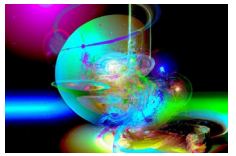
Developing the National Strategy for Quantum Technology

Peter Knight

UK National Quantum Technology Programme

Lessons from quantum on building a large collaborative exercise

S&T Framework: https://www.gov.uk/government/publications/uk-science-and-technology-framework/the-uk-science-and-technology-framework



How is strategy set for new initiatives?

Used a robust and repeatable approach to identify the technologies that are most critical to the UK

DSIT have assessed over 50 technologies against 8 criteria:

- sustainable environment
- health and life sciences
- digital economy
- national security and defence
- international comparison
- foundational
- market potential
- threats and resilience

a portfolio of 5 critical technologies.

- **Artificial Intelligence (AI)** – machines that perform tasks normally performed by human intelligence, especially when the machines learn from data how to do those tasks.
- **Engineering biology** – the application of rigorous engineering principles to the design of biological systems.
- **Future telecommunications** - evolutions of the infrastructure for digitised data and communications.
- **Semiconductors** – a class of electronic materials with unique properties that sit at the heart of the devices and technology we use every day.
- **Quantum technologies** – devices and systems which rely on quantum mechanics, to provide capabilities that 'classical' machines cannot.

The National Science and Technology Council will review this list annually to ensure that the UK keeps pace and continues to develop global competitive advantage - although there will be a high bar to major change given the need for long-term planning.

UK NATIONAL QUANTUM PROGRAMME

A Brief Timeline

Launch The UK National Quantum Technologies Programme (NQTP)

PHASE 0:

Workshop at Chicheley Hall

PHASE 1:

Focus on converting research and excellence into technology prototypes and plugging the skills deficit

£380m investment over 5 years.

PHASE 2:

Focus on driving commercialisation and economic impact (investment, supply chain growth, international collaboration)

Additional £350m over 5 years plus £153m for industry-led activities.

National Quantum Computing Centre (NQCC) launched Sept 2020

PHASE 3

Publication of UK Quantum Strategy affirms UK continued commitment to quantum technologies for the next 10 years. Strategy provides an additional investment of £2.5 billion, starting in 2024

So far, NQTP has provided awards to over 123 businesses and 38 universities and RTOs collaborating in over 95 projects

THE UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME (NQTP): PARTNERS AND GOVERNANCE

Department for Science, Innovation & Technology

UK Quantum Strategy lead department

Parent department of UKRI and sponsor for NPL

Engineering and Physical Sciences Research Council

Funds research and training in quantum, including:
(1) a national network of research hubs;
(2) centres for doctoral training;
(3)-domestic and international research grants;
(4)-fellowships.

Innovate UK

Delivering a national challenge programme to develop new commercial quantum products involving academia, industry and Government

Science and Technology Facilities Council

Delivering the Quantum Technologies for Fundamental Physics programme;

Home of the National Quantum Computing Centre

NPL National Physical Laboratory

Home of the Quantum Metrology Institute (QMI)

Leads activities to test, validate and commercialise new quantum R&D

Ministry of Defence

Government lead for defence applications of quantum technologies

[dstl]

Responsible for delivering MOD R&D programme in quantum technologies

Provides specialist technical support to national quantum programme partners

GCHQ

One of the UK's Intelligence and Security Agencies

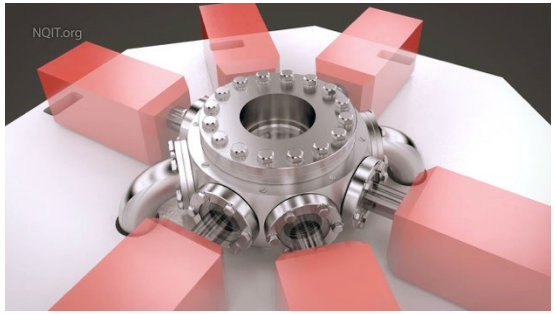
Home of the National Cyber Security Centre (NCSC): conducts research and provides advice on 'post-quantum' security

