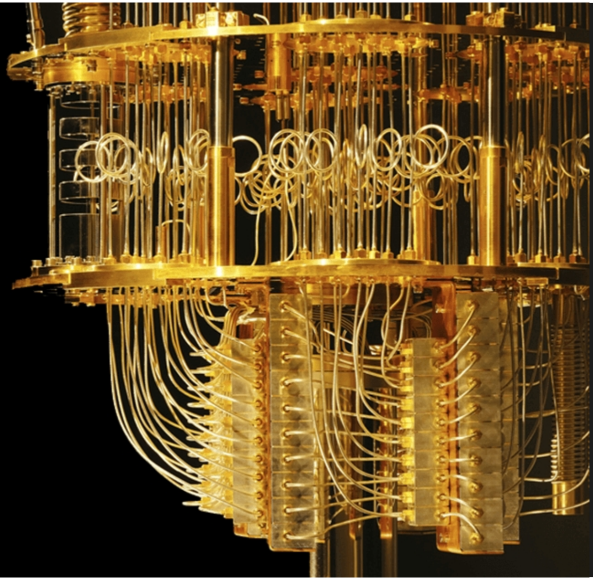

IBM quantum computer

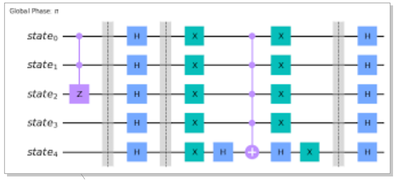
Overview of Quantum Computing:
Revolution or Evolution?

Honorary Assoc. Prof. Jacob L. Cybulski
School of IT, SEBE, Deakin University

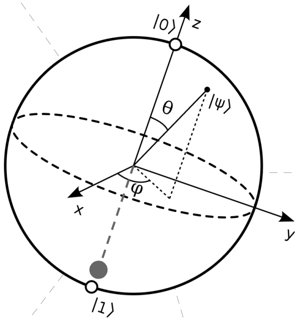
October 2023

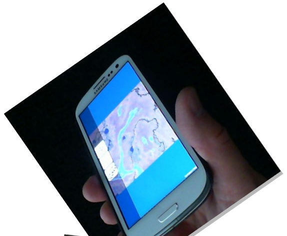
Presenter

Jacob Cybulski
jacob.cybulski@deakin.edu.au



Honorary A/Prof
In Quantum Computing
School of IT, SEBE
Deakin University
Melbourne, Australia



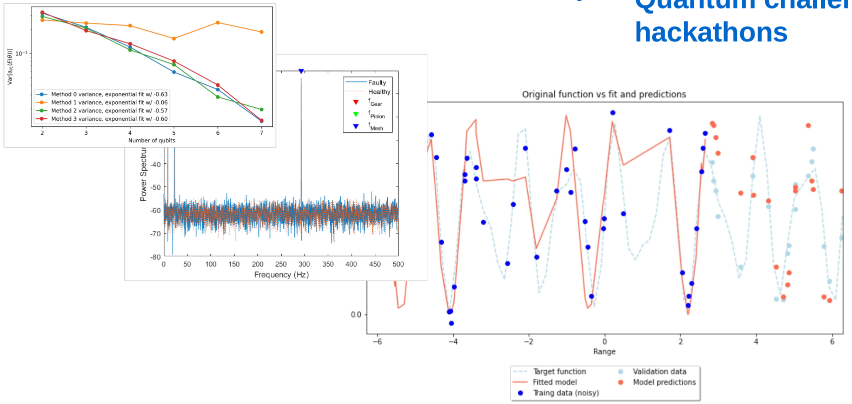


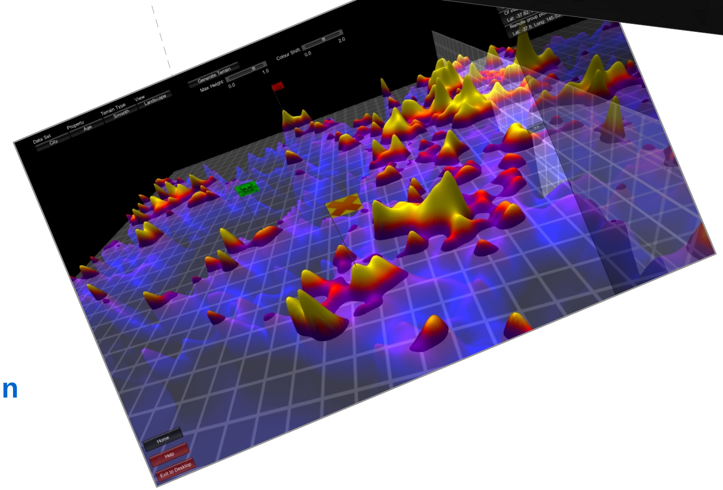
Research

- Quantum computing
- Quantum machine learning
- Quantum time series analysis and anomaly detection
- Classical machine learning
- Data visualisation

Personal

- Recreational cycling
- Reading science and Sci-Fi
- Quantum challenges and hackathons

