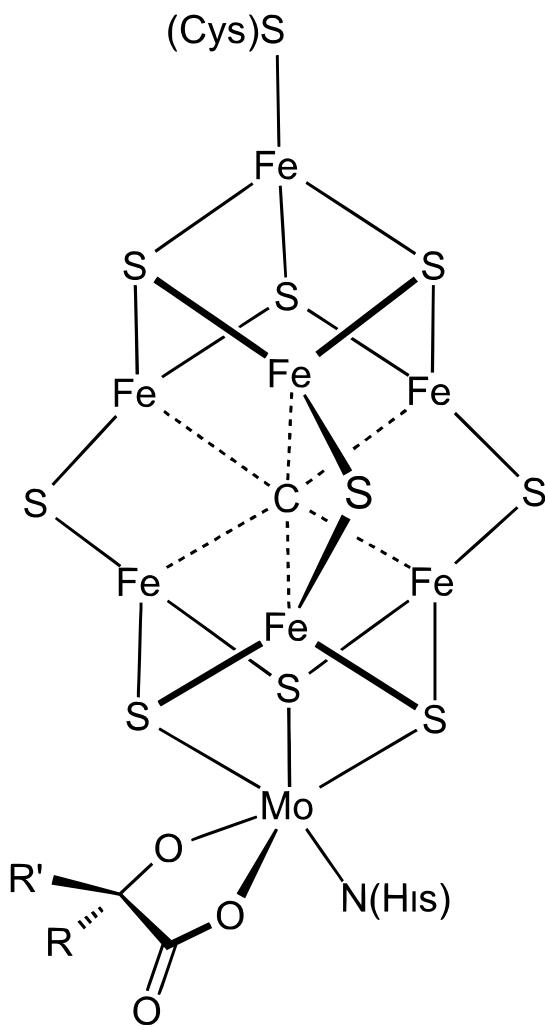
Although quantum computers are currently small and noisy, a great way to exploit their non-classical properties is to adopt an hybrid approach which leverage both quantum and classical computation.

Direct collaboration with a software provider or an end-to-end provider allows partners to take early advantage of rising technology maturity. However, at this stage companies should avoid locking into a particular technology or approach.

More to come in next lectures !

