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FMF

Fakulteta za matematiko
in fiziko

will the second quantum revolution change your life?

olivier ezratty

⟨ author | ... ⟩

Ljubljana, April 17th, 2024

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14 May 2018

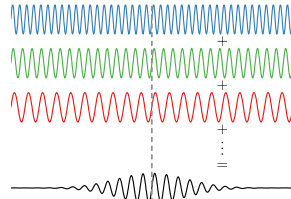
Alain Aspect

Fanny Bouton
at OVHcloud since June 2020

the second quantum revolution

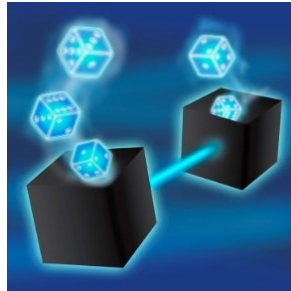
superposition

linked to wave-particle duality and linearity of Schrödinger's equation



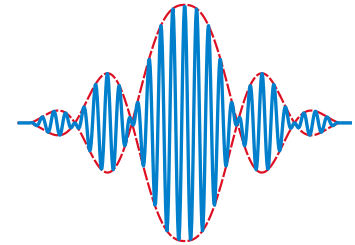
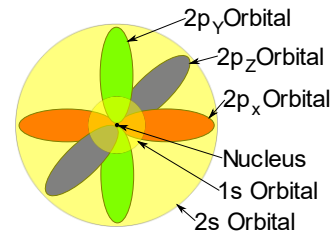
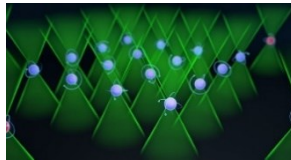
entanglement

state correlation of distant quantum objects, but random and after measurement



individual control of quantum objects

electrons, photons, atoms



quantum computing

quantum telecommunications

quantum cryptography

quantum sensing

sciences used with quantum technologies



physics

electromagnetism
quantum physics
quantum matter
thermodynamics
fluids mechanics
photonics



mathematics

linear algebra
groups theory
analysis
complexity theories



human sciences

philosophy
epistemology
sociology
technology ethics
economics of innovation
R&D policy making
geopolitics
startups ecosystem



engineering

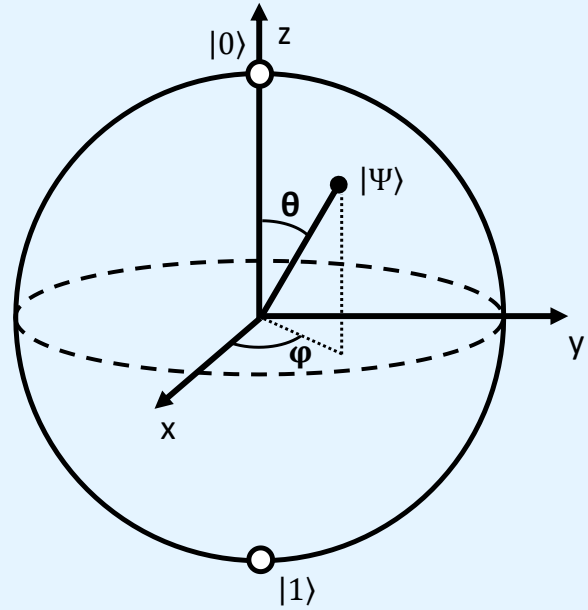
materials design
electronics engineering
cryogenics



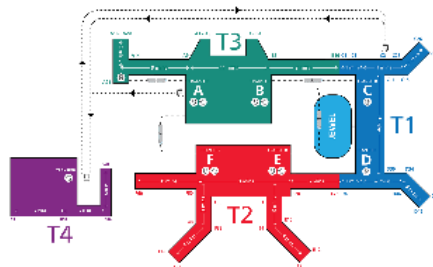
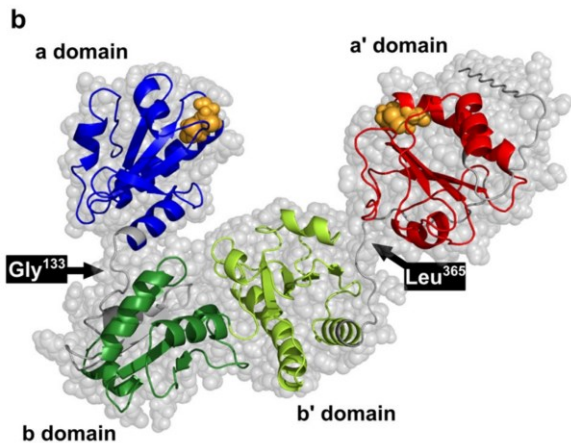
computer science

information theory
algorithms design
programming
classical computing
telecommunications
machine learning

quantum computing



typical difficult problems



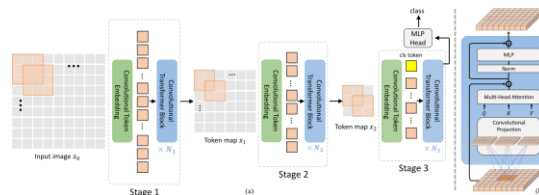
combinatorial optimizations

$$\begin{aligned} \frac{\partial^2 u_1}{\partial x_1^2} + \frac{\partial^2 u_2}{\partial x_2 \partial x_1} + \frac{\partial^2 u_3}{\partial x_3 \partial x_1} + \frac{\partial^2 u_1}{\partial x_1^2} + \frac{\partial^2 u_1}{\partial x_2^2} + \frac{\partial^2 u_1}{\partial x_3^2} + f_1 &= 0 \\ \frac{\partial^2 u_1}{\partial x_1 \partial x_2} + \frac{\partial^2 u_2}{\partial x_2^2} + \frac{\partial^2 u_3}{\partial x_3 \partial x_2} + \frac{\partial^2 u_2}{\partial x_1^2} + \frac{\partial^2 u_2}{\partial x_2^2} + \frac{\partial^2 u_2}{\partial x_3^2} + f_2 &= 0 \\ \frac{\partial^2 u_1}{\partial x_1 \partial x_3} + \frac{\partial^2 u_2}{\partial x_2 \partial x_3} + \frac{\partial^2 u_3}{\partial x_3^2} + \frac{\partial^2 u_3}{\partial x_1^2} + \frac{\partial^2 u_3}{\partial x_2^2} + \frac{\partial^2 u_3}{\partial x_3^2} + f_3 &= 0 \end{aligned}$$

solving partial derivative equations

$$i\hbar \frac{\partial \Psi(x,t)}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi(x,t)}{\partial x^2} + V(x)\Psi(x,t)$$

solving Schrodinger's wave equation
to simulate quantum matter

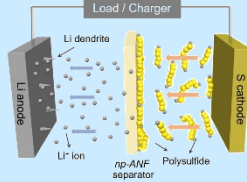


machine learning
and deep learning

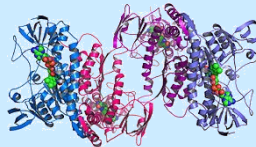
quantum computing usage categories

research

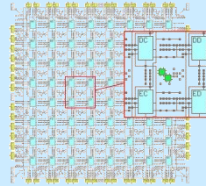
operations



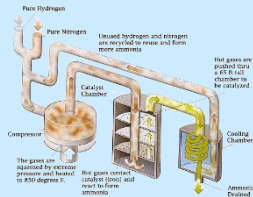
batteries



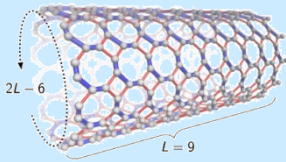
drugs



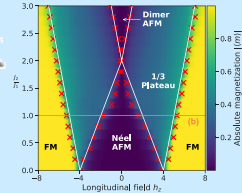
semiconductors



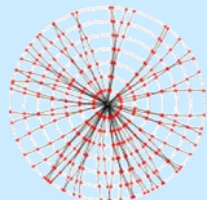
fertilizers production



materials design

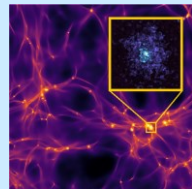


condensed matter physics

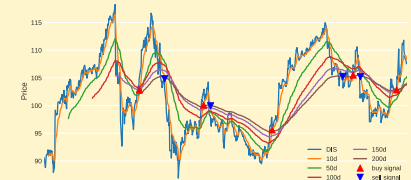


high-energy particle physics

astrophysics



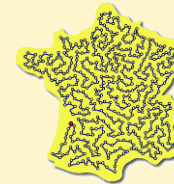
transportation



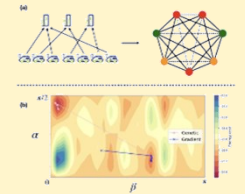
financial services



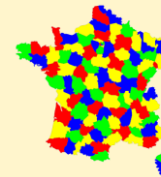
logistics



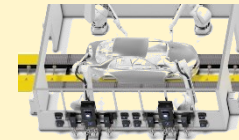
delivery



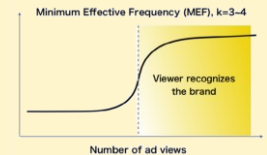
energy utilities



telecoms



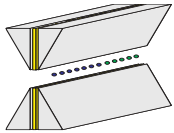
manufacturing



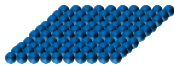
marketing

QPUs vendors per qubit type

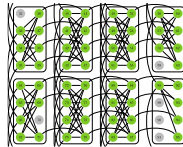
atoms



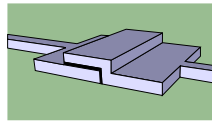
trapped ions



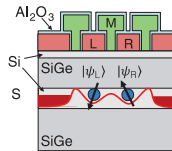
cold atoms



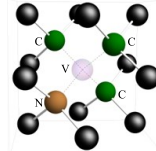
annealing



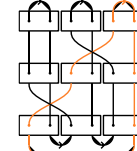
super-conducting



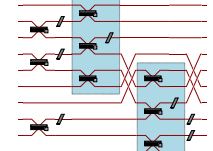
silicon



vacancies



topological



photons

electron superconducting loops & controlled spin



all qubit types have their challenges

quantum annealing

- mature **development tools** offering.
 - large number of **software startups**, particularly in Japan and Canada.
 - quantum annealers are available in the **cloud** by D-Wave and Amazon Web Services.
 - the greatest number of well documented **case studies** in many industries although still at the proof of concept stage.
 - most universal qubits gates algorithms can have an equivalent on quantum annealing.
- all algorithms are **hybrid**, requiring some preparation on classical computers.
 - only **one operational commercial vendor**, D-Wave.
 - computing **high error rate**.
 - most **commercial applications** are still at the pilot stage and not production-grade scale, but they are closer than gate-based use cases.
 - **no generic operational proof** of quantum advantage.