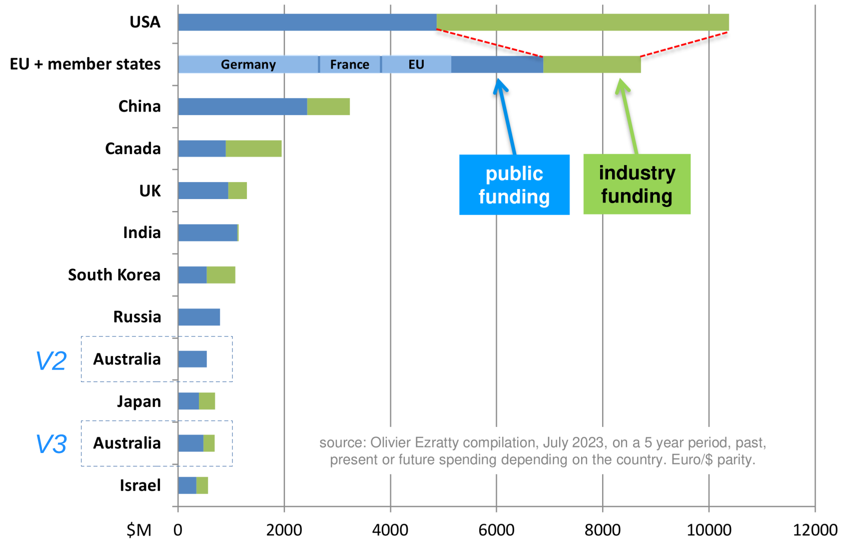




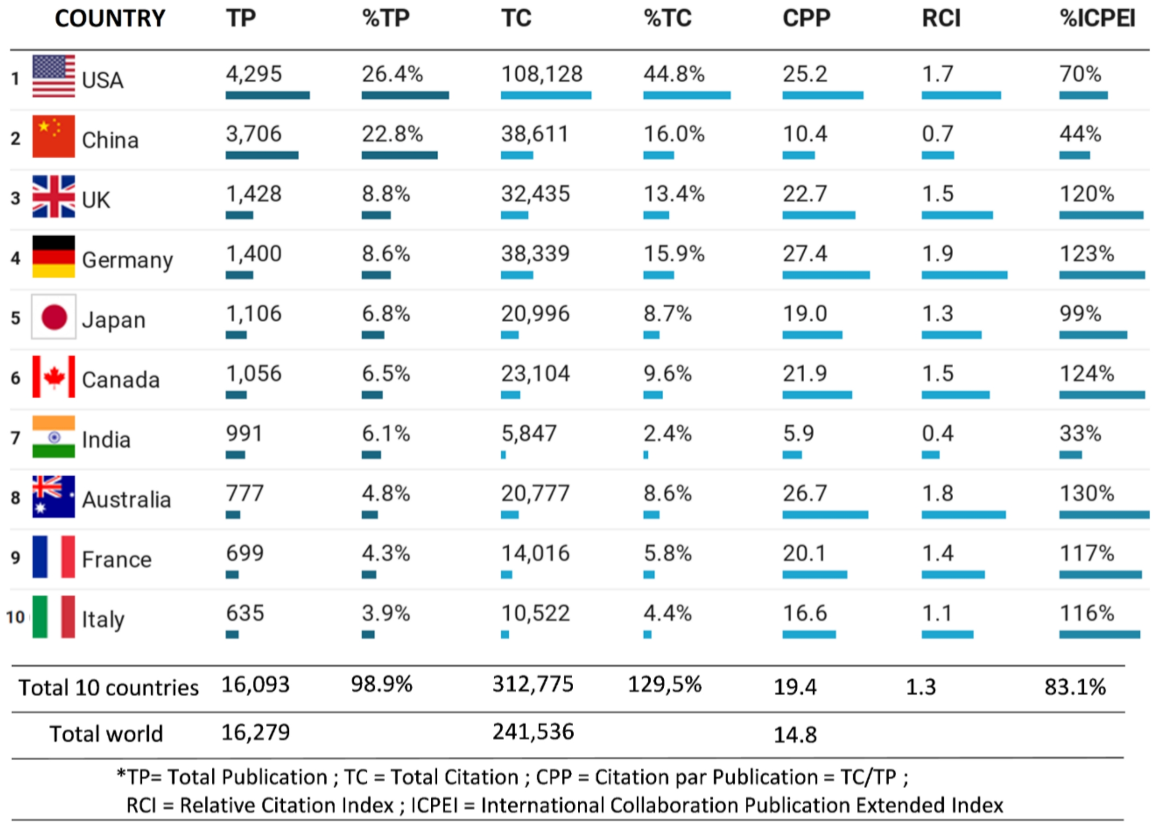
Research collaboration and supervision of research students in QC + QML

Quantum Tech Worldwide (2023)

public and industry funding



source: Olivier Ezratty compilation, July 2023, on a 5 year period, past, present or future spending depending on the country. Euro/$ parity.



	COUNTRY	TP	%TP	TC	%TC	CPP	RCI	%ICPEI
1	USA	4,295	26.4%	108,128	44.8%	25.2	1.7	70%
2	China	3,706	22.8%	38,611	16.0%	10.4	0.7	44%
3	UK	1,428	8.8%	32,435	13.4%	22.7	1.5	120%
4	Germany	1,400	8.6%	38,339	15.9%	27.4	1.9	123%
5	Japan	1,106	6.8%	20,996	8.7%	19.0	1.3	99%
6	Canada	1,056	6.5%	23,104	9.6%	21.9	1.5	124%
7	India	991	6.1%	5,847	2.4%	5.9	0.4	33%
8	Australia	777	4.8%	20,777	8.6%	26.7	1.8	130%
9	France	699	4.3%	14,016	5.8%	20.1	1.4	117%
10	Italy	635	3.9%	10,522	4.4%	16.6	1.1	116%
	Total 10 countries	16,093	98.9%	312,775	129,5%	19.4	1.3	83.1%
	Total world	16,279		241,536		14.8		

*TP= Total Publication ; TC = Total Citation ; CPP = Citation par Publication = TC/TP ;
RCI = Relative Citation Index ; ICPEI = International Collaboration Publication Extended Index

intellectual property

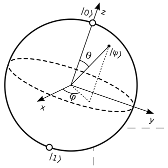
hype to gold

Olivier Ezratty. Understanding Quantum Technologies. Sixth Edition. Le Lab Quantique, 2023.
https://www.oezratty.net/wordpress/2023/understanding-quantum-technologies-2023/.

What is
Quantum Technology

Quantum computing and *Quantum information science*

study of the information processing tasks that can be accomplished using quantum mechanical systems (Nielsen and Chuang, 2010)



$$d_{\gamma,n}(\mathcal{M}_\Theta) = \frac{2\log\left(\frac{1}{V_\Theta}\int_\Theta \sqrt{\det\left(\mathrm{id}_d + \frac{\gamma n}{2\pi\log(n)}\hat{F}(\theta)\right)}\mathrm{d}\theta\right)}{\log\left(\frac{\gamma n}{2\pi\log n}\right)}$$

$$\hat{F}_{i,j}(\theta) = d\frac{V_\Theta}{\int_\Theta \mathrm{tr}(F(\theta))\mathrm{d}\theta}F_{i,j}(\theta),$$

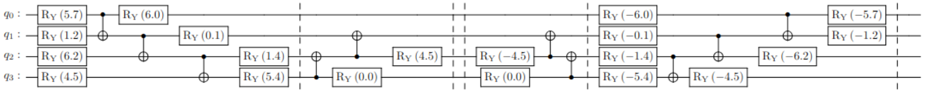
Not an easy path

$$V_\Theta = \int_\Theta \mathrm{d}\theta$$

Quantum finance
Quantum chemistry
Quantum optimisation
Quantum machine learning

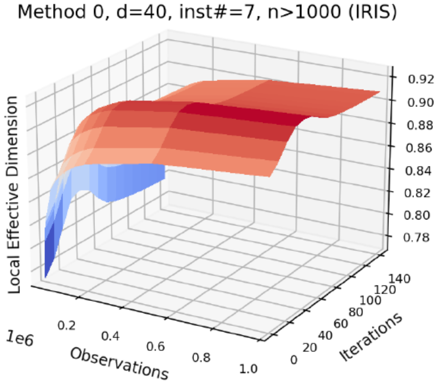
application sub-fields of quantum computing

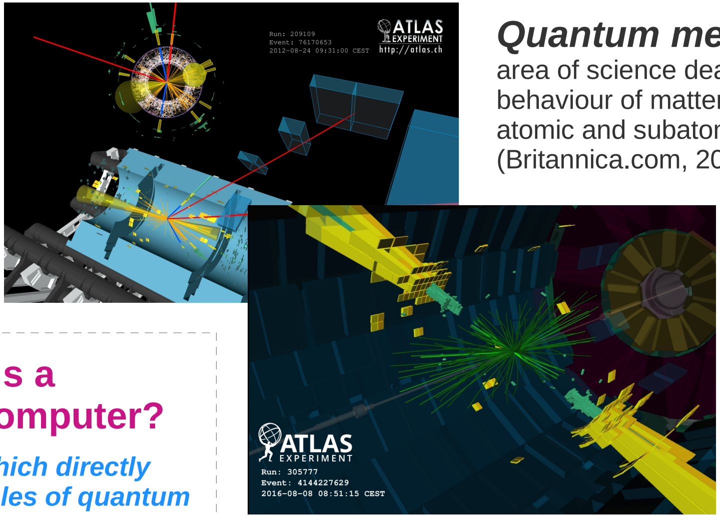
Cybulski & Nguyen
Barren Plateaus
in QNNs and VQAs



What is a Quantum Computer?