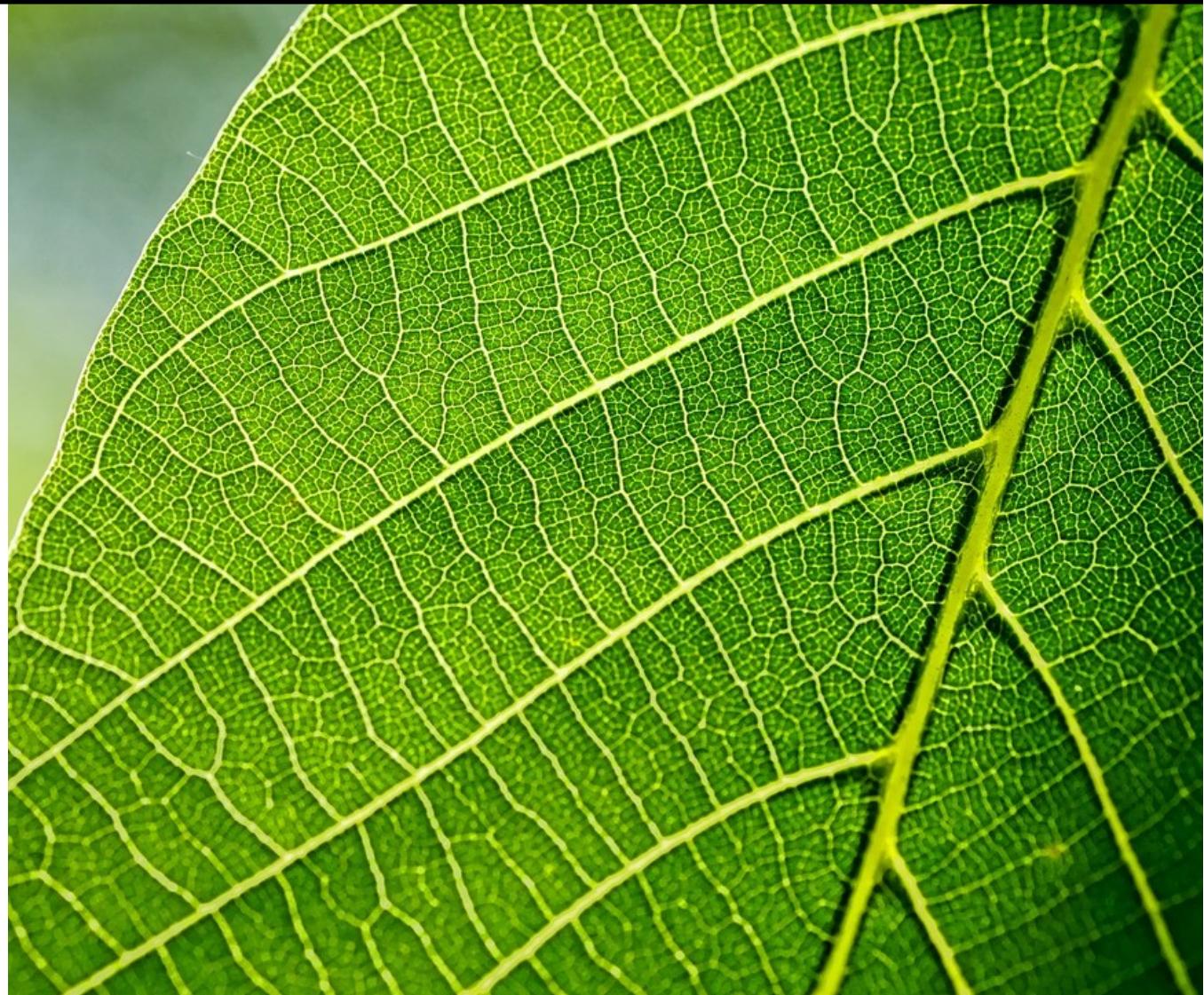
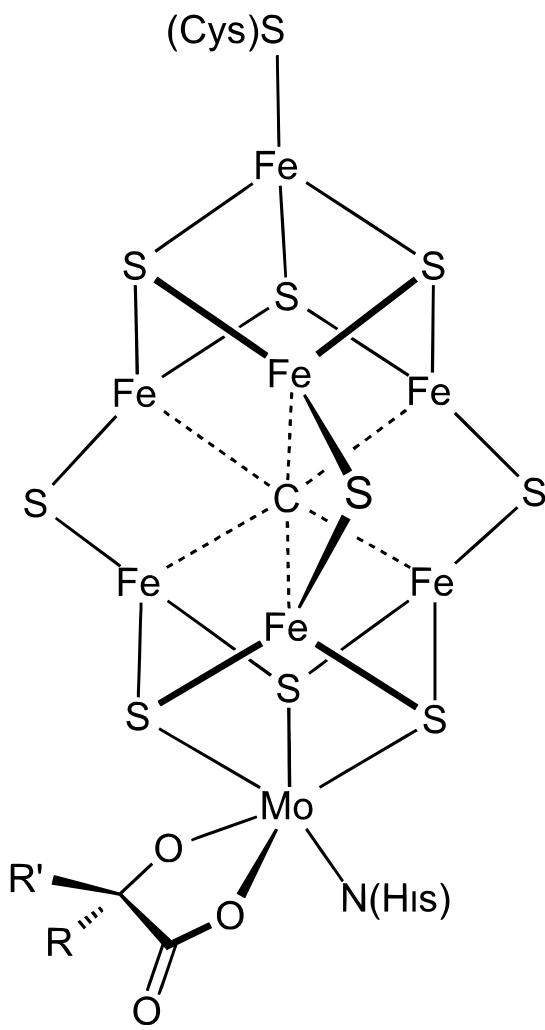