superconducting qubits

- **key technology** in public research and with commercial vendors (IBM, Google, Rigetti, Intel, Amazon, OQC, IQM, etc).
 - **record of 433 programmable qubits** with IBM.
 - constant progress in **noise reduction**, particularly with the cat-qubits variation which could enable a record low ratio of physical/logical qubits.
 - many existing **enabling technologies**: cryostats, cabling, amplifiers, logic, sensors.
 - **potentially scalable technology** and deployable in 2D geometries.
- qubit coherence time usually $< 300 \mu\text{s}$.
 - cryogeny constrained technology at $< 15 \text{ mK}$.
 - heterogeneous qubits requiring calibration and complex micro-wave frequency maps.
 - qubit coupling limited to neighbor qubits in 2D structures (as compared with trapped ions).
 - **cabling complexity** and many passive and active electronic components to control qubits with micro-waves.
 - qubits size and uneasy miniaturization.
 - qubit fidelities are average with most vendors.

silicon spin qubits

- good **scalability potential** to reach millions of qubits, thanks to their size of $100 \times 100 \text{ nm}$.
 - works at around **100 mK - 1K** \Rightarrow larger cooling budget for control electronics vs superconducting qubits.
 - **relatively good qubits fidelity** reaching 99.6% for two qubits gates in labs for a small number of qubits.
 - adapted to **2D architectures** usable with surface codes or color codes QEC.
 - can leverage existing semiconductor fabs.
 - good quantum gates speed.
- active research in the field started later than with other qubit technologies and spread over several technologies (full Si, SiGe, atom spin donors).
 - less funded startup scene.
 - qubits variability to confirm.
 - high fabs costs and long test cycles (18 months average).
 - so far, only 4 to 15 entangled qubits (QuTech, UNSW, Princeton, University of Tokyo).
 - scalability remains to be demonstrated.

qubits NV centers

- works at **4K**, with simple cryogeny without dilution and helium 3.
 - can also potentially work at **ambient temperature**, with some limitations on entanglement.
 - long coherence time $> 1 \text{ ms}$.
 - **strong and stable diamond structure**.
 - can also help create **quantum memory** for other qubits types, like superconducting qubits.
 - possible to integrate it with **optical quantum telecommunications**.
- room-temperature operations need some fact-check.
 - not demonstrated at scale so far.
 - qubits controls complexity with lasers and microwaves \Rightarrow not easy to scale.
 - NV centers applications are more centered on quantum magnetometry and sensing than computing.
 - high-complexity of NV centers circuits manufacturing.

trapped ions qubits

- **identical ions** \Rightarrow no calibration required like with superconducting/electron spin qubits.
 - **good qubits stability**.
 - **excellent qubit gate fidelities** and high ratio between coherence time and gate time \Rightarrow supports deep algorithms in number of gate cycles.
 - **entanglement** possible between all qubits on 1D architecture which speeds up computing, avoiding SWAP gates.
 - requires some cryogeny at 4K to 10K \Rightarrow simpler.
 - easy to entangle ions with photons for long distance communications.
- unproven scalability options beyond 50 qubits (ions shuttling, 2D architectures, photon interconnect, micro-Penning traps).
 - two-qubit gate times increasing with ion distance in 1D and 2D settings.
 - relatively slow computing due to long quantum gate times which may be problematic for deep algorithms.

neutral atoms qubits

- long qubit coherence time and fast gates.
 - **operational systems** with 100-300 atoms.
 - **identical atoms**, that are controlled with the same laser and micro-wave frequencies (but dual-elements architectures are investigated).
 - works in both **simulation and gate-based** paradigms.
 - no need for specific integrated circuits.
 - uses **standard apparatus**.
 - low energy consumption.
- adapted to quantum simulations more than to universal qubits computing.
 - crosstalk between qubits that can be mitigated with two-elements atom architectures.
 - not yet operational QND (quantum non demolition) measurement that is required for QEC and FTQC.
 - slow operations (1 Hz simulation cycle).
 - hard to implement with gate-based model.
 - losing atoms during computing.

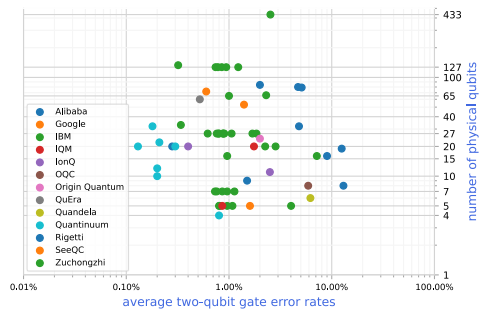
Majorana fermions

- **theoretically very stable qubits** with low level of required error correction.
 - long coherence time and gates speed enabling processing complex and deep algorithms.
 - **potential qubits scalability**, built with technologies close to electron spin qubits.
 - some researches in the topological matter field could be fruitful with no Majorana fermions.
- topological qubits programming is different and requires an additional software layer.
 - rather few laboratories involved in this path.
 - no startup was launched in this field. Microsoft is the only potential vendor. IBM is investigating the field in Zurich.
 - works at low cryogenic temperatures like superconducting qubits $< 20 \text{ mK}$.
 - no Majorana fermion qubit demonstrated yet.

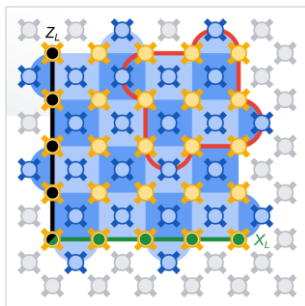
photons qubits

- **stable qubits** with absence of decoherence.
 - qubits processing at **ambient temperature**.
 - **emerging nano-photonics** manufacturing techniques enabling scalability.
 - **easier to scale-out** with inter-qubits communications and quantum telecommunications.
 - MBQC/FBQC circumventing the fixed gates depth computing capacity.
- need to cool photon sources and detectors, but at relatively reasonable temperatures between 2K and 10K, requiring lightweight cryogenic systems.
 - boson sampling based quantum advantage starts to being programmable but a practical quantum advantage remains to be proven.
 - not yet scalable in number of operations due to probabilistic character of quantum gates and the efficiency of photon sources in most paradigms.

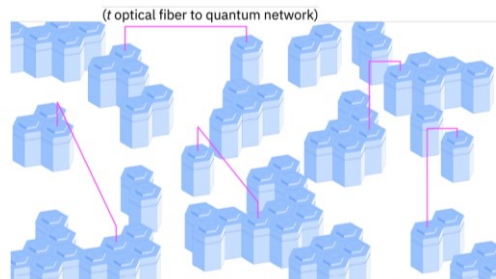
key QPU challenges



qubits fidelities

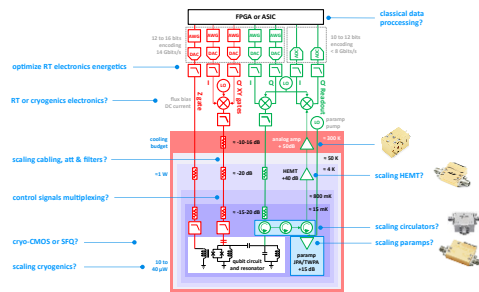


errors mitigation and correction

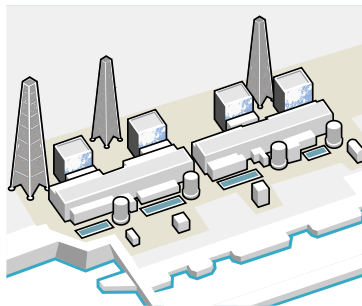


(e) type modularity involves microwave-to-optical transduction to link QPUs in different dilution refrigerators.

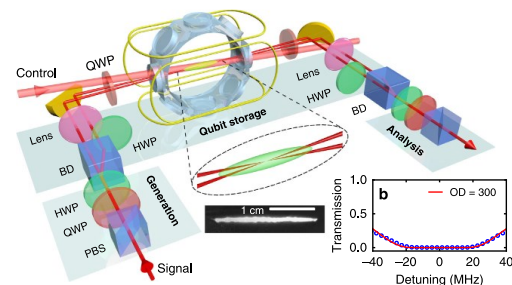
quantum interconnect



enabling technologies scalability



energy consumption



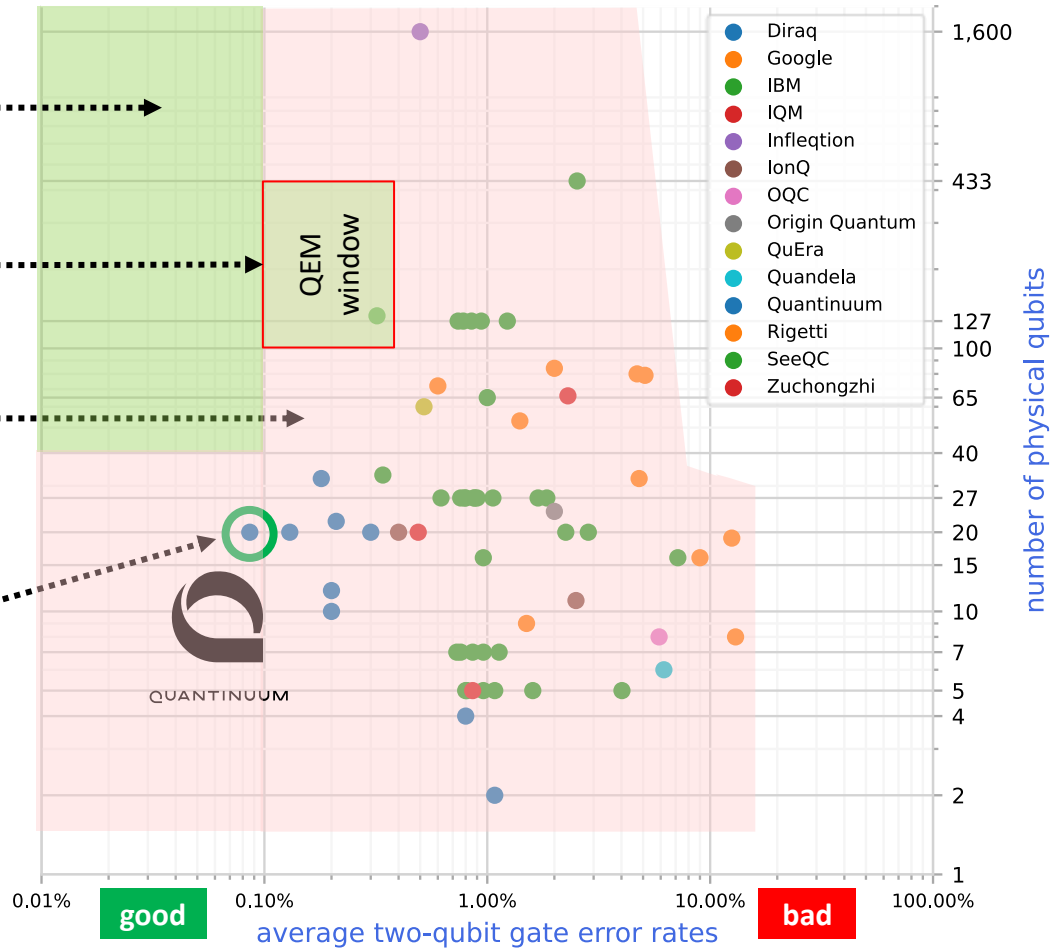
quantum memory

useful NISQ*
requirements

with quantum error mitigation

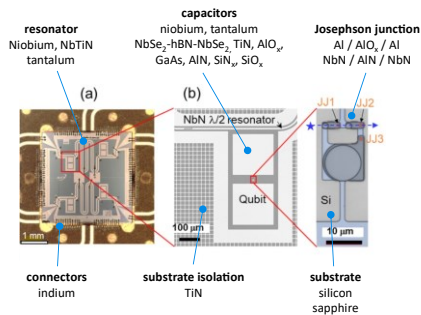
state of the art
 easy to emulate classically,
 too noisy to be useful

