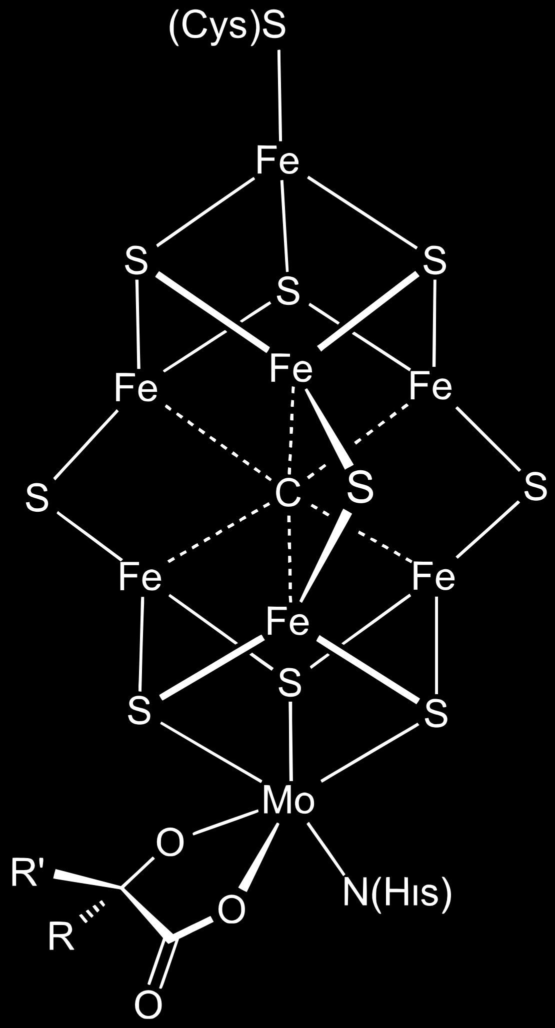
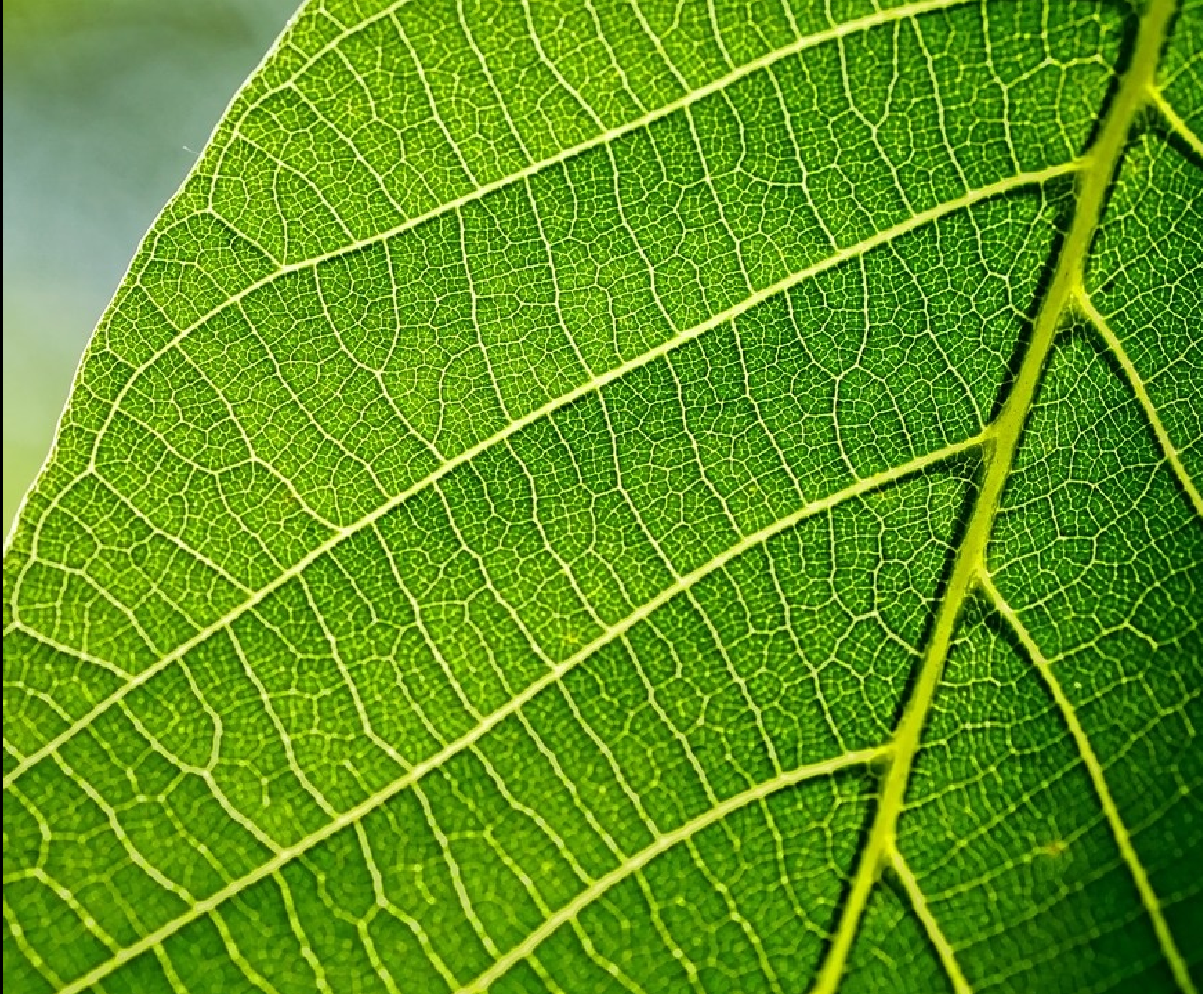
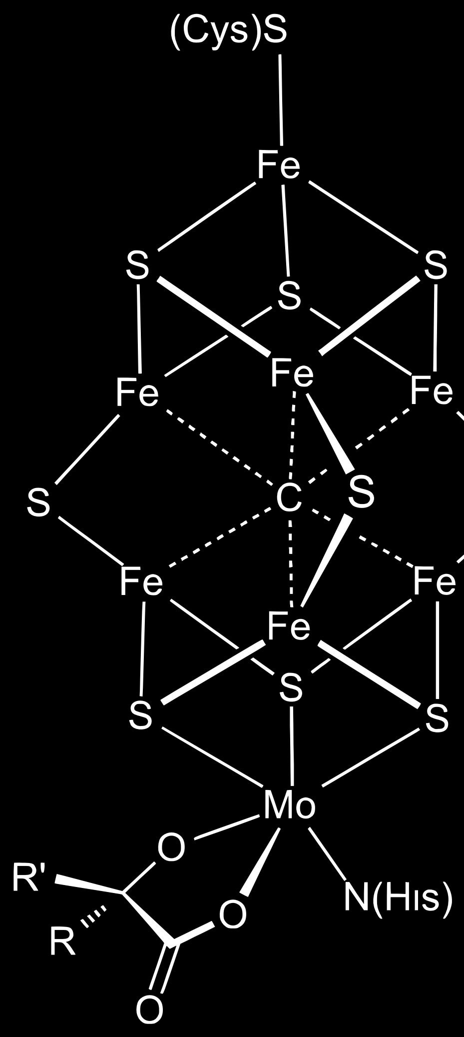
Ch1: Quantum Computing in a Nutshell


(Cys)S
Fe
S
S
S
Fe
Fe
Fe
S
C
S
S
Fe
Fe
Fe
S
S
S
Mo
O
R'
R
O
O
N(His)



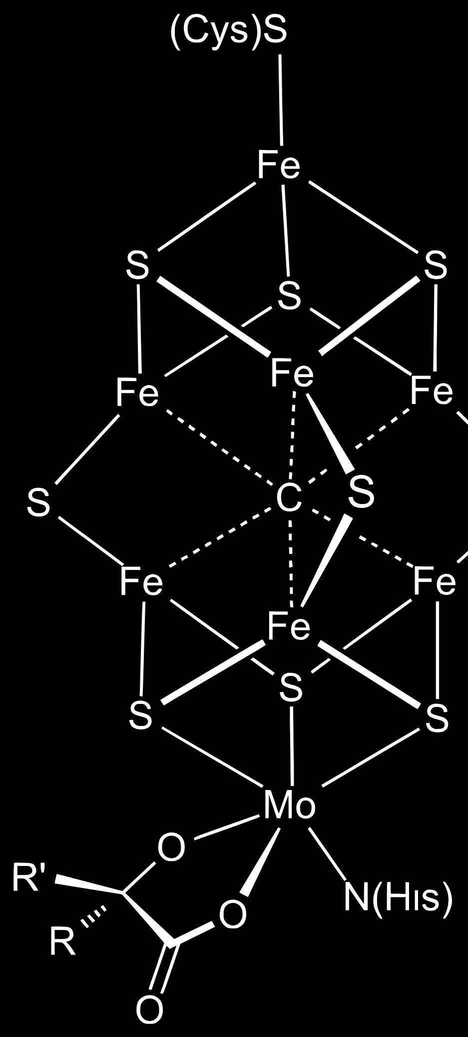
Character	Bits
7	111
A	01000001
$	00100100
:)	0011101000101001


(Cys)S
Fe
S
S
S
Fe
Fe
Fe
S
C
S
S
Fe
Fe
Fe
S
S
S
Mo
O
R'
R
O
O
N(His)

Classical

$\sim 10^{32}$

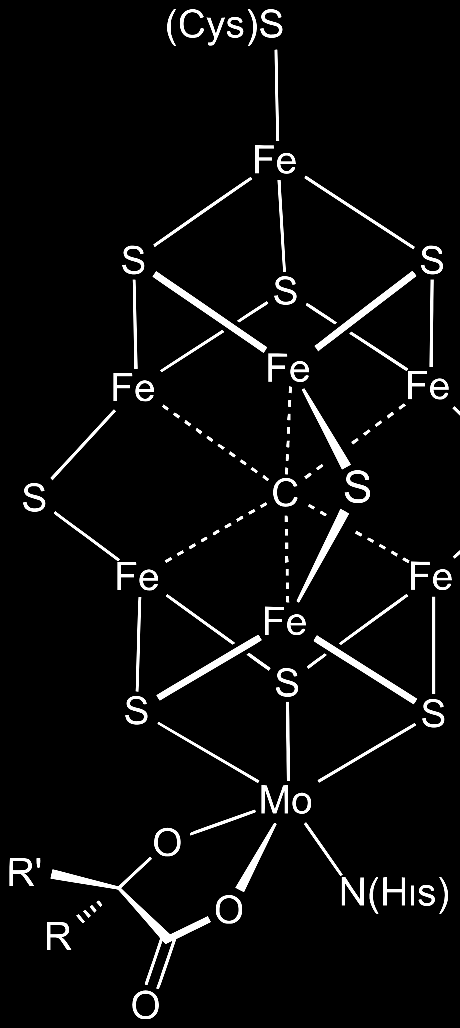
bits



Classical

$\sim 10^{32}$

bits



Quantum

~ 108

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

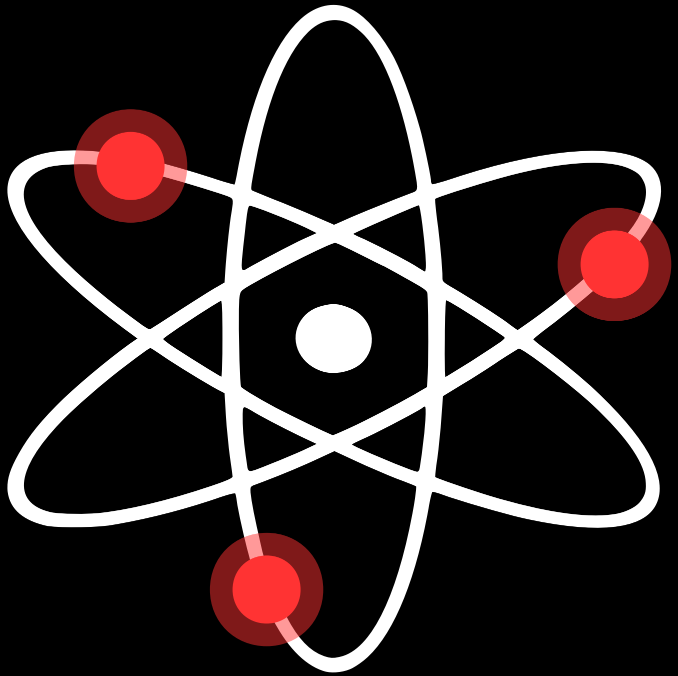
Industry Landscape

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

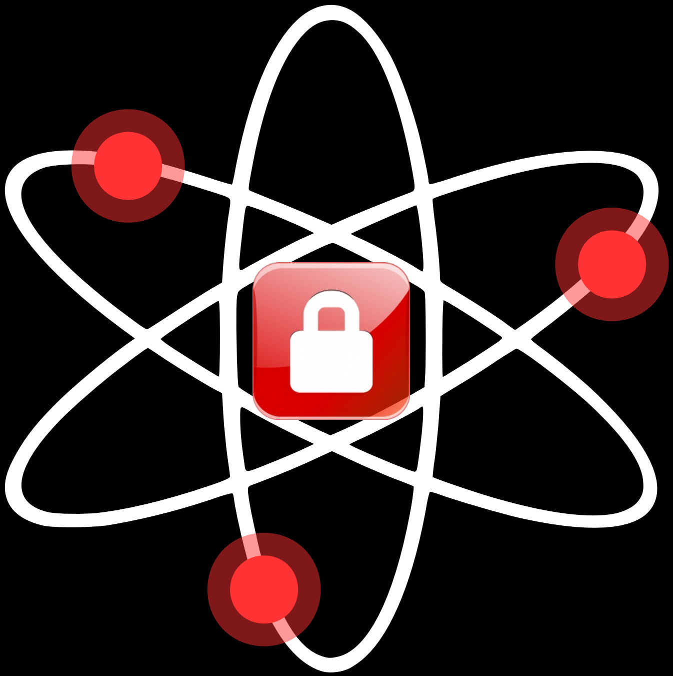
Finding the best solution with the least error from a multitude of possible solutions

Prediction

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

Simulation

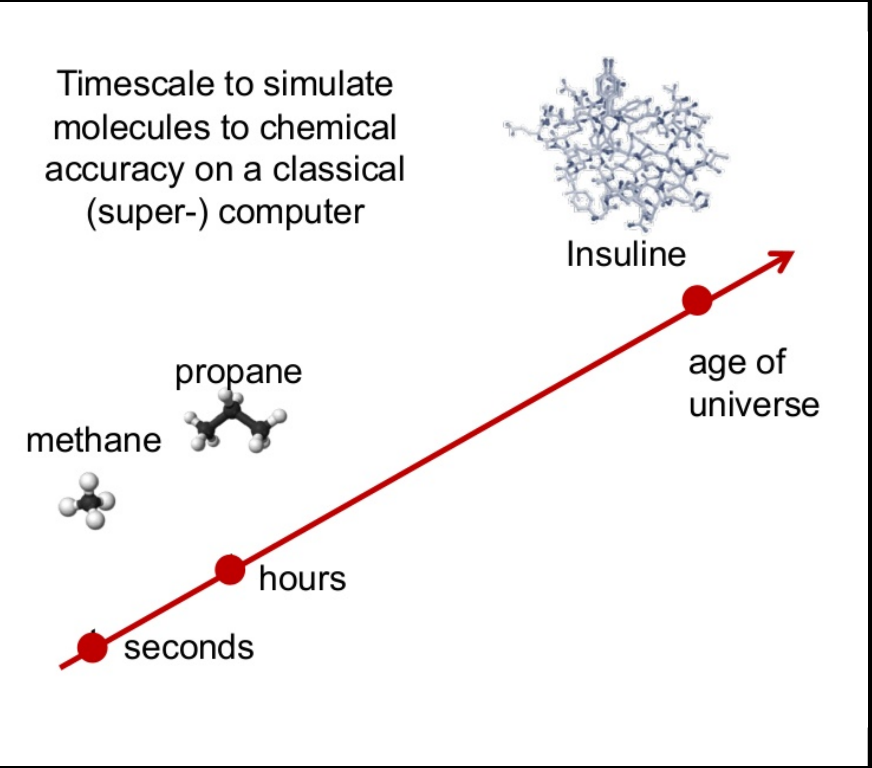
The imitation of the operation of a real-world process or system over time



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.



Catalyst and enzyme design, such as nitrogenase

Pharmaceutical R&D, such as faster drug discovery

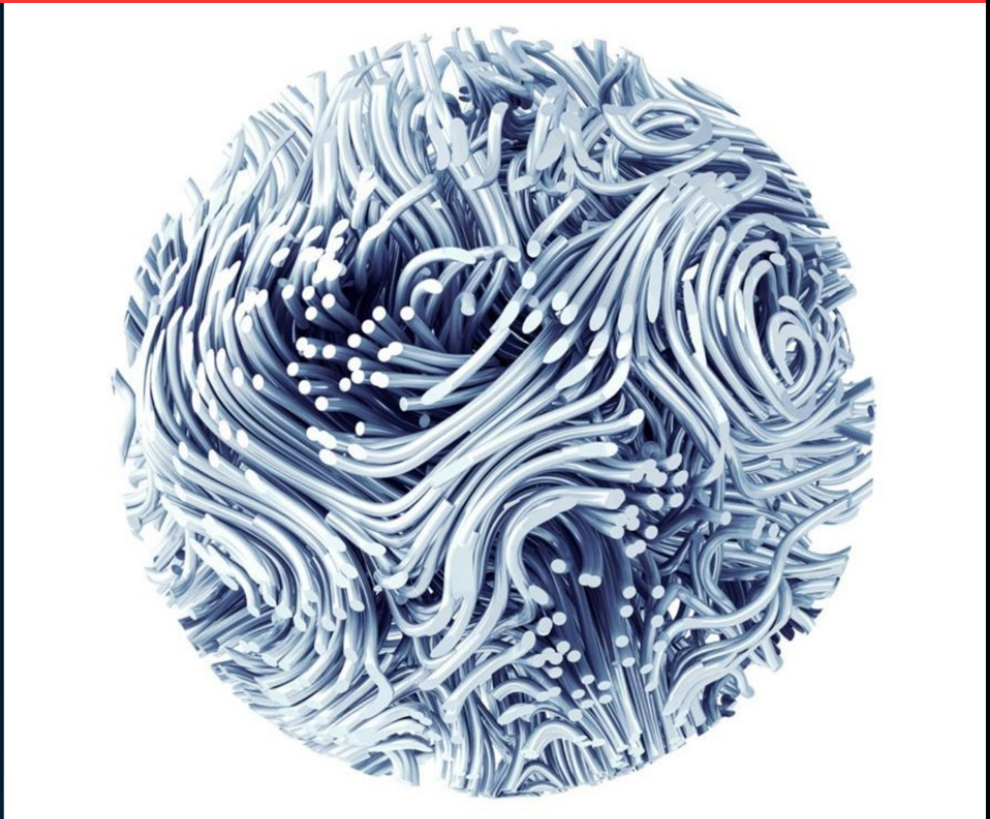
Bio-informatics, such as genomics

Patient diagnostic for health care

McKinsey & Company report on Quantum Computing (2019)

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

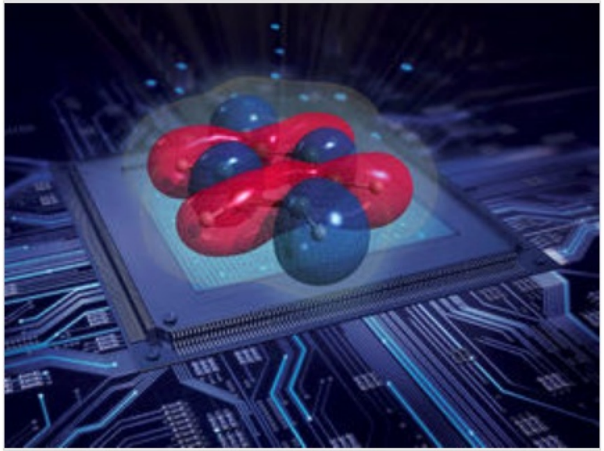
July 2019 | Article



Merck cooperates with start-up HQS Quantum Simulations

Unique approach to quantum chemistry on near-term quantum computers

06-Jun-2019



Merck 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.

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".*

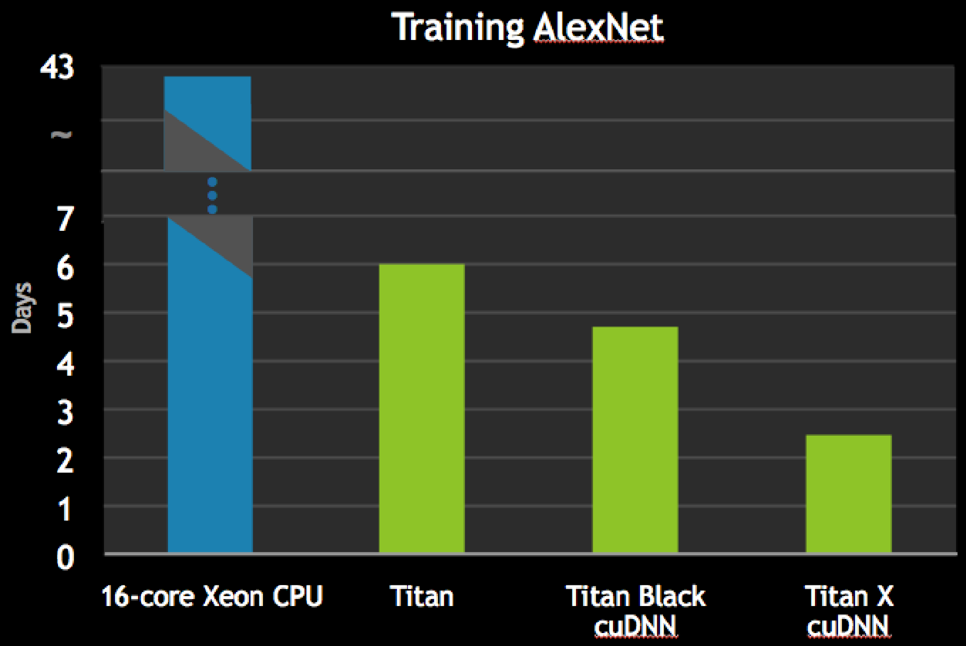
While artificial intelligence is a natural test bed for quantum computing, large scale quantum computers are expected to be threats for cybersecurity.

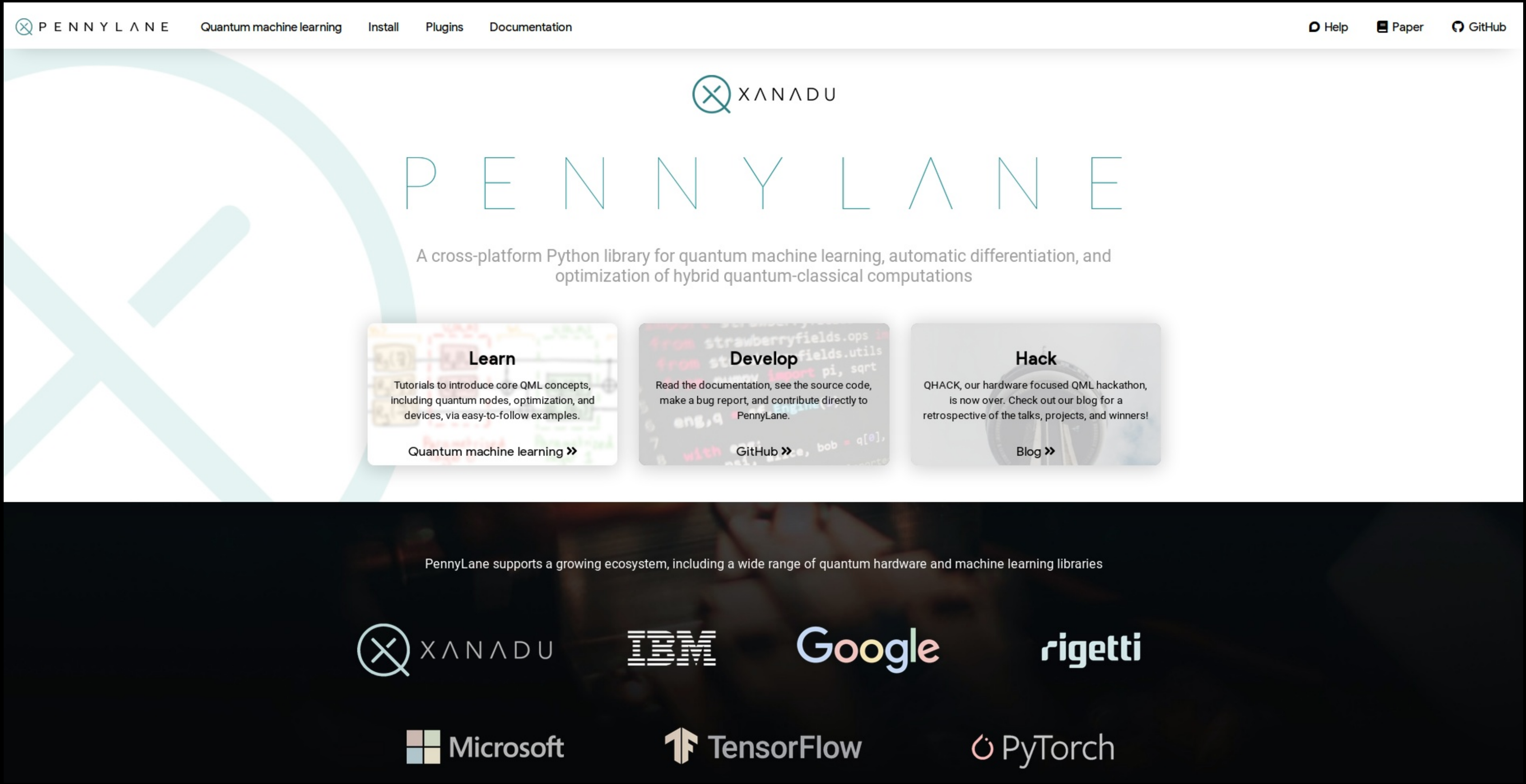
Machine learning and artificial inteligence

Search

Cybersecurity

Software verification and validation




PENNYLANE
Quantum machine learning
Install
Plugins
Documentation
Help
Paper
GitHub
XANADU
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
XANADU
IBM
Google
rigetti
Microsoft
TensorFlow
PyTorch

NIST

Search CSRC | CSRC MENU

Information Technology Laboratory

COMPUTER SECURITY RESOURCE CENTER

CSRC

PROJECTS

Post-Quantum Cryptography

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.