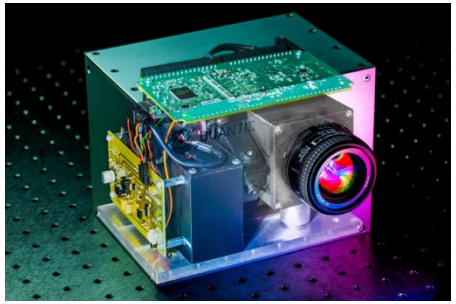
COORDINATING BODIES

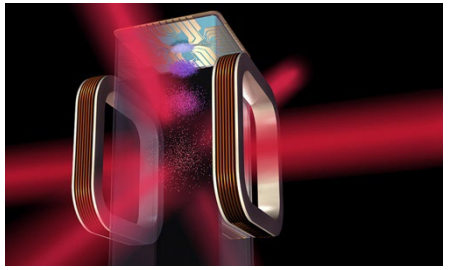
Programme Board
Provides coordination and strategic direction for the programme with representation from each of the partner agencies.. Chaired by Dame Lynn Gladden, Executive Chair, EPSRC.

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

Strategic Advisory Board
Provides independent advice to help steer the strategic direction of the programme and policy on quantum technologies, and is made up of eminent figures from across industry, academia and Government. Chaired by Sir Peter Knight.







UK Quantum Technologies
Not just computing

Quantum Computing &Simulation

NQCC Testbeds Q Readiness

Industry led Challenges

Quantum Networking

Quantum Sensing, Imaging & Timing

The International Landscape as of 2021- rapidly evolving so needs update

	Quantum spend (2021)	Quantum publications	Quantum patent applications	2021 ranking
China	1	4	1	1
USA	2	1	3	1
Germany	3	2	4	3
UK	**5**	**2**	**9**	**4**
Japan	8	6	2	4
France	4	6	10	6
Canada	10	5	8	7
Australia	9	11	7	8
Italy	12	8	12	9
Korea	15	13	5	10

	Corporate Engagement	Number of Start-ups	Start-up Capital Raised	Supply Chain Maturity*	2021 ranking
USA	1	1	1	1	1
UK	**3**	**2**	**3**	**3**	**2**
Canada	-	3	2	4	3
Japan	4	6	7	6	4
France	5	5	8	5	4
China	2	8	9	7	6
Germany	5	4	16	2	7
Australia	-	8	4	9	8
Italy	-	14	20	9	10
Korea	-	23	20	-	10

** excluding nanofabrication infrastructure*

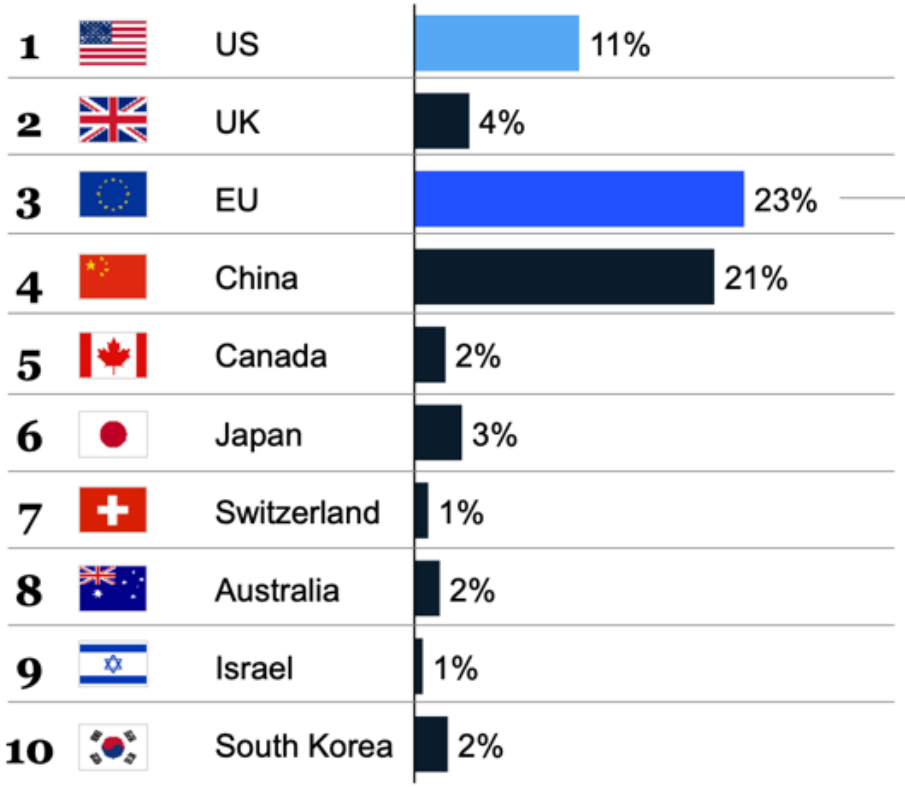
The European Union leads in quantum-relevant publications, but the United States outcompetes in impact