first 99.9% fidelities
 April 16th, 2024

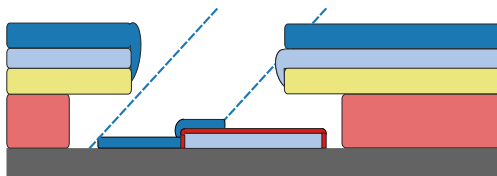


* NISQ = noisy intermediate scale quantum computers.

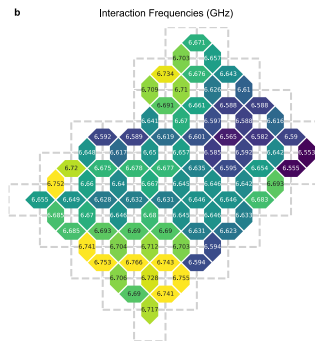
how to improve qubit fidelities? *



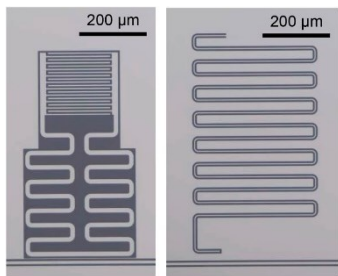
materials



manufacturing



reduce crosstalk



tune qubit parameters

Cross-Cross Resonance Gate

Kentaro Heya^{1,2,*} and Naoki Kanazawa^{1,†}

¹IBM Quantum, IBM Research Tokyo, 19-21 Nihonbashi Hakozaki-cho, Chuo-ku, Tokyo 103-8510, Japan

²Research Center for Advanced Science and Technology (RCAST), The University of Tokyo, Meguro-ku, Tokyo 153-8904, Japan

High-fidelity three-qubit *i*Toffoli gate for fixed-frequency superconducting qubits

Yosep Kim,^{1,*} Alexis Morvan,¹ Long B. Nguyen,¹ Ravi K. Naik,^{1,2} Christian Jünger,¹

Larry Chen,² John Mark Kreikebaum,^{2,3} David I. Santiago,^{1,2} and Irfan Siddiqi^{1,2,3}

¹Computational Research Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

²Department of Physics, University of California, Berkeley, California 94720, USA

³Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

(Dated: December 21 2022)

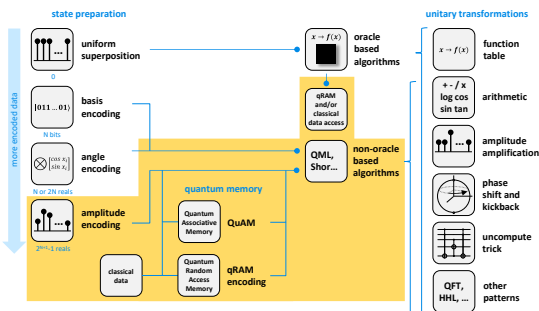
use different primary gates



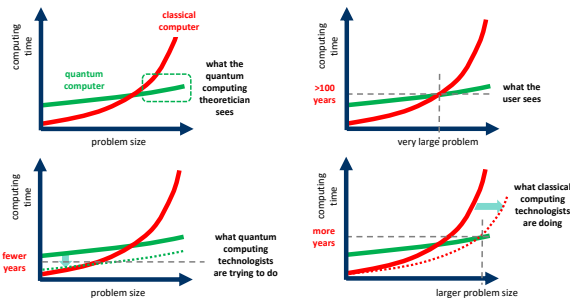
improve control signals quality

* using here the example of superconducting qubits

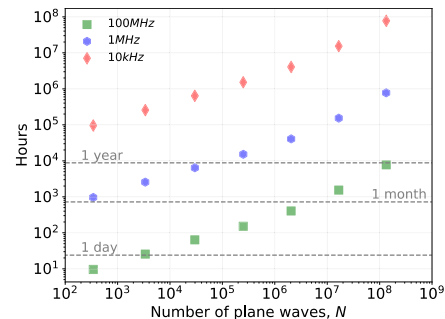
some software challenges



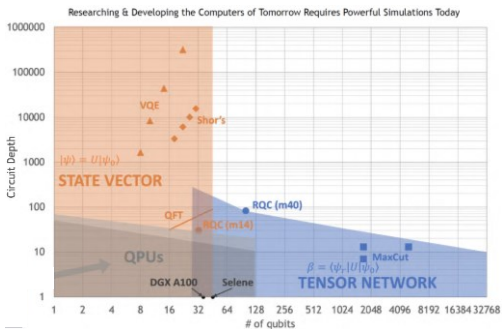
data loading



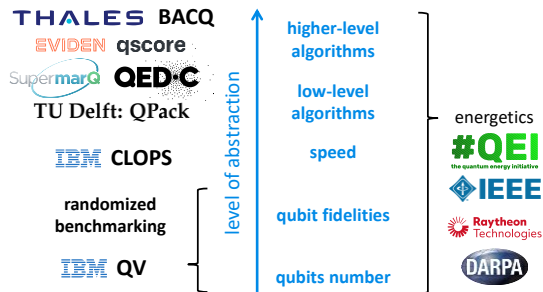
actual speedups



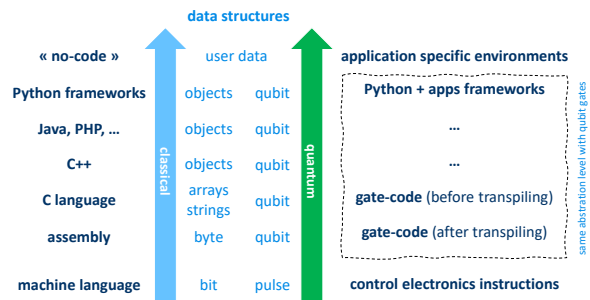
actual computing time



tensor networks competition

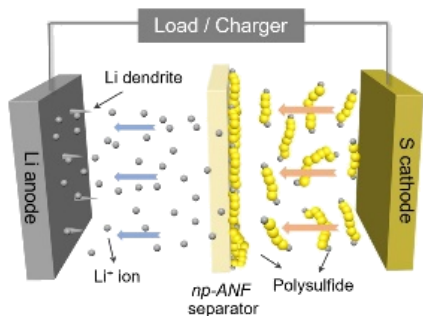


benchmarking



coding abstraction level

simulate matter for...



**quantum digital
twins to create
better batteries**



battery simulation

lithium-oxygen

source: IBM



Mercedes-Benz

battery simulation

estimating the cost of electrolyte
simulation on PsiQuantum's future QPU.

source: PsiQuantum, Mercedes-Benz



battery simulation

model lithium oxide to understand how
batteries age over time

source: Hyundai, IonQ

DAIMLER

battery simulation

lithium-sulfur battery design

source: IBM



battery simulation

simulating magnetism and spins

source: Samsung, Honeywell



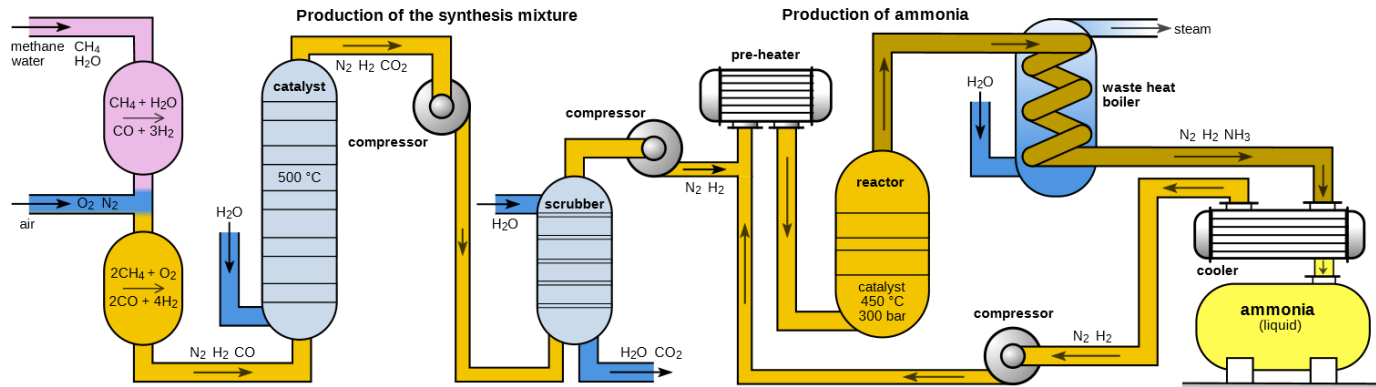
TotalEnergies

battery materials design

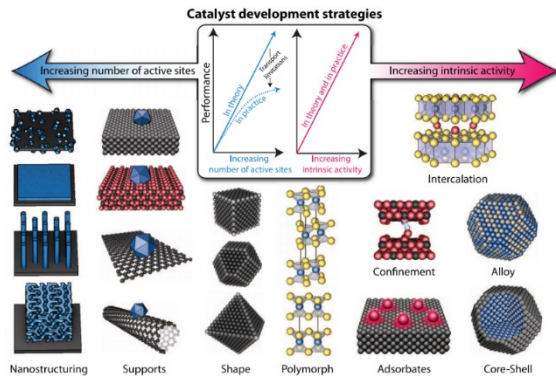
simulating Mott insulator transitions in battery
electrode materials and ceramic superconductors
and discharge curve of Li_xCoO_2 .

source: Total, Pasqal

simulate matter for...