It is a device which directly applies the principles of quantum mechanics to perform computational tasks



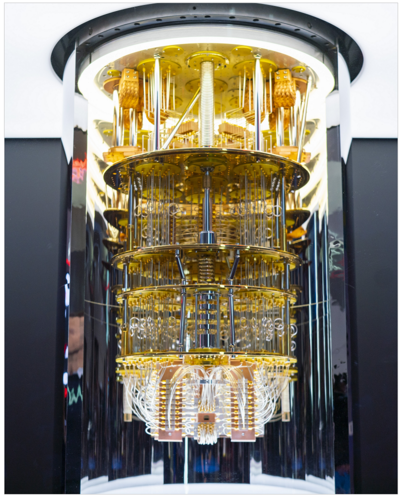


Quantum mechanics

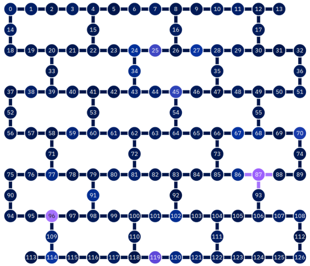
area of science dealing with the behaviour of matter and light on the atomic and subatomic scale (Britannica.com, 2020)

CERN
Atlas particle detector
Large Hadron Collider

There are other quantum technologies e.g. quantum sensing



IBM superconducting
quantum machine
(127 qubits on cloud)



Quantum engineering

building quantum devices

Recently in the news ...

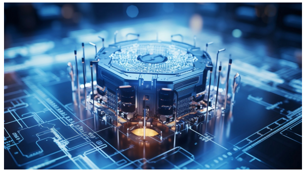
Quantum Machines

(2023)

Univ of Sci and Tech of China with Shanghai Inst of Microsystem and Info Tech (*Jiuzhang 3* - Photonic)

Again achieved quantum supremacy

Gaussian Boson Sampling



SpinQ
(N. Magnetic Resonance)

IQM / VTT
(Superconducting)

IBM (Superconducting)

D-Wave
(Quantum Annealing)

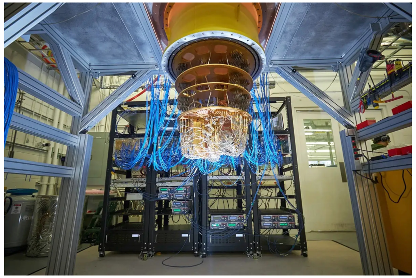
PASQAL
(Neutral Atoms)

They all use:

Qubits
the fundamental models of quantum information and its processing

Quantum circuits
models of computation, involving qubits and operations on them

Quantum Brilliance
(Diamond)



Google
(Superconducting)

Xanadu (Photonic)

Microsoft Azure Quantum

Providers
- Quantinuum
- IonQ
- QCI
- Rigetti
- Pasqal
- 1QBit
- Microsoft QIO
- Toshiba ...

AWS Braket

(Platforms)

Providers
- IonQ
- Rigetti
- OQC
- Xanadu
- D-Wave
- QuEra ...

Qubits

Explanation in technical terms

In practice qubits are made of *elementary particles*, such as electrons or photons, and are governed by the rules of the Universe

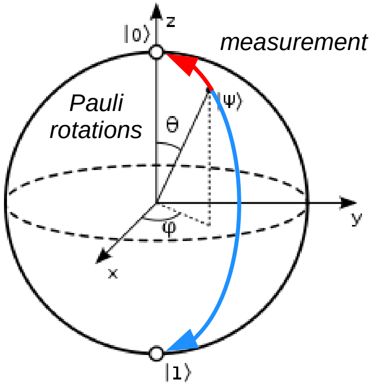
A qubit *represents a state* of such a particle, e.g. an electron spin, which can be up or down, which we call the *basis states*

A qubit is in a state of *superposition*, or a combination, of its basis states up and down

The superposition state is the actual state of elementary particles, not just a mathematical concept used in their description

It is possible to change the state of a qubit with certain predetermined *operations*, like rotation or reversing the position of the qubit state

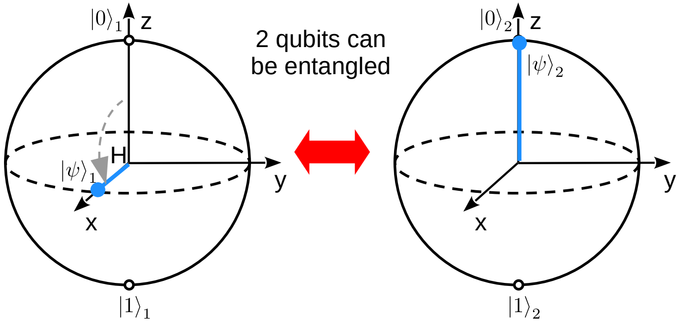
It is in the very nature of elementary particles that it is impossible to determine their state without *measuring* them



Qubit measurement returns only the basis state that is “likely” to be closest to its superposition state, which also destroys the measured state

The outcome of measurement is probabilistic

Qubits can be *entangled*, then they start behaving as a unit with a common complex state, until they are measured or until some external factor (*noise*) destroys their entanglement



2 qubits can be entangled

Explanation in human terms comes next

What makes quantum computers special?

A combination of qubit superposition (parallelism) and entanglement (composition), as well as its measurement, is what gives quantum computers their immense computational power allowing some problems to be solved in minutes rather than 1000s of years!

Cybulski’s Quantum Computer

Not as cruel as Schrödinger’s Cat Experiment

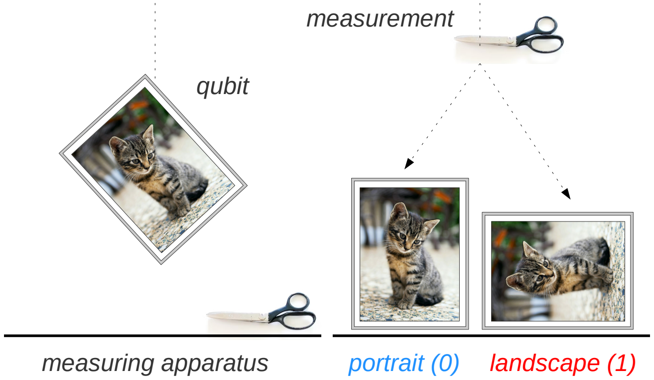
To make a quantum computer we need a framed picture of a cat (must be a cat), a nail in the wall, a string attached to the middle of the picture’s back and scissors (see figure to the right).