As of 2020

XX Rank of country's h-index

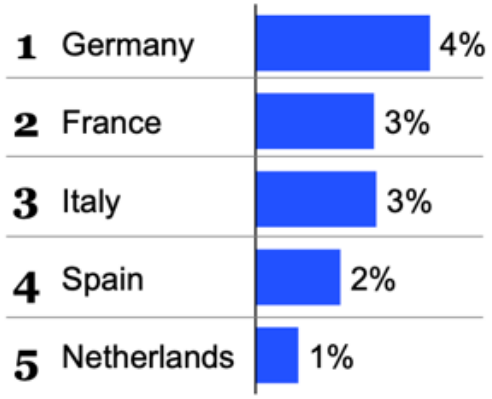
Top 10 countries worldwide 2020, by h-index

Share of articles and country's h-index[2] in quantum-relevant publications



Top 5 EU countries

Share of articles and H index, 2020



1. Quantum relevant publications defined as publications in physics, mathematics, and statistics, and information and communications technology
2. The h-index is the number of articles (h) in a country that have been cited at least h times

Source: SCImago Journal & Country Rank; McKinsey analysis

Key takeaways

US publications have the **highest impact** measured by h-index indicating a leading position in academic research

The EU is leading in terms of **published articles** in 2020 in quantum-relevant fields, followed by China and the US

From 2013-2024, UK government committed £1bn to QT

UK Quantum strategy: March 2023 Budget commits further £2.5bn

15 March 2023 — Policy paper

National quantum strategy

A 10-year vision and actions for the UK to be a leading quantum-enabled economy, recognising the importance of quantum technologies for the UK's prosperity and security.

New Government Department: DSIT; New Office for Quantum

UK National Quantum Strategy: Objectives

Committing to **invest £2.5 billion** of government funding in a new quantum R&D programme over the ten years from 2024.

Increasing our investment in quantum technologies from this year, with new funding available for missions programmes, skills, a quantum networking accelerator amongst other activities.

Committing to **launch new research hubs** and wider activities representing £100m.

Launch **new skills initiatives**, including doctoral training and fellowships.

Commission an **independent review** of the quantum sector's **infrastructure requirements**.

Showcase UK quantum companies at home and overseas, and support global quantum companies to come to the UK.

Accelerate government procurement of quantum technologies.

Expand our **partnerships** with **global allies**.

Department for Science, Innovation & Technology

2023-2024 ACTIONS – extra £265M Already Underway

- ~~£70M~~ £85M missions in quantum computing and PNT ✓
- £100 million in research hubs ✓
- £25 million for skills including quantum fellowships and doctoral training ✓
- £15 million Quantum Catalyst to boost government procurement. ✓
- £20 million Quantum Networks Accelerator ✓
- £20 million additional funding the National Quantum Computing Centre ✓
- Increased international collaborations via the new International Science Partnerships Fund ✓
- Preparations for the next Spending Review for delivery plan

UKRI Innovate UK

Department for Science, Innovation & Technology

What's happening in NQTP in '24: Infrastructure?