1.1 Applications





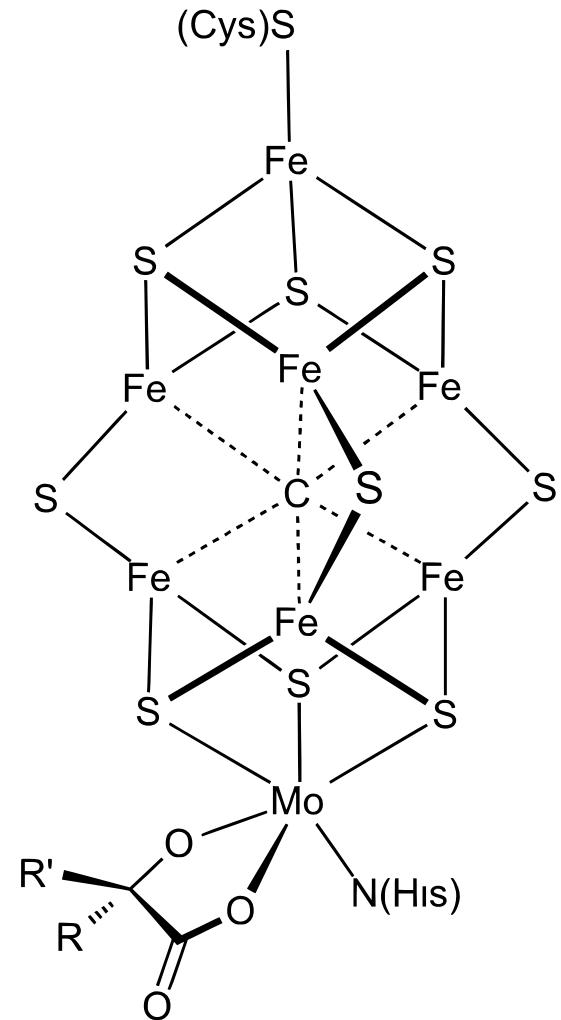
1.1 Applications





Character	Bits
7	111
A	01000001
\$	00100100
:)	0011101000101001

1.1 Applications

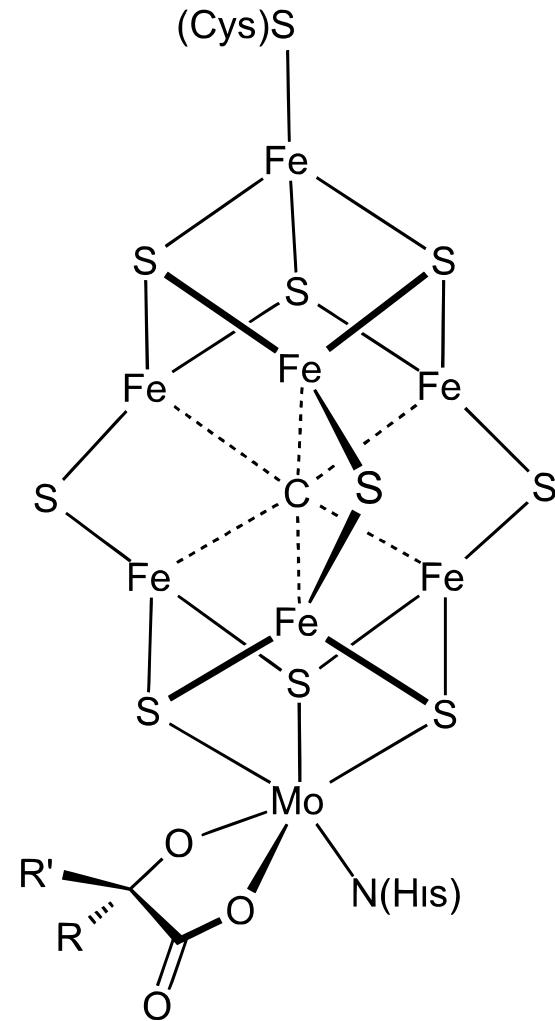




Classical

$\sim 10^{32}$

bits

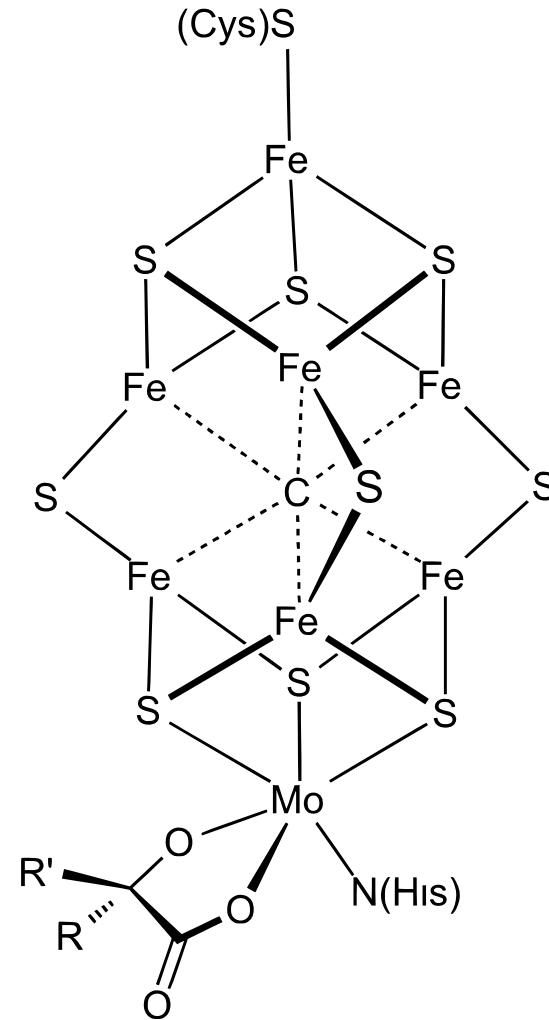




Classical

$\sim 10^{32}$

bits



Quantum

$\sim 10^8$

quantum bits

N bits $\rightarrow 2N$ bits

Doubling classical computers power

N qubits $\rightarrow N+1$ qubits

Doubling quantum computers power*

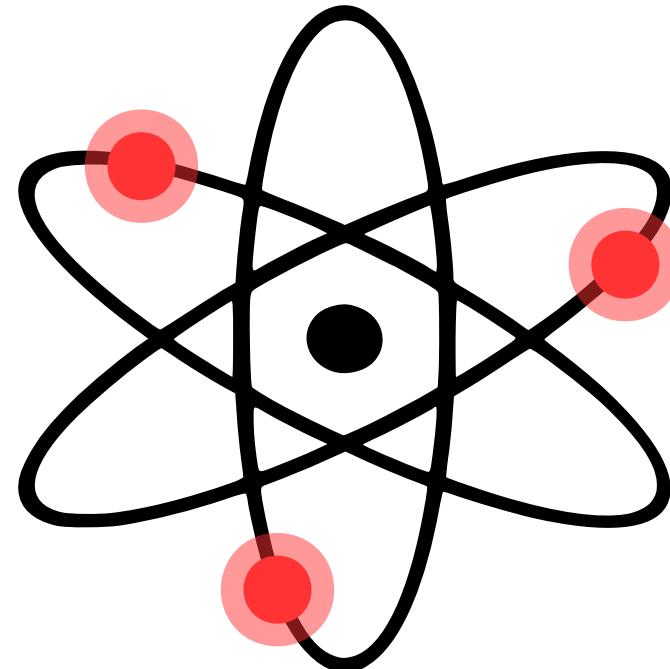
Quantum computing's potential is enormous !