producing
fertilizers with
less energy



FeMoCo role in nitrogen fixation

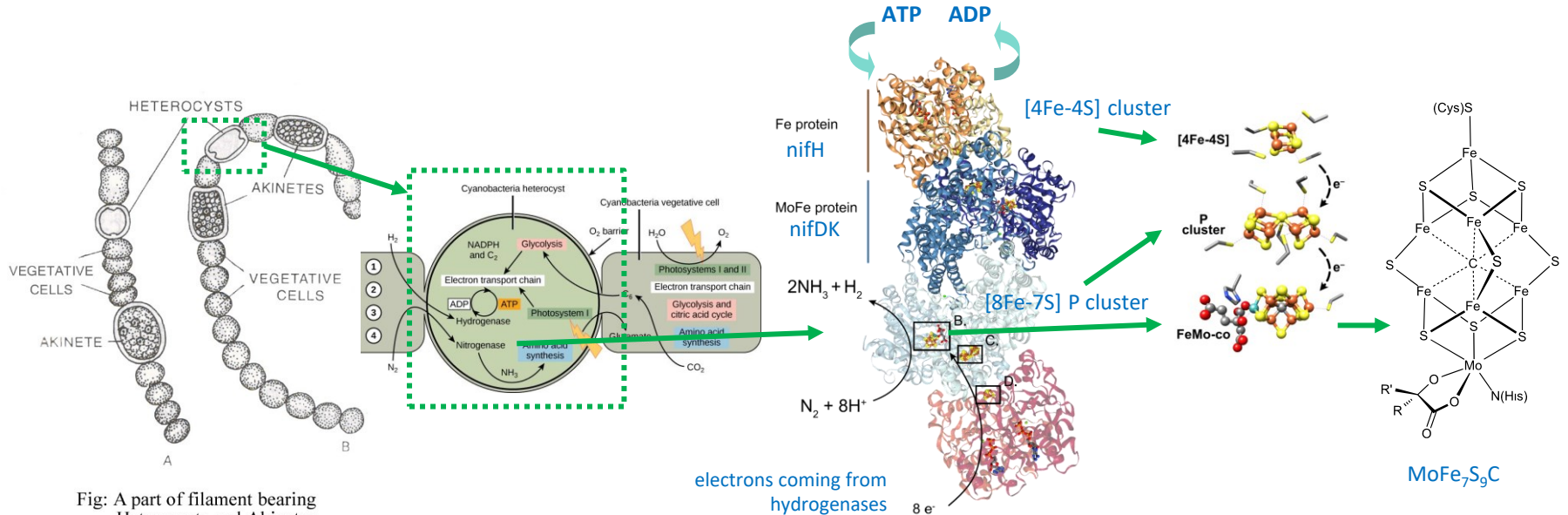


Fig: A part of filament bearing Heterocysts and Akinetes.

cyanobacteria

bacteria producing ammonia in soil and water or legume plants root nodules

heterocyst

cell within cyanobacteria that support the chemical pathways producing ammonia using dinitrogen

nitrogenase

protein complex producing ammonia in heterocyst cells

FeMoCo complex

part of the two nifDK proteins in some nitrogenases that is involved in ammonia production

quantum sensors

- less invasive imaging (MRI, MEG) and better precision biological sensors (NV centers).

drugs discovery

- DNA sequence alignment.
- de novo DNA sequence.
- protein folding and interactions with ligands.
- force field and electronic structure computation.
- screening and generation of molecular entities as drug candidates.
- drug retargeting.

diagnostics

- medical images classification and reconstruction.
- disease assesement based on genomic samples.
- clinical data classification and analysis.
- disease risk prediction.
- clustering of similar individuals.

treatments

- persistence and health-related behavior prediction.
- treatment and intervention effectiveness forecasting.
- disease outbreak prediction and spread modeling.
- precision oncology.
- tailored radiotherapy.
- hospital capacities optimization.

simulating nature

- chemical simulations.

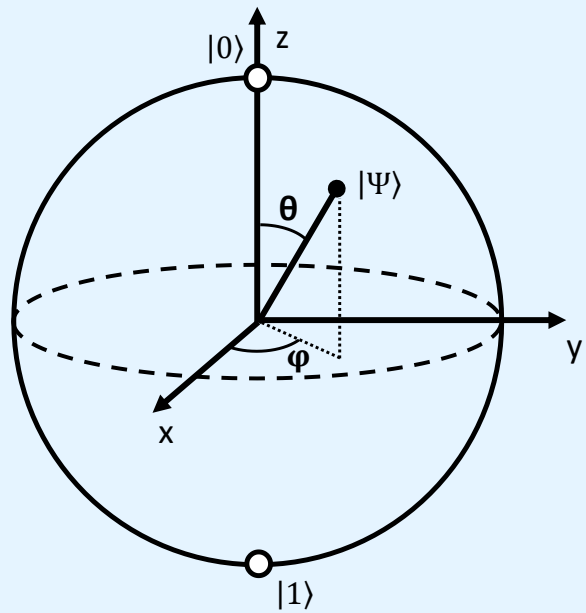
data processing

- images and structured data.
- quantum machine learning.

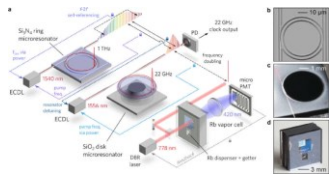
search and optimizations

- various datasets.

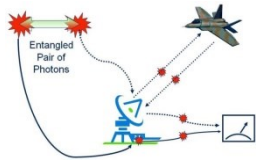
quantum sensing



quantum sensing



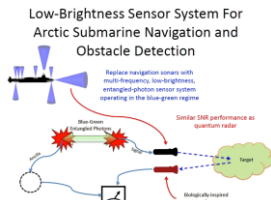
clocks
spectrographs
ultra-sound mikes



radars
LiDARs



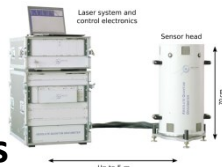
entangled photons



ultra-sensitive
imaging



RF
analysis



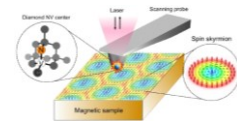
gravimeters



cold atoms

gyroscopes

sonars



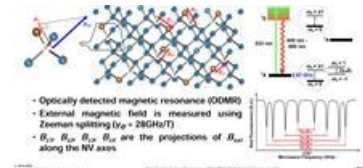
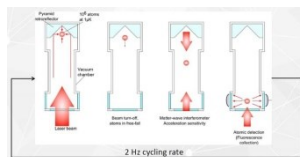
microscopy, medical imaging

magnetometers thermometers

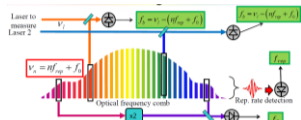


SQUIDs

NV centers



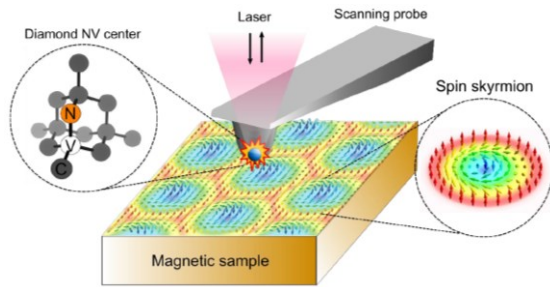
(cc) Olivier Ezratty, 2021-2023.



lasers and
frequency combs

sensor type			qubit nature		type I	type II	type III	rotation	acceleration	force	pressure	displacement	time	frequency	refractive index	magnetic field	electric field	voltage	temperature	mass		
neutral atoms	atomic vapor		atomic spin			X	X	X					X	X		X						
	cold atom clouds		atomic spin			X	X		X				X	X		X						
Rydberg atoms			Rydberg states			X	X										X					
trapped ions			electronic state			X	X	X			X		X	X								
			vibrational mode			X					X								X			
solid state	spin ensembles	NMR		nuclear spins			X									X						
		NV/SiC center ensembles		electron spins			X		X			X					X	X		X		
	single spins	P donor in Si		electron spins			X									X						
		quantum dot		electron spins		X	X										X	X				
		single NV center		electron spins			X		X		X					X	X		X			
superconducting circuits			SQUIDs		supercurrent		X	X								X						
			flux qubits		circulating current			X										X				
			charge qubits		charge eigenstates			X											X			
single electron transistor			charge eigenstates		X												X					
optomechanics			phonons		X				X	X						X		X				
interferometer			photons, atoms			X	X	X				X			X							