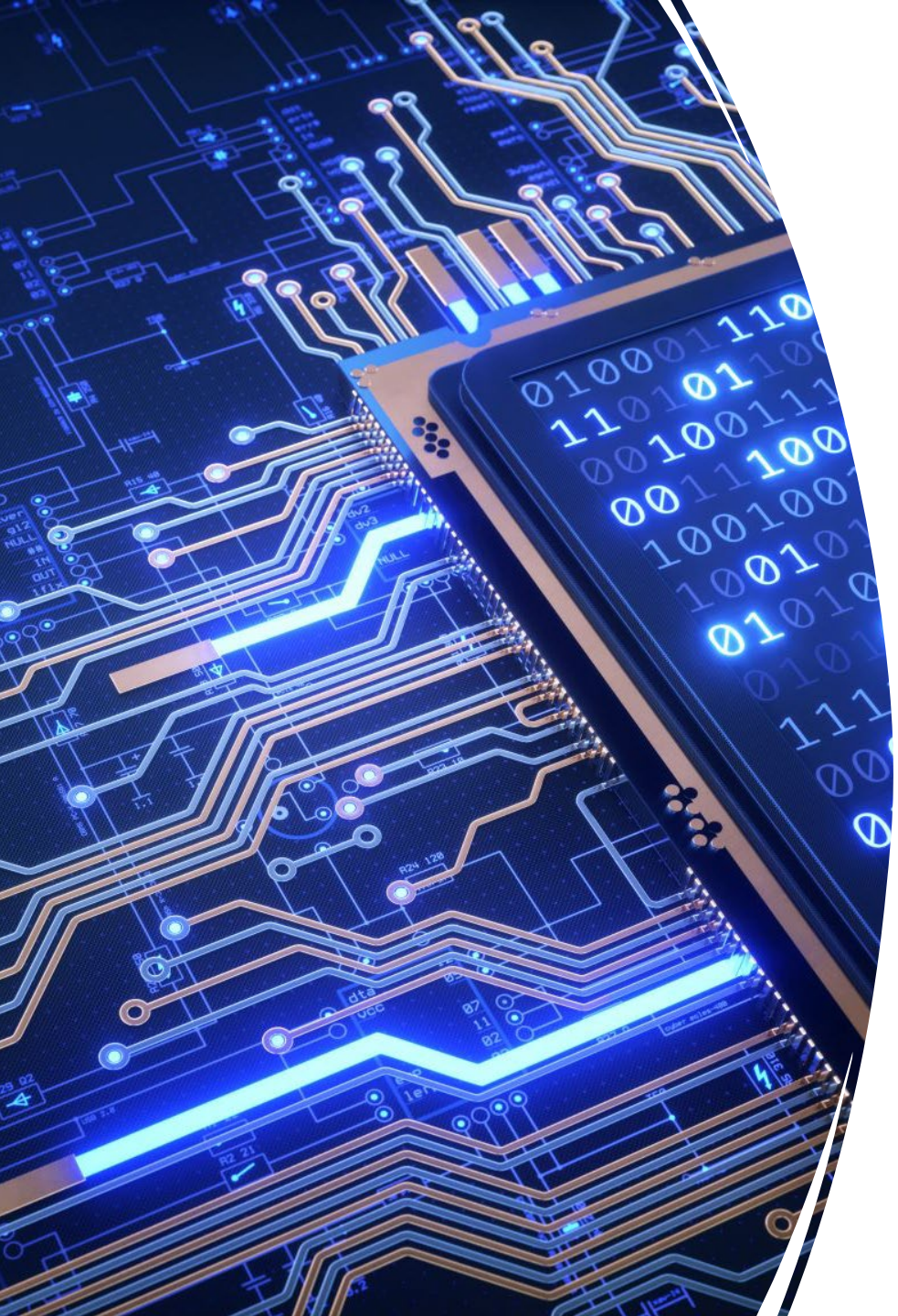
- Infrastructure and Facilities?
- UK Semiconductor strategy?
- Royal Academy of Engineering Task force 23-4
- IOP Skills Task Force
- Research fabrication of semiconductors, superconductors, silicon photonic structures
- Test facilities
- Fabrication at scale and trusted international partners.
- Developing 5 quantum missions at scale for the next decade.