The *picture+string* will be called a **qubit**, while the *floor+scissors* (+your eyes) will be called a **measuring apparatus**

We can hang the picture on the wall and rotate it to our liking, all such picture adjustments are simply qubit **operations**

We measure our qubit by cutting the string, and then the picture falls, bounces a bit, and settles in either a *portrait* or *landscape* position on the floor – not surprising when the picture is on the floor, we call its positions the **basis states**, written as |0> and |1> and measured as 0 and 1

However, when the picture is hanging on the wall, it is neither in its |0> or |1> state, it is in a “combination” of these two states, their measurement outcome cannot be known in advance - this is quantum **indeterminacy**

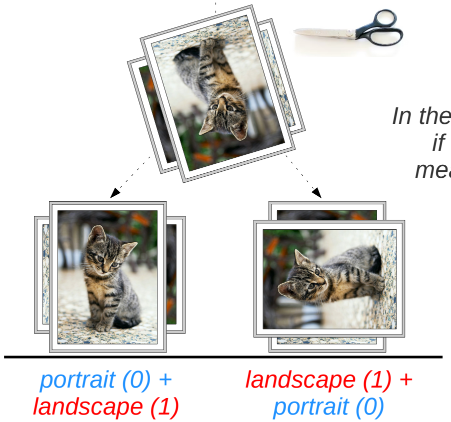


If we repeat this experiment many times (say 100 times), then we will be able calculate the probability of the qubit measurement to be 0 or 1, let’s say we’ll end up with 25% of 0s, 75% of 1s, which means that before measurement the qubit was in a **superposition** state of:

$$\sqrt{0.25} \times |0> + \sqrt{0.75} \times |1>$$

We will also say that the measurement collapses the qubit’s quantum state into a classical value, 0 or 1

We can take two or more qubit pictures, glue them and hang them in some configuration on the wall, this is **entanglement**



In these settings, if one qubit is measured as 0 the other is always 1

When the string is cut, the qubits tumble together and their repeated measurements can be shown to be **highly correlated**

The higher we hang the pictures the more energy and bouncing we get, and the more unpredictable results we get – this is **noise**

To deal with noise we keep the energy low, a fridge is an option!

If glued pictures fall apart on impact, we call it **decoherence** – destroyer of all entanglement

Qubits

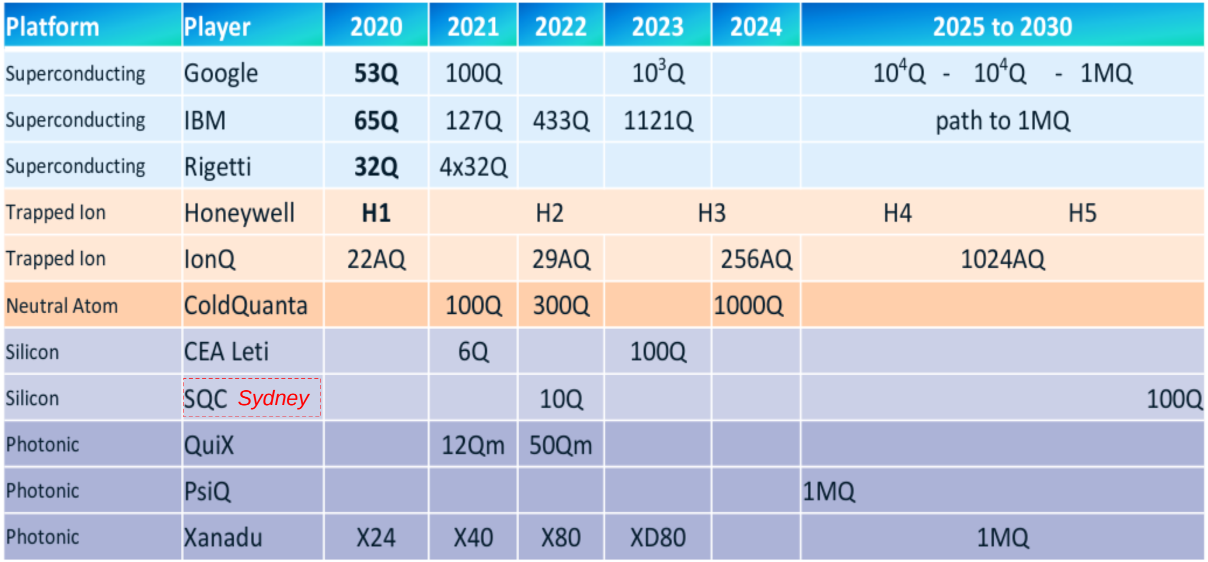
Quantum machine vendors use different standards to measure their products

It is common to measure the power and utility of a quantum machine in terms of the *number of qubits*

However, apart from their number it is equally important to measure their *quality*, *functionality* and *utility*

It also takes several hardware qubits to deal with *quantum errors*, to make a single high-quality logical qubit

David Shaw., Quantum Business Europe, Fact Based Insight, 2021,
URL: https://www.factbasedinsight.com/quantum-hardware-platforms-a-brief-overview/



Platform	**Player**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025 to 2030**
Superconducting	Google	**53Q**	100Q		10^3Q		10^4Q - 10^4Q - 1MQ
Superconducting	IBM	**65Q**	127Q	433Q	1121Q		path to 1MQ
Superconducting	Rigetti	**32Q**	4x32Q				
Trapped Ion	Honeywell	**H1**		H2	H3		H4 H5
Trapped Ion	IonQ	22AQ		29AQ		256AQ	1024AQ
Neutral Atom	ColdQuanta		100Q	300Q		1000Q	
Silicon	CEA Leti		6Q		100Q		
Silicon	SQC *Sydney*			10Q			100Q
Photonic	QuiX		12Qm	50Qm			
Photonic	PsiQ						1MQ
Photonic	Xanadu	X24	X40	X80	XD80		1MQ

Source: Fact Based Insight

As a result, it is very hard to compare vendor claims as to their product features, plans, timelines and roadmaps

Qubits

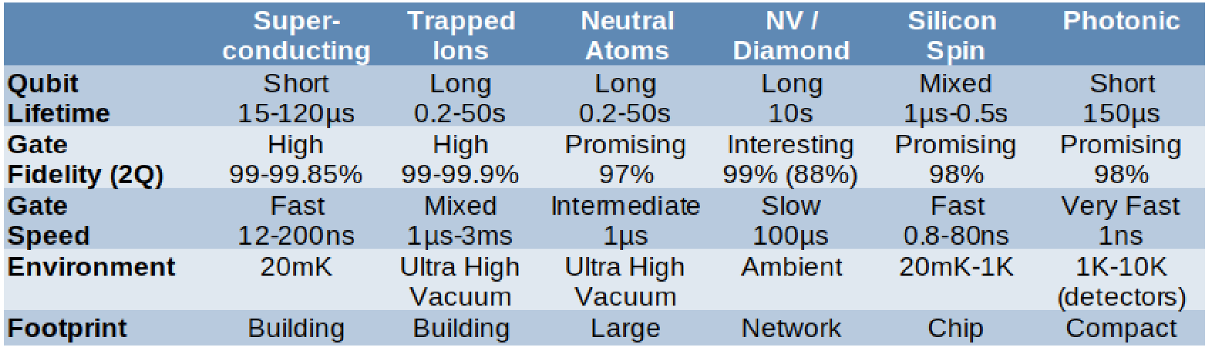
Qubits rely on individual particles: *ions*, *photons*, *neutral atoms*, *electrons* or even *defects in diamonds*