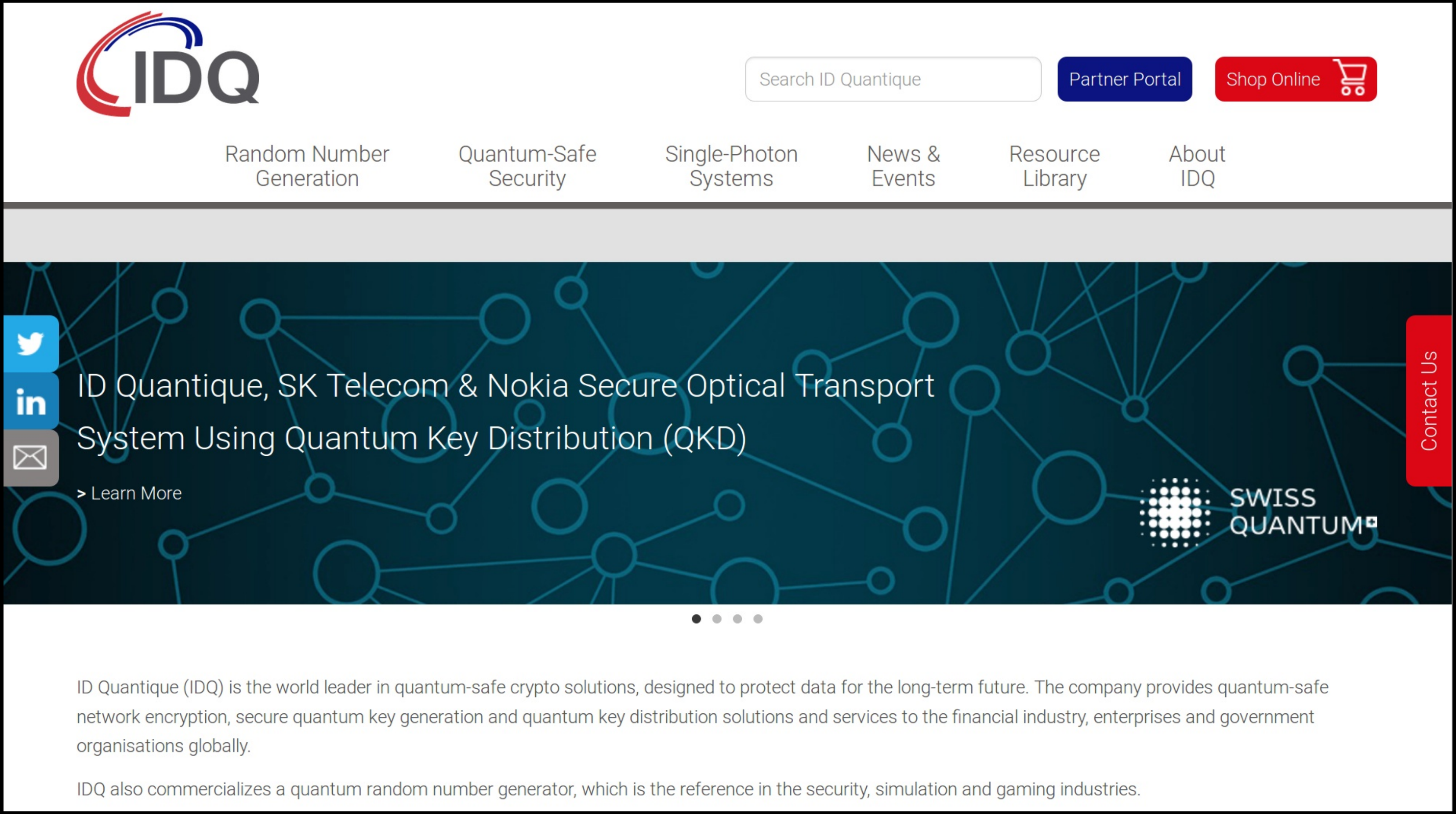
PROJECT LINKS

Overview
FAQs
News & Updates
Events
Publications
Presentations

ADDITIONAL PAGES

Post-Quantum Cryptography Standardization
Call for Proposals
Example Files
Round 1 Submissions

Applications | Q-Algorithms | Q-Bits | Q-Circuits | Hardware | Industry



Type of problems | Chemistry/Pharma | High-tech | Industrial goods | Finance | Energy

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

Logisitics: 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

Applications | Q-Algorithms | Q-Bits | Q-Circuits | Hardware | Industry

THE WALL STREET JOURNAL.

Subscribe | Sign In

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

Search

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

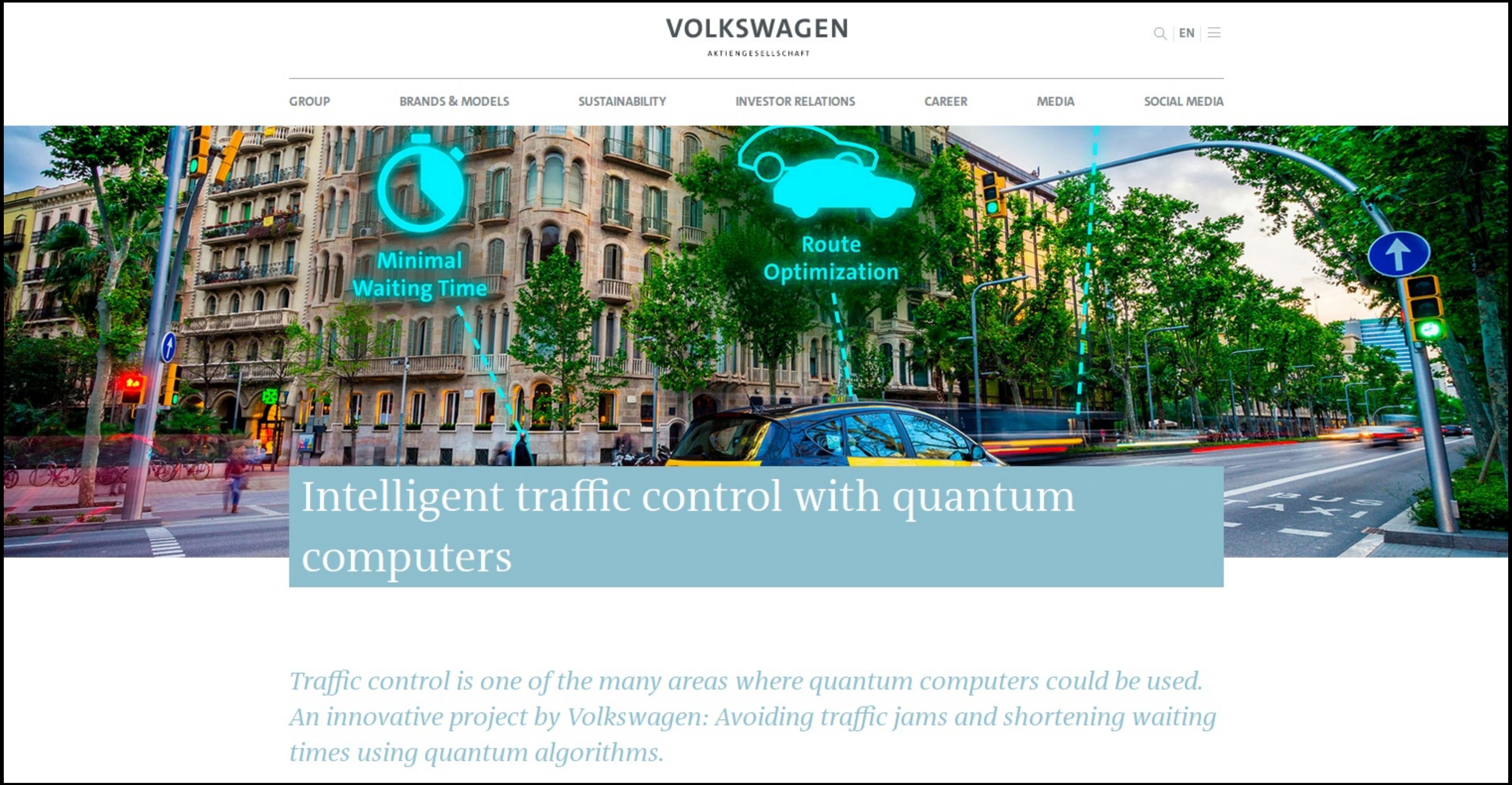
RECOMMENDED VIDEOS

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

Type of problems | Chemistry/Pharma | High-tech | Industrial goods | Finance | Energy


VOLKSWAGEN
AKTIENGESELLSCHAFT
EN
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 relayed 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

Why banks like Barclays are testing quantum computing

By
Penny Crosman

Published
July 16 2018, 4:12pm EDT

More in
High performance computing
Bank technology
Barclays
Morgan Stanley
IBM

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.

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

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

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

15

3 x 5

7110379909909823469971673725424473064353882489427176741102057973000889379665565049610836498148428158908772246304866860943192
0907344516262190407768933383377381407878353760499455979319960700906894699032445175759904798500685134300942629461309714010525
8451183638689370751031611701475016230049806026342053176134099092008619376369645670455584888994220854383100330689198272181971
4646273989819664246923150740873954504626617855555157407339193547990580114163271213899734697576741853036676191288057688972233
3216854588089690421544040301537811000428377757537533165315590643914173011914509168646819605343438902256216469789162186128

? x ?

Classical

$\sim 10^{14}$

years

Quantum*

~ 10

seconds

*assuming a quantum computer with 4096 perfectly stable qubits

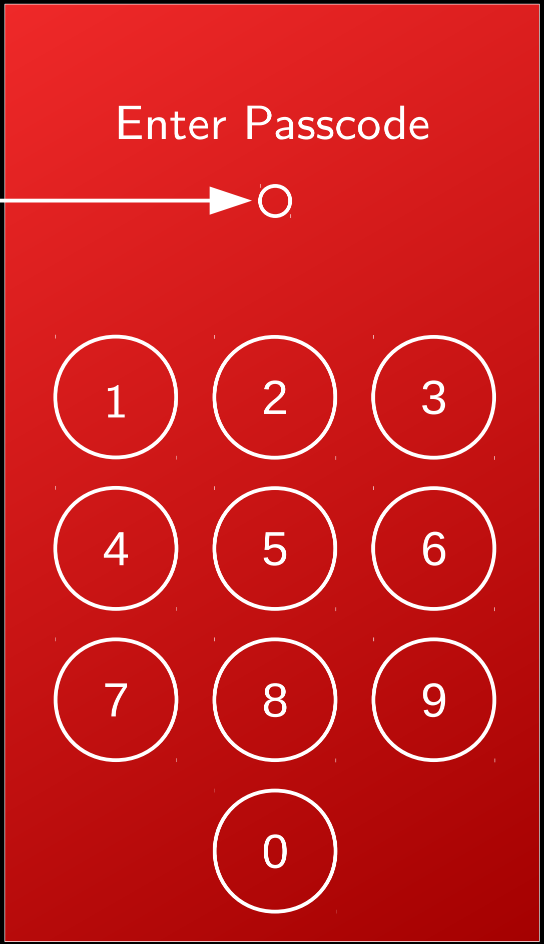
Task:

Integer Factorization

Quantum algorithm:

Shor's Algorithm

1 digit

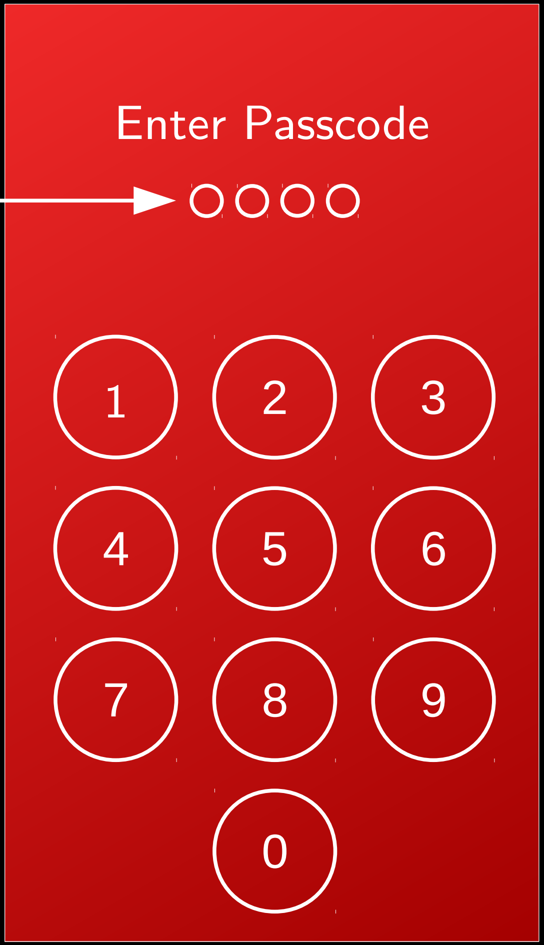


Number of digits

Number of tries

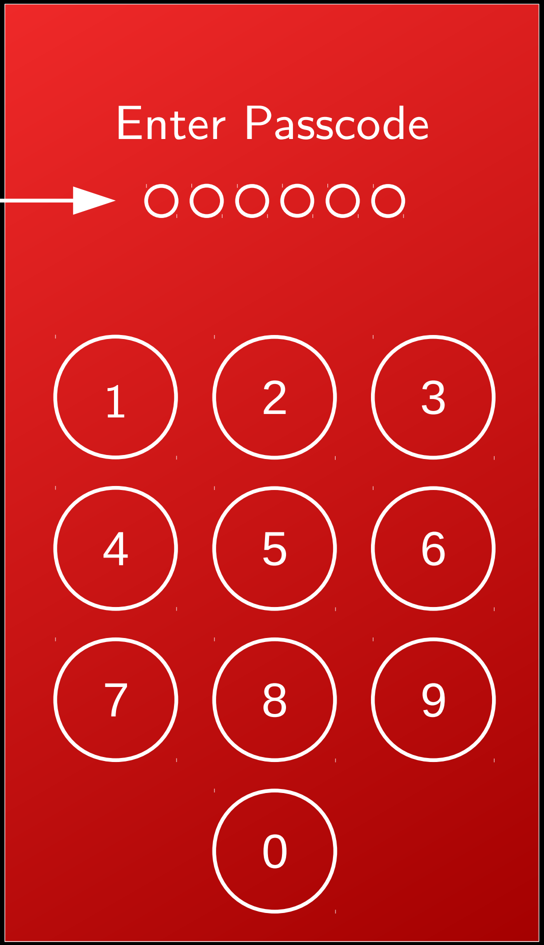
1 → 10

4 digits

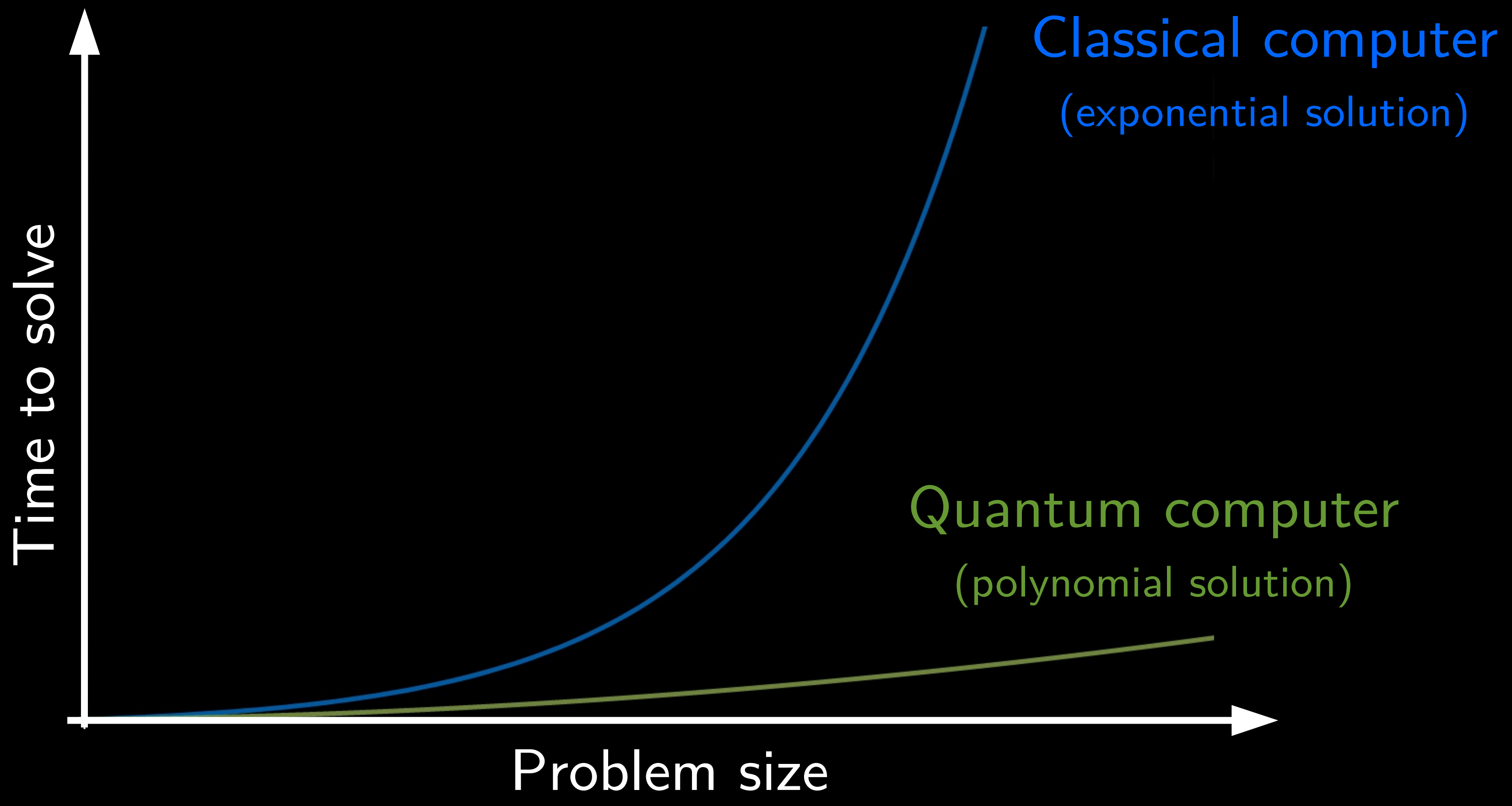


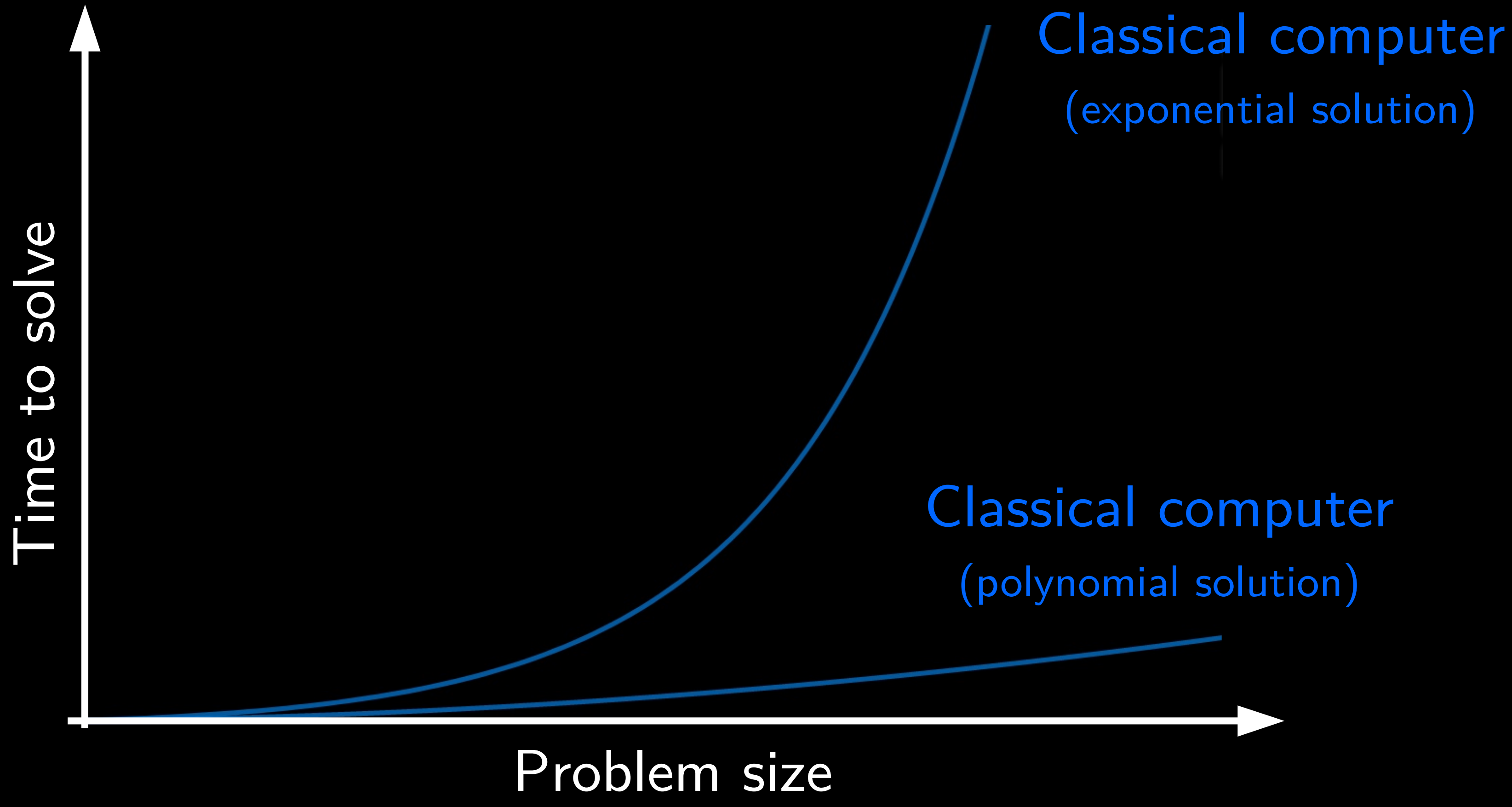
Number of digits		Number of tries
1	→	10
4	→	10,000