*we will be more precise on this point later in class



Prediction

Extracting information from data
and using it to predict trends
and behaviour patterns



Simulation

The imitation of the operation
of a real-world process or system
over time

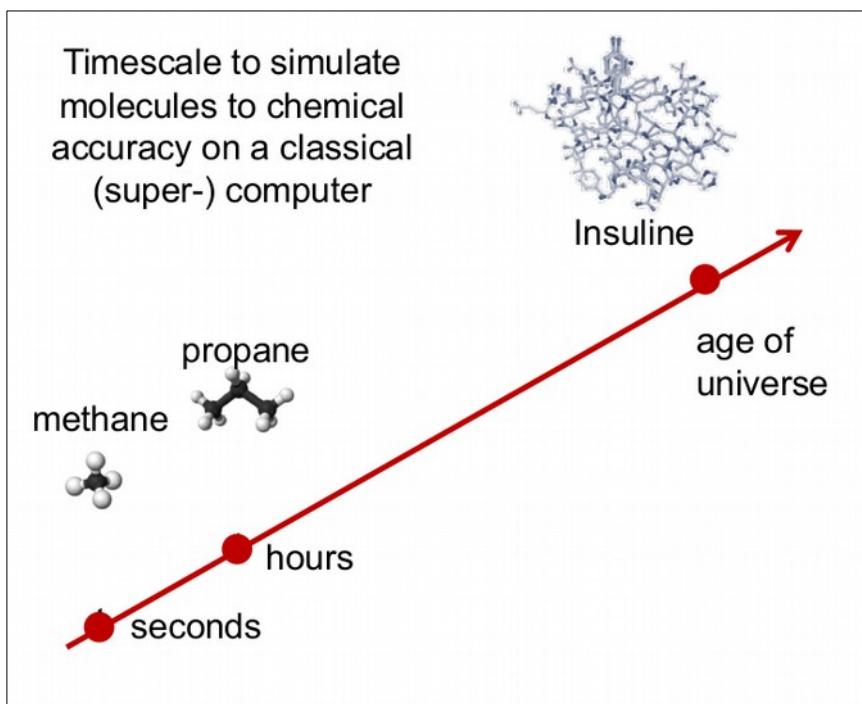
Optimization

Finding the best solution
with the least error from
a multitude of possible
solutions



Chemistry/Pharma

Computational-chemistry can be a highly valuable tool, but scales very poorly on classical computers; which is why in the 1980s the concept of quantum-computing was proposed.