Consequently, each type of qubit has different *life-time*, *speed* and *fidelity*

While quantum technology is being perfected, some companies build *classical quantum simulators*, with:

- GPUs and TPUs (e.g. Nvidia, ATOS)
- Digital annealers (e.g. Fujitsu)
- Quasi-quantum bifurcation (e.g. Toshiba)
- Software simulators (e.g. Intel, and all)
- and many others...

David Shaw., Quantum Business Europe, Fact Based Insight, 2021,
URL: https://www.factbasedinsight.com/quantum-hardware-platforms-a-brief-overview/



	Super-conducting	Trapped Ions	Neutral Atoms	NV / Diamond	Silicon Spin	Photonic
Qubit Lifetime	Short 15-120µs	Long 0.2-50s	Long 0.2-50s	Long 10s	Mixed 1µs-0.5s	Short 150µs
Gate Fidelity (2Q)	High 99-99.85%	High 99-99.9%	Promising 97%	Interesting 99% (88%)	Promising 98%	Promising 98%
Gate Speed	Fast 12-200ns	Mixed 1µs-3ms	Intermediate 1µs	Slow 100µs	Fast 0.8-80ns	Very Fast 1ns
Environment	20mK	Ultra High Vacuum	Ultra High Vacuum	Ambient	20mK-1K	1K-10K (detectors)
Footprint	Building	Building	Large	Network	Chip	Compact

While we can make qubits of elementary particles and we can predict their behaviour with extremely high precision, we still do not fully understand how they work!

We still do not understand how the Universe works!

But we have some really good theories!

QC program & its results

Quantum circuits

Qubits can be combined to form quantum circuits, which are the essence of quantum algorithms, however, they can be defined in many different ways and for different purposes

e.g. consider a Grover Algorithm

Mathematical model

Oracle

$$O|x\rangle = (-1)^{f(x)}\,|x\rangle$$

Oracle matrix

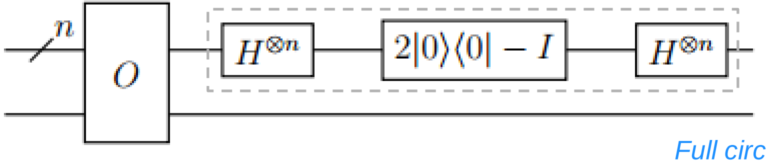
$$O\,|x\rangle = \begin{bmatrix} (-1)^{f(0)} & 0 & \cdots & 0 \\ 0 & (-1)^{f(1)} & \cdots & 0 \\ \vdots & 0 & \ddots & \vdots \\ 0 & 0 & \cdots & (-1)^{f(2^n-1)} \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ \vdots \\ x_{2^n-1} \end{bmatrix}$$

Grover operator

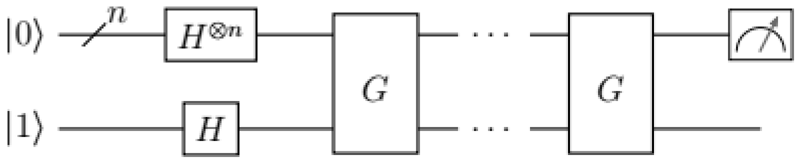
$$G = (H^{\otimes n}(2\,|0\rangle\,\langle 0| - I)H^{\otimes n})O$$

Conceptual circuit diagram

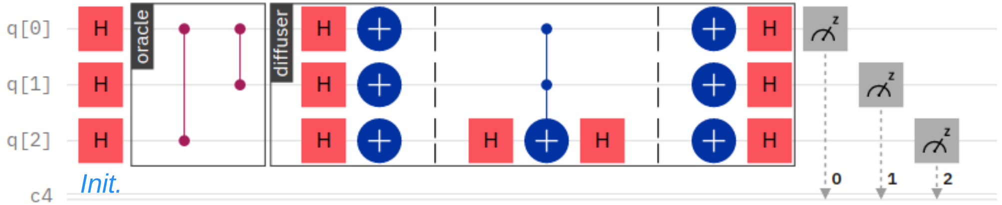
Grover operator (Oracle + Diffuser)



Full circuit with repeated Grover operator



Executable circuit diagram

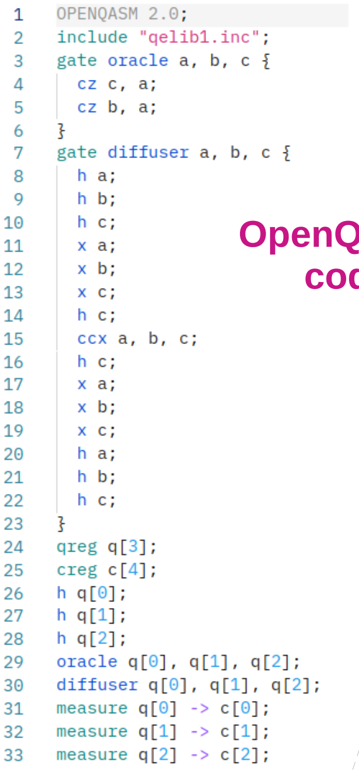


Init.

Oracle encoding two numbers

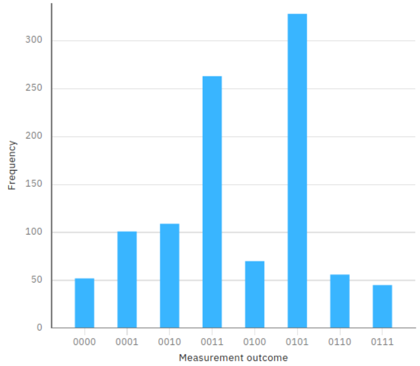
Diffuser amplifying the solution

OpenQASM code



```
OPENQASM 2.0;
include "qelib1.inc";
gate oracle a, b, c {
  cz c, a;
  cz b, a;
}
gate diffuser a, b, c {
  h a;
  h b;
  h c;
  x a;
  x b;
  x c;
  h c;
  ccx a, b, c;
  h c;
  x a;
  x b;
  x c;
  h a;
  h b;
  h c;
}
qreg q[3];
creg c[4];
h q[0];
h q[1];
h q[2];
oracle q[0], q[1], q[2];
diffuser q[0], q[1], q[2];
measure q[0] -> c[0];
measure q[1] -> c[1];
measure q[2] -> c[2];
```

Circuit Execution



Results obtained on a NISQ machine

Problems suitable for quantum applications

What kind of problems are quantum computers good for?