quantum sensors in healthcare

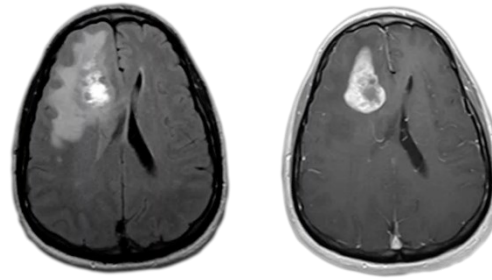


magnétomètres ultrasensibles
 $210 \text{ fT}/\sqrt{\text{Hz}}$

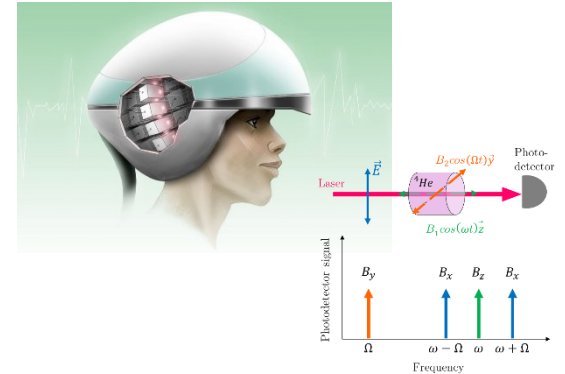
medical imaging
biological analysis



chipiron

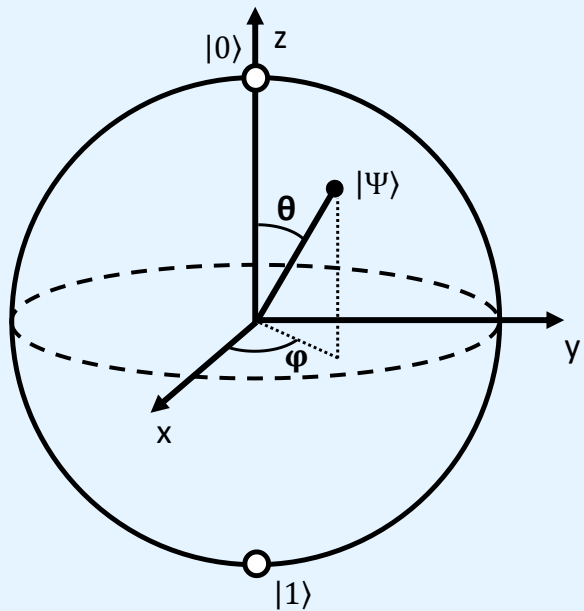


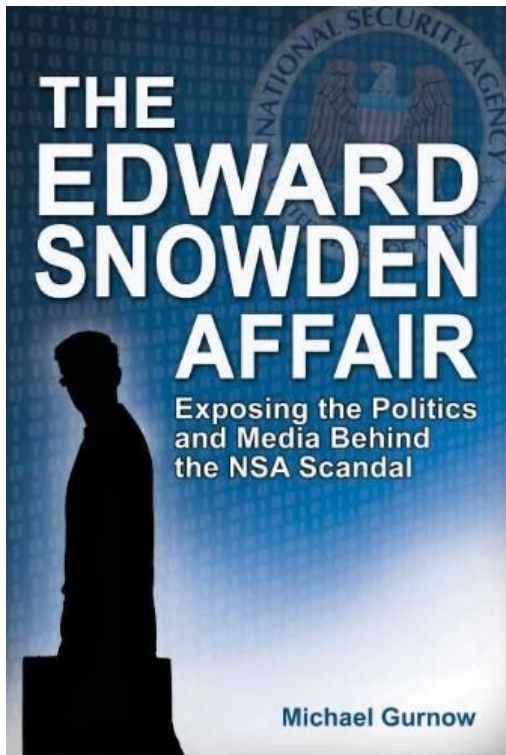
SQUID based
ultra-low field MRI



helium 4 nucleus spin
MEG brain imaging

quantum communications and cryptography





Quantum Computing Paranoia Creates a New Industry

Even though quantum computers don't exist yet, security companies are preparing to protect against them.

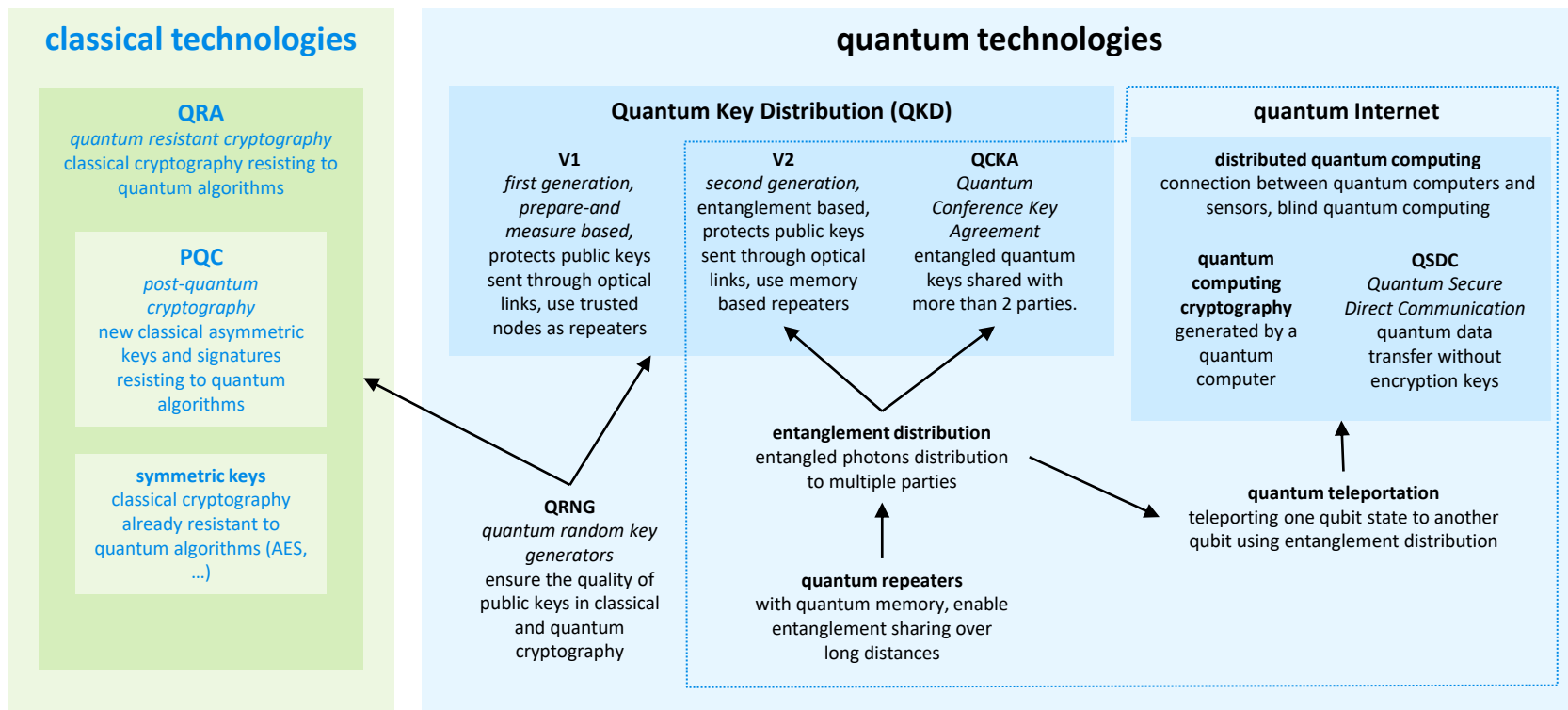
by Tom Simonite January 30, 2017

**MIT
Technology
Review**

Fear sells in the computer security business. And in late 2015 Massachusetts-based **Security Innovation** got an unexpected boost from one of the scariest organizations around—the National Security Agency.

For six years the company had been trying to create a new revenue stream by licensing an unusual encryption technology called NTRU, which it **acquired** from four Brown University mathematicians. It was invented as a solution to the powerful code-breaking power of computers that exploit quantum physics, but interest was slack because quantum computers didn't yet exist or look likely to exist anytime soon.

quantum telecommunications



quantum random number generators

photons
counting



Q → NU



photons
arrival time



PICOQUANT



vacuum
fluctuations



⟨InfiniQuant⟩



other



phase noise



self-certified SDI
QRNG



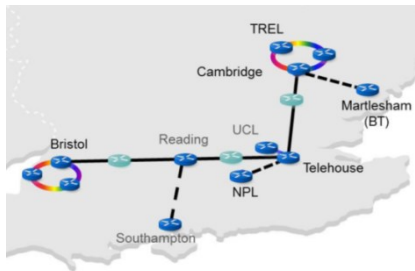
QUANTUM
DICE

radioactive
decay



qubits
measurement





Netherlands
Delft, Leiden, Amsterdam, The Hague OpenQKD project 2019

Germany
QKD project, 165M€ 2019-*

Tchekia
OpenQKD project 2019

Poznan
2021

Denmark
Dantze Bank DTU 2022

Ireland
2022

Cambridge – London – Bristol
2018

Ile de France
2020-
OpenQKD project

Nice/Sophia
2020
3 sites

Madrid
2018
Telefonica & Huawei

Barcelona
2020

Canaries
2007/2010
144 km free to air



(cc) Olivier Ezratty, 2022-2023



Vienna
2008
SECOQC, 5 nodes, 20/25 km



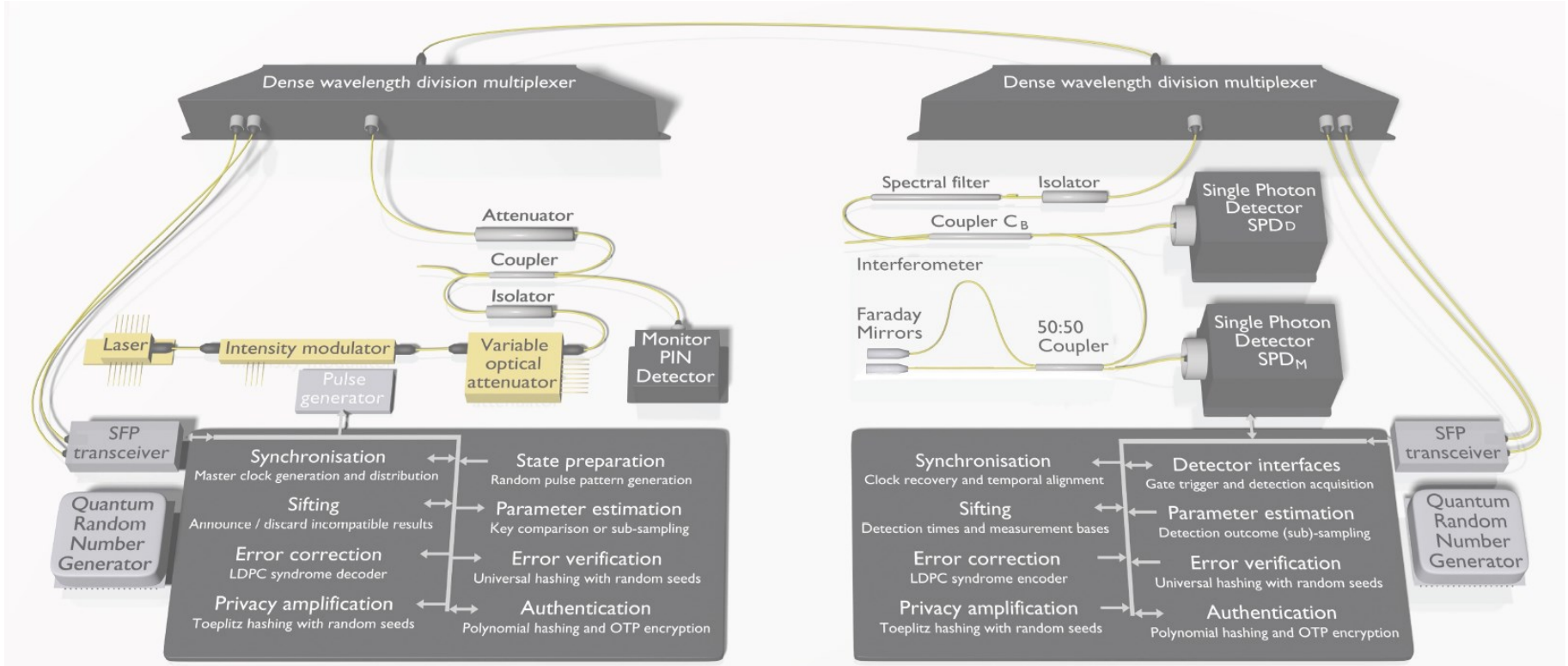
Geneva
1993, 1995, 2007, 2018 (400 km)

Italy-Slovenia-Croatia network

Italian Quantum Backbone (IQB) 1,850 km QKD link connects Turin, Milan, Bologna, ..., a 150 km fiber reaches Modane in France, and connects to Grenoble, Lyon and Paris, then Europe + Padua satellite/ground QKD experiment