Catalyst and enzyme design, such as nitrogenase

Pharmaceutical R&D, such as faster drug discovery

Bio-informatics, such as genomics

Patient diagnostic for health care, such as improved diagnostic capability for MRI

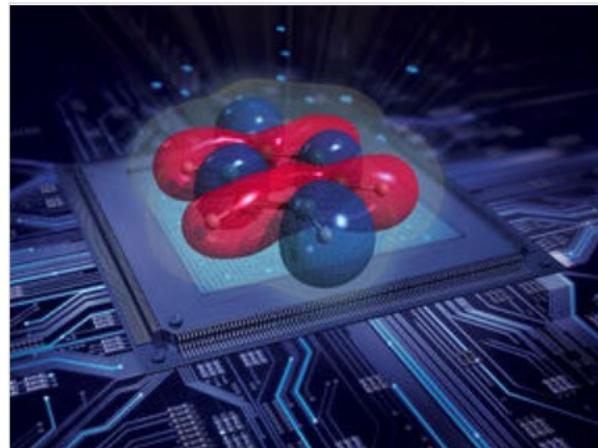


Chemistry/Pharma

Merck cooperates with start-up HQS Quantum Simulations

Unique approach to quantum chemistry on near-term quantum computers

06-Jun-2019



Merck KGaA
Merck and HQS Quantum Simulations Cooperate in
Quantum Computing

Merck announced a three-year cooperation with HQS Quantum Simulations, a start-up based in Karlsruhe, Germany. The cooperation between the startup and the Chief Digital Organisation of Merck will focus on applying and commercializing software for quantum chemical applications on quantum computers. Merck has the option for a distribution license.

“Quantum computing is poised to disrupt classical computing and enable a variety of unprecedented opportunities. The applications touch upon many fields with direct relevance to Merck and to our customers, for example materials research, drug discovery, artificial intelligence, and e-commerce,” said Philipp Harbach, Head of In Silico Research at the Chief Digital Organisation of Merck.

Chemistry/Pharma

Atos, Bayer and RWTH Aachen University use Atos Quantum Learning Machine to study human disease patterns

Quantum computing to accelerate research in the Health sector

Paris, Leverkusen, Aachen, November 7, 2018

Atos, a global leader in digital transformation, Bayer, an international life science company, and RWTH Aachen University announce that they are working together to evaluate the use of Quantum Computing in research and analysis of human disease patterns. Computing and life science experts from these three institutions will use the Atos Quantum Learning Machine, the world's highest-performing quantum simulator, to research the evolution of multi-morbidity human diseases from large data repositories.

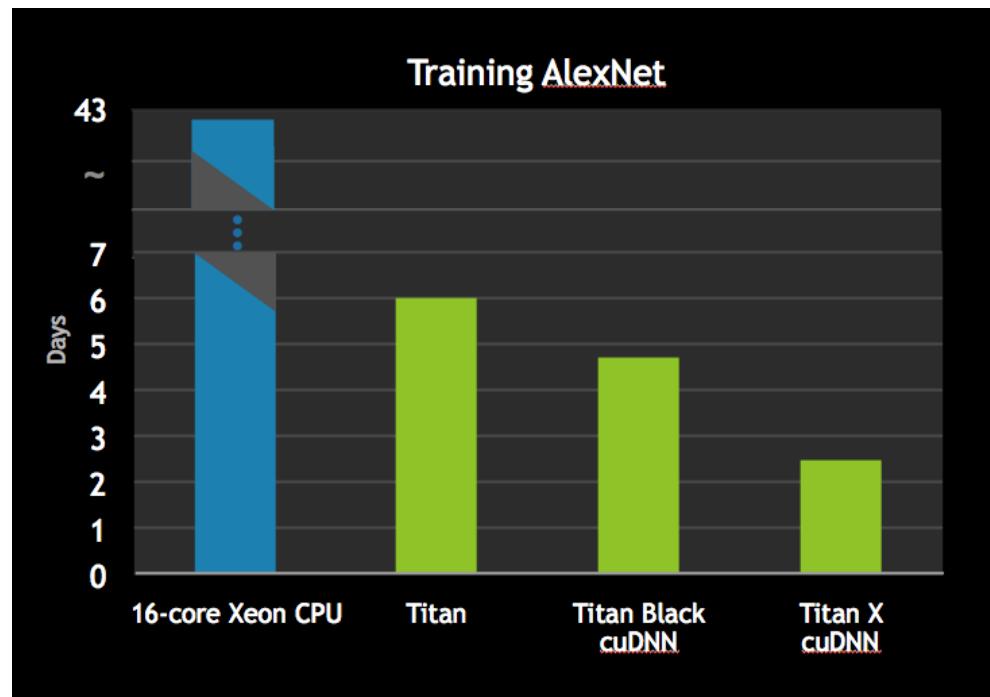
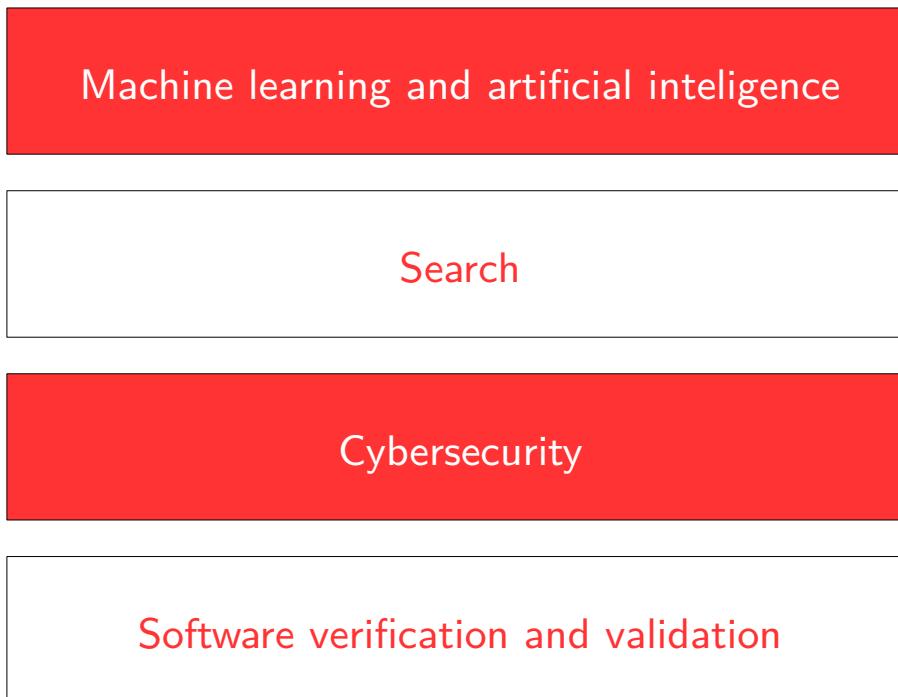
"Quantum Computing is one of the up and coming technologies that will have a game-changing impact on the life science industry, healthcare providers and of course treatment options for patients. While we consider it being early days for QC we want to make sure to learn how and in which areas it can best be used.", says Dirk Schapeler, VP G4A Digital Innovation from Bayer.