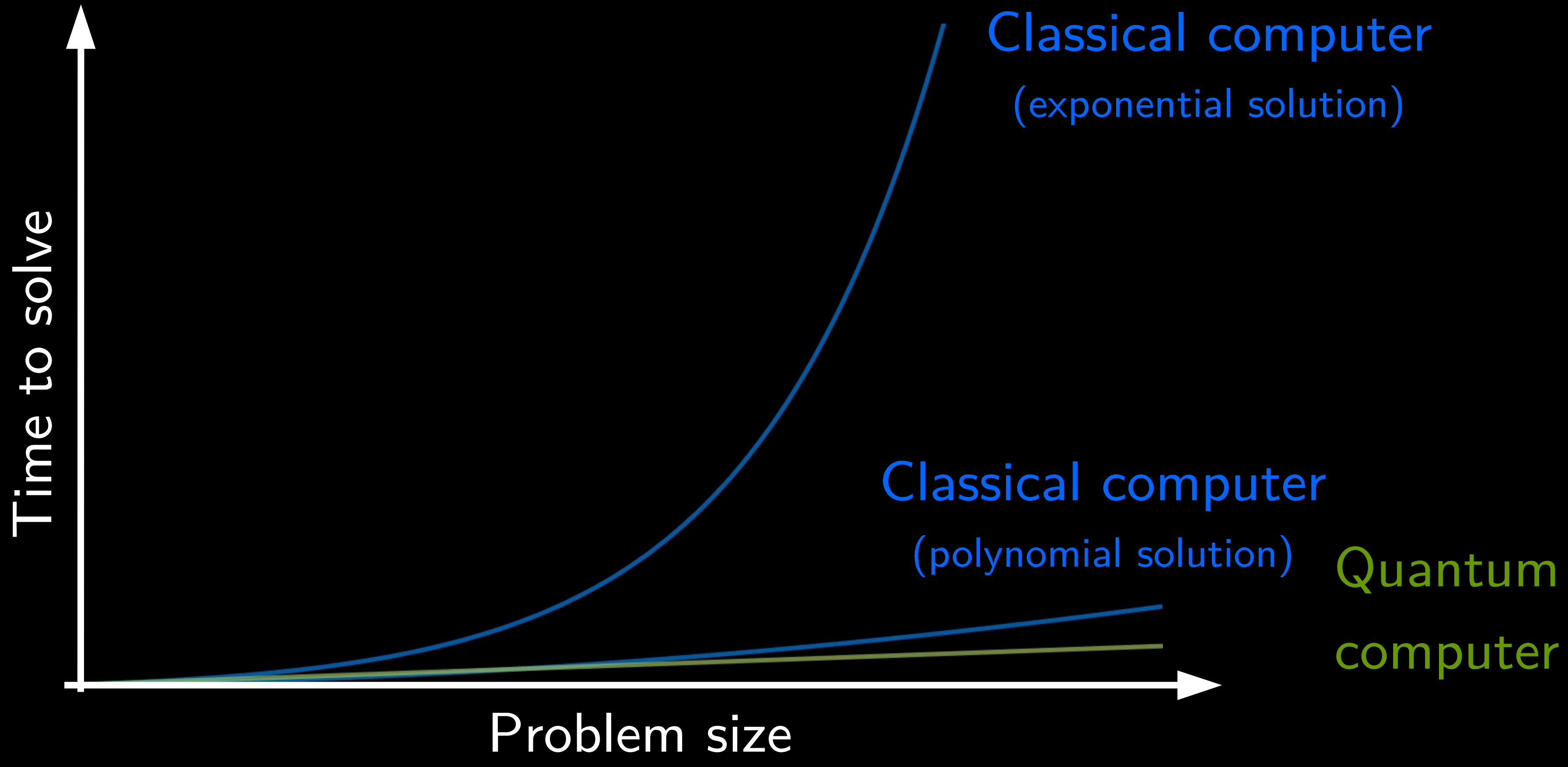
6 digits

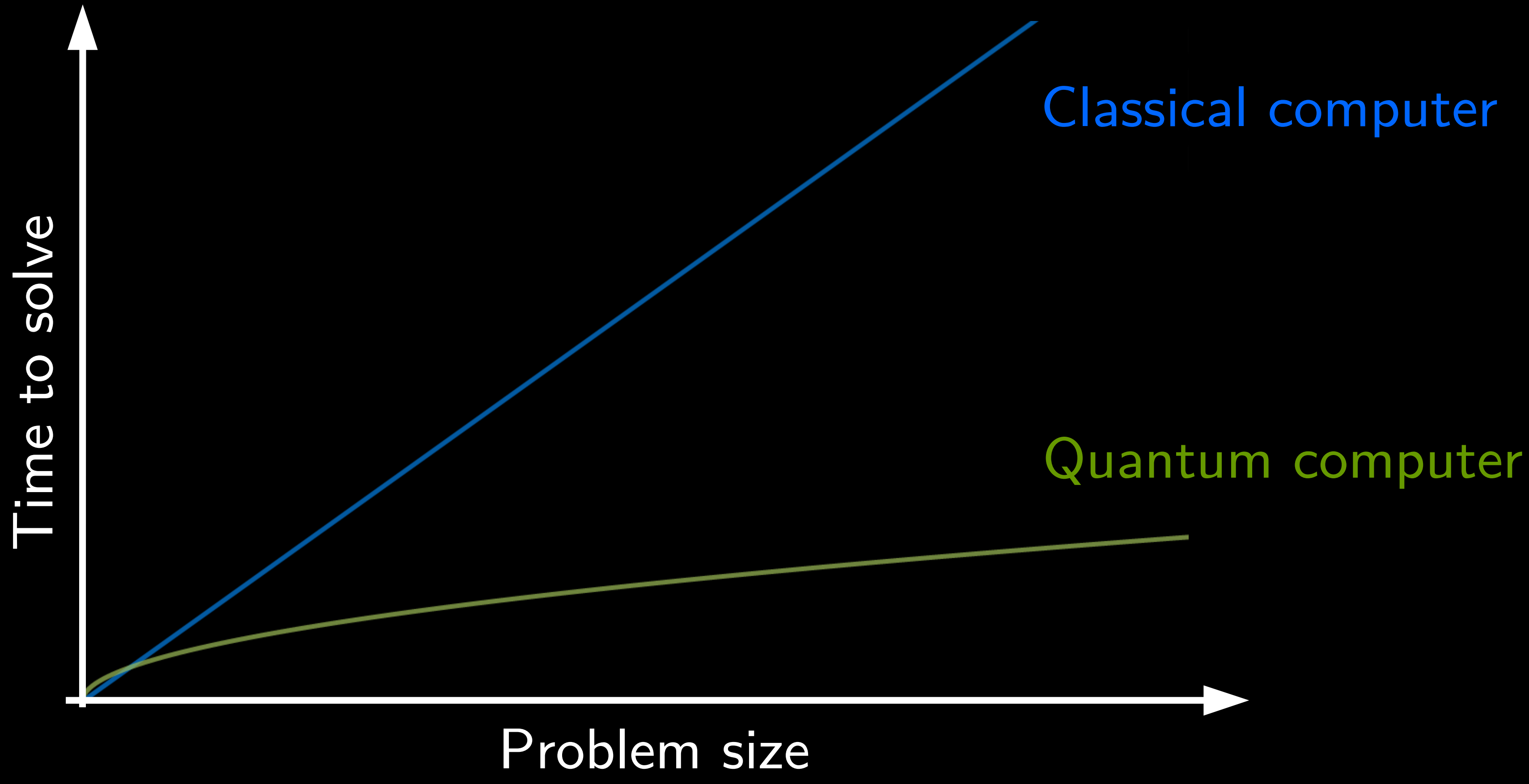


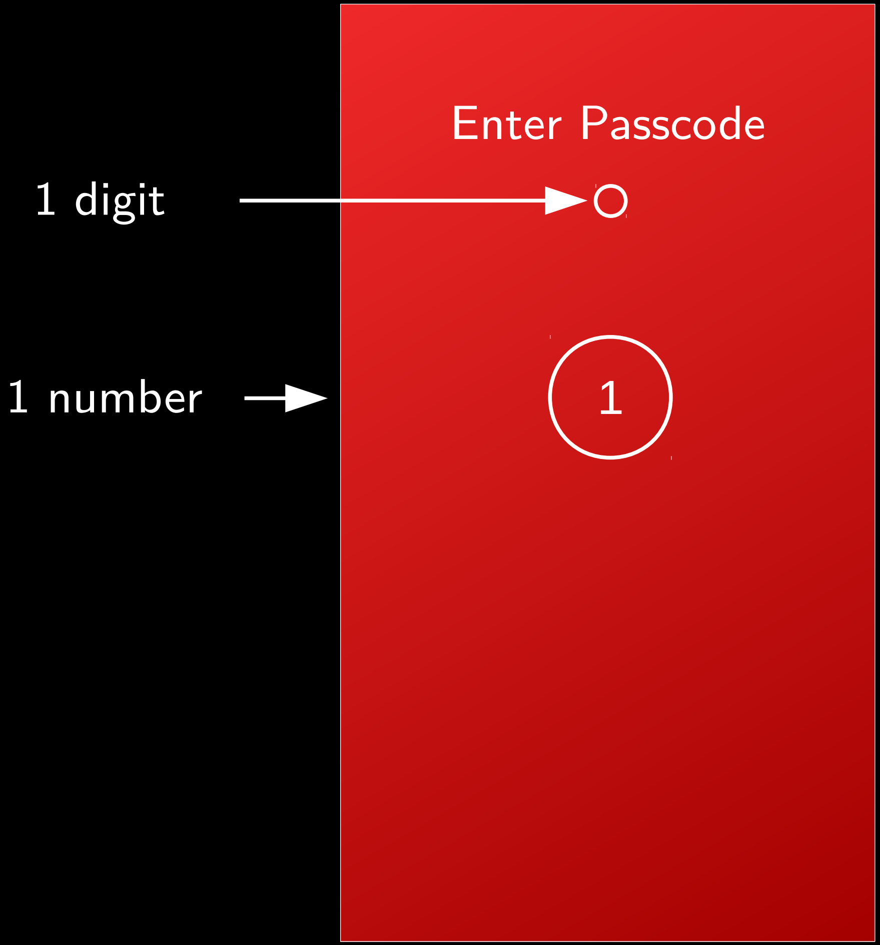
Number of digits		Number of tries
1	→	10
4	→	10,000
6	→	1,000,000

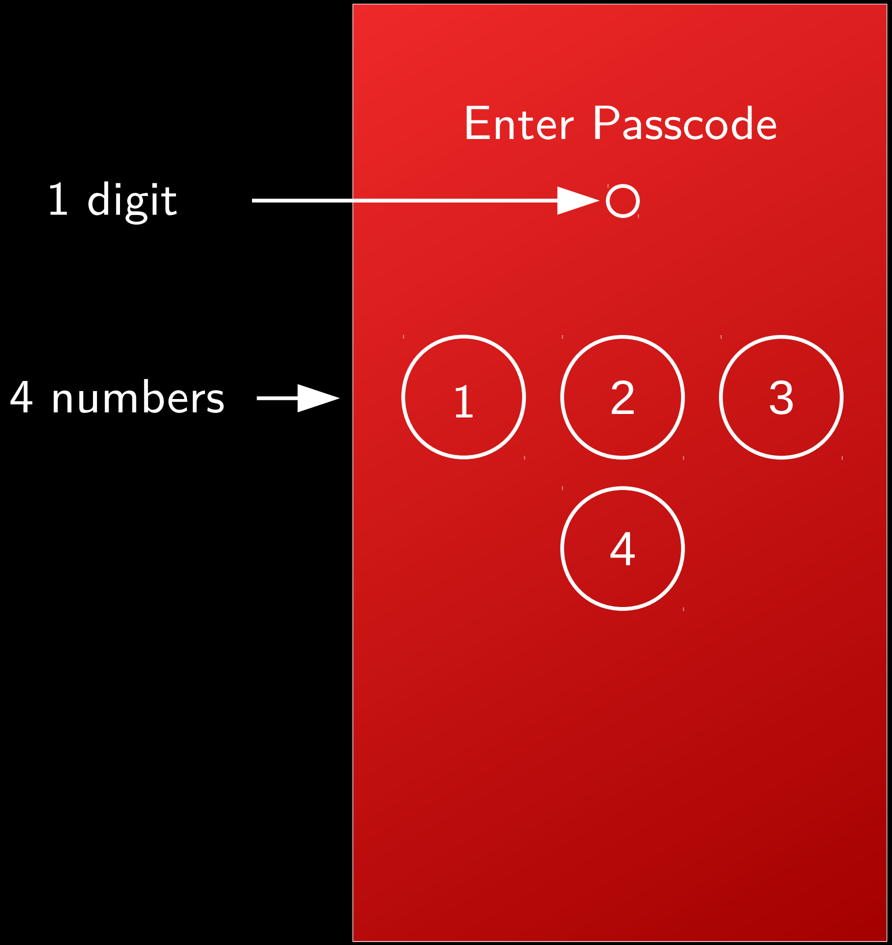

Classical computer
(exponential solution)
Quantum computer
(polynomial solution)
Time to solve
Problem size

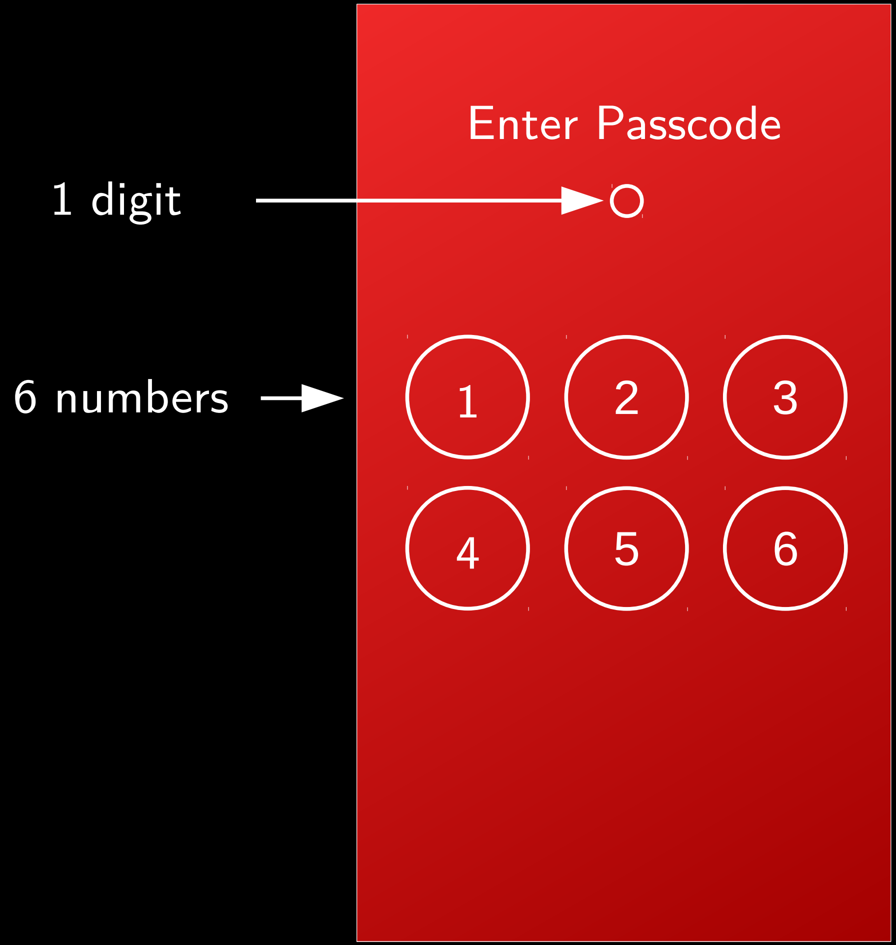

Classical computer
(exponential solution)
Classical computer
(polynomial solution)
Time to solve
Problem size


Classical computer
(exponential solution)
Classical computer
(polynomial solution)
Quantum computer
Time to solve
Problem size


Classical computer
Quantum computer
Time to solve
Problem size


Enter Passcode
1 digit
1 number
1

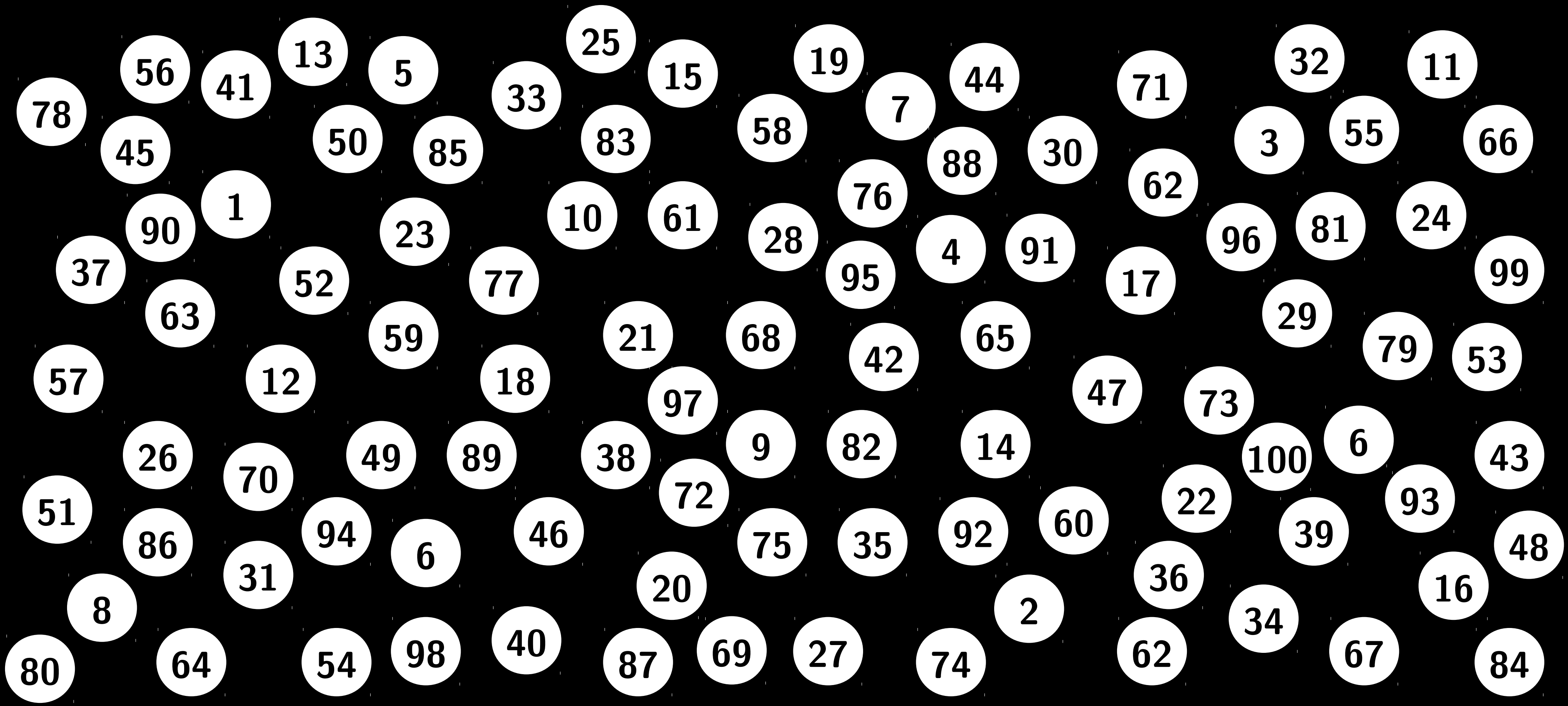

Enter Passcode
1 digit
4 numbers
1
2
3
4


1 digit
6 numbers
Enter Passcode
1
2
3
4
5
6

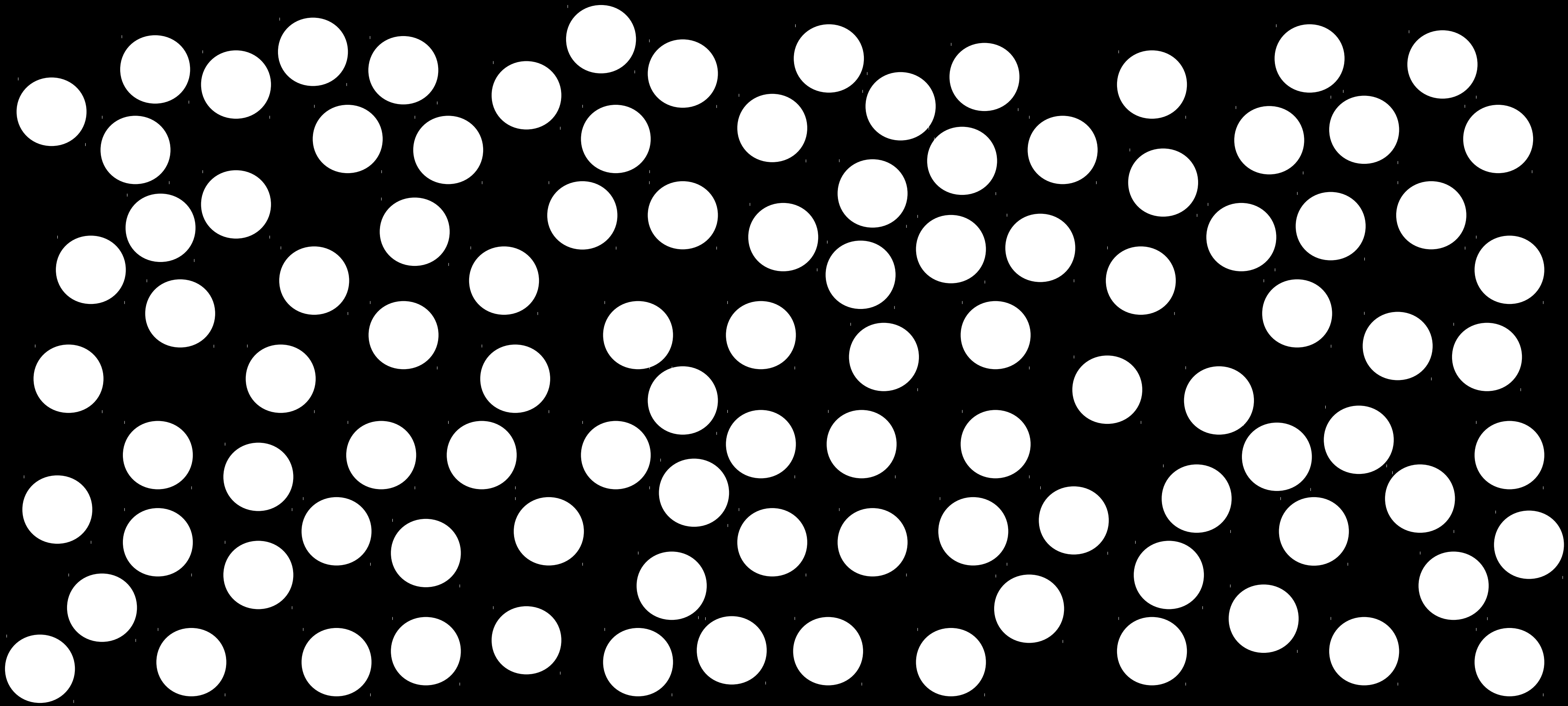
Task:

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	Quantum
n	$\sqrt{n}$
tries	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

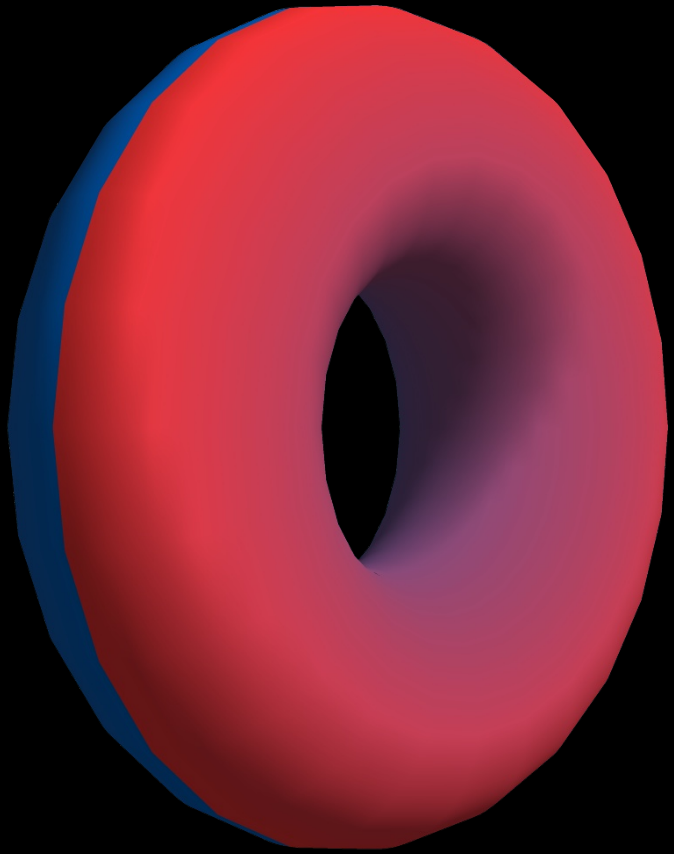
Industry Landscape

1. Superposition

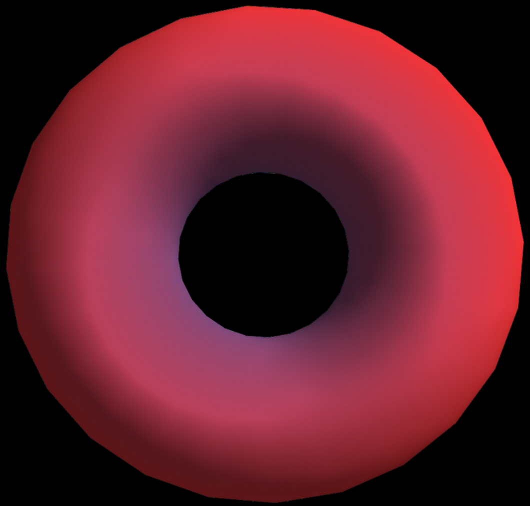
2. Entanglement

1. Superposition

2. Entanglement

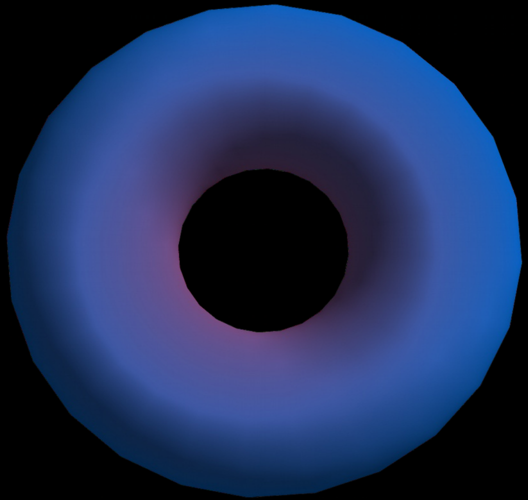


Classical bit:



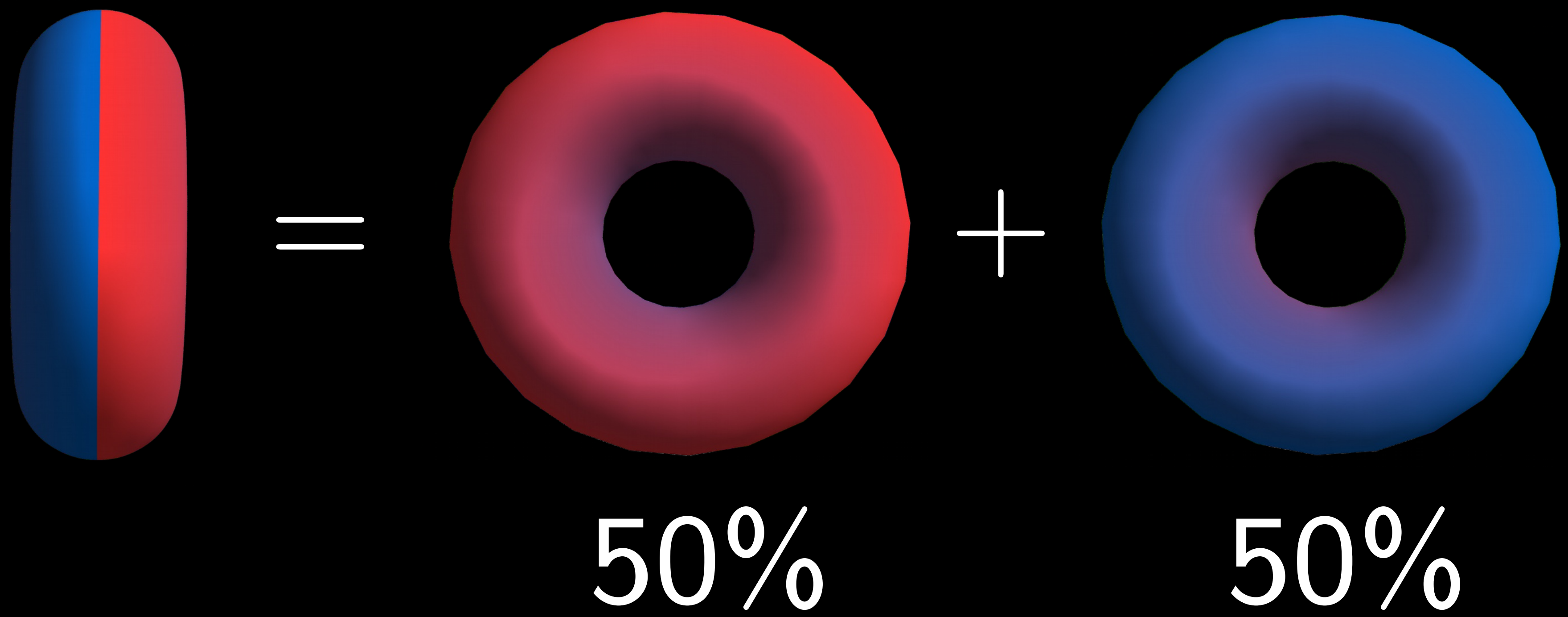
0

Classical bit:

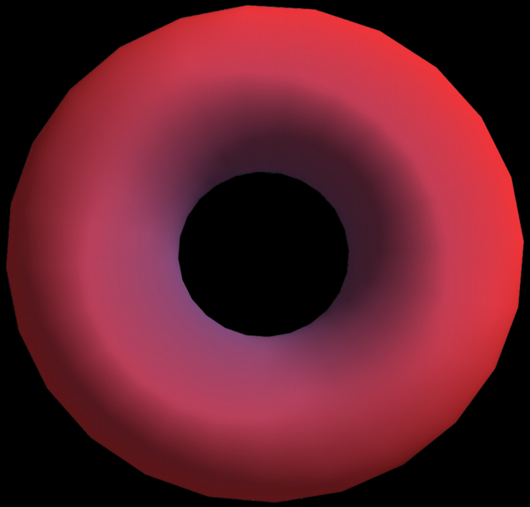


1

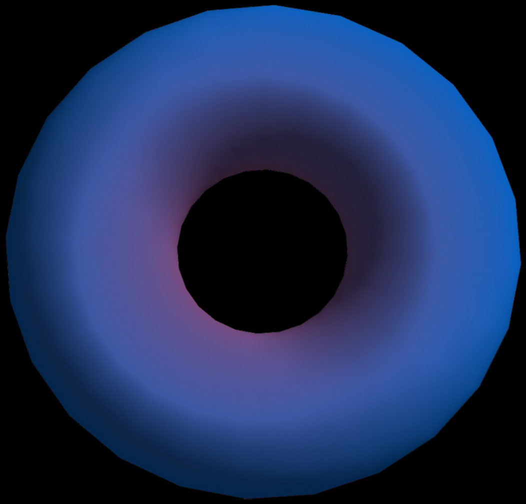
Superposition:



Measurement:

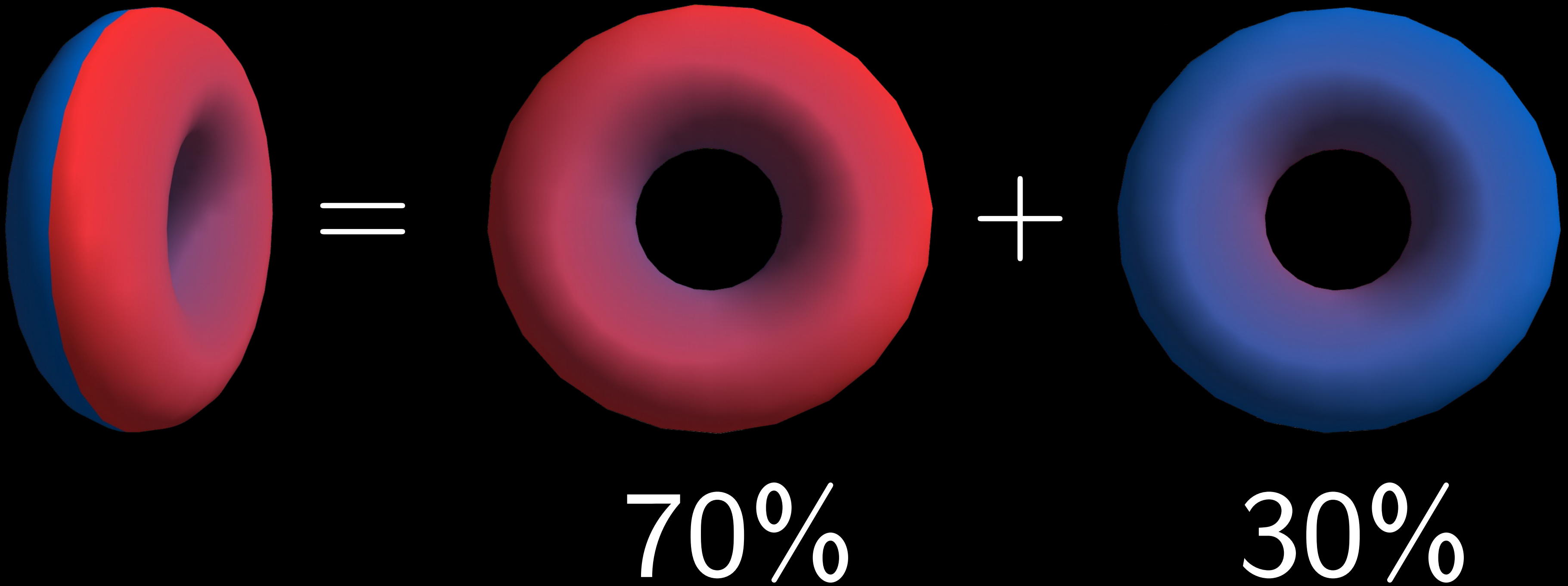


50%

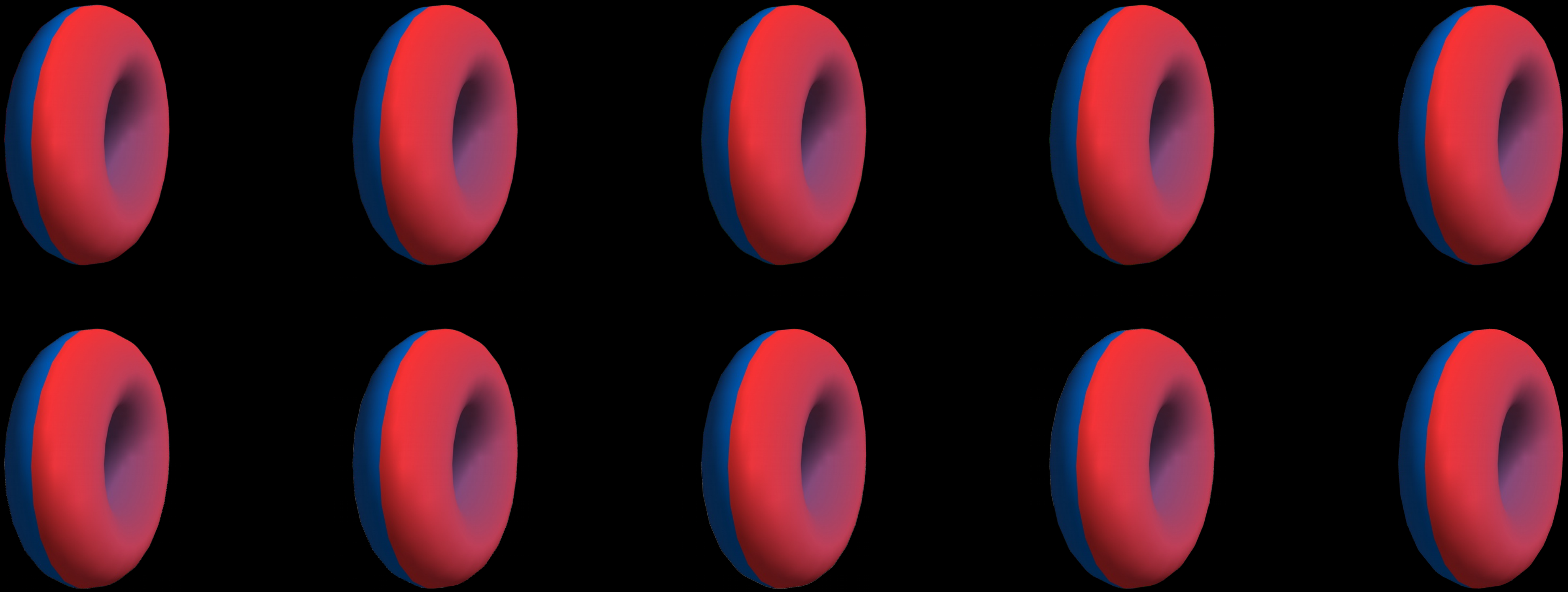


50%

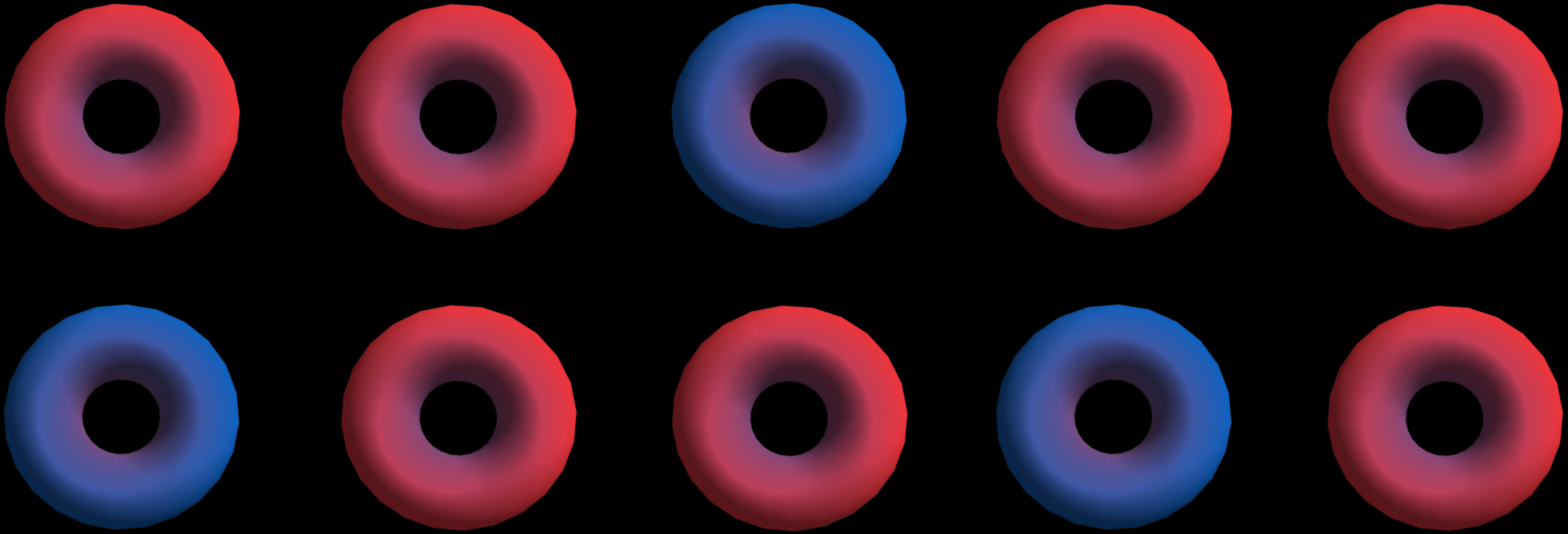
Superposition:



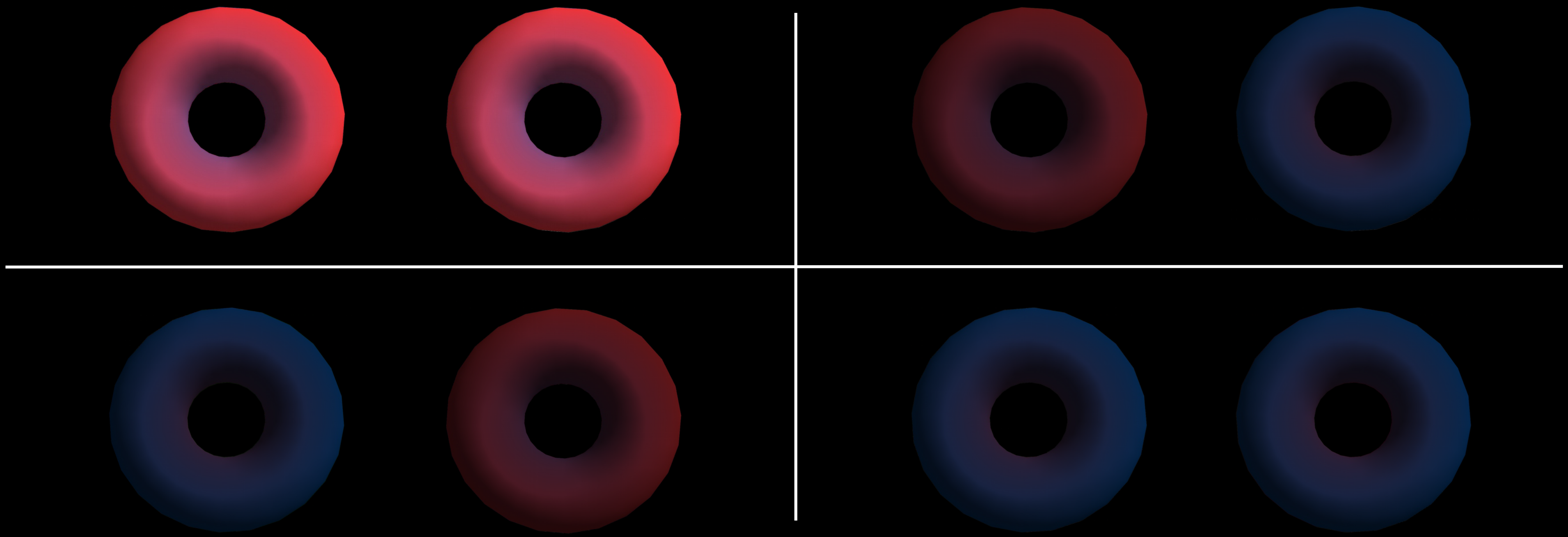
Multiple qubits:



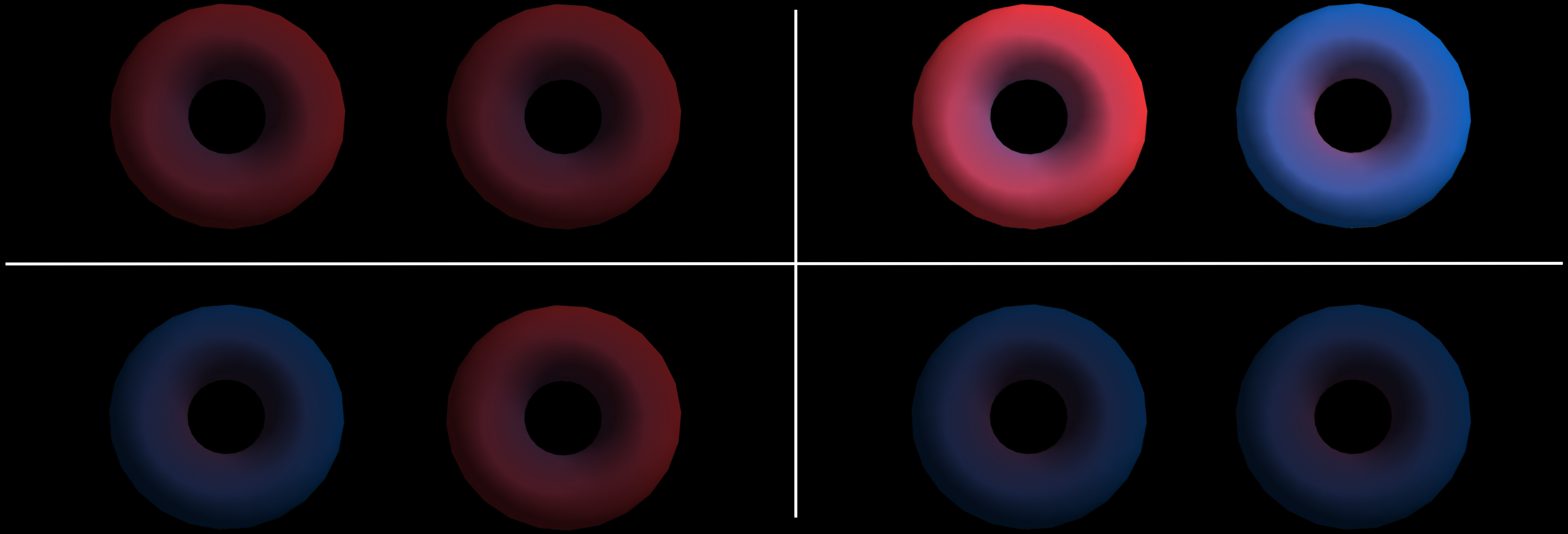
Multiple measurements:



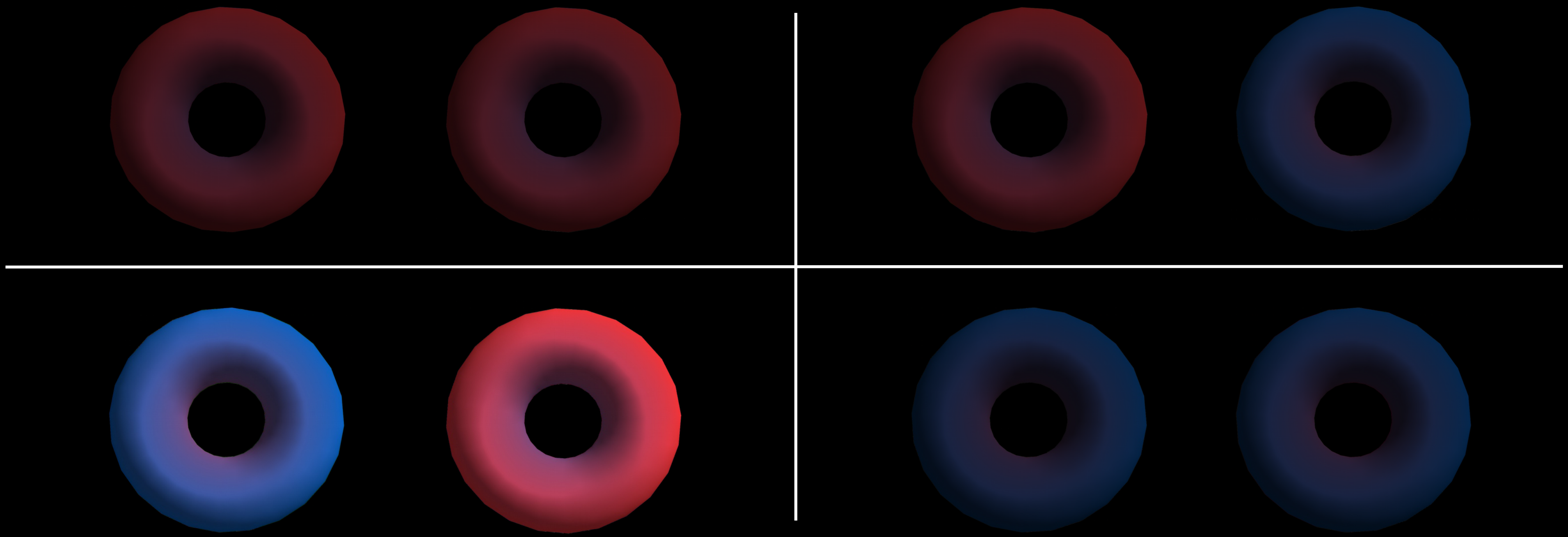
2 (classical) bits:



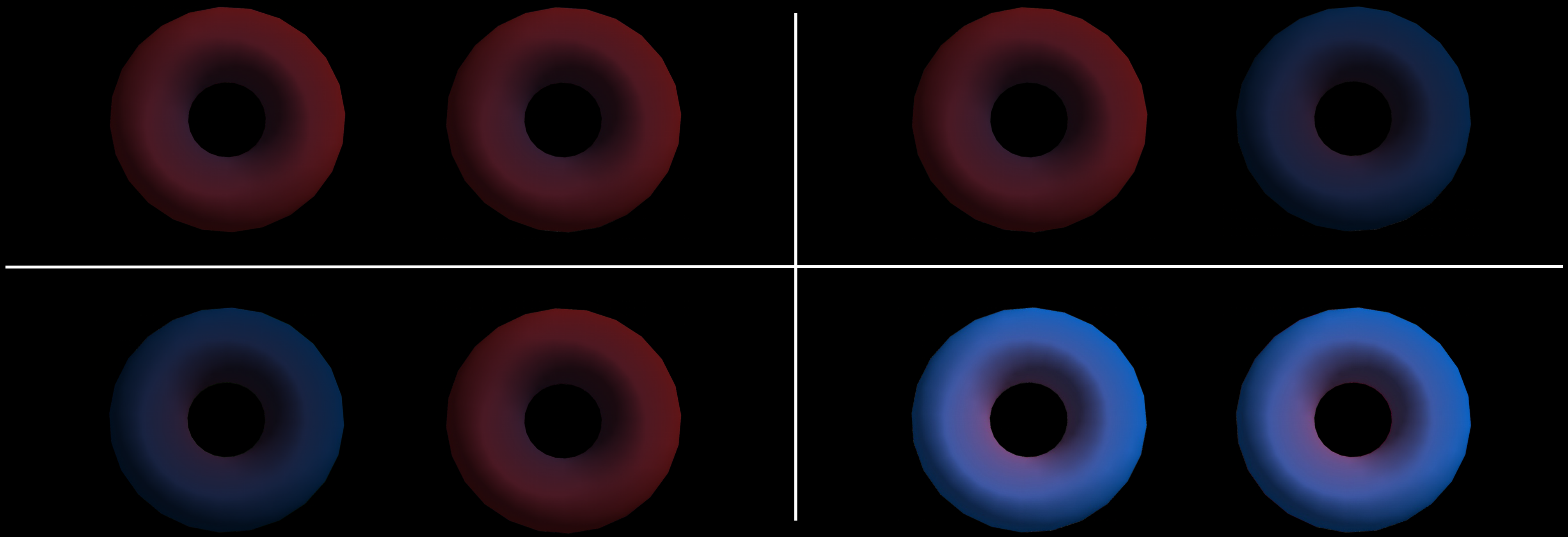
2 (classical) bits:



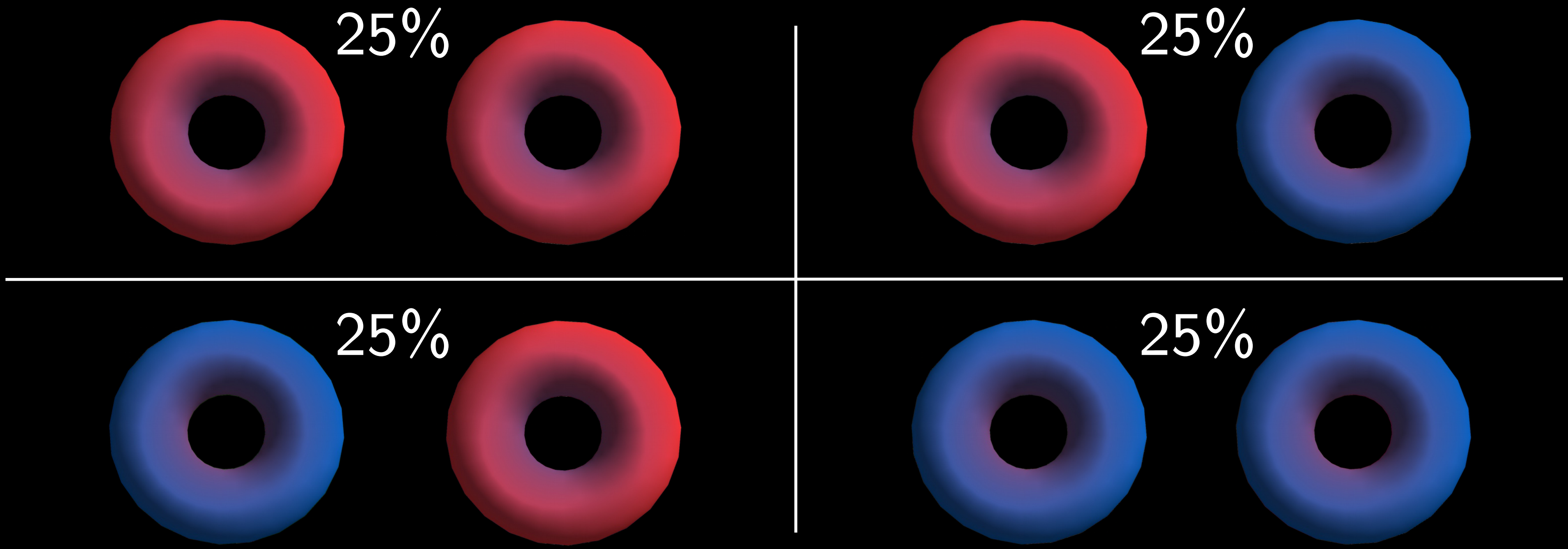
2 (classical) bits:



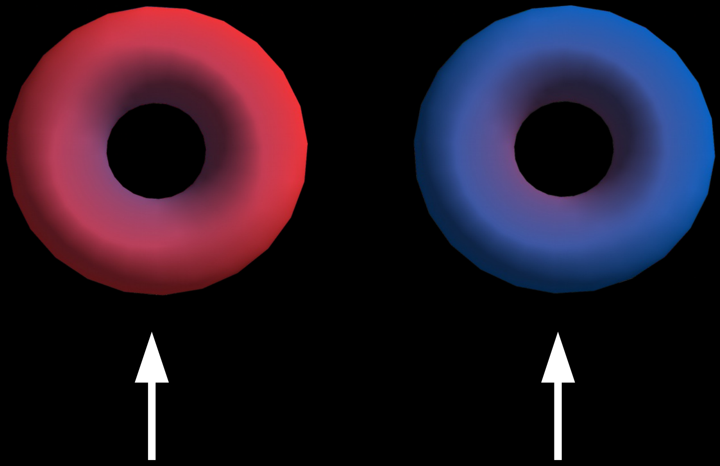
2 (classical) bits:



2 qubits:



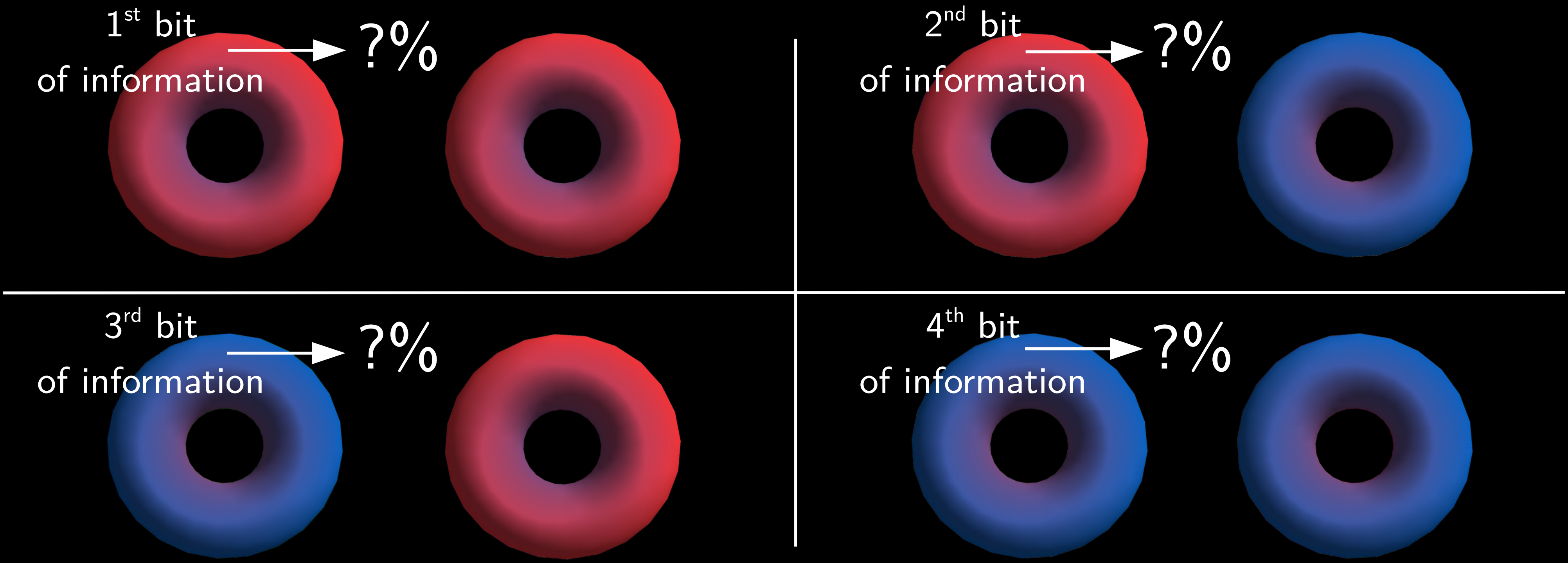
2 (classical) bits:



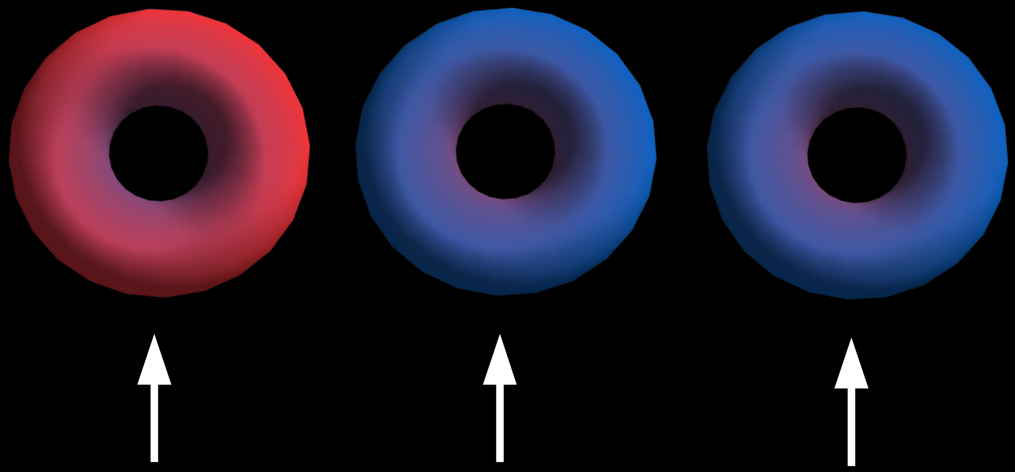
1^{st} bit
of information

2^{nd} bit
of information

2 qubits:

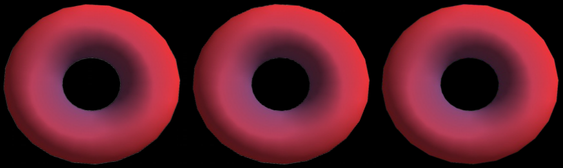

1st bit
of information
?%
2nd bit
of information
?%
3rd bit
of information
?%
4th bit
of information
?%

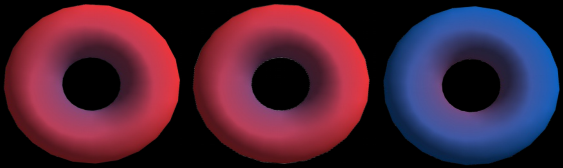
3 (classical) bits:

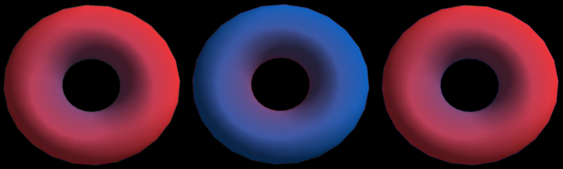


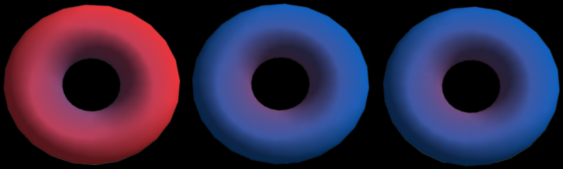
1st bit of information | 2nd bit of information | 3rd bit of information

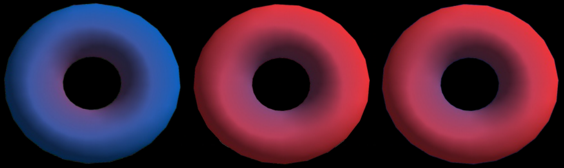
3 qubits:

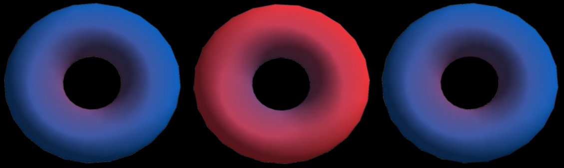
1st bit of information → ?% 

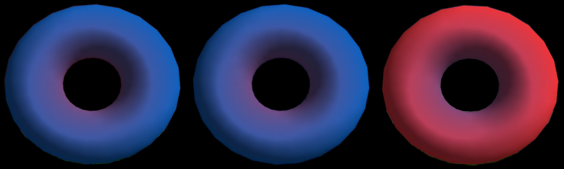
2nd bit of information → ?% 

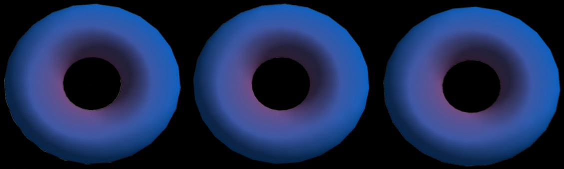
3rd bit of information → ?% 

4th bit of information → ?% 

5th bit of information → ?% 

6th bit of information → ?% 

7th bit of information → ?% 

8th bit of information → ?% 

n

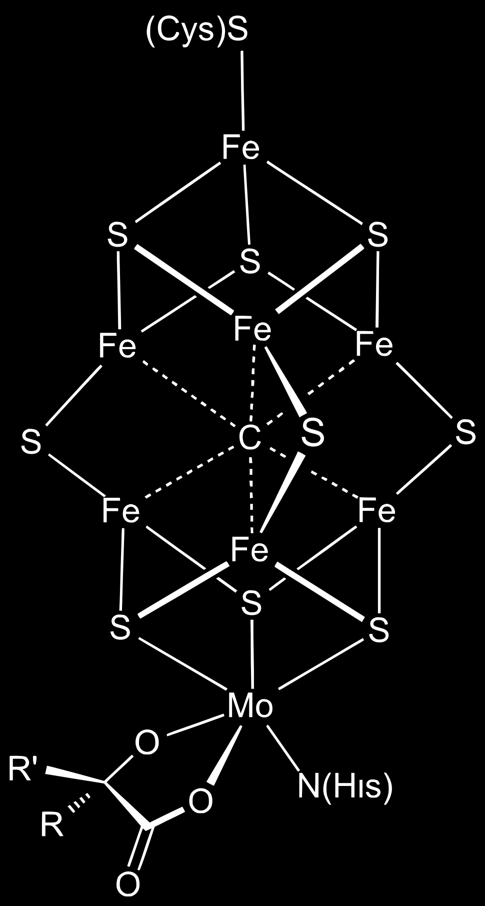
qubits

2^n

bits

108

qubits



$$2^{108}$$

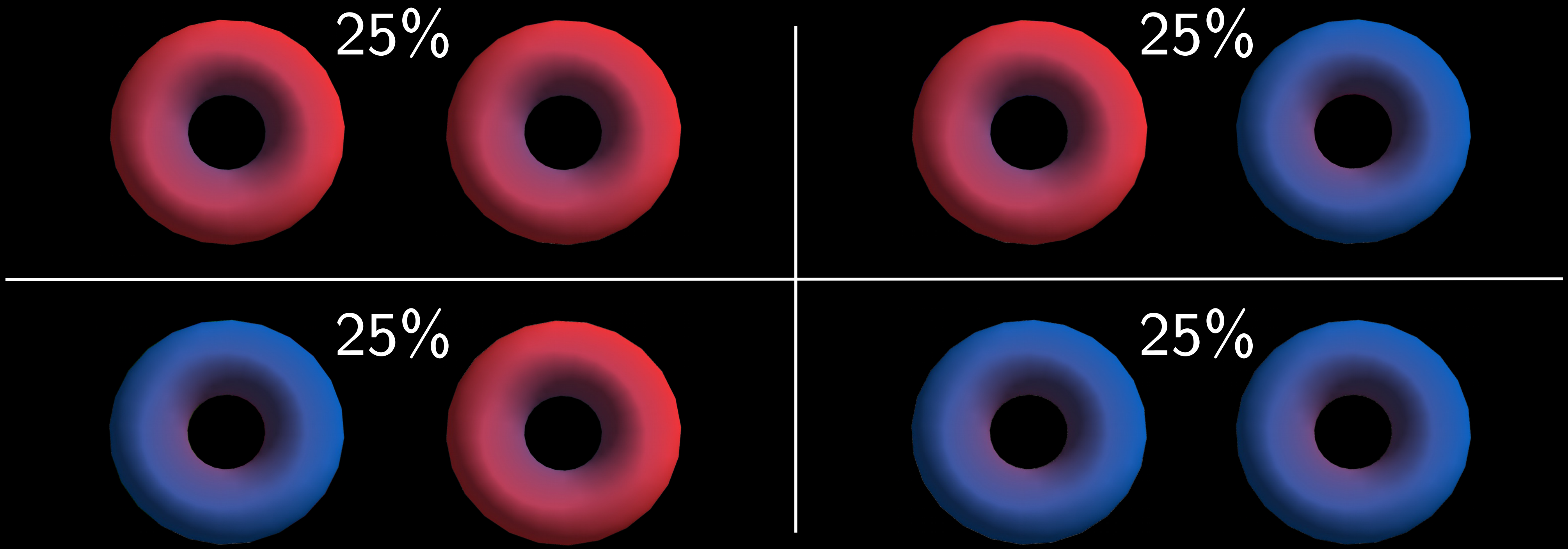
$$\approx 10^{32}$$

bits

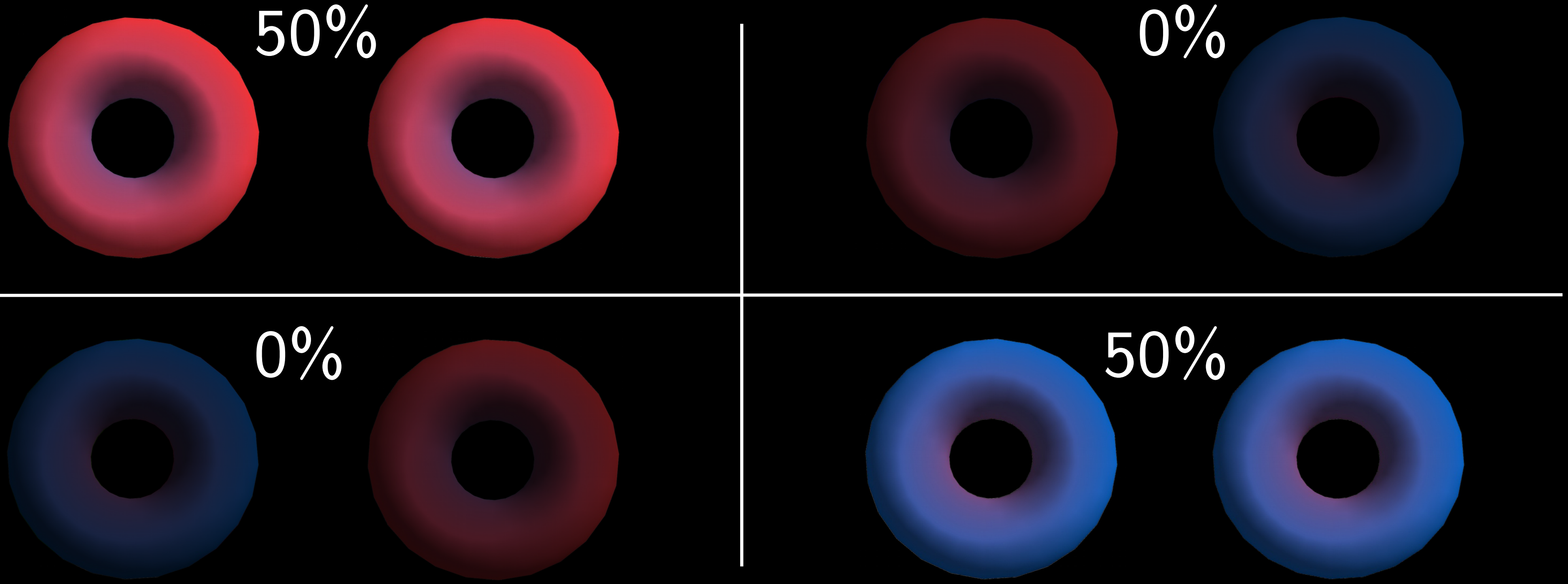
1. Superposition

2. Entanglement

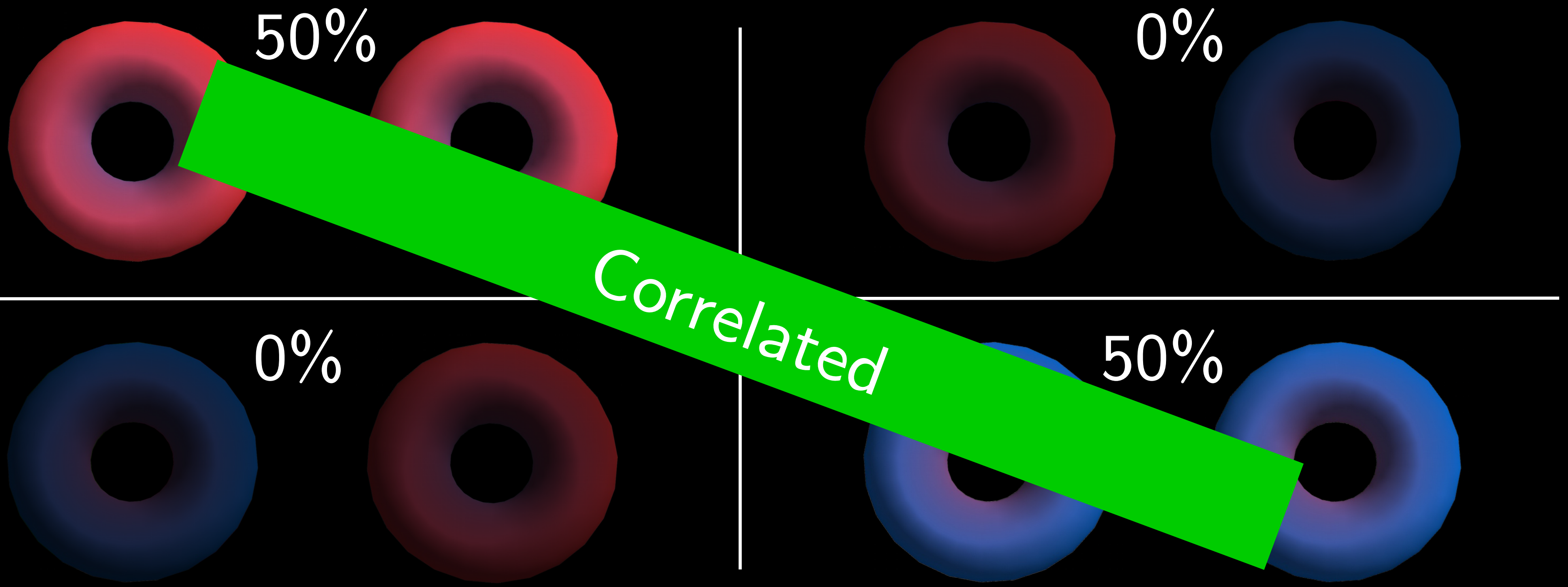
Superposition:



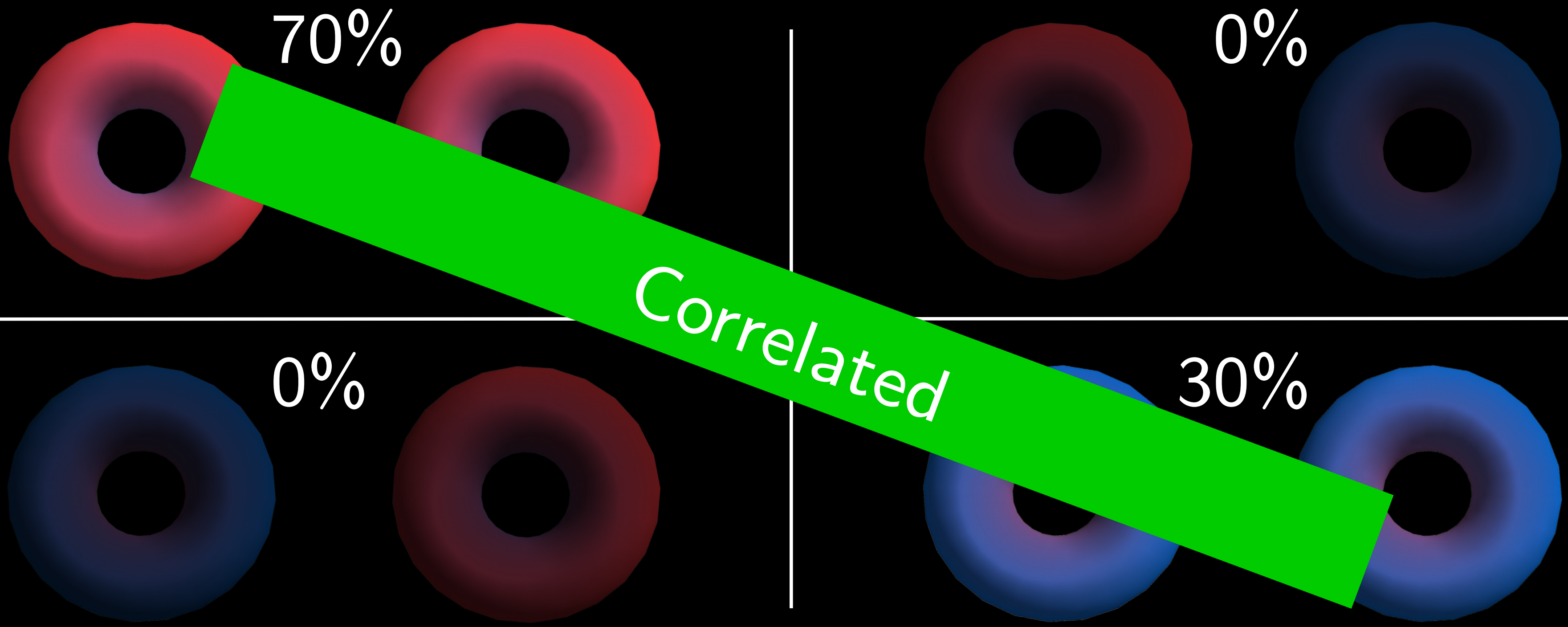
Entanglement:



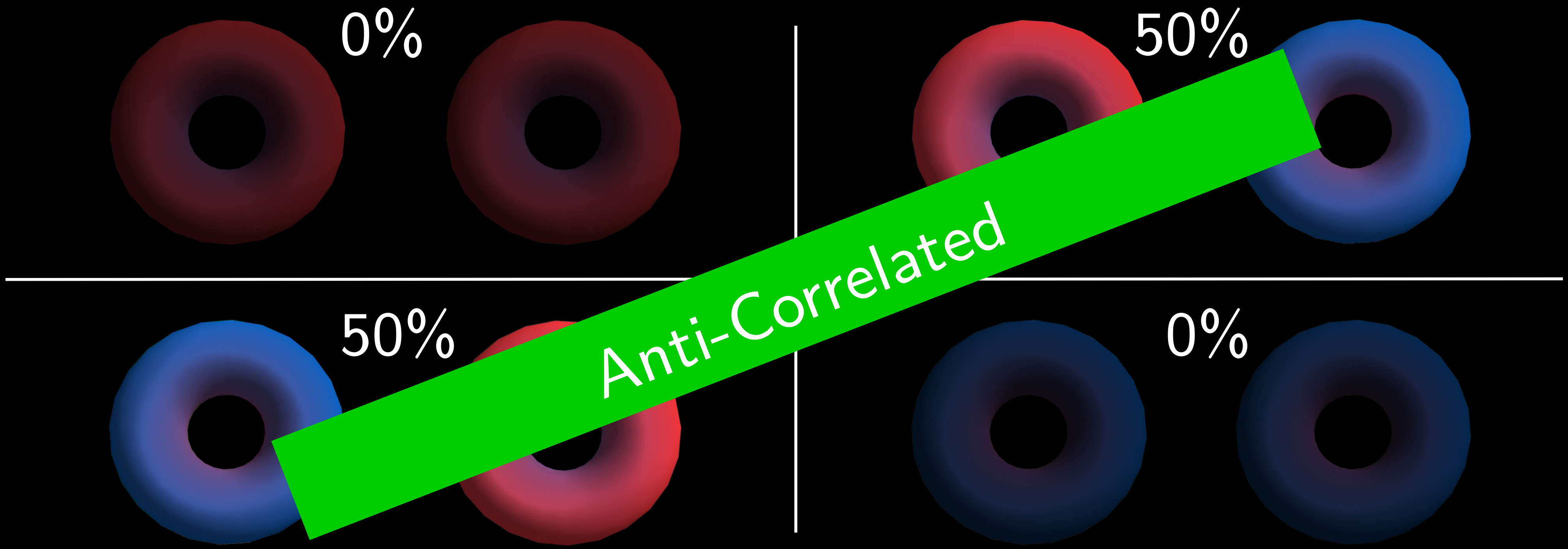
Entanglement:



Entanglement:



Entanglement:



Applications

Quantum Algorithms

Quantum Bits

Quantum Circuits

Hardware

Industry Landscape

Applications

Quantum Algorithms

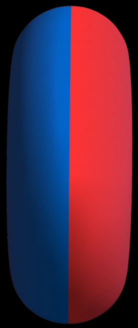
Quantum Bits

Quantum Circuits

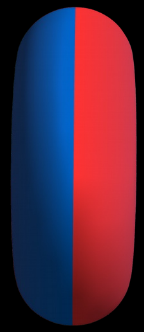
Hardware

Industry Landscape

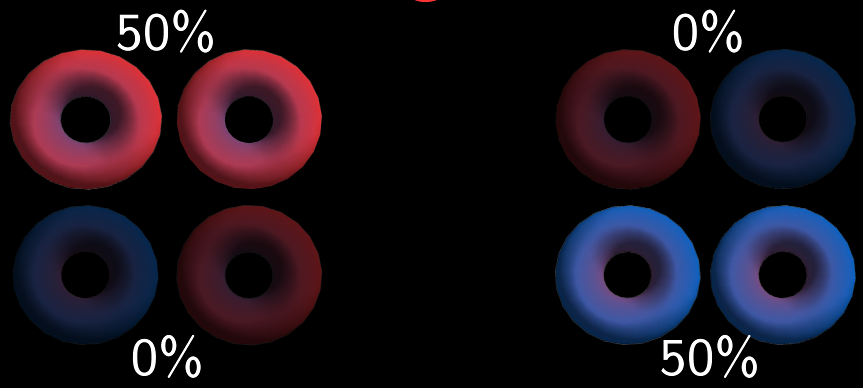
Superposition



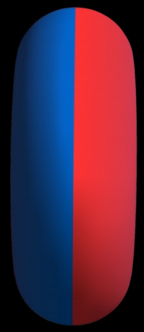
Superposition



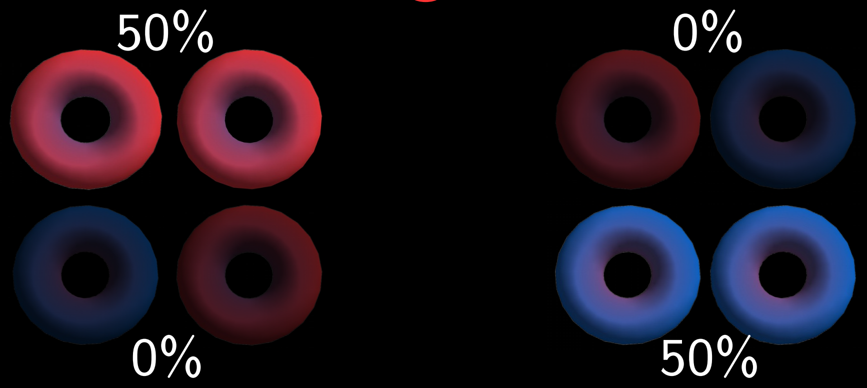
Entanglement



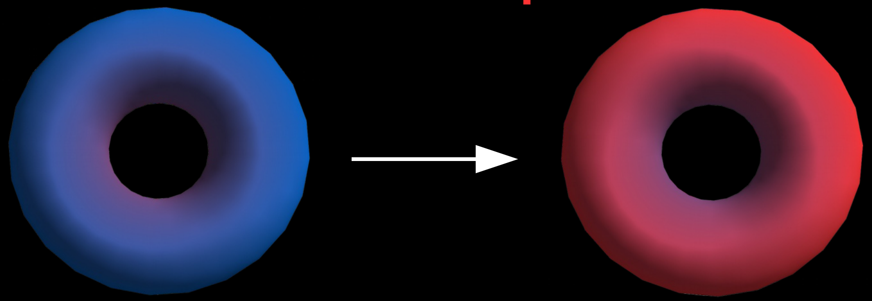
Superposition



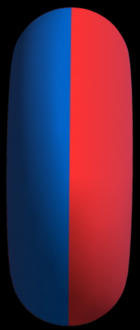
Entanglement



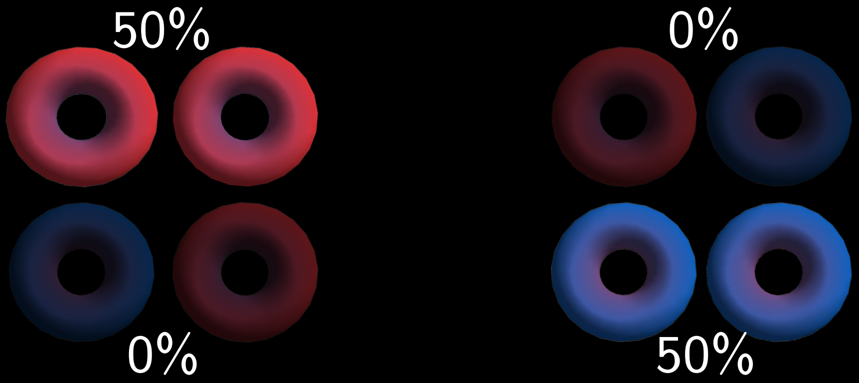
Bit flip



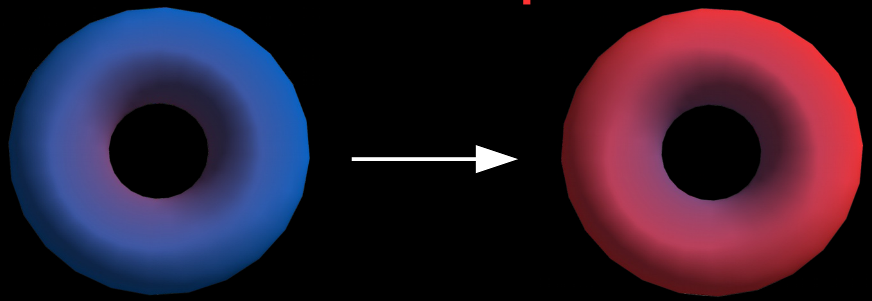
Superposition



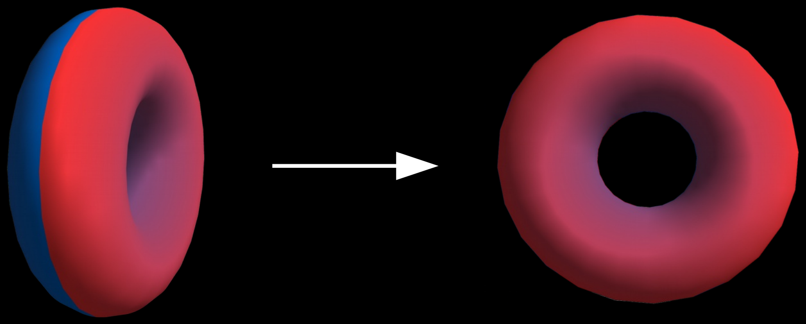
Entanglement



Bit flip

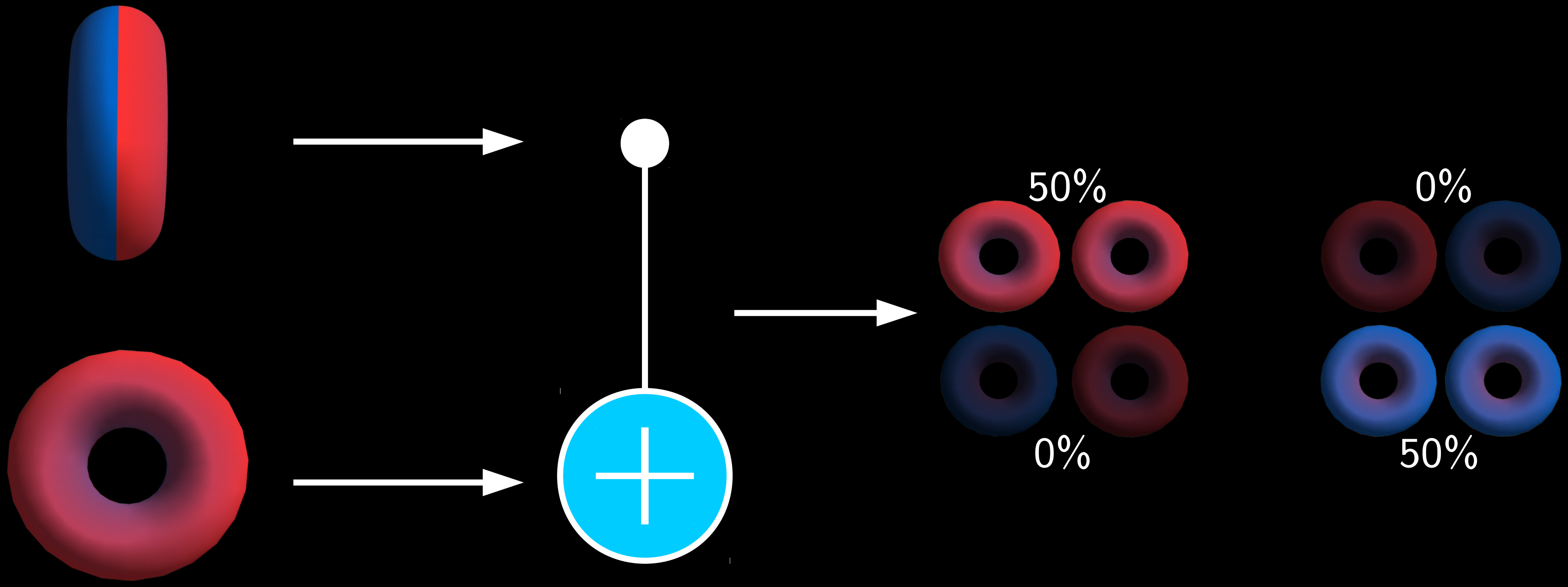


Measurement

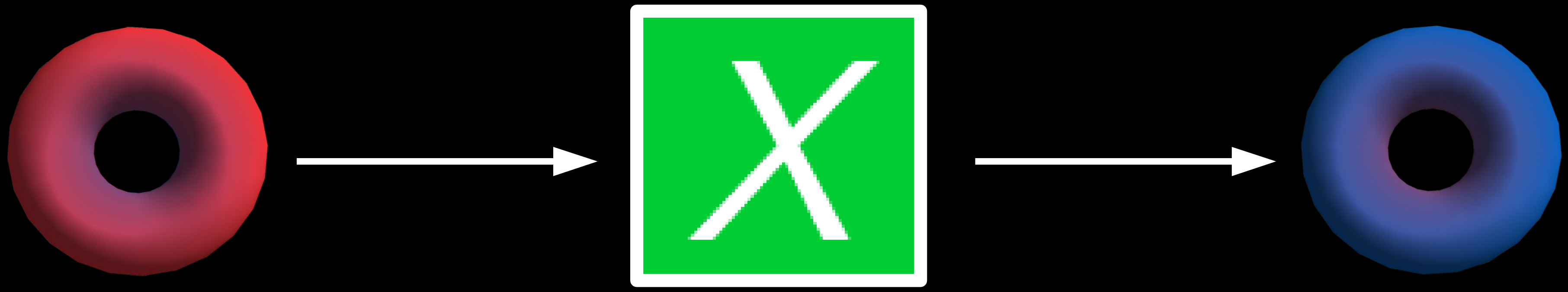


Hadamard H-gate:

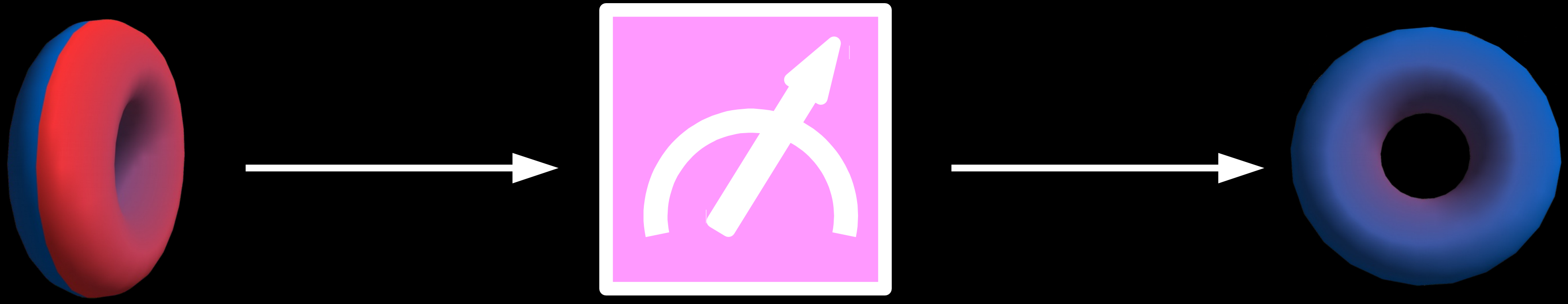
C-NOT gate:



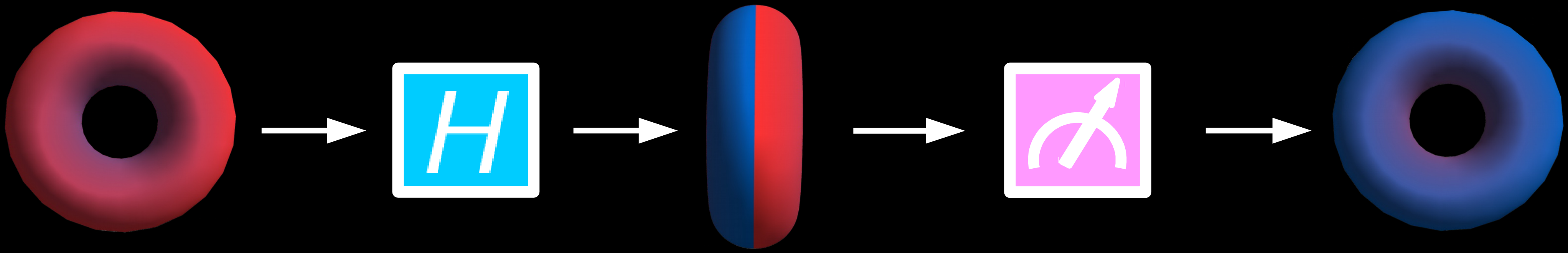
Bit flip X-gate:



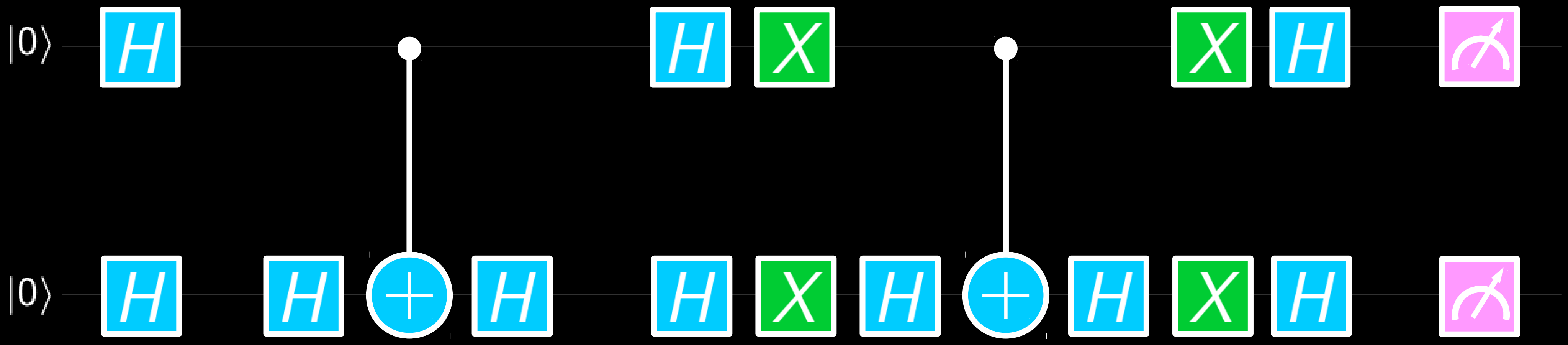
Measurement:



Quantum circuit:



Grover's search:



Grover's search:

0 2 3 1

Grover's search:

0 2 3 1

Classical

4

tries

Quantum

1

try

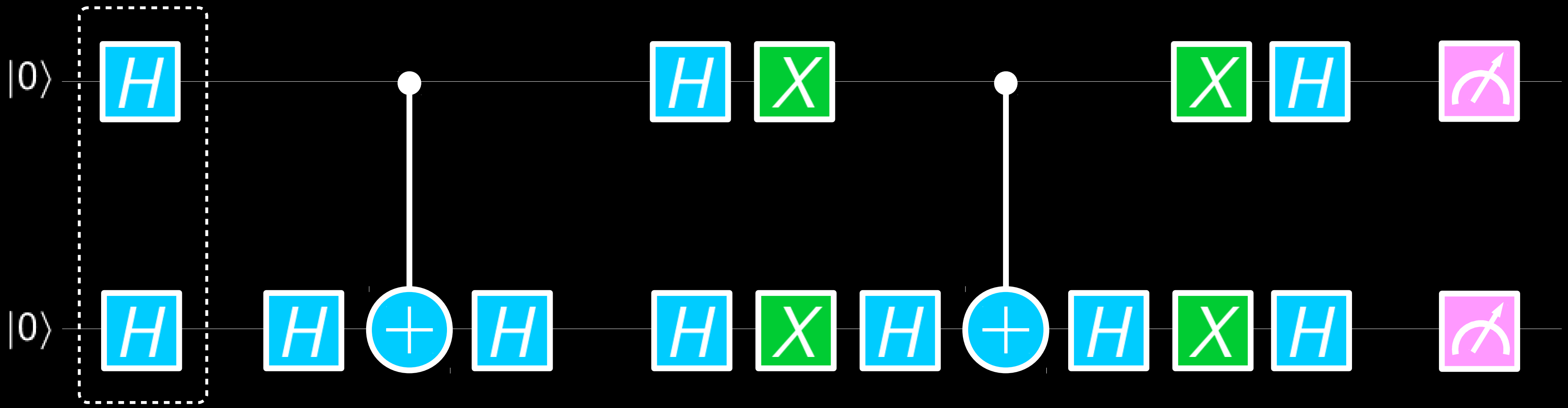
Grover's search:

Number	Bits
0	00
1	01
2	10
3	11

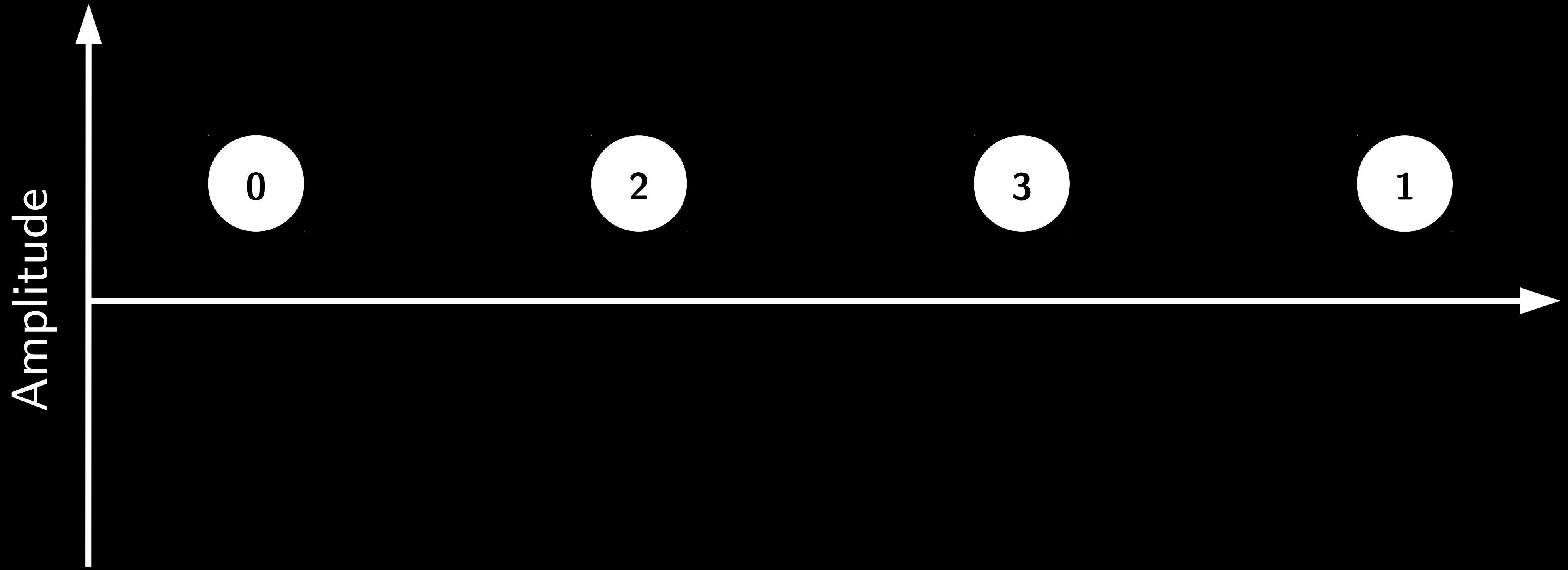
Grover's search:

Number	Bits
0	00
1	01
2	10
3	11

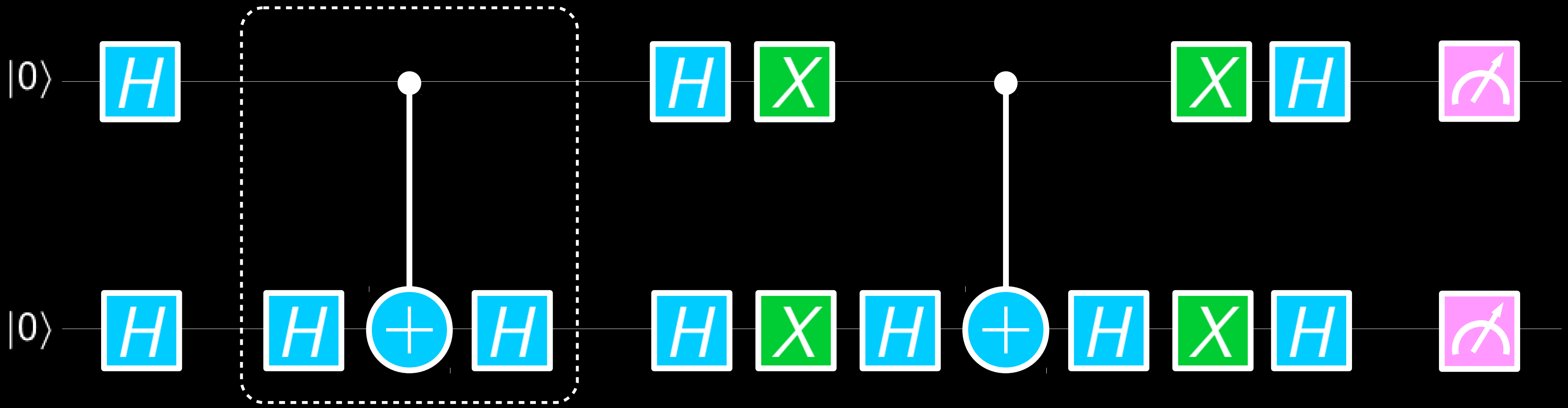
Grover's search: Step 1 – Superposition



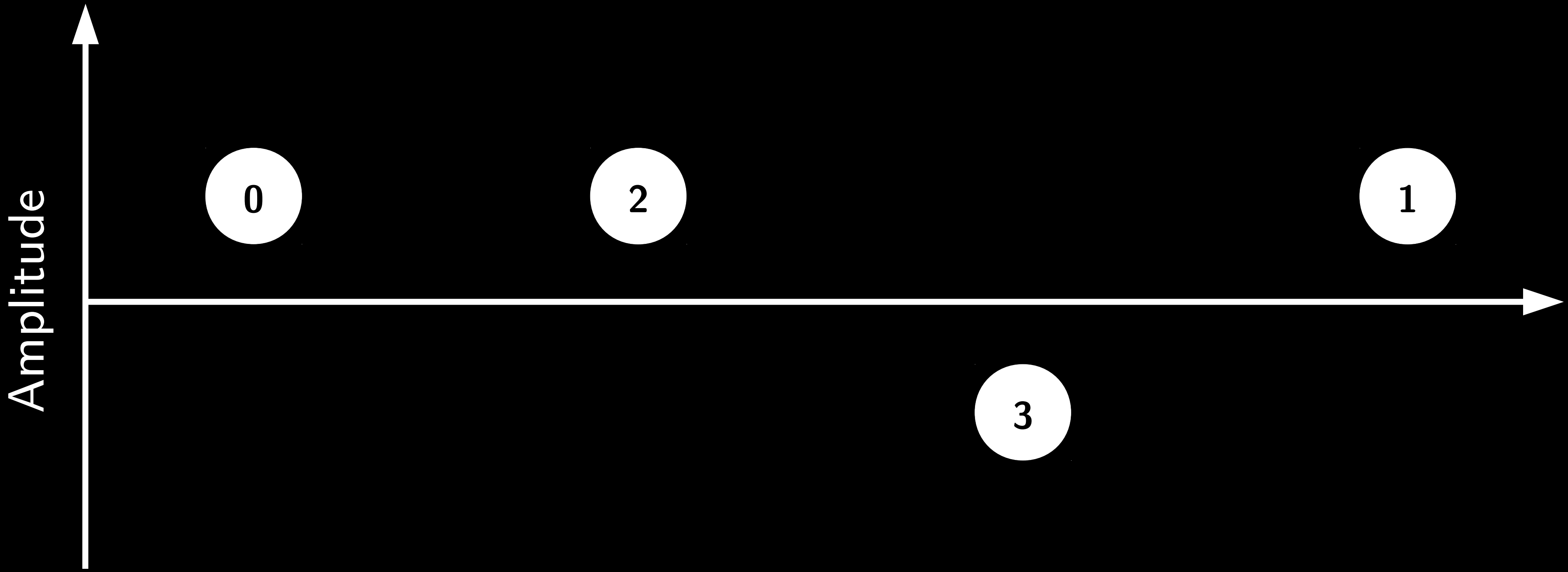
Grover's search: Step 1 – Superposition



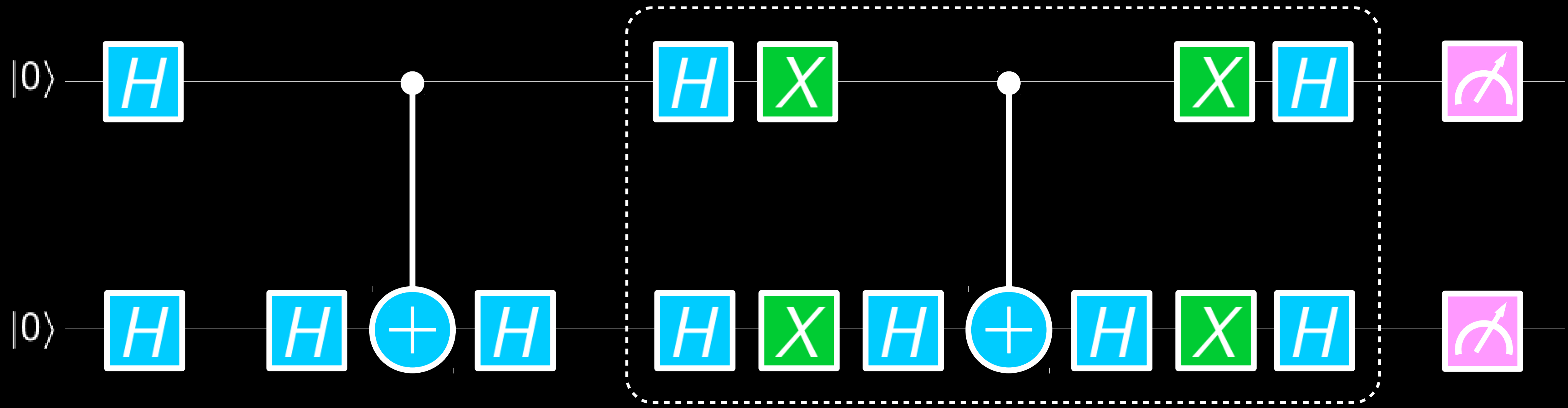
Grover's search: Step 2 – Oracle



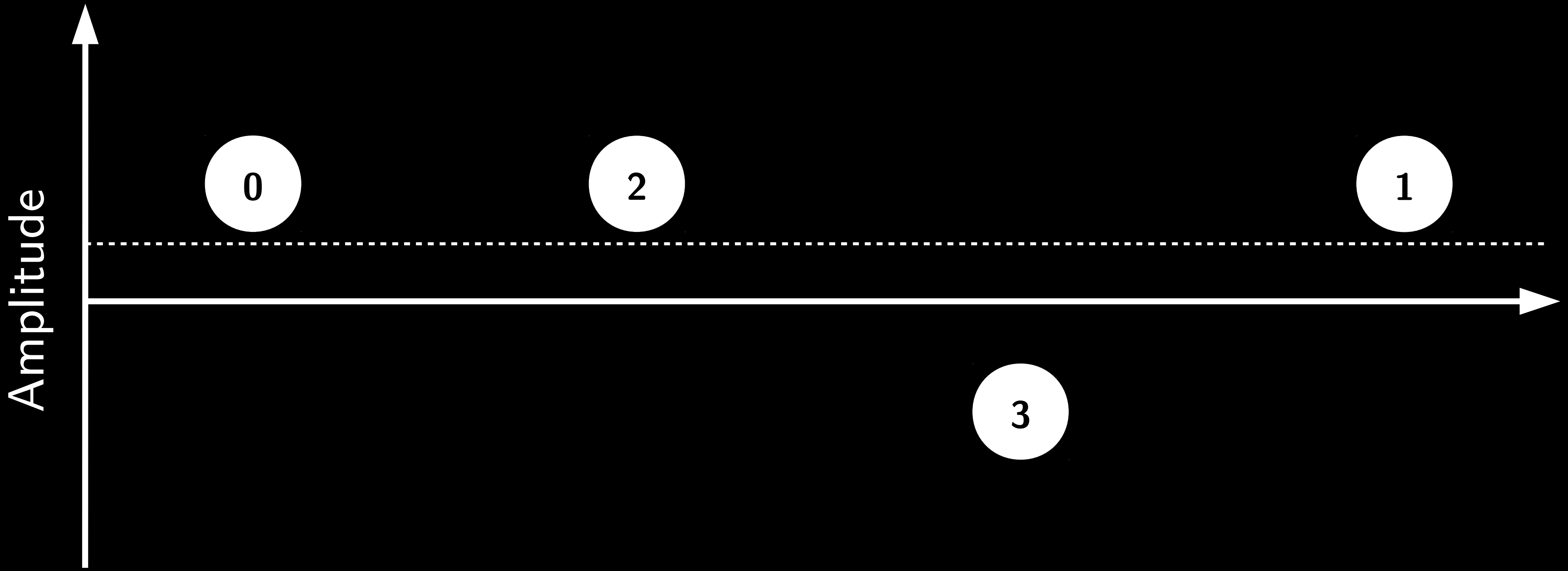
Grover's search: Step 2 – Oracle



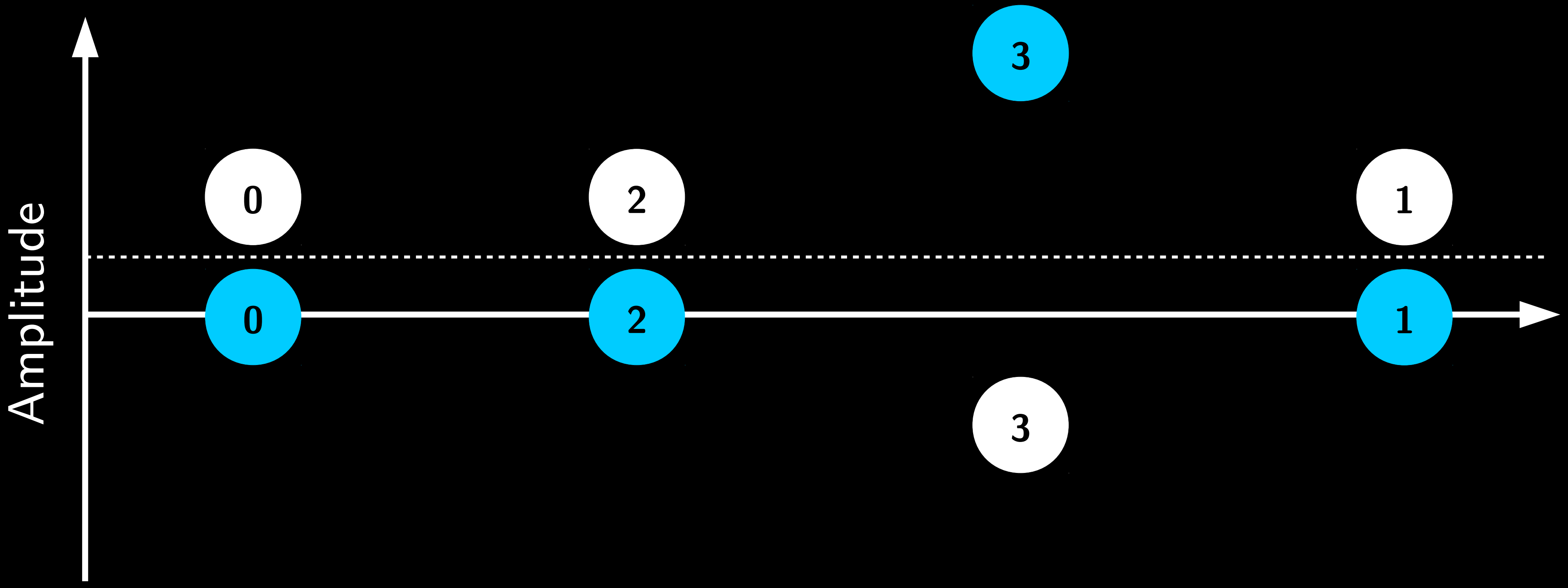
Grover's search: Step 3 – Reflection



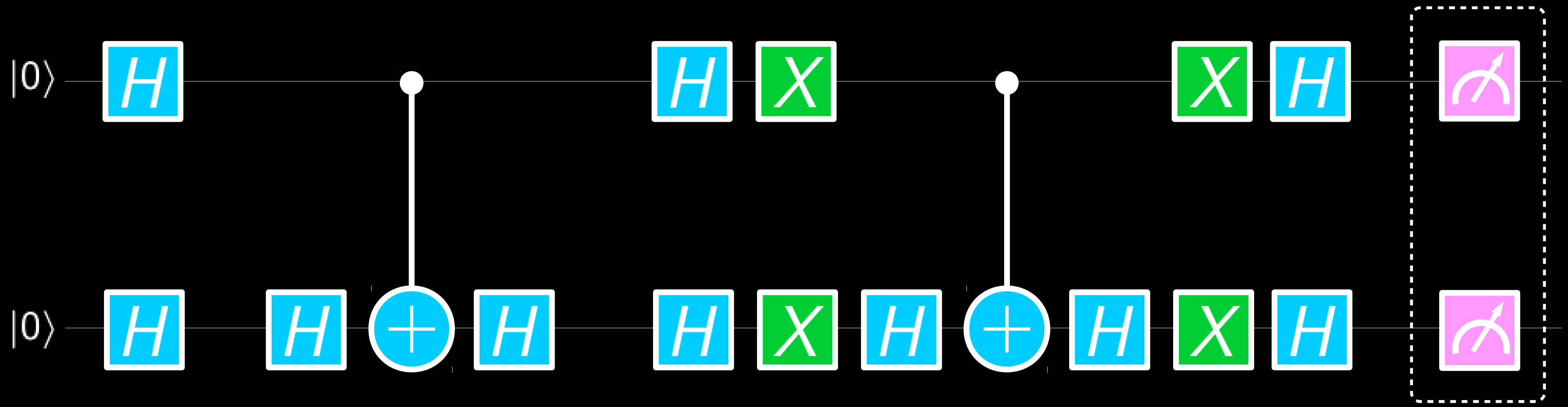
Grover's search: Step 3 – Reflection



Grover's search: Step 3 – Reflection



Grover's search: Step 4 – Measurement



Grover's search: Step 4 – Measurement

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 ?

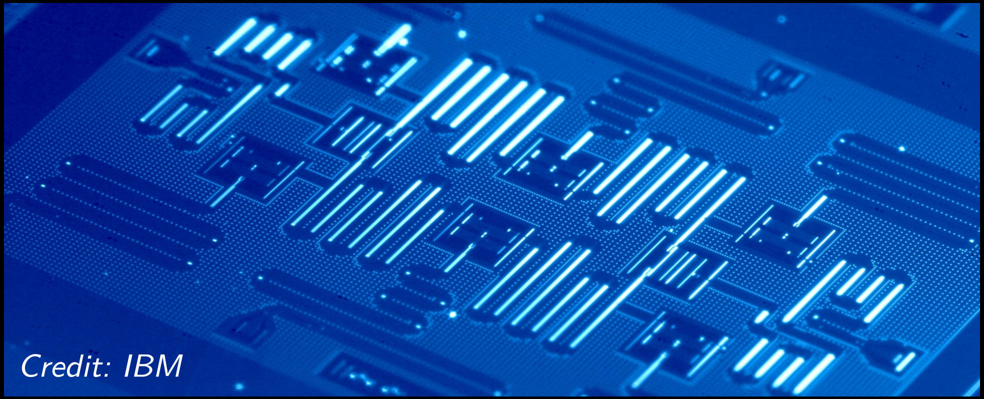
We want qubits to interact strongly with one another.

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

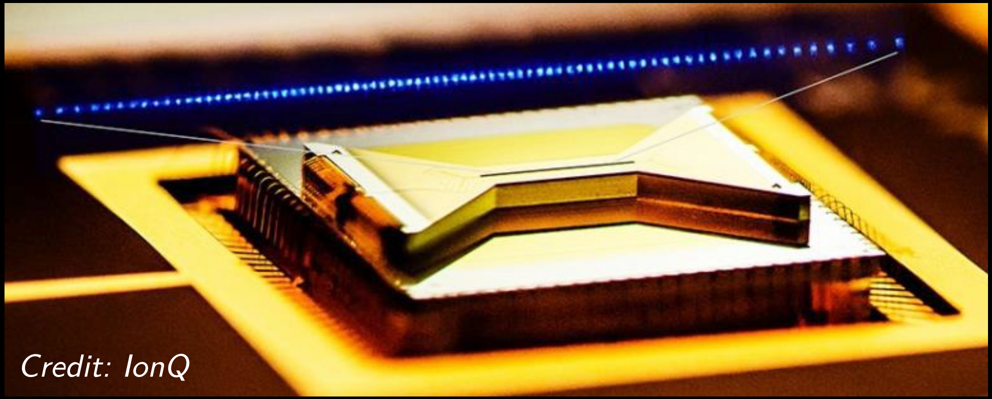
Until we measure them.

Superconducting circuits

Trapped ions



Credit: IBM



Credit: IonQ

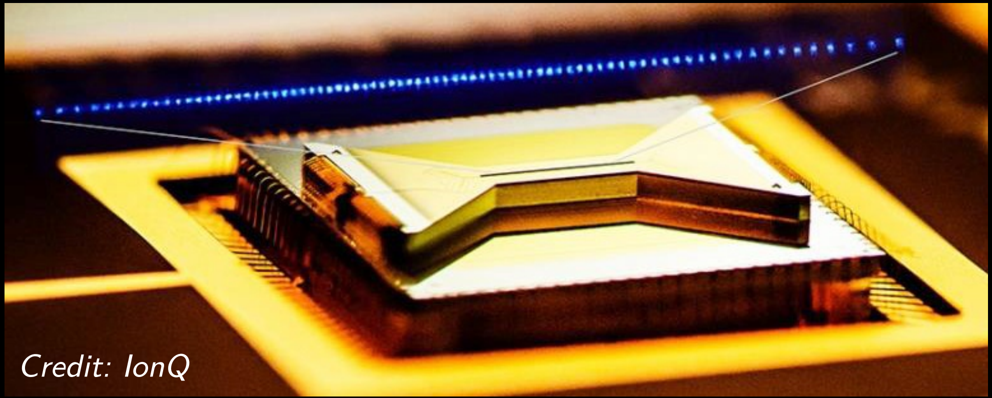
Superconducting circuits

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

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

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

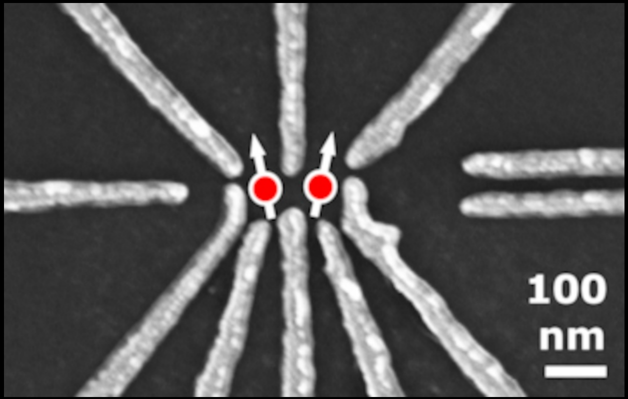
In this week's issue, John Martinis and his colleagues describe a significant step in the development of quantum computing. For the first time, the researchers have demonstrated experimentally that a programmable quantum computer can outperform the world's most powerful conventional processors – a state 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...