Athens
2019
OpenQKD project DataCom

QKD hardware settings



UPDATES 2023

Comments Requested on Three Draft FIPS for Post-Quantum Cryptography

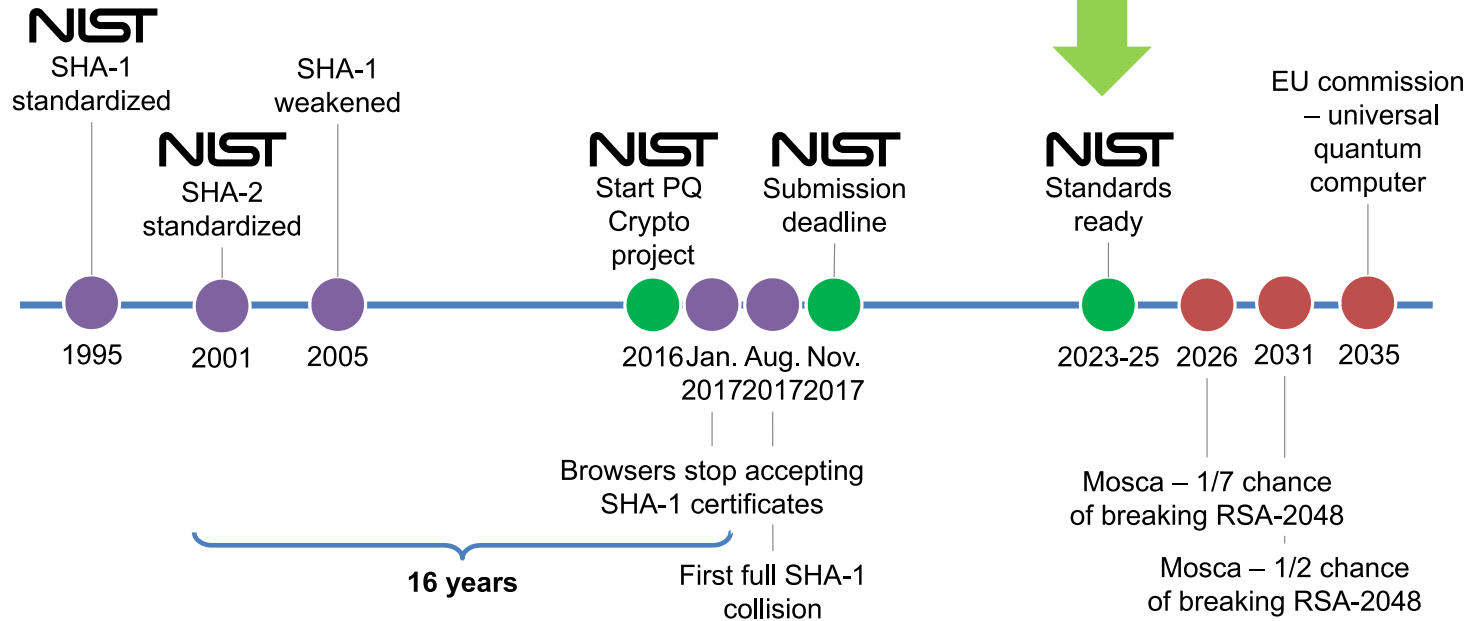
August 24, 2023

f t

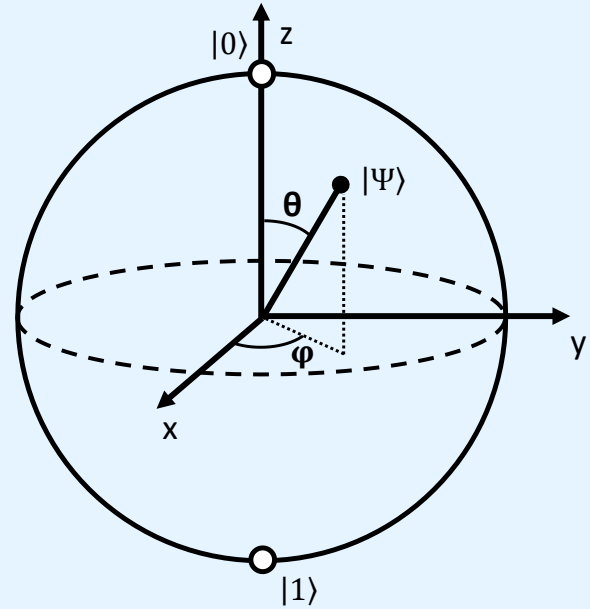
NIST requests comments on the initial public drafts of three Federal Information Processing Standards (FIPS):

1. FIPS 203, [Module-Lattice-Based Key-Encapsulation Mechanism Standard](#)
2. FIPS 204, [Module-Lattice-Based Digital Signature Standard](#)
3. FIPS 205, [Stateless Hash-Based Digital Signature Standard](#)

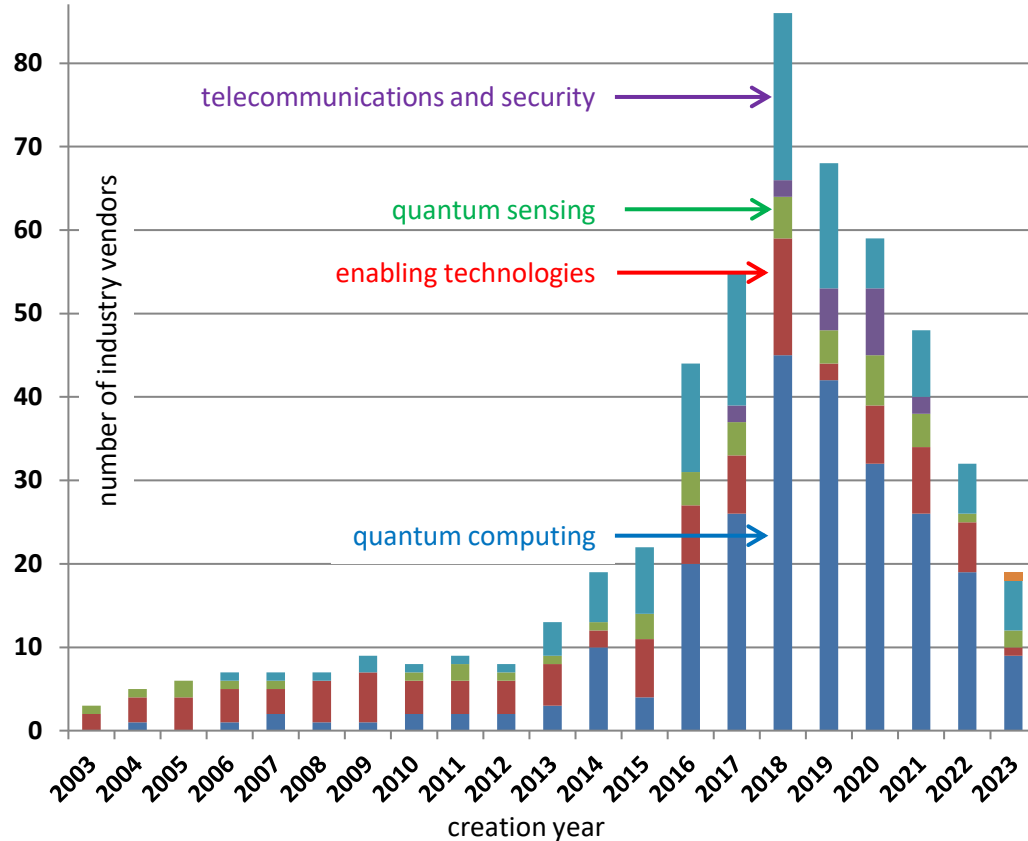
we are here



quantum technologies ecosystem



industry vendors country + creation year

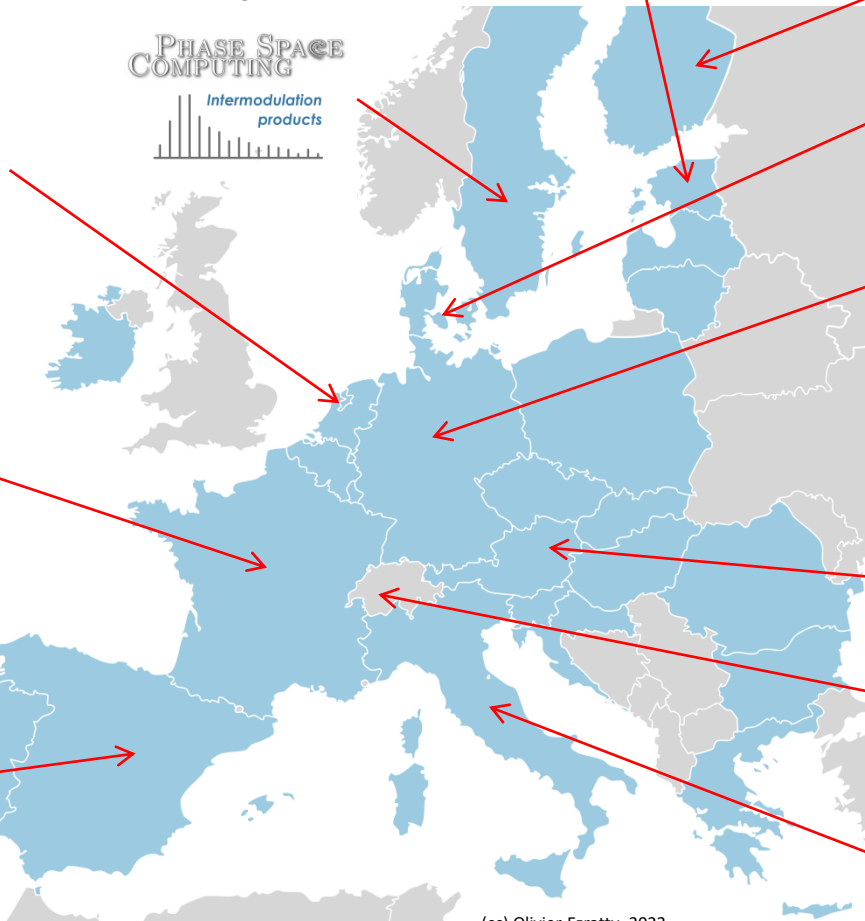
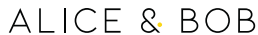