Solving highly complex problems (NP-complete) which relate to quantum phenomena, e.g. in Chemistry and Physics

Surprisingly other complex problems can be expressed using the same principles, e.g. in Finance, Logistics and Machine Learning

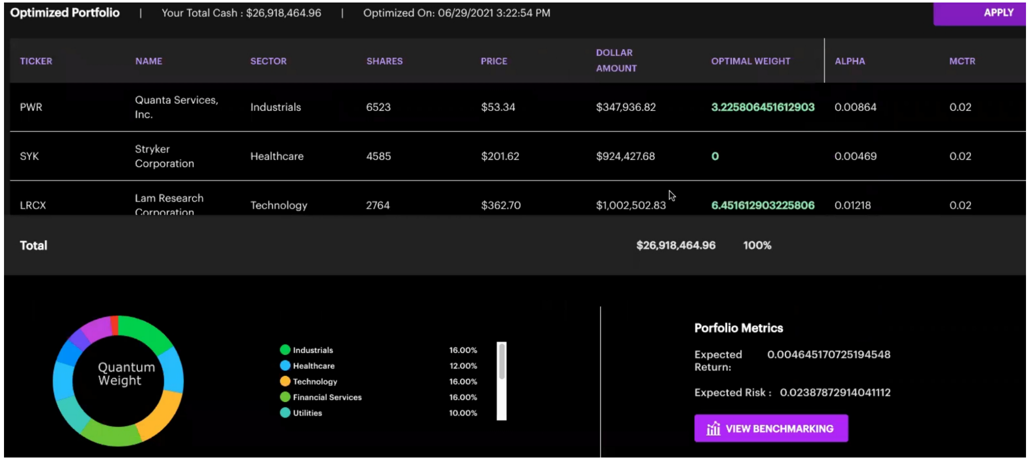
- Defence Systems – Cryptography, control, sensing, etc.
- Rigetti – Weather forecasts
  https://thequantuminsider.com/2021/12/07/quantum-machine-learning-may-improve-weather-forecasting/
- NASA (QuAIL) – Mission control, space vehicle / rover design and coordination, air traffic management, planning and scheduling, fault diagnosis, etc.
  https://www.sciencedirect.com/science/article/pii/S0167819116301326
- Accenture – Financial, logistics, communications and security services
  https://www.accenture.com/au-en/services/technology/quantum-computing-services
- BASF – Quantum chemical computations: new catalysts and polymers
  https://www.qutac.de/basf-how-quantum-computing-can-help-develop-chemical-catalysts/?lang=en
- Ford / VW / BMW – Traffic, batteries, financials, materials, production optimisation
  https://spectrum.ieee.org/ford-signs-up-to-use-nasas-quantum-computers
  https://www.volkswagenag.com/en/news/stories/2021/08/volkswagen-takes-quantum-computing-from-the-lab-to-the-factory.html
  https://www.zdnet.com/article/bmw-explores-quantum-computing-to-boost-supply-chain-efficiencies/
- Boeing / Airbus – Manufacturing, materials, logistics, aerospace, flight dynamics
  https://www.ibm.com/blogs/research/2020/09/quantum-industry/
- Goldman Sach / JPMorgan – Financial: derivatives, simulations, pricing, etc.
  https://www.efinancialcareers.com.au/news/2020/12/quantum-computing-at-goldman-sachs-and-jpmorgan
- Boehringer Ingelheim – Medical molecular dynamics
  https://www.boehringer-ingelheim.com/press-release/partnering-google-quantum-computing

Sample Applications

Accenture: Portfolio rebalancing

- In 2021 *Accenture* presented a demo of portfolio rebalancing in financial services.
- The presented system was running on AWS Braket with D-Wave Leap backend, using 52 weeks of ticker stock data from Yahoo Finance.
- The aim was to minimise the difference between the target and the final portfolio while maximising the return, but also keep the minimum number of stocks and the number of transactions (implied cost) needed to obtain the final portfolio.
- Note that quantum portfolio optimisation has been explored by other companies, e.g. *Multiverse Computing*, *Chicago Quantum*, *KPMG*, *JPMorgan Chase Bank*, etc.

Quantum Tech 2021 (Sept) one day conference.



Optimized Portfolio | Your Total Cash : $26,918,464.96 | Optimized On: 06/29/2021 3:22:54 PM

APPLY

TICKER	NAME	SECTOR	SHARES	PRICE	DOLLAR AMOUNT	OPTIMAL WEIGHT	ALPHA	MCTR
PWR	Quanta Services, Inc.	Industrials	6523	$53.34	$347,936.82	3.225806451612903	0.00864	0.02
SYK	Stryker Corporation	Healthcare	4585	$201.62	$924,427.68	0	0.00469	0.02
LRCX	Lam Research Corporation	Technology	2764	$362.70	$1,002,502.83	6.451612903225806	0.01218	0.02
Total					$26,918,464.96	100%		

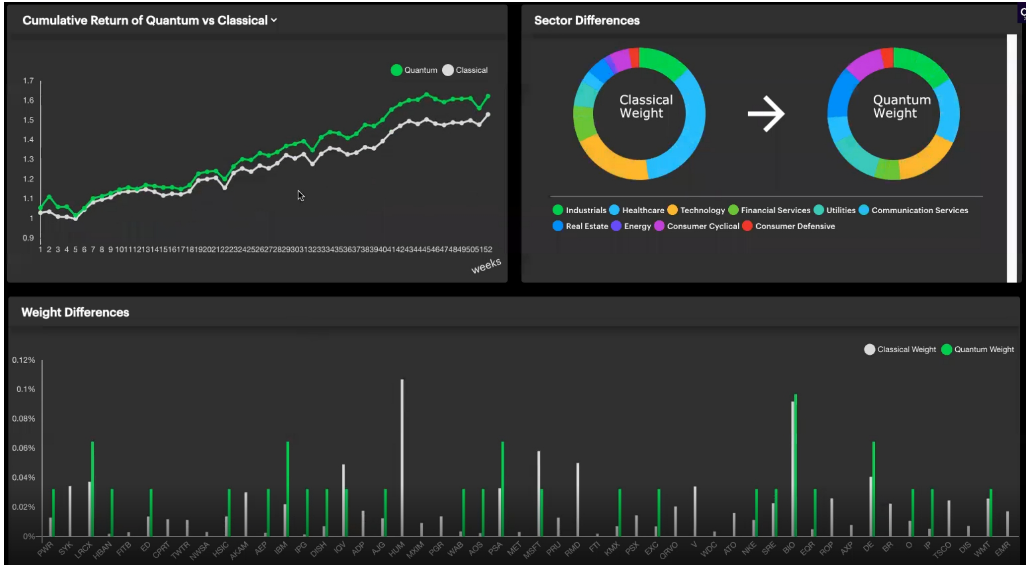
● Industrials	16.00%
● Healthcare	12.00%
● Technology	16.00%
● Financial Services	16.00%
● Utilities	10.00%