Next phase of the UK programme – quantum missions at scale

- **Mission 1**
- By 2035, there will be accessible, UK-based quantum computers capable of running 1 trillion operations and supporting applications that provide benefits well in excess of classical supercomputers across key sectors of the economy.
- **Mission 2**
- By 2035, the UK will have deployed the world's most advanced quantum network at scale, pioneering the future quantum internet.
- **Mission 3**
- By 2030, every NHS Trust will benefit from quantum sensing- enabled solutions, helping those with chronic illness live healthier, longer lives through early diagnosis and treatment.
- **Mission 4**
- By 2030, quantum navigation systems, including clocks, will be deployed on aircraft, providing next-generation accuracy for resilience that is independent of satellite signals.
- **Mission 5**
- By 2030, mobile, networked quantum sensors will have unlocked new situational awareness capabilities, exploited across critical infrastructure in the transport, telecoms, energy, and defence sectors.

Where did the mission ideas come from?

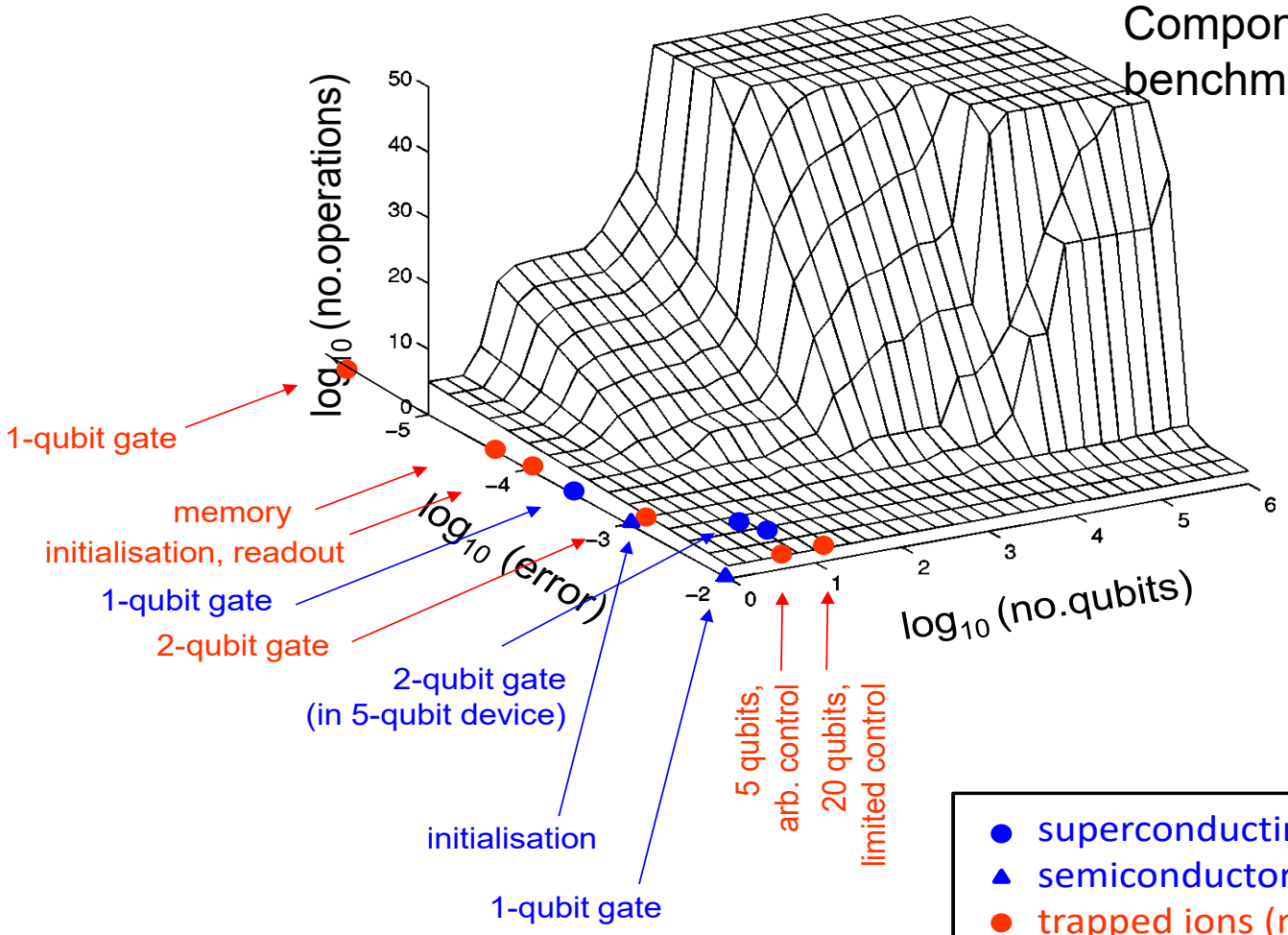
- *Under the National Quantum Strategy (NQS), the government committed to developing 10-year missions in partnership with the community.*
- *The aim is to identify ambitious 'moonshots' that crystallise investment and global partnerships around key outcomes for the technologies.*
- *The missions will not cover all activity which needs to happen as part of the delivering the NQS. Instead, they cover areas thought to be best suited to a mission focus on a particular outcome or outcomes that galvanise investment and collaboration.*
- *These missions have been prepared with input from experts in the sector and national programme. They will be refined during the next few months with Ministers and HMT as part of SR planning.*