Country	Computing	Enabling	Sensing	Services	Comm - Sec	Total
USA	70	43	19	4	32	168
UK	23	17	8	5	20	73
France	14	29	10	4	6	63
Canada	34	8	5		14	61
Germany	25	22	4	1	7	59
Japan	13	7		1	4	25
China	11		2		10	23
India	13			3	5	21
Switzerland	4	9	1		5	19
Netherlands	8	4	1	1	3	17
Spain	9	4			2	15
Finland	5	3		2	3	13
Israel	6	2	2		3	13
Australia	6	1	3	1	2	13
Italy	3	3	1	1	3	11
Denmark	3	6			2	11
Singapore	6	1	1	1	1	10
Sweden	3	5				8
Poland	4	1			2	7
Russia		2			4	6
South-Korea	2				3	5
Austria	3				2	5
Taiwan	1	1			2	4
Estonia	2				1	3
Tchekia				1	1	2
Turkey		1	1			2
Hong-Kong	2					2
Belgium		2				2
UAE	2					2
Bulgaria	1				1	2
Greece	2					2
Chile					1	1
Bielorussia	1					1
Luxembourg		1				1
Columbia	1					1
Lybia	1					1
Uruguay	1					1
Slovenia	1					1
Norway	1					1
Ukraine	1					1
Total	282	172	58	25	139	676

source : Olivier Ezratty compilation, 2023




QUANTASTICA |Ketita)



(cc) Olivier Ezratty, 2023

computers



OpenSuperQPlus
superconducting qubits



AQTION
trapped ion qubits



microQC
trapped ion qubits



QLSI
silicon qubits



QUANTUM FLAGSHIP
European Flagship
Quantum Technologies

simulators




Qombs
cold atoms



PASQuanS²
cold atoms and trapped ions



PhoQuS
Photons for Quantum Simulation
photons



SQUARE
trapped ions (simulation and universal QC)

software



NE|AS|QC
software applications

telecoms



QIA | QUANTUM INTERNET ALLIANCE
repeater network, interface with qubits



CiviQ
QKD on photonics, telcos



UNIQUORN
Affordable Quantum Communication for Everyone
system on chip



QMiCS
IPC micro-waves



QRANGE
QRNG, CMOS SPADs



S2QUIP
photonic



2D-SIPC
photonic

sensing



ASTERIOS
NV centers



MetaboliOS
IRM & NV centers



macQsimal
cold atoms



laClock
optical clock

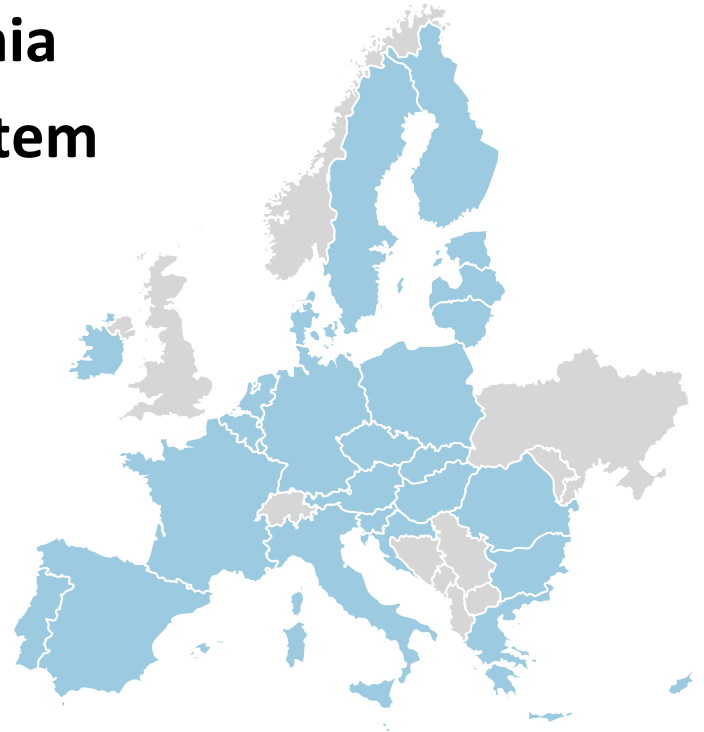


PhoG
photons

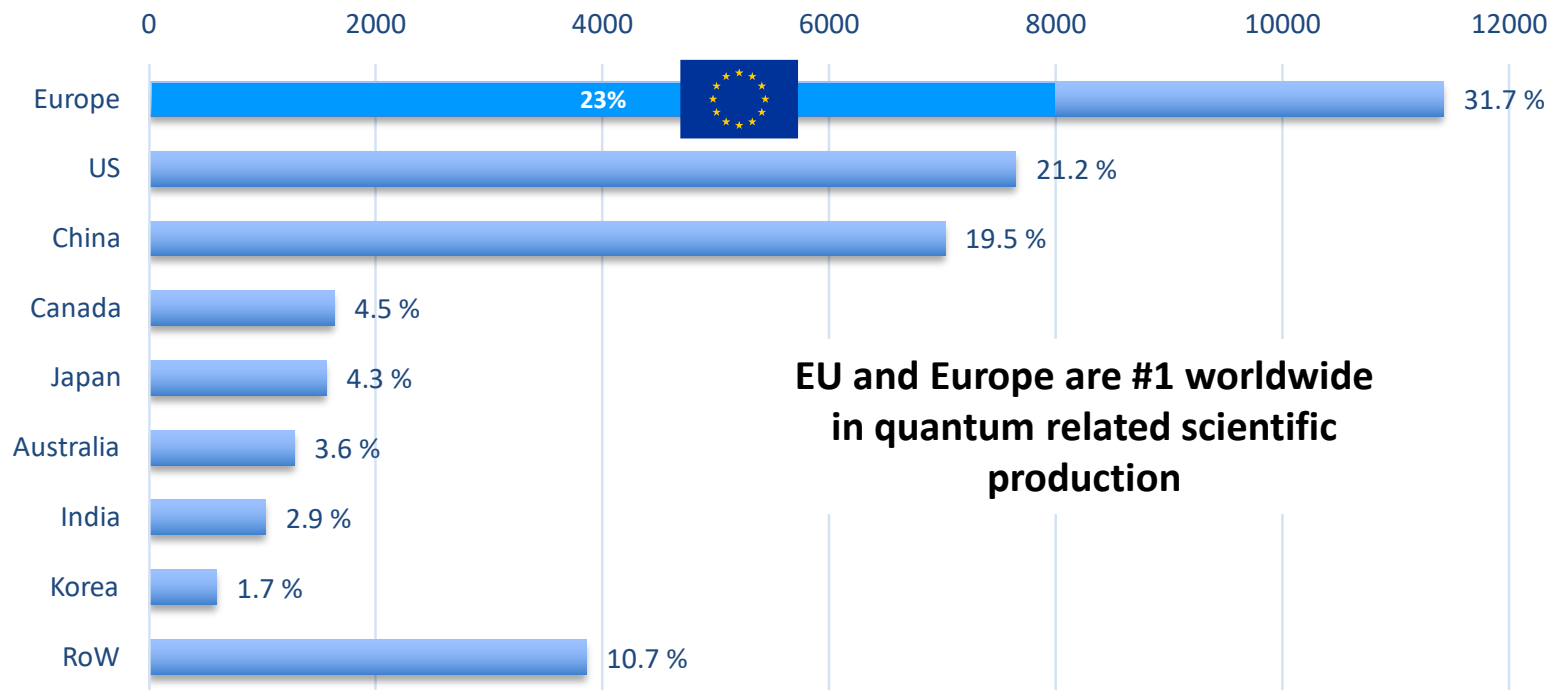
what makes EU* unique in quantum

1. strong public research and academia
2. dynamic quantum industry ecosystem
3. enabling technologies leadership
4. HPC and early pilot projects
5. responsible innovation

* adding UK and
Switzerland when
convenient

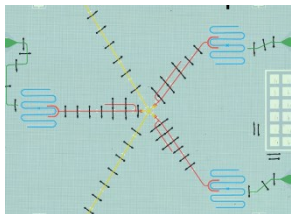


Breakdown of scientific publications by country of origin over the period 2010 - 2020



first quantum computers in EU

IQM



superconducting



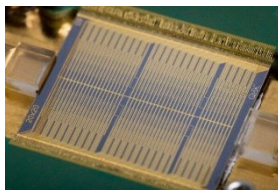
AQT



trapped ions

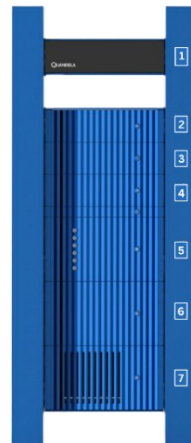


QUANTUM



photons

QUANDELA



photons

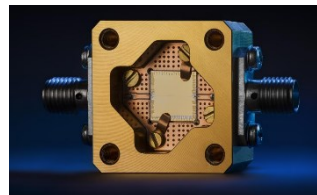
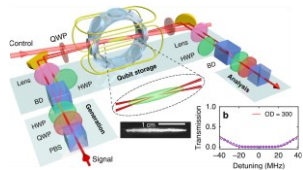
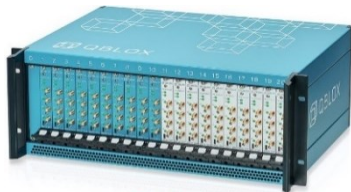