The project is based on anonymized real-world data of intensive care patients, to analyze and identify correlations between comorbidities and relevant patterns of disease evolution. This concept complements the approach of clinical trial studies that usually focuses on a limited number of patients and well-structured data to analyze disease criteria.

"We need to better understand the health state of patients with more than one disease. The Atos Quantum Learning machine will help us analyze the evolution of a disease and the interaction with comorbidities.", says Dr. Ulf Hengstmann, G4A Digital Health Innovation Manager from Bayer. "We already know that patients with specific diseases like heart failure can have several typical comorbidities. Now we need to understand why this is happening and how it affects therapy".

High-Tech

While artificial intelligence is a natural test bed for quantum computing, large scale quantum computers are expected to be threats for cybersecurity.



1.1 Applications

High-Tech

The screenshot shows the homepage of the PennyLane library. At the top, there are three colored circular icons (red, yellow, green) on the left, followed by the title "1.1 Applications". Below the title is a large section titled "High-Tech" with a background image of a futuristic city skyline at night.

The main header features the Xanadu logo (a stylized "X" inside a circle) and the text "PENNYLANE" in large, light blue letters. Below this, a sub-header reads "A cross-platform Python library for quantum machine learning, automatic differentiation, and optimization of hybrid quantum-classical computations".

The page is divided into several sections:

- Learn:** Tutorials to introduce core QML concepts, including quantum nodes, optimization, and devices, via easy-to-follow examples. Includes a "Quantum machine learning >>" link.
- Develop:** Read the documentation, see the source code, make a bug report, and contribute directly to PennyLane. Includes a "GitHub >>" link.
- Hack:** QHACK, our hardware focused QML hackathon, is now over. Check out our blog for a retrospective of the talks, projects, and winners! Includes a "Blog >>" link.

A dark banner at the bottom states: "PennyLane supports a growing ecosystem, including a wide range of quantum hardware and machine learning libraries". Below this banner are logos for Xanadu, IBM, Google, rigetti, Microsoft, TensorFlow, and PyTorch.