Platforms for Quantum Processors

- Many different types:
  - Trapped ions – longest useful qubit lifetimes; needs chip scale fab
  - Neutral atoms
  - Superconducting – largest current qubit count but surface noise
  - Semiconductors
  - Photonics- needs chip-scale fabrication
- Current - Noisy Intermediate Scale Quantum (NISQ)
  - 100’s of physical qubits with no error correction
- Experimental devices fabricated US UK EU and China
  - US and China lead on superconducting types
  - US, UK and China fabricating trapped ion types
  - Photonics in UK, China, Canada
- Quantum computers will be used in combination with High Performance Computers; quantum networks
- Quantum sensors for PNT, healthcare, civil engineering

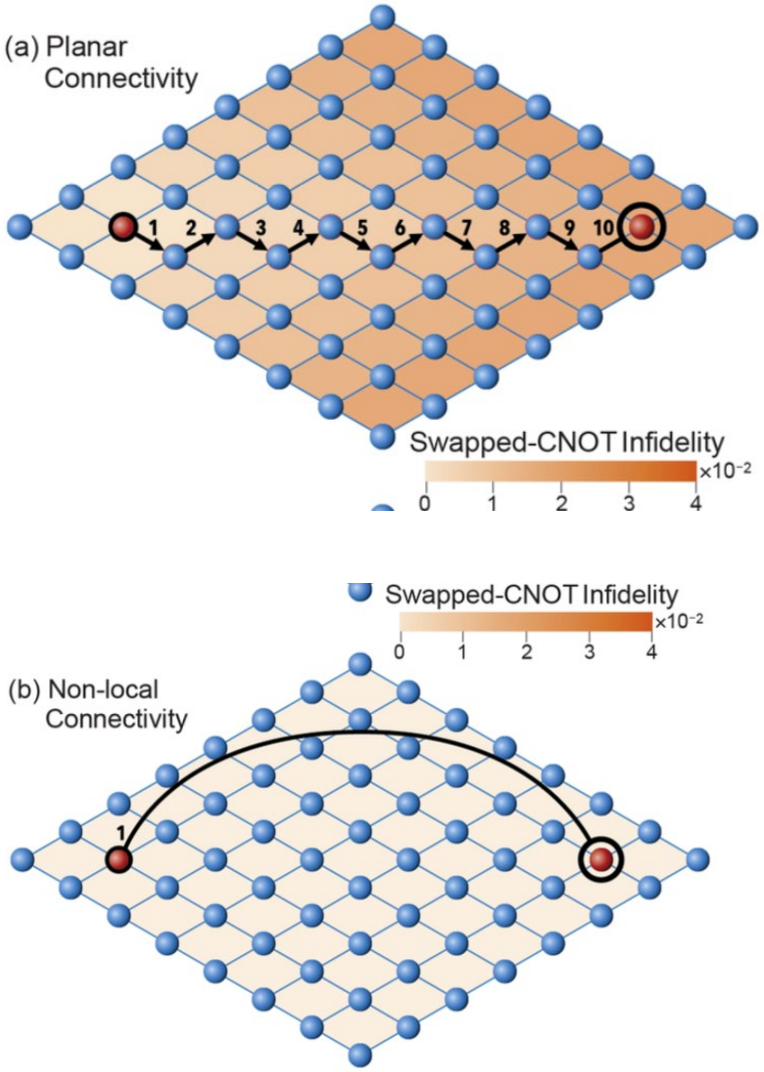