PASQAL

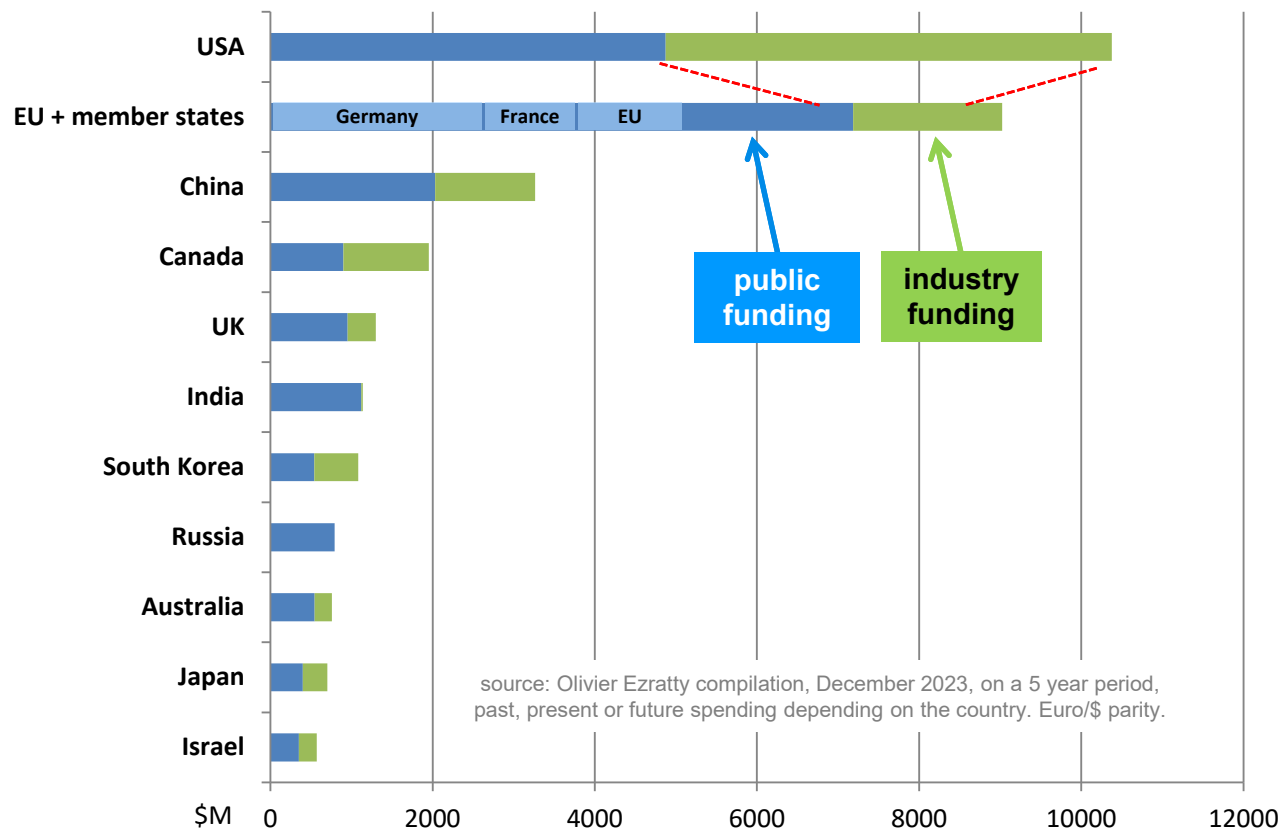


cold atoms





the « true » global investments



Key findings:

The European Union and its member states are #1 worldwide public investors in quantum technologies.

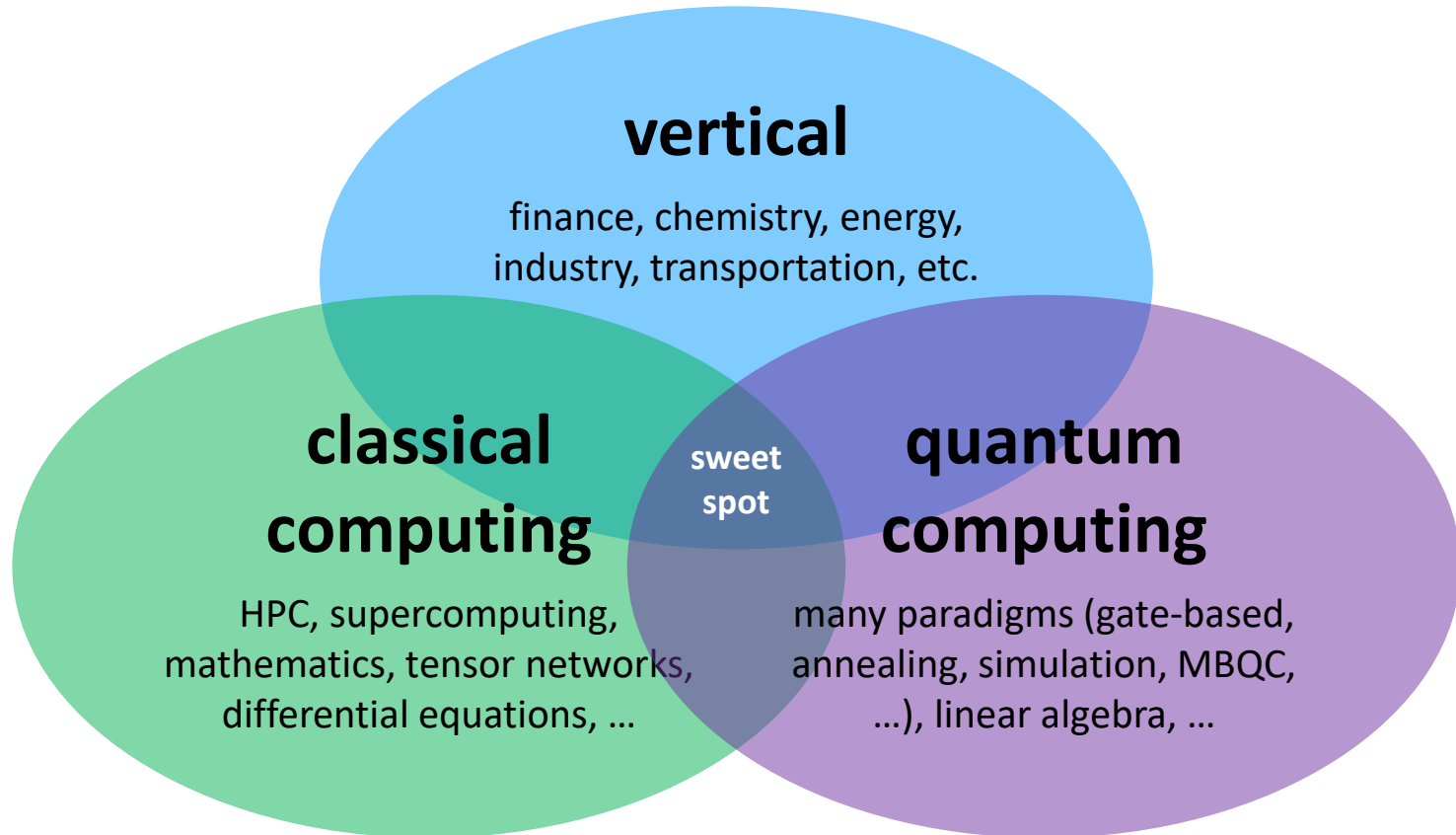
EU lags the USA only in private investments, both due to the large IT investments (can't be fixed) and larger funding rounds for their large startups (could be fixed).

China is behind the USA and the EU for both private and public investments in quantum technologies.

Chart hypothesis:

- **Classified military/intelligence expenses, in the USA and China:** estimated at 30% of civil expenses.
- **Most countries do not include legacy public investments in their numbers:** unlike France.
- **Investment duration:** data normalized over 5 years period, particularly for the UK.
- **Large IT vendors quantum investments are guestimates:** IBM, Google, Microsoft, Intel, Alibaba, Baidu, etc.
- **Undisclosed early stage investment in startups:** is usually negligible.
- **Unspent amounts not accounted for:** like probably in India.

skills needs



Today

Qubit Gate Fidelity Uncert.  

Previous 7 Days

Contrôle sécurité aéroport: identif

Terminal 2G en RER.

Previous 30 Days

New chat

Quantum Computing with ML


Long-term Scientific Frontiers

Quantum Heralding vs. Post-selec

Quantum Superpolynomial Speed

Field Theory & Type III

Quantum Tech for Scaling

 Add Team workspace
Collaborate on a Team plan

 Olivier E



You

in the scientific litterature, qubit gate fidelities are often presented like this: 99.914(3)%
what is the meaning of the number between parentheses?



ChatGPT

In scientific literature, when qubit gate fidelities are presented as "99.914(3)", the number in parentheses—(3) in this case—indicates the uncertainty or the error margin of the last digits in the reported measurement. This is a concise way to express the standard error or uncertainty associated with the measurement.

Here's a breakdown of what each part means:

- **99.914%** is the central or mean value of the fidelity. It suggests that the fidelity of the qubit gate, or how well it performs its intended operation, is 99.914%.
- **(3)** is the uncertainty in the last digit of the fidelity, scaled to the same decimal place. In this case, it indicates an uncertainty of 0.003%. This means the true fidelity is expected to be within the range of 99.911% to 99.917%.

This notation helps in understanding the precision of quantum gate operations and is crucial for developing reliable quantum computing systems.



 Message ChatGPT... 



Anne Matsuura
Director of Quantum & Molecular Technologies, Intel.



Krysta Svore
Microsoft Quantum Software GM, MBQC, QML, LIQUI|>, surface codes, FTQC. USA.



Ilana Wisby
CEO of Oxford Quantum Circuits, UK



Maud Vinet
CEO of Quobly, France



Elham Kashefi
CNRS LIP6, University of Edinburgh, blind computing, qPUFs, cofounder of Veriqloud.



Stephanie Wehner
Coordinator of Quantum Internet Alliance, German, TU Delft.



Maria Schuld
quantum machine learning, Xanadu, based in South Africa, German.



Mio Murao
runs the Murao group from University of Tokyo, distributed quantum computing, simulation algorithms, quantum telecommunication protocols, Japanese.



Michelle Simmons
atomic scale devices, single electron transistors, electron spins qubits, director of CQC2T, CEO of SQC, Australia.



Sarah Sheldon
IBM Research, superconducting qubits, quantum volume, USA.



Sarah Sheldon
IBM Research, superconducting qubits, quantum volume, USA.



Elena Calude
quantum supremacy, complexity theories, algorithms, New Zealand.



Alexia Auffèves
CNRS MajuLab Singapore, quantum thermodynamics, cofounder of the Quantum Energy Initiative, CSM ontology, Singapore.



Tracy Northrup
optical cavities and trapped ions, University of Innsbruck, USA.



Tracy Northrup
optical cavities and trapped ions, University of Innsbruck, USA.



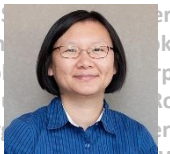
Jacqueline Bloch
polaritons guru, CNRS C2N, France. Member of the French Academy of Science.



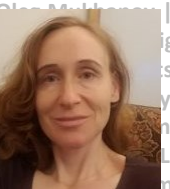
Christine Silberhorn
quantum optics, ultrafast pulse lasers, Paderborn University, German.



Sophia Economou
condensed matter physics, Virginia Tech, USA.



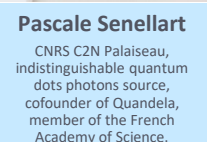
Patty Lee
Honeywell Quantum System Chief Scientist, USA.



Julia Kempe
random walks, FTQC, Director of Data Science NYU, French, German and Israeli.



Elvira Shishenina
BMW Quantum Software lead, Russian and French.



Pascale Senellart
CNRS C2N Palaiseau, indistinguishable quantum dots photons source, cofounder of Quandela, member of the French Academy of Science.



Dorit Aharonov
threshold theorem, quantum algorithms, computational complexity, QEDMA cofounder, Israeli.



Eleni Diamanti
quantum cryptography and telecoms, CNRS LIP6, WeLiNQ cofounder, France.

photo credits: Olivier Ezratty for Alexia Auffèves, Maud Vinet, Elham Kashefi, Pascale Senellart, Elvira Shishenina and Eleni Diamanti; various other photographers for the other scientists.

discussion



get the slides