High-Tech

The screenshot shows the homepage of the NIST Computer Security Resource Center (CSRC). The top navigation bar includes the NIST logo, a search bar labeled "Search CSRC", and a menu button labeled "CSRC MENU". Below the header is a blue banner with the "CSRC" logo. The main content area features a section titled "Post-Quantum Cryptography" with social media sharing buttons (Facebook, Google+, Twitter). Below this is a "Project Overview" section, followed by a "Background" section which discusses the threat posed by quantum computers. To the right is a sidebar titled "PROJECT LINKS" containing links to "Overview", "FAQs", "News & Updates", "Events", "Publications", and "Presentations". At the bottom right is a section titled "ADDITIONAL PAGES" with links to "Post-Quantum Cryptography Standardization", "Call for Proposals", "Example Files", and "Round 1 Submissions".

NIST

Information Technology Laboratory

COMPUTER SECURITY RESOURCE CENTER

CSRC

PROJECTS

Post-Quantum Cryptography

f G+ t

Project Overview

NIST has initiated a process to solicit, evaluate, and standardize one or more quantum-resistant public-key cryptographic algorithms. Full details can be found in the [Post-Quantum Cryptography Standardization](#) page.

The *Round 2 candidates* were announced January 30, 2019. [NISTIR 8240, Status Report on the First Round of the NIST Post-Quantum Cryptography Standardization Process](#) is now available.

Background

In recent years, there has been a substantial amount of research on quantum computers – machines that exploit quantum mechanical phenomena to solve mathematical problems that are difficult or intractable for conventional computers. If large-scale quantum computers are ever built, they will be able to break many of the public-key cryptosystems currently in use. This would seriously compromise the confidentiality and integrity of digital communications on the Internet and elsewhere. The goal of *post-quantum cryptography* (also called quantum-resistant cryptography) is to develop cryptographic systems that are secure against both quantum and classical computers, and can interoperate with existing communications protocols and networks.

PROJECT LINKS

Overview

FAQs

News & Updates

Events

Publications

Presentations

ADDITIONAL PAGES

Post-Quantum Cryptography Standardization

Call for Proposals

Example Files

Round 1 Submissions

1.1 Applications

High-Tech

The screenshot shows the homepage of ID Quantique's website. At the top left is the IDQ logo. To the right are a search bar, a "Partner Portal" button, and a "Shop Online" button with a shopping cart icon. Below the header is a navigation menu with links: Random Number Generation, Quantum-Safe Security, Single-Photon Systems, News & Events, Resource Library, and About IDQ. The main content area features a dark blue background with a network graph pattern. On the left, there are social media icons for Twitter, LinkedIn, and email, followed by text about a secure optical transport system using QKD. A "Contact Us" button is on the right. At the bottom, there is a brief description of ID Quantique's mission and a note about their quantum random number generator.

ID Quantique (IDQ) is the world leader in quantum-safe crypto solutions, designed to protect data for the long-term future. The company provides quantum-safe network encryption, secure quantum key generation and quantum key distribution solutions and services to the financial industry, enterprises and government organisations globally.

IDQ also commercializes a quantum random number generator, which is the reference in the security, simulation and gaming industries.



Industrial goods

Product development and process optimization are among the manufacturing areas likely to witness major innovations with quantum computing.



Logistics: scheduling, planning, product distribution, routing

Automotive: traffic simulation, e-charging station
and parking search, autonomous driving

Material science: effective catalytic converters for cars,
battery cell research, more efficient material for solar cells,
and property engineering uses such as OLEDs

1.1 Applications

Industrial goods

THE WALL STREET JOURNAL

Home World U.S. Politics Economy Business Tech Markets Opinion Life & Arts Real Estate WSJ Magazine

Subscribe | Sign In

Search (X)

SHARE

AA TEXT

4

CIO JOURNAL

Mercedes Enlists Quantum Computing to Build a Better Electric Vehicle Battery

Auto maker, working with IBM quantum experts, sees 'huge opportunity' in the technology



Mercedes-Benz is working with IBM on the goal of deploying the next-generation computing power. Above, a quantum scientist walks across the IBM Q computation center in Yorktown Heights, N.Y. PHOTO: CONNIE ZHOU/IBM

RECOMMENDED VIDEOS

1. Impeachment Inquiry: Why High Crimes Is Inherently Subjective
2. Dissecting the Vaping Illness Mystery
3. Timeline: Interactions Between Trump's Camp and Ukraine
4. U.S. Begins Withdrawal of Troops From Northern Syria
5. Anatomy of an IPO Valuation

MOST POPULAR ARTICLES

1. Appeals Court Stays Order That Trump Release Tax Returns
2. WeWork Investors Turned Off by 'Sloppy' IPO Filings

Industrial goods

The image shows a screenshot of the Volkswagen website. At the top, there is a navigation bar with links for GROUP, BRANDS & MODELS, SUSTAINABILITY, INVESTOR RELATIONS, CAREER, MEDIA, and SOCIAL MEDIA. There is also a search icon, language selection (EN), and a menu icon. The main content area features a photograph of a city street with a car at a traffic light. Overlaid on the image are two glowing blue icons: a stopwatch labeled "Minimal Waiting Time" and a car with a cloud above it labeled "Route Optimization". Below this image is a blue banner with white text that reads "Intelligent traffic control with quantum computers". At the bottom of the page, there is a block of text in a different color.