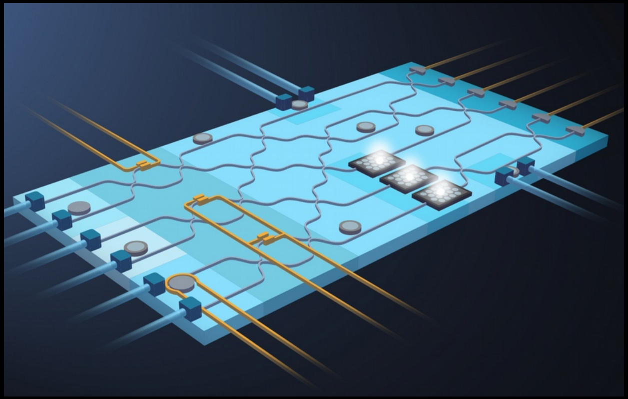
show more

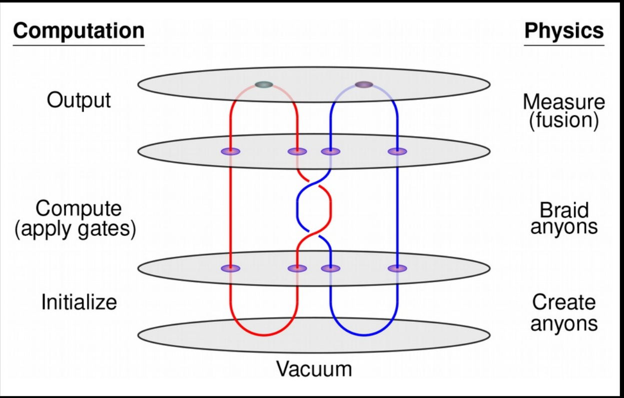
Quantum dots

Photonic

Topological







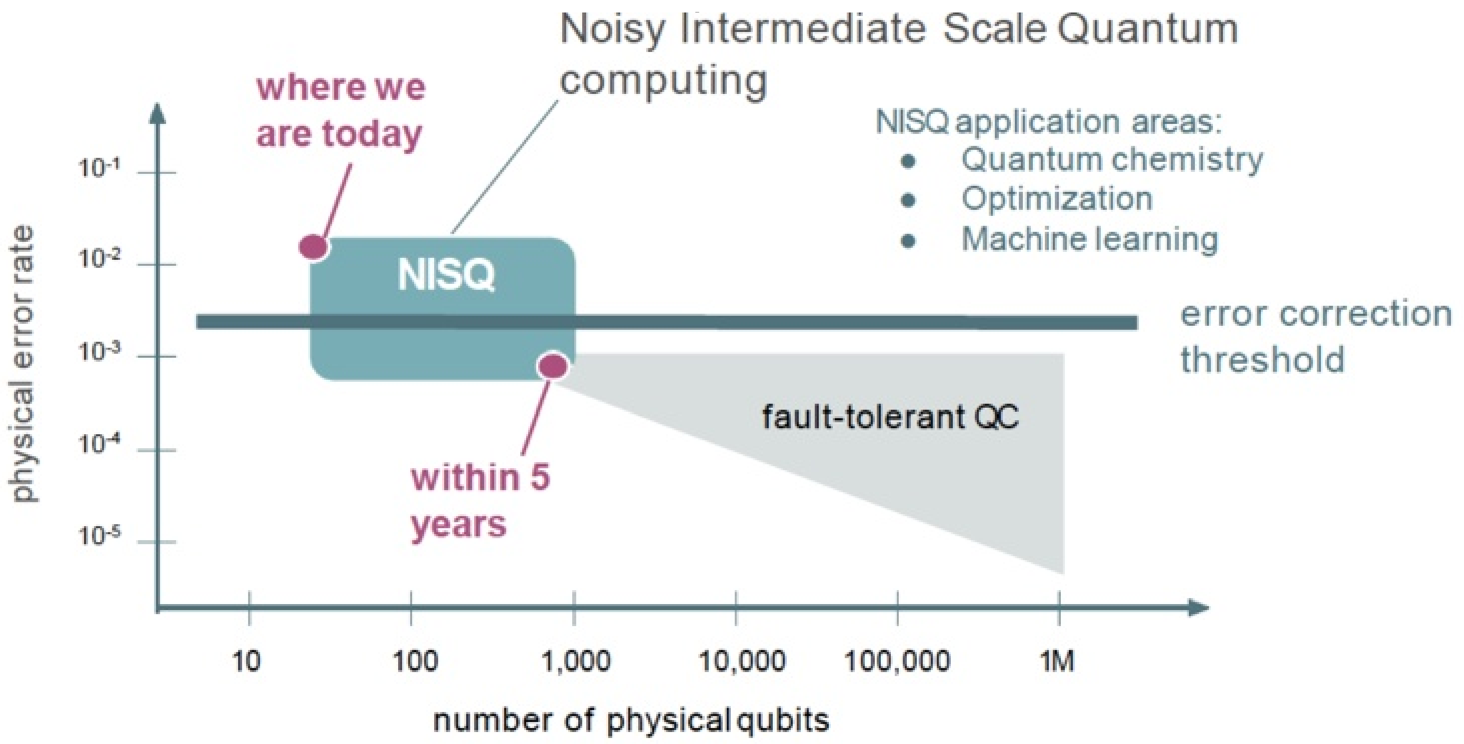
Quantum error correction

Long term goal $\rightarrow$ Fault-Tolerant QC

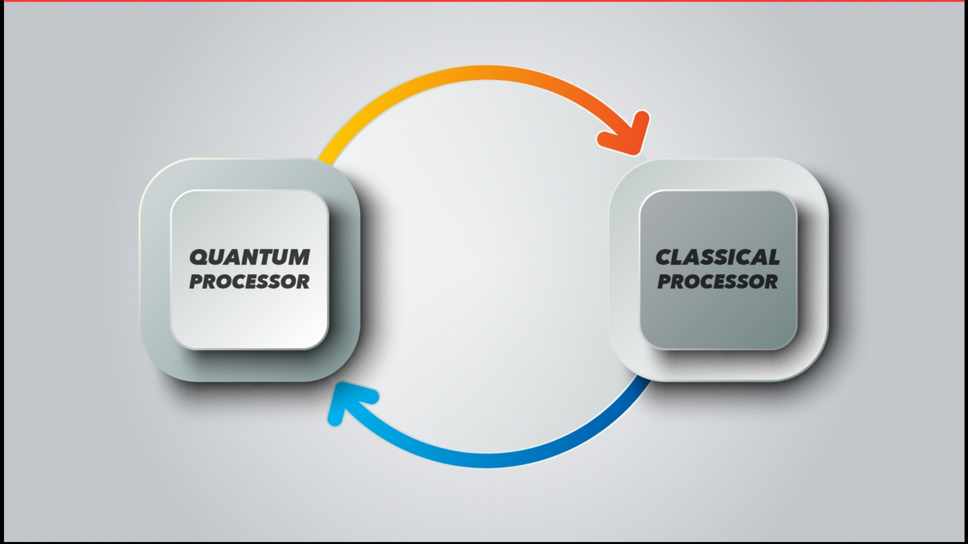
The protected “logical” quantum information is encoded in a highly entangled states of many physical qubits.

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)

GATE MODEL QC

qBLAS: *quantum basic linear algebra subroutines*	**algorithm focus**: can we do linear algebra faster, on perfect hardware? QQ: quantum data, quantum algo *Mostly HHL-based, QFT, QPE, Quantum Matrix Inversion, qPCA, qSVM*
NISQ: *noisy intermediate scale quantum devices*	'Early development on QPU' **hardware focus**: can we do it different, with current (noisy) hardware? CQ: classical data, quantum algo *variational circuits, QAOA, kernel methods, 'qNN', approximate thermalization*

Applications

Quantum Algorithms

Quantum Bits

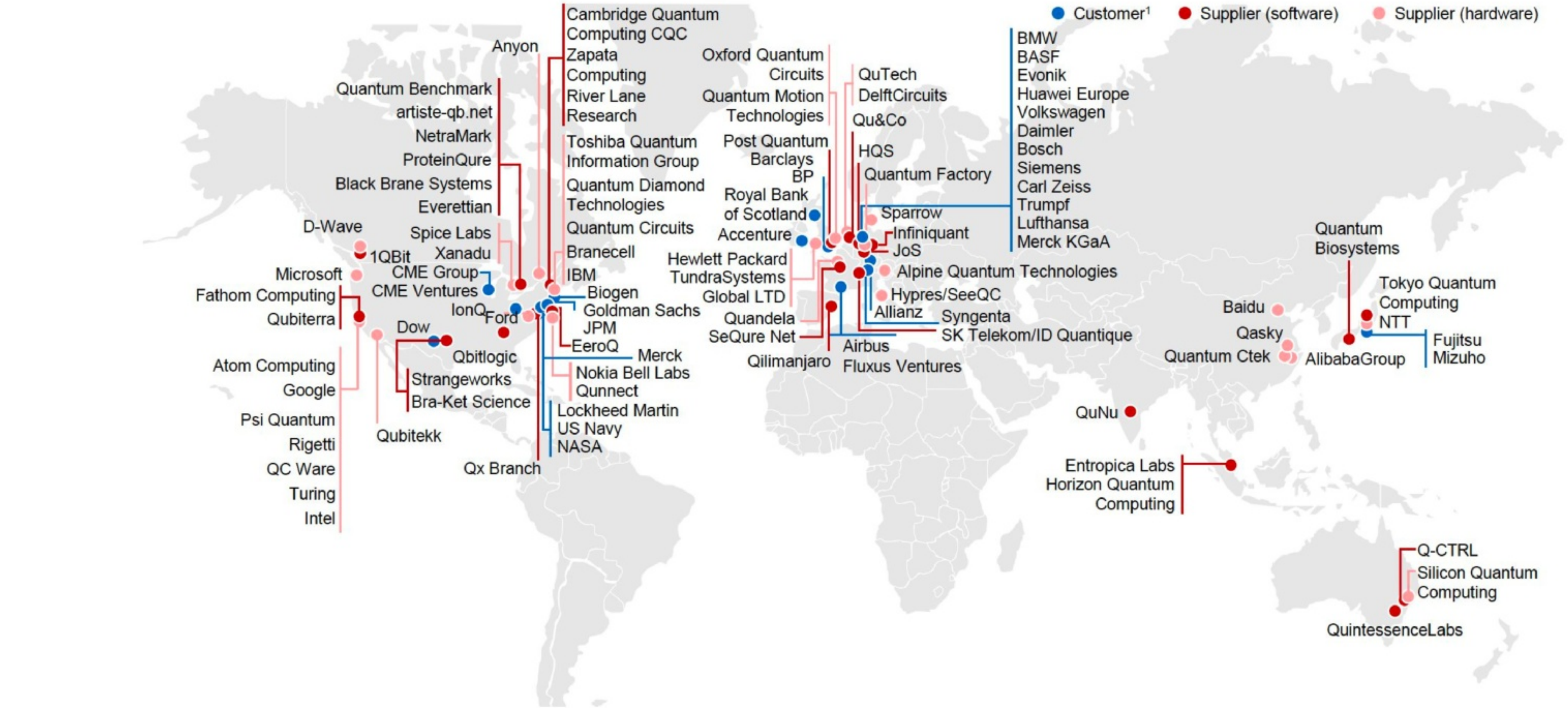
Quantum Circuits

Hardware

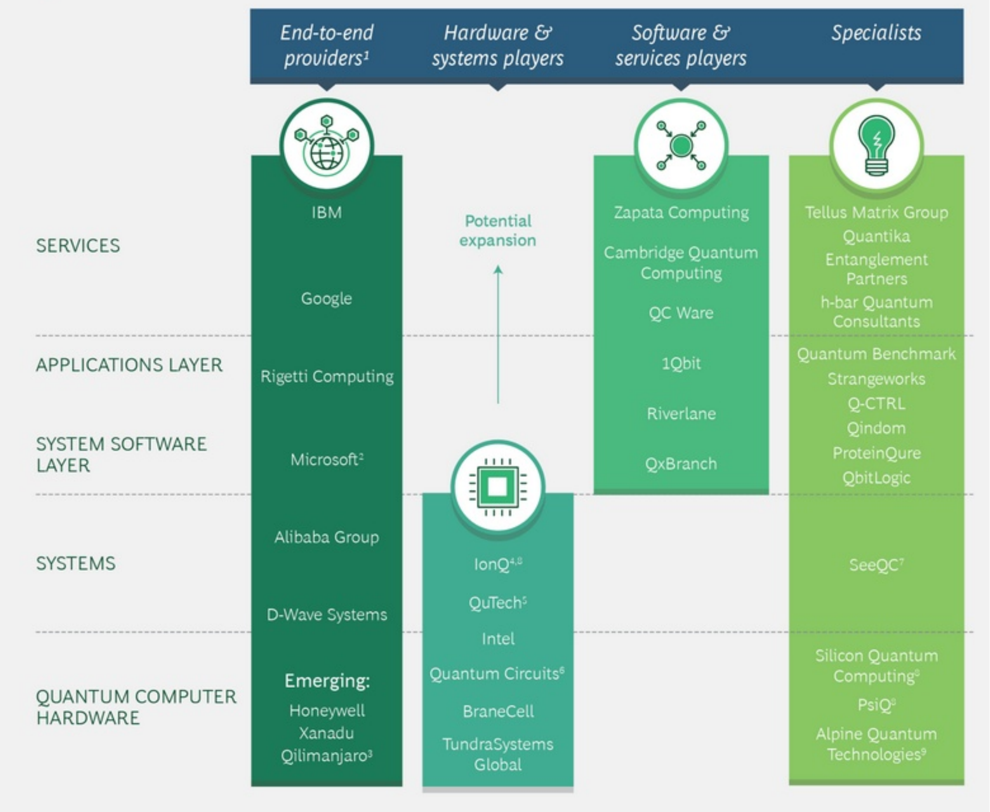
Industry Landscape

- Applications
- Quantum Algorithms
- Quantum Bits
- Quantum Circuits
- Hardware
- **Industry Landscape**

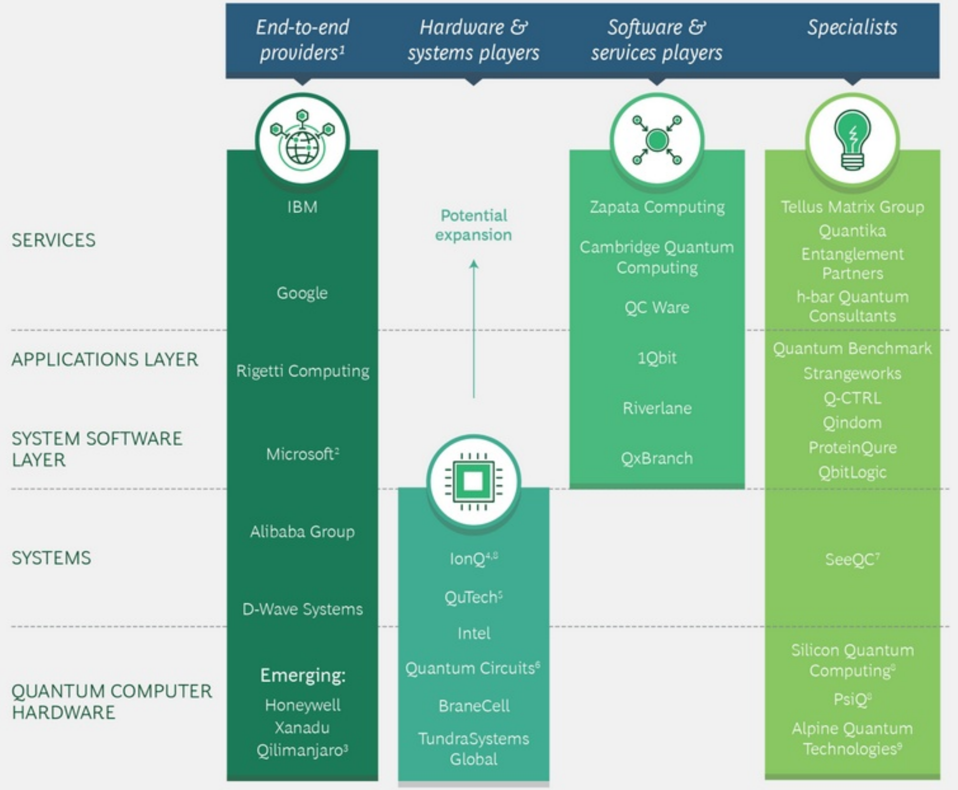
Non-exhaustive overview of quantum computing players (2019)



Boston Consulting Group report on Quantum Computing (2019)



Boston Consulting Group report on Quantum Computing (2019)



Startup	Total [US$ millions]	Most recent funding	
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).

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.

Japan

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

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

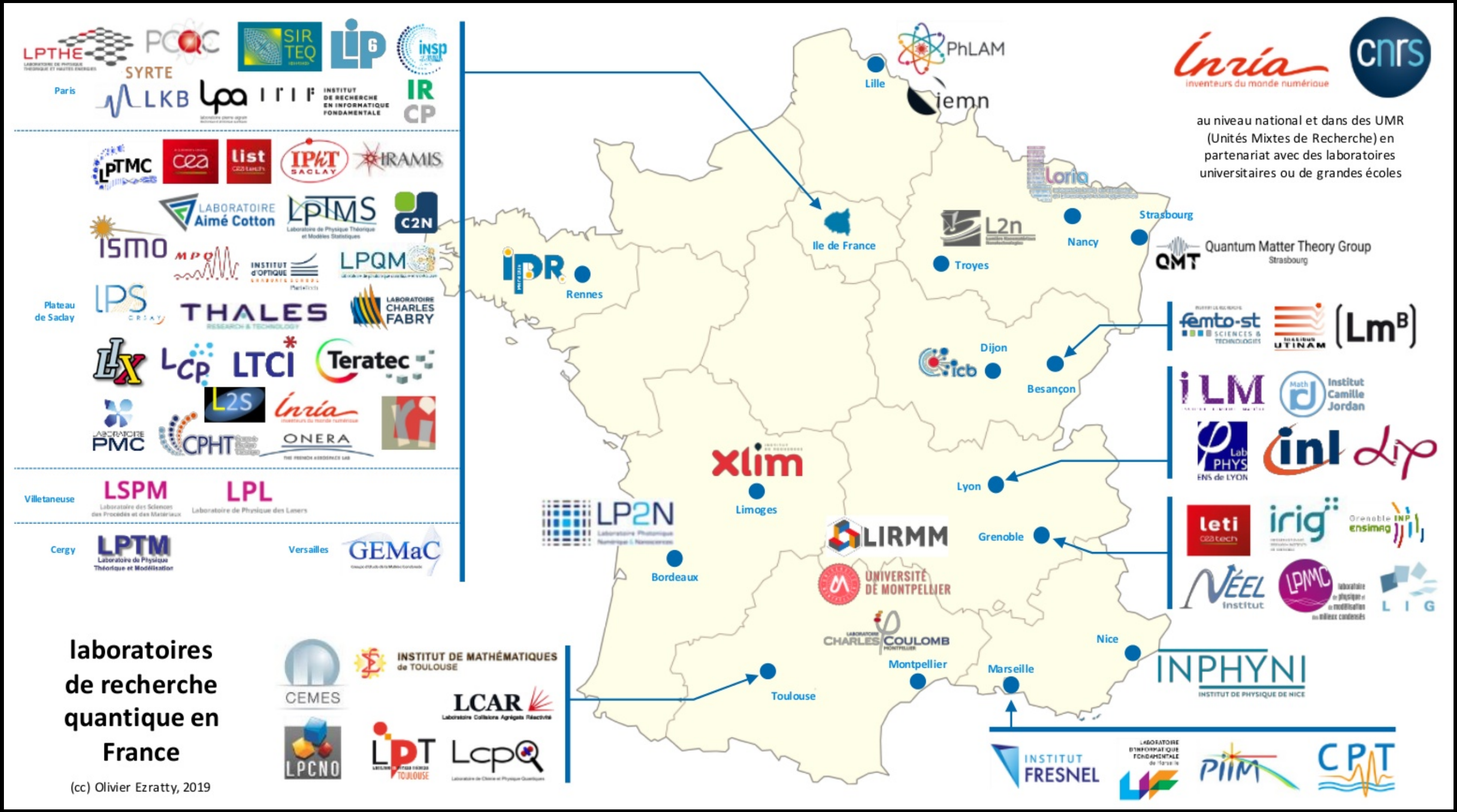
Numerous research groups funded over past 20 years through framework programs. 1 billion euro investment announced in 2016 (European flagship on Quantum Technologies).

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.

Australia

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


Paris
Plateau de Saclay
Villetaneuse
Cergy
Versailles
Lille
Ile de France
Rennes
Troyes
Nancy
Strasbourg
Quantum Matter Theory Group
Dijon
Besançon
Limoges
Lyon
Grenoble
Bordeaux
Toulouse
Montpellier
Marseille
Nice
au niveau national et dans des UMR (Unités Mixtes de Recherche) en partenariat avec des laboratoires universitaires ou de grandes écoles
laboratoires de recherche quantique en France
(cc) Olivier Ezratty, 2019

LES NOTES SCIENTIFIQUES DE L'OFFICE

OFFICE PARLEMENTAIRE D'ÉVALUATION DES CHOIX SCIENTIFIQUES ET TECHNOLOGIQUES

ASSEMBLÉE NATIONALE — SÉNAT

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

© monsitj/ Adobe Stock

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 étatiques sont la Chine et les États Unis.*

M. Cédric Villani, Député, Premier vice-président

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 :

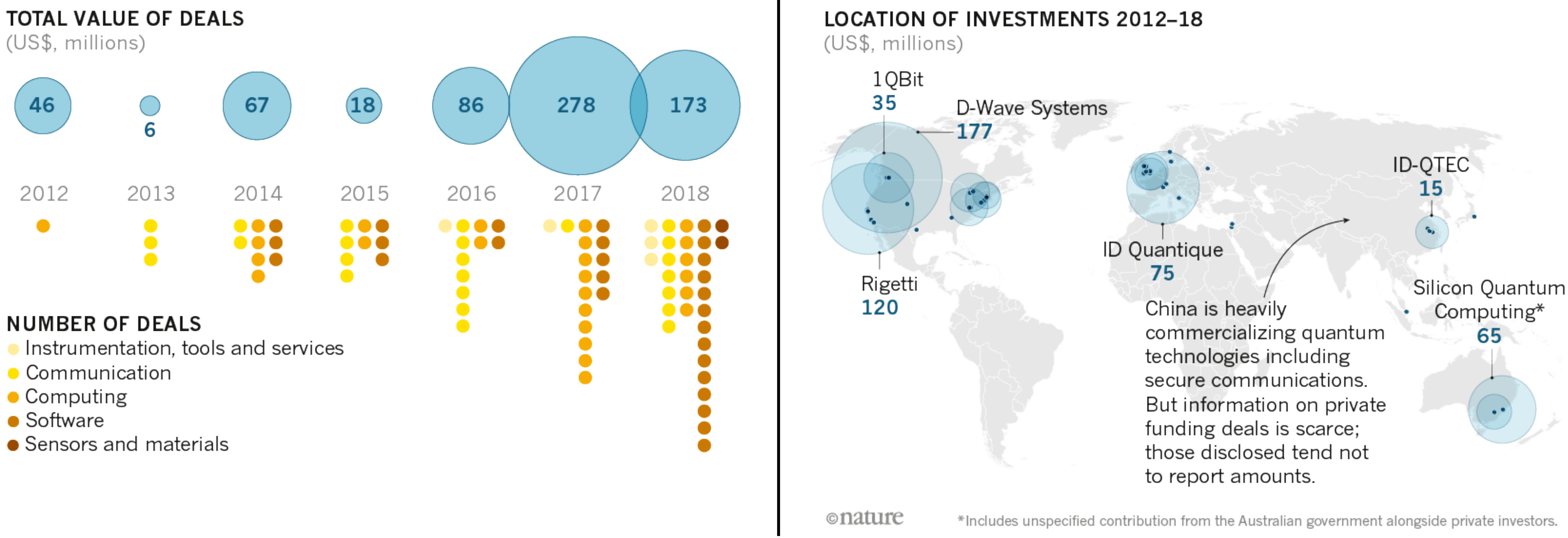
Article 1 En savoir plus sur cet article...

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.

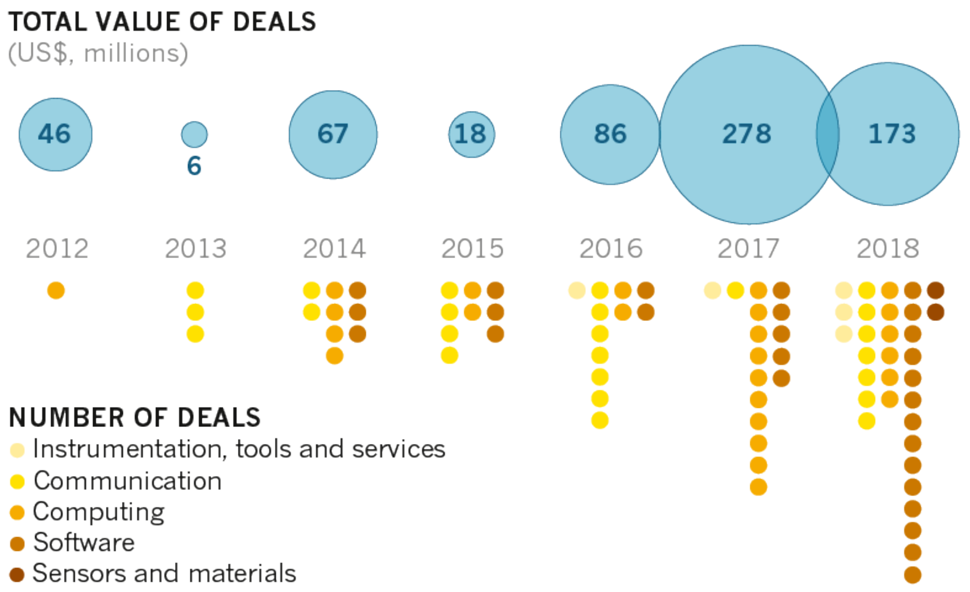
03:26 - 6 avr. 2019

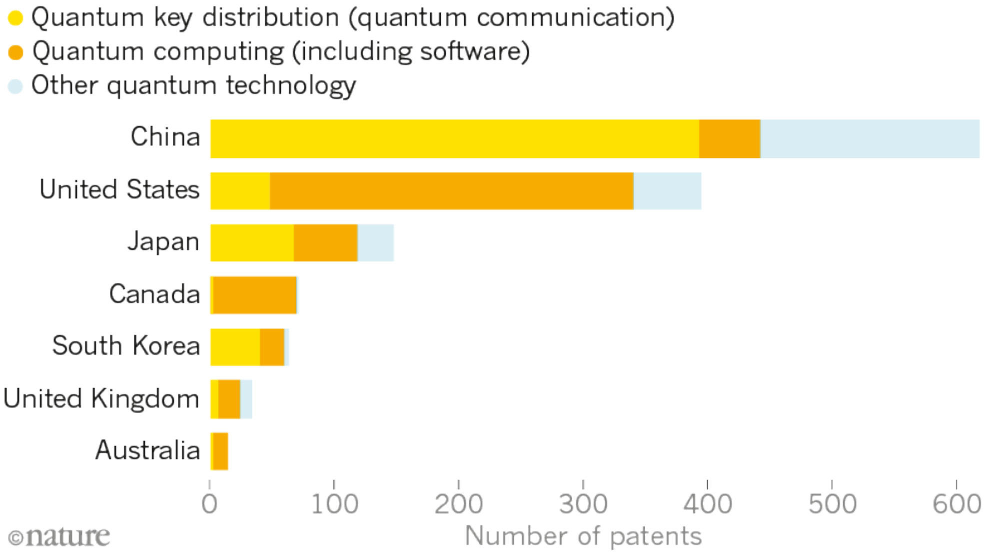
67 Retweets 205 J'aime

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



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





"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 !