Porfolio Metrics

Expected Return: 0.004645170725194548

Expected Risk : 0.02387872914041112

VIEW BENCHMARKING



Cumulative Return of Quantum vs Classical

Sector Differences

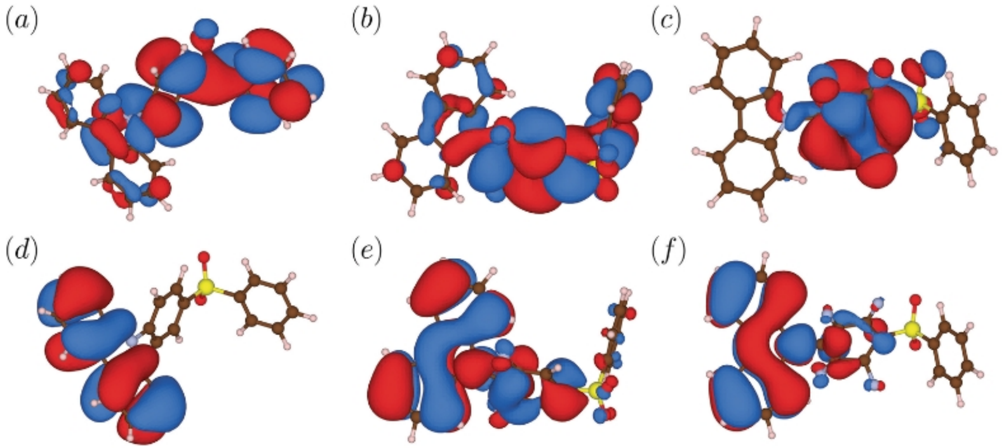
Weight Differences

Sample Applications

Mitsubishi, IBM, ...: Chemistry

Gao, Qi, Gavin O. Jones, et al. “Applications of Quantum Computing for Investigations of Electronic Transitions in Phenylsulfonyl-Carbazole TADF Emitters.” Npj Computational Materials 7, no. 1 (May 20, 2021): 1–9.

- Organic Light Emitting Diodes (OLED) have become increasingly popular in the fabrication of thin, flexible TV and mobile phone displays that emit light upon application of an electric current.
- Recent studies have been looking at electronic transitions of high energy states in some molecules, which could could potentially produce OLEDs that are 100% efficient. The conventional methods make OLEDs of 25% efficiency.
- A project by *IBM Quantum and partners* was successful in developing quantum methods to improve accuracy for the calculation of excited states for very efficient OLEDs, making it the world's first research case of applying quantum computers to the calculation of excited states of commercial materials.
- The project reported (May 2021) methods of calculating the exact values and predicting properties, such as excited states of different materials used in OLED production, by using the currently available NISQ devices with various quantum algorithms and error mitigation schemes.
- Note that the project and its methods were reproduced and tested by the participants of the IBM Quantum Challenge 2021 (November).



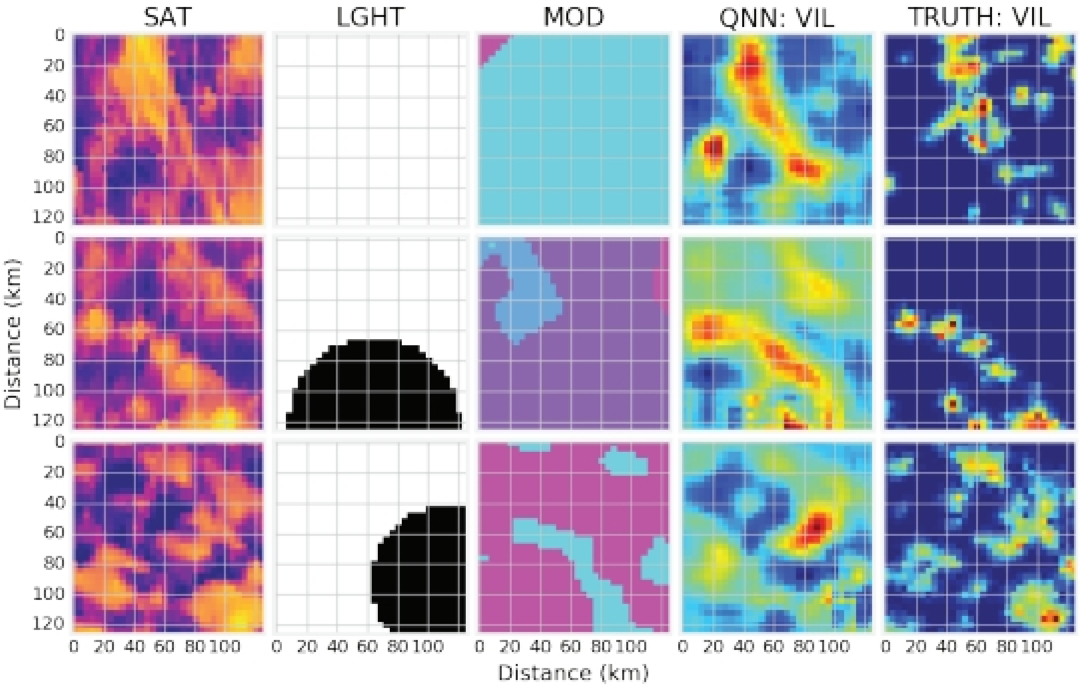
Sample Applications

Rigetti: Weather

Enos, Graham R., Matthew J. Reagor, Maxwell P. Henderson, Christina Young, Kyle Horton, Mandy Birch, and Chad Rigetti. “Synthetic Weather Radar Using Hybrid Quantum-Classical Machine Learning.” arXiv, November 30, 2021. https://doi.org/10.48550/arXiv.2111.15605.

- Global Synthetic Weather Radar (GSWR) is a class of techniques for assimilating diverse meteorological data types, in order to produce synthetic weather radar images (Enos et. al., 2021).
- GSWR models are used in those cases when radar data is not available, e.g. in remote areas or in disaster response.
- *Rigetti Computing* announced in 2021 that it developed a hybrid classical-quantum solution to enhance GSWR weather modelling.
- The approach resulted in high-quality synthetic weather radar data, and was able to improve classical machine learning models for storm prediction.

- Several approaches were developed running on Rigetti’s 32-qubit machine and the best performance was achieved using a Quantum Neural Network.