The Quantum Computing mountain



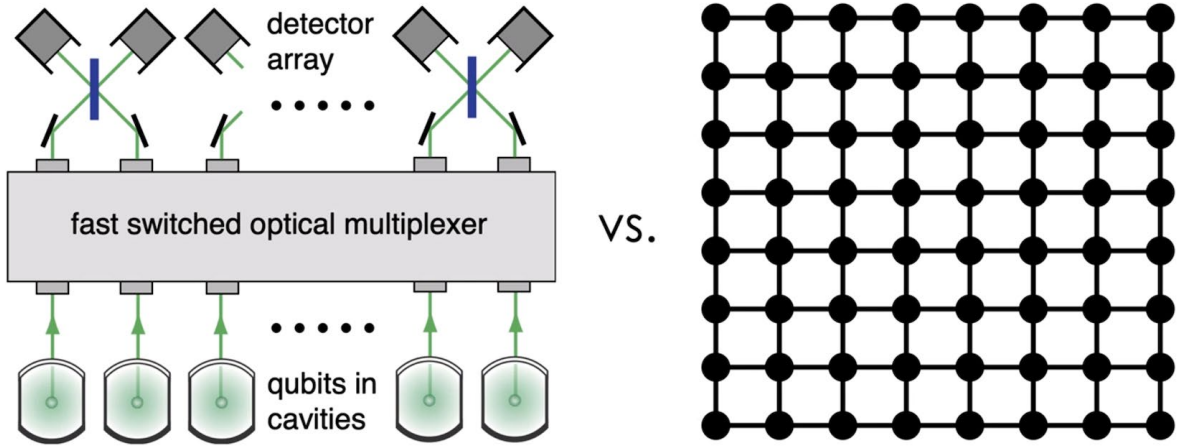
- Qubits are fragile, difficult to control, difficult to read ,full of errors, slow.
- Quantum Error Correction (QEC) enables fault tolerant QC with “logical“ qubits with large(?) physical qubit overhead
- Overhead depends on qubit quality

Points from David Lucas. Graph from *Overhead and noise threshold of fault-tolerant quantum error correction,* A.M.Steane, PRA 2003.

Connectivity: Stef Simmons &Photonic



Si^{28} T centres, electron spin plus 1 H and 2 C spins, don't need dil fridge- 1K ok, addressable with telecoms wavelengths. Embed in Purcell-cavities to link to fibre multiplexer; nuclear-electron spin swaps to initialize/read-out



Figs from Stef Simmons

Thank you for your attention