Traffic control is one of the many areas where quantum computers could be used. An innovative project by Volkswagen: Avoiding traffic jams and shortening waiting times using quantum algorithms.



Finance

Traditionally, financial players have relayed on the power of computing to reduce the risk. Bigger profits result from analyzing a situation faster and in more detail.

Trading strategies

Portfolio optimization

Asset pricing

Fraud detection

Risk analysis

Market simulation





Finance

AMERICAN BANKER [All Sections ▾](#) [Resources](#) [Events](#)

NOW READING: [The Latest](#) [Why banks like Barclays are testing quantum computing](#) [Morning Scan Deutsche Bank plans new tech division; bitcoin ...](#) [BankThink Streamlined Volcker Rule could encourage some ...](#) [Subprime card lender introduces ex-Barclays exec as CEO](#) [Warren: Trump DOJ settles ... let big banks off easy >](#)

Why banks like Barclays are testing quantum computing

By [Penny Crosman](#) Published [July 16 2018, 4:12pm EDT](#)

[Print](#) [Reprint](#)

Quantum computing — technology based on the principles of quantum theory — is increasingly attracting the interest of financial services firms that are seeking to process transactions, trades and other types of data as fast as possible.

Barclays and JPMorgan Chase have been experimenting with IBM's quantum computing technology since December, when they joined the tech company's Q network. Salvatore Cucchiara at Morgan Stanley last week articulated the bank's hope of speeding up portfolio optimizations like Monte Carlo simulations with the help of quantum computing.

Trending

[Does it really matter where Wells Fargo's CEO is based?](#)

[The Most Powerful Women in Banking](#)

[A battle royal for online deposits](#)

Energy

Energy optimization, for example, requires far too much traditional computing power to identify the ideal balance of resources from different energy sources to meet ever-changing consumption needs in real time.



Network design

Energy distribution

Oil well optimization



1.1 Applications

Energy

The screenshot shows the ExxonMobil website's navigation bar with links for Energy, Technology, Current issues, Environment, Community, Company, and a search icon. Below the navigation is a breadcrumb trail: News and updates > News releases. A news card is displayed with a red 'News' badge, the date Jan 8, 2019 - 12:01 a.m. EST, and the title "ExxonMobil and IBM to Advance Energy Sector Application of Quantum Computing". The main content area lists four bullet points detailing the strategic commitment to joint research and the company's entry into the IBM Q Network.

ExxonMobil
Energy lives here™

Energy Technology Current issues Environment Community Company

News and updates > **News releases**

News Jan 8, 2019 - 12:01 a.m. EST

ExxonMobil and IBM to Advance Energy Sector Application of Quantum Computing

- Strategic commitment to advance joint research into quantum computing for energy
- ExxonMobil becomes first energy company to join the IBM Q Network
- Technology could further enhance ExxonMobil's own research and development capabilities

Energy

Microsoft and DEWA bringing quantum computing to Dubai

June 28, 2018 | Microsoft News Center



DEWA will work with Microsoft and access new quantum Microsoft Azure services to create quantum-inspired solutions to power energy optimization and improve sustainability efforts in Dubai and the United Arab Emirates

DUBAI, United Arab Emirates — June 28, 2018 — The Dubai Electricity and Water Authority (DEWA) on Thursday announced plans to work with Microsoft Corp. to develop new quantum-based solutions to address energy optimization and other challenges where classical computers have serious limitations, making it the first organization outside the U.S. to participate in the Microsoft Quantum program.

Energy

Microsoft and DEWA bringing quantum computing to Dubai

June 28, 2018 | Microsoft News Center



DEWA will work with Microsoft and access new quantum Microsoft Azure services to create quantum-inspired solutions to power energy optimization and improve sustainability efforts in Dubai and the United Arab Emirates

DUBAI, United Arab Emirates — June 28, 2018 — The Dubai Electricity and Water Authority (DEWA) on Thursday announced plans to work with Microsoft Corp. to develop new quantum-based solutions to address energy optimization and other challenges where classical computers have serious limitations, making it the first organization outside the U.S. to participate in the Microsoft Quantum program.



A new island on the complexity map