Selected areas of Quantum applications

Most successful quantum computing applications can be found in disciplines such as: *Science* & *Finance* using *Quantum Optimisation* & *Quantum Machine Learning*

Organisations & Society

- *Portfolio optimisation*
- *Price / option prediction*
- *Fraud indicators*
- *Credit scoring*
- *Financial risk assessment*

Finance / Insurance

- *Traffic control*
- *Supply chain optimisation*
- *Inventory control*
- *Distribution optimisation*
- *Planning & scheduling*

Transport / Logistics

Economy

- Quantum info & comms
- Encryption
- Quantum repeaters
- Key distribution

Networks & Security

- *Measurement*
- *Instruments*
- *Timing*
- *Seismology*
- *Navigation*
- *Microscopy*
- *Imaging*
- *Radars*

Quantum Sensors

- *Vehicle / Spacecraft design*
- *Fault diagnosis*
- *Efficient fuels*
- *Effective assembly*
- *Route planning*

Aerospace / Automotive

- *Machine condition monitoring*
- *Structural analysis*
- *Efficient batteries*
- *Semiconductor chip layout & fault analysis*
- *Electronic circuits for quantum tech*

Materials / Manufacturing

Discovery & Knowledge

- *Energy distribution & optimisation*
- *Carbon capture*
- *Oil exploration*

Energy / Resources

- *Simulation of chemical reactions*
- *Computational chemistry*
- *Drug Development*

Chemistry / Pharmaceutical

- *Genetics*
- *Omics*
- *Protein folding*
- *Study of genetic diseases*

Bio-Technology

People

- *Radiotherapy*
- *Medical imaging*
- *Precision medicine*

Medical / Healthcare

Environment

Quantum technology ...

Quantum Technology is still Science
rather than Business...

Yet its potential is extremely promising!

Benefits	vs.	Challenges
Seamless integration of algorithms with maths and physical phenomena	?	Difficult to conceptualise, design, develop, execute and understand results
Can handle massive parallelism and randomness (via quantum superposition and measurement)	?	Must carefully constrain qubit interaction to get meaningful results (via quantum entanglement)
Quantum algorithms drastically reduce complexity as compared with classical ones	?	Quantum advantage can only be demonstrated in niche application areas
Quantum supremacy is possible and exponentially reducing complexity	?	Quantum supremacy cannot be proven in general case, also new classical algorithms challenge quantum advantages
By using quantum-classical hybrid approaches quantum machine learning is very effective	?	Classical machine learning algorithms do not readily translate to quantum computing, often there is no quantum advantage
There is a lot of free QC learning resources, tutorials, communities, challenges and hackathons	?	There is still acute shortage of knowledge, skills and expertise in conceptualising and developing quantum solutions
Recent emergence of high-end specialist QC community	?	QC requires highly specialised skills and there is a shortage of QC development tools for “humans” (problem owners)
QC experts have a track record of generating insightful quantum applications	?	There are no accepted “software engineering” QC methods ensuring teamwork, repeatable process and quality results
Cloud-based QC lowered access costs with freely available software tools	?	Majority of QC development is for proof-of-concept solutions, There are no tools for future quantum machines (1k-1M qubits)
Quantum technology very effectively harnesses processes at sub-atomic level	?	There are charlatans trying to hijack quantum concepts and apply them to the whole body, mind or soul

Working with Quantum Tech

- You can enter the field from many different areas of expertise, e.g.
  - Physics / Science / Engineering
  - Computer Science / Data Science
  - Software Engineering
  - Business / Law / Defence
  - Arts / Journalism ...
- You can contribute to the quantum field in many different ways, e.g.
  - Work on new quantum hardware
  - Develop new quantum algorithms
  - Solve problems with existing tech
  - Teach / promote quantum tech
  - Specialise in one of the aspects
  - Manage a quantum team ...
- The most important trait of people in quantum tech is their enthusiasm and commitment

Domain	Skill/Knowledge	Naive Experiments with quantum concepts	Basic Writes simple quantum programs	Medium Takes part in quantum challenges	Advanced Has a technical job in quantum technology	Expert Other people in quantum think they are super
Mathematics	Complex Numbers	✔	✔	✔✔	✔✔	✔✔
	Linear Algebra		✔	✔✔	✔✔	✔✔✔
	Calculus			✔	✔✔	✔✔✔
	Differential Equations				✔	✔✔
	Partial Differential Eqs				✔	✔✔
	Fourier Transforms				✔	✔
	Probability Theory	✔	✔	✔✔	✔✔	✔✔
	Statistics	✔	✔	✔	✔✔	✔✔
Data Science	Programming (Python)		✔	✔✔	✔✔	✔✔
	Optimisation Techniques			✔✔	✔✔	✔✔
	Machine Learning			✔✔	✔✔	✔✔
Quantum Computing	Foundations (Bell State)	✔	✔	✔✔	✔✔✔	✔✔✔
	Circuits, Qubits, Gates, Bloch Sphere	✔	✔	✔✔	✔✔✔	✔✔✔
	Quantum Circuit Simulators	✔	✔	✔	✔✔	✔✔
	Circuit Execution	✔	✔	✔✔	✔✔✔	✔✔✔
	Results Interpretation / Visualisation	✔	✔	✔✔	✔✔✔	✔✔✔
	Algorithms (Grover, Shor, …)		✔	✔✔	✔✔✔	✔✔✔
	Simple Error Mitigation		✔	✔✔	✔✔✔	✔✔✔
Quantum Machine Learning	Variational Quantum Algorithms			✔	✔✔	✔✔✔
	Data Encoding			✔	✔✔	✔✔✔
	Result Interpretation			✔	✔✔	✔✔✔
	Quantum Optimisation			✔	✔✔	✔✔✔
	Quantum Linear Models			✔	✔✔	✔✔✔
	Quantum Neural Networks			✔	✔✔	✔✔✔
	Quantum Kernel Methods			✔	✔✔	✔✔✔
	Quantum Probabilistic Models				✔	✔✔
	Quantum Annealing				✔	✔✔
Quantum Hardware	Configuration				✔	✔✔
	Calibration			✔	✔	✔✔
	Complex Error Mitigation			✔	✔	✔✔

Bird-view of quantum computing...
Summary, reflections and questions

Opportunities
for quantum R&D

Global
quantum initiatives

New ways of
solving “impossible”
problems

Many new quantum
tech products

Practical quantum
solutions are
in development

Quantum enabled
discoveries in science
are being reported

Variety of quantum
tools and methods
for developers

You can be
part of it

Discussion

- Is it evolution or revolution?
- Will it replace the currently used digital technology?
- Is it a threat? How?
- Will it be the saviour of humanity? Why?

Jacob’s Vision

- Is it evolution or revolution?

  Quantum technology is based on revolutionary ideas, however till now changes in quantum technology have been evolutionary. As the level of its sophistication grows and its cost decreases we can expect quantum technology to have huge impact on our lives.

- Will it replace the currently used digital technology?

  At this point in time, quantum technology will be used only in the specific niche areas, where its use will prove to have advantage over digital technology. However, as it is combined with other technologies, in its hybrid form it is likely to replace existing digital devices.

- Is it a threat? How?

  Quantum technology will make many existing technologies obsolete (e.g. data encryption), it is also an unstoppable threat to many international standards. Standard replacement in haste and panic will be very costly, especially that such prospect is being ignored by many governments.

- Will it be the saviour of humanity? Why?

  Advances in quantum technology will bring many benefits to the society (e.g. creation of new and more effective medicines), in building efficient and environmentally friendly devices (such as highly efficient batteries), or in management of financial assets (e.g. in more accurate market predictions).

  However, the greatest threat to humanity are people themselves –
  quantum technology cannot